A.4 Cost Estimates of Action Plan

A.4.1 Cost Estimation Methodology

The JICA Study Team and GOM Counterpart Team collected information and prepared an inventory for 140 landfills, some already closed and others operating. The inventory for those sites is discussed in Chapter 5.

For each landfill site a safe closure level (C1 to C4) was determined as outlined in Chapters 2 and 3. Of the total landfill sites, a certain number of sites were identified for inclusion in the Action Plan.

The cost estimation has been prepared for each individual site of the total sites shown in the inventory. Costs of the landfills selected for the Action Plan are taken from the larger list prepared.

The cost estimation covers both capital costs (CAPEX) and operation costs (OPEX). Methodology for estimation of the costs is described hereafter.

Step 1:

Safe closure levels are described in Chapters 2 and 3 in terms of the expected closure effect on the site. Physical construction of the facilities required to achieve these levels has been determined in order to estimate the construction costs. **Table 6.1.1** describes this process.

Table 6.1.1 Classification of Candidate Sites for the Pilot Project

Physical Construction	Description	C1	C2	C3	C4
1. Final Cover (a) Cap (b) Slope	Thickness 1.5m	O	O	O	O
2. Stable Waste Storage Structure					
(a) Slope re-formation	1:2		O	O	O
(b) Vegetation & spot turfing	Thickness 150 mm		O	O	O
3. Storm water Management					
(a) Drainage at Slope	40m pitch		O	O	O
(b) Drainage at Steps	Step every 3m		O	O	O
(c) Drainage pipes at steps	Step width = 4.0m		O	O	O
4. Gas Vents (HDPE 150mm)					
(a) Vertical vents	40m pitch		O	O	O
(b) Horizontal vents	40m pitch		O	O	O
5. Leachate Collection System					
(a) Main pipes (RC 450mm)	40m pitch			O	O
(b) Branch pipes (RC 300mm)	40m pitch			O	O
6. Leachate Re-circulation System					
(a) Re-circulation pump & piping				O	O
(b) Pond	10m x 2m			O	O
(c) Maintenance Road	7m			O	O
(d) Aerator				O	O
7. Groundwater Protection System					
(a) Vertical liner (downstream part)	10m x 1m				O
8. Monitoring					
(a) Groundwater (d. 15m)	2 wells/site				O
(b) Gas (waste depth)	1 well/site				O
(c) Surface water		O	O	O	O

Step 2:

The physical construction requirements shown in **Table 6.1.1** are quantified for each site as a function of the area of the site. Some assumptions were made as follows:

- Waste heights
  - Areas <1ha; assumed height is 3.0m
  - Areas 1 – 3 ha; assumed height is 6.0m
  - Areas >3ha; assumed height is 9.0m
- Sites shapes are rectangular
- Present slopes finished to 1:1

Step 3:

Unit rates for the physical construction were estimated based on data collection and tendering for the pilot projects. The unit rates are shown in **Table 6.1.2**.

Table 6.1.2 Construction Unit Rates

Item	Sub-item	Unit Rate
1. Final Cover		19.0 RM/m^2
2. Stable waste storage structure	a) Slope re-formation	17.0 RM/m^3
	b) Vegetation & spot turfing	6.58 RM/m^2
3. Storm water	a) Drainage at slope	42 RM/m
	b) Drainage at steps	42 RM/m
	c) Underground Pipes	124 RM/m
4. Gas Vents	a) Vertical vent	1,500 RM/unit
	b) Horizontal vent	70 RM/unit
5. Leachate Collection	a) Main pipes	351 RM/m
	b) Branch pipes	151 RM/m
6. Leachate re-circulation	a) Pump and piping	8,500 RM/site (a<2.5ha) 187,000 RM/site (a>90ha)
	b) Pond excavation	5.0 RM/m^3
	c) Maintenance road	46.0 RM/m^3
	d) Aerator	42,000 – 900,000 RM/site
7. Vertical liner		1,150 RM/m^2
8. Monitoring	a) Groundwater	440 RM/m
	b) Gas	350 RM/m

Step 4:

Taking into consideration the operation levels for each site the unit costs were discounted as follows:

Open Dump	No discount of the unit cost
Operation Level 1	40% discount
Operation Level 2	50% discount
Operation Level 3	60% discount
Operation Level 4	70% discount

Based on the quantities, unit costs and operation levels the facilities construction cost for each landfill site in the landfill inventory were calculated.

A contingency cost of 15% was added to the facilities construction cost.

Engineering and design costs were estimated at 5% of the above cost.

The total cost formed the CAPEX.

Step 5:

The annual OPEX for each site was estimated as a share of the CAPEX cost.

O&M activities and assumed share of CAPEX for each item are described in **Table 6.1.3**.

Table 6.1.3 O&M activities and assumed share of CAPEX

Item	O&M Activity	Annual Share (%) of CAPEX
1. Final Cover	Inspection, supplementary cover materials application	10%
2. Stable waste storage structure	Inspection, supplementary vegetation and turfing application	10%
3. Storm water system	Inspection, clearing of drains, replacement of damaged drains and pipes, etc.	10%
4. Gas vents	Inspection, replacement of damaged drains, etc.	10%
5. Leachate collection	Inspection, clearing of pipes, replacement of damaged pipe sectioned, etc.	5%
6. Leachate re-circulation	Inspection, operating expenses for pumps and aerators, pond deepening, service road maintenance, etc.	40%
7. Groundwater protection	Inspection of vertical liner, reinforcement and repairs as required	5%
8. Monitoring	For all sites sampling and analysis 4 times per year x 2 samples per time for leachate, surface water and gas. For sites of Group A additional sampling and analysis of groundwater.	32,280 RM/yr (Group A) 23,120 RM/yr (Groups B, C & D)

CHAPTER 6 PILOT PROJECT

6.1 INTRODUCTION

The three Pilot Projects (PP) for safe closure of landfills have been implemented at the Ampang Jajar Landfill Site, Pekan Nenasi Landfill Site and the Ampang Jaya Closed Landfill Site. The purpose and the scope of work of the Pilot Projects are as follows;

- To develop and to analyse/examine the standards as set out in the Guidelines for landfills under different conditions.
- To consider the suitability of construction methods and materials.
- To estimate the necessary construction costs.
- To identify the issues associated with the construction programme and the project period.
- To ascertain the capability of local engineers and contractors with regards to design, construct and monitoring.
- To show and learn from the progress and results of the safe closure and rehabilitation of landfills.
- To establish standard monitoring and maintenance requirements in the post safe closure phase.
- To provide actual pilot project case study and implementation examples for future references.

A brief outline of the pilot projects implementation is shown in **Table 6.1.1.**

Table 6.1.1 Brief Description of the Pilot Projects

Item	Pilot Projects		
	Ampang Jajar Landfill	Pekan Nenasi Landfill	Ampang Jaya Closed Landfill
Status of landfill	Closed (2003)	In Operations	Closed (1998)
Key points in safe closure consideration	Safety closure of landfill that has been operated under improved conditions	Model for rehabilitation of landfill located on wetlands	Safety closure of landfill previously operated as an open dump site and poorly located
Targeted safe closure levels	Landscaping and safety closure to Level C3	Safety closure to Level C3	Safety closure to Level C2
Brief description of the pilot projects	Improvement of the slopes and installation of storm water drains, leachate collection pipes and gas vents	Upgrading to semi-aerobic landfill with leachate collection pipes, recirculation system and gas vents	Provision of leachate collection pipes and gas vents. Installation of surface storm water drainage system
Major works carried out	• Topographic and geological survey	• Topographic and geological survey	• Topographic and geological survey
	• Re-forming 250m stretch of slopes from 3.2m to 7m high • Applying 8,000m^2 cover soil (150mm thick) • Plant 11,400m^2 turfing & 240 trees • Installing 275m of 450mm dia. leachate collection pipes • Installing 600m of 150mm dia. Leachate/gas pipes • Installing 900m of pre-cast surface / stormwater drains	• Install 84m of 450mm dia. leachate collection pipe • Install 330m of 225mm dia. branch pipes • Excavation of 100m x 10m x 2m(deep) leachate collection pond • Installation of one 7.5kw surface aerator c/w control systems • Installation of one 5kw recirculation pump c/w piping and control panel	• Construct 1km, 7m wide access road • Install 1km stormwater drains alongside access road • Install 126m of 450mm dia. HDPE leachate collection pipe • Install 500m of 100mm dia. leachate / gas collection pipes • Install 500m stormwater drains • Excavation of wetland area for leachate pond
Environmental monitoring	Before and after PP • Surface & groundwater • Leachate • Landfill gas	Before and after PP • Surface & groundwater • Leachate • Landfill gas	Before and after PP • Surface & groundwater • Leachate • Landfill gas

6.2 SELECTION OF PILOT PROJECTS SITES

The pilot project (PP) sites were selected based on the landfill inventory data for both operating and closed landfill sites prepared by MHLG, and the site reconnaissance survey carried out by the JICA Study Team. A total of 19 landfill sites in the Peninsular Malaysia were identified as candidate sites for the pilot projects. The two main factors for the selection considerations were, i) their geographical locations, and ii) their closure stages, i.e. in operations, about-to close or closed sites. The brief descriptions of the candidate sites are shown in **Table 6.2.1**.

The general procedures for the selection of the PP sites are shown in **Figure 6.2.1**.

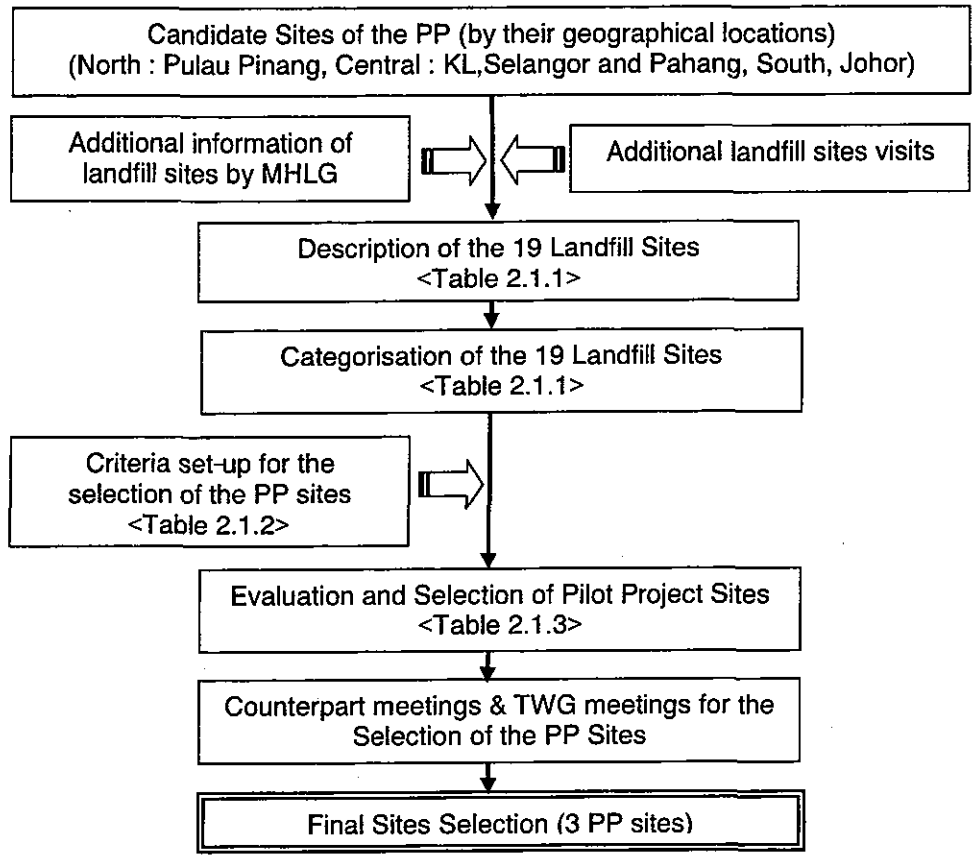


Figure 6.2.1 Site Selection Procedure for the Pilot Projects

Table 6.2.1 Descriptions of Candidate Sites for the Pilot Projects

No	Name	State	Area (ha)	Operation year	Landfill level	Waste amount received (ton/day)	Sitting condition	Distance from City/Town Centre (Km)	Managed by	Post closure utilisation
1	Ampang Jajar	Pulau Pinang	17	1980'/ 2003	3/4	400	Flatland	5	Local authority	(Operating)
2	Pulau Burung	Pulau Pinang	64	1980'/ 2006	3	1000	Flatland	25	Private	(Operating)
3	Jelutong	Pulau Pinang	20	1980'/ 2001	0/1	n.a.	Sea shore	4	Local authority	None
4	Matang (Taiping)	Perak	8	2000 / 2010	1/2	200	Swamp area	8	Local authority	(Operating)
5	Jabor (Kuantan)	Pahang	24	1990'/ 2005	3	400	Swamp area	20	Private	(Operating)
6	Gambang	Pahang	7	1980'/ 2001	0	n.a.	Hilly slope	30	Local authority	None
7	Pekan Nenasi	Pahang	5	1970'/ 2010	0/1	n.a.	Swamp area	8	Private	(Operating)
8	Larkin	Johor	15	1980'/ 1998	1/2	n.a.	Hilly slope	5	Local authority	None
9	Ulu Tiram	Johor	44	1997 / 2003	3	1500	Hilly area	30	Private	(Operating)
10	Pasir Gudang	Johor	12	1980'/ 2002	0/1	n.a.	Swamp	12	Local authority	None
11	Tanjung Langsat	Johor	25	2002 / 2015	4	250	Flat land	16	Local authority	(Operating)
12	Air Hitam	Selangor	45	1998 / 2008	4	1200	Hilly area	35	Private	(Operating)
13	Kelana Jaya	Selangor	48	1981 / 1996	1/2	400	Former quarry	6	Local authority	None
14	Sri Petaling	FTKL	21	1979 / 1991	1	1500	Former quarry	15	Local authority	Park
15	Paka 1	FTKL	13	1989 / 1994	0/1	1400	Flatland	1	Local authority	Housing
16	Sungai Besi	FTKL	14	1989 / 1995	1/2	1200	Former quarry	10	Local authority	Commercial
17	Taman Beringin	FTKL	12	1991 / 2003	1/2	600	Former quarry	3	Private	(Operating)
18	Jinjang Utara	FTKL	65	1979 / 1996	0/1	1000	Former quarry	20	Local authority	None
19	Ampang Jaya	Selangor	10	1980' / 1997	1/2	n.a.	Hilly slope	5	Local authority	Fruits field

6.2.1 Categorisation of Candidate Sites

In order to examine and to evaluate the characteristics of the 19 pilot project candidate sites, they were categorised into the following parameters;

i. Closure stage of landfill
ii. Risk to the environment
iii. Potential for post closure utilisation
iv. Landfill facility level

(1) Selection of Pilot Project Sites

From the evaluation the candidate sites were presented to the Technical Working Group (TWG) for discussion and their consideration. As a result of the discussions, the 3 Pilot Project sites were selected. They are;

i. Ampang Jajar Landfill site (Pulau Pinang)
ii. Pekan Nenasi Landfill site (Pahang)
iii. Ampang Jaya Closed Landfill site (Selangor)

6.3 PILOT PROJECTS IMPLEMENTATION PROCESS

6.3.1 Implementation Flowchart

The implementation flowchart for the Pilot Project is shown in **Figure 6.3.1**.

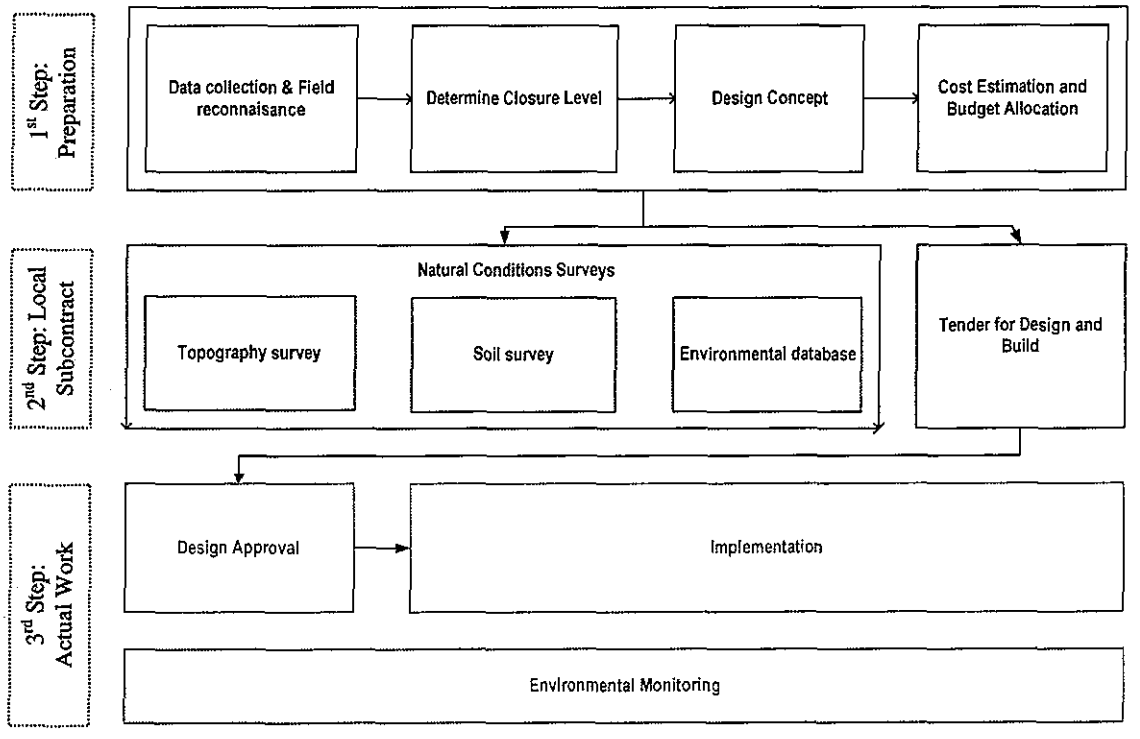


Figure 6.3.1 Implementation Flow

Once the 3 Pilot Project sites have been identified, detailed site investigations were carried out to gather site specific data for each of the sites. Examples of the data gathered were as follows:

- Records of previous operations and previous improvement projects
- Records on previous leachate testing and analysis results
- The land use and development surrounding the site
- The effects of the new transfer station adjacent to the landfill site
- Carry out surface water, groundwater, leachate and gas sampling for the preparation of the environmental database
- Information on the tidal conditions for the sites that are is situated on a swamp land or near to the coast

6.3.2 Cost Estimation

The preliminary cost estimation was based on the available maps and data collected by the Study Team to prepare the conceptual designs for each of the 3 PP sites. From the preliminary design, separate bill-of-quantities (BQs) for each of the project construction works and materials were prepared. With the BQs, the tender documents for each of the sites were prepared. Three tenders were called and competent contracting companies were invited to submit their tenders. From the tender submissions, the tendered values and the unit rates for the scope of works were collected. From the tender evaluation, the most suitable unit rates were adopted and the construction costs for the entire project were determined based on the tendered values.

The scope of works and the BQs have been presented in ***Volume 4, Chapters 6, 7*** and ***8***, for the Ampang Jajar PP, the Pekan Nenasi PP and the Ampang Jaya PP, respectively.

6.3.3 Survey of Existing Natural Condition

Prior to the commencement of the Pilot Projects, the topography surveys and soil investigations of the existing natural condition were carried out. The topography survey plans provide an up-to-date representation of the landfills that were later used for the detailed designs for the construction works. The soil investigations data were used to study and determine the groundwater flow both upstream and downstream of the closure works.

For the Ampang Jajar PP, 3 soil investigation boreholes were drilled and later converted to the groundwater monitoring wells at the foot of the slope and along the site perimeter both upstream and downstream the site. An additional borehole was drilled on top of the landfill to provide for the landfill gas ventilation and also as the gas monitoring well.

For the Pekan Nenasi PP, only 3 soil investigation boreholes were drilled and since the site was previously provided with the gas ventilation pipes, the new gas monitoring well was not necessary. Borehole locations were selected with one near the site entrance and the other two upstream and downstream of the active landfill cell.

As for the Ampang Jaya PP, only 2 soil investigation boreholes and one gas ventilation borehole were provided. The soil boreholes were located at the upper elevation of the site and at the valley bed, downstream of the leachate collection system. The landfill gas monitoring well was located at the upper level of site were waste is accumulated.

The technical specifications for the surveys are explained in more details in ***Volume 4, Chapters 6, 7*** and ***8***.

6.3.4 Pilot Project Design

(1) Design and Build Contracts

Due to the time constraints with the Pilot Project Implementation Period, the "Design and Build" construction method was selected. The tendering process was initiated with close coordination with MHLG to short list the qualified construction companies for each of the Pilot Project from a list of about 5 to 7 companies suggested by each of the 3 respective Local Authorities.

The short listed companies were then invited to bid for the "Design and Build" contract for detailed design and construction work. The pre-tender briefing and site visits were held at each of the Pilot Project sites with the participation of the respective Local Authorities. As for the Ampang Jaya PP, the meeting was held in MHLG and attended by the Counterpart members.

The summary of the pre-tender briefing including the explanation of the tendering process and scope of work were as follows:

- Presentation of the design concept of the Pilot Project
- Explanation of the Bill of Quantities (BQ)
- The proposed project schedule, i.e. 4 weeks for detailed design, submission and approval, and 3 months for construction, followed by three months of the defects liability period.
- Presentation of the proposed technical specifications and design requirements
- Presentation of the "Design and Build" conditions of contract

(2) Design Submission and Approval

The successful contractors for each of the Pilot Projects were notified and the contracts awarded to them. All the contractors were provided with the necessary topographical plans and were given the 3 weeks period to prepare and submit their detailed designs to the JICA Study Team for approval.

On submission of their designs, meetings were held to verify the designs and once all the issues were discussed and agreed upon, the final approval was given by the Study Team. Copies of the final detailed designs were submitted to MHLG and the respective Local Authorities for their reference and perusal.

6.3.5 Pilot Project Implementation

Once the detailed designs have been approved, the Pilot Projects were implemented and construction work commenced at each of the 3sites. Some of the major activities carried out by the Study Team Members during the project implementation period included:

1. The assignment of a local engineer to each of the 3 PP sites to acts as Study Team Site Supervisors to supervision of the works, liaison with the contractors and LA, etc.

2. To ensure that the work schedule is adhered to, especially during the rainy seasons, and to ensure that the PP work will not disrupt the day to day operations of the operating landfill sites.

6.3.6 Monitoring Programme for the Pilot Projects

(1) General

The main objective of the monitoring programme under the pilot project is to evaluate the effect of the landfill improvements. Some components of the improvements, such as leachate water quality, landfill gas composition, etc., can be best evaluated only on a long-term basis. It is expected that significant effects of improvement may not be observed for some components during the short period of these pilot projects. Therefore, for such components, this monitoring program will provide short-term observation but also it should be considered as an example of how the monitoring shall be continued by the own effort of MHLG or the Local Authorities until completion of the stabilisation process of the site.

(2) Monitoring parameters for water quality and gas composition

Water quality parameters for monitoring of leachate, surface water and groundwater are based on the effluent standard applied to the landfill site in Malaysia (standard B). Water quality parameters and gas composition parameters, as well as their analytical method are as shown in **Table 6.3.1**.

Table 6.3.1 Analytical Parameters

(a) Water Quality

Water Quality Analysis			Method
1	Water temperature	°C	APHA 2550B
2	pH	-	APHA 4500 H+ B
3	Electric conductivity (EC)	mS/cm	APHA 2510 B
4	Dissolved oxygen (DO)	mg/l	APHA 4500-O G
5	Turbidity	NTU	APHA 2130B
6	Oxidation-reduction potential (ORP)	mV	APHA 2580B
7	BOD_5 at 20°C	mg/l	APHA 5210 B
8	COD	mg/l	APHA 5220 D
9	Suspended solids (SS)	mg/l	APHA 2540 D
10	Total nitrogen	mg/l	APHA 4500
11	Mercury (Hg)	mg/l	APHA 3112 B
12	Cadmium (Cd)	mg/l	APHA 3112 B

13	Hexavalent chrome (Cr^{+6})	mg/l	APHA 3500-Cr D
14	Arsenic (As)	mg/l	APHA 3120 B
15	Cyanide	mg/l	APHA 4500 CN C
16	Lead (Pb)	mg/l	APHA 3120 B
17	Trivalent chrome (Cr^{+3})	mg/l	APHA 3500 Cr D & 3120 B
18	Copper (Cu)	mg/l	APHA 3120 B
19	Manganese (Mn)	mg/l	APHA 3120 B
20	Nickel (Ni)	mg/l	APHA 3120 B
21	Tin (Sn)	mg/l	APHA 3120 B
22	Zinc (Zn)	mg/l	APHA 3120 B
23	Boron (B)	mg/l	APHA 3120 B
24	Iron (Fe)	mg/l	APHA 3120 B
25	Phenol	mg/l	APHA 5530 D
26	Chloride ion	mg/l	APHA 4500 Cl G
27	Sulphide	mg/l	APHA 4500 S2-D
28	Fat and oil	mg/l	APHA 5520 B
29	Ammonium-nitrogen	mg/l	APHA 4500 NH3 G
30	Nitrate-nitrogen	mg/l	APHA 4500 NO3-H
31	Nitrite-nitrogen	mg/l	APHA 4500 NO2-B

(b) Gas Quality

	Gas Quality Analysis		Method
1	Oxygen (O_2)	%	Galvanic cell sensor
2	Nitrogen (N_2)	%	Computation as residual gas
3	Methane (CH_4)	%	Infra-red absorption
4	Carbonic dioxide (CO_2)	%	Infra-red absorption

Note: APHA = American Public Health Association)

(3) Sampling Schedule

For each sampling location, samples will be taken four times (once before the pilot project improvement and three times after the project) according to the schedule shown in the following **Table 6.3.2** (◎ indicates sampling timing).

Table 6.3.2 Sampling Schedule

Sample type	2003					2004							
	Aug	*Sep*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*
Surface water	◎						◎			◎		◎	
Leachate	◎						◎			◎		◎	
Groundwater	◎						◎			◎		◎	
Landfill gas	◎						◎			◎		◎	

6.4 PILOT PROJECT - AMPANG JAJAR LANDFILL SITE (PULAU PINANG)

6.4.1 Outline of the site

(1) General

The Ampang Jajar landfill site started operations in the 1980s on a wetland beside the Perai River. The site was used as an open dumping site and it was improved to level L3 sanitary landfill in 1988 with advice and cooperation from the JICA experts. For the improvement works, leachate collection pipes, gas ventilation pipes, leachate pond and leachate re-circulation system were provided. With the leachate re-circulation system,

the site was operated as a semi-aerobic landfill site. The landfill site is operated by MP Seberang Perai (MPSP) and is considered to be one of the best landfill sites in Malaysia. About 400 tonne per day of municipal waste were disposed at the site and for the past 15 years, more than 2.2 million tonnes of waste has been disposed.

The site occupies an area of about 17 ha and the final height of the waste layers is about 20 m. Ever since its closure in November 2003, all the waste are now sent to the neighbouring new transfer station and hauled to the Pulau Burung landfill site for disposal, about 40 km south of Ampang Jajar. Currently, MP Seberang Perai is providing the final cover on the top layer as part of their safe closure work.

The site is about 5 km from the MP Seberang Perai Council building and sandwiched between the riverside park on the West and the North-South Highway on the East. There are some housing development projects planed for at the neighbouring lot to the South.

At present, the site has been earmarked for development as an "urban forest/park" after closure.

The brief description of the landfill operations and site characteristics are summarised in **Table 6.4.1**.

Table 6.4.1 Ampang Jajar Landfill Operations and Site Characteristics

Operational Characteristics	Site Characteristics
⇒ Started operations in 1980s and scheduled for to closure in June 2003 but was later closed in November 2003. ⇒ Upgraded to a Level 3 landfill in 1988 with the installation of leachate collection pipes, pond, recirculation system, and gas vents ⇒ After the upgrading, it was operated as a semi-aerobic landfill ⇒ About 2 2 million tonnes of waste has been disposed at the landfill(about 400t/d)	⇒ Located on a wetland area ⇒ The site occupied and area of about 17 ha and the landfill height is about 20m ⇒ The western side of the landfill was developed as a riverside park ⇒ The North-South Highway passes along the eastern side

6.4.2 Total safe closure plan

The proposed safe closure plan for the Ampang Jajar landfill siteis summarised in **Table 6.4.2**.

Table 6.4.2 Summary of the Total Safe Closure Plan for Ampang Jajar Landfill Site

Items	Measures
1. Hydrogeologic information	Wet land covered with marine clay layer
2 Final site topographic plan	Height about 20 m from ground level. Steep slope should be moderated to a gradient of 1:2
3. Final cover design	Barrier layer should be about 0 6 m thick including existing covering soil Top layer should be between 0 15m to 0 3 m thick
4 Covering soil material	Good topsoil
5. Final landscape and site plan	Redeveloped as an urban forest

6. On site facilities	Hilltop	Playground/sports ground and park (Proposed temporary use for gas extraction project)
	Slope	Urban forest & park
	South part	Facility area including new transfer station
7. Phase closure plan	Phase I	Transfer station and facility area
	Phase II	Closure of slope
	Phase III	Closure of hilltop
8. Surface water management plan	Main drainage Surrounding drainage of hill top Drainage system of slope	
9. Ground water management plan	Monitoring	
10. Leachate management plan	Leachate collection system at the bottom (already installed) Leachate and gas collection at steps of slope Leachate aeration pond (already installed) Leachate re-circulation system (already installed) Leachate filtration and discharge (already installed)	
11. Landfill gas management plan	Gas collection system and discharge pipe for slope (Proposed temporary use for gas extraction project at top of landfill)	
12. Monitoring	Groundwater monitoring well Gas and waste layer monitoring well Leachate pond and gas discharge pipe will be used for monitoring Monitoring of surrounding stream	

6.4.3 Proposed land use plan

Based on discussions with MPSP, it was learnt that the landfill site have been planned to be used for redevelopment to an urban forest area that includes a park, a playground and a sports ground. The proposed zoning plan is summarised in **Table 6.4.3**.

Table 6.4.3 Proposed Land Use Plan for Ampang Jajar Landfill Site

Area	Characteristic	Land use
West slope	- Beside the riverside park - View from park and bridge shall be considered	Park and green zone
East and north slope	- View from highway shall be considered	Green zone
Top of hill	- Proposed temporary use for gas extraction project - Flat area	Playground and sports ground zone
South part	- New transfer station in operations - Near to the housing area	Facility zone including transfer station Buffer zone for housing area

6.4.4 Ampang Jajar Pilot Project Implementation

Due to the Pilot Project is not a full-scale project certain limitations and budget constraints, the Pilot Project implementation could only be carried out on a partial section of the entire site.

Two sections of the landfill site were identified, i.e. the Western Slopes, facing the park and river and the Eastern Slopes, facing the highway. An evaluation of the 2 areas was

carried out and the selection of the Pilot Project area was decided based on the aesthetic viewpoint, the higher public consciousness factor and the overall higher improvement factor. As such, the Eastern Slopes area was selected.

Subsequent to the PP tender and evaluation exercise, the Ampang Jajar Pilot Project was eventually awarded the successful contracting company, Asia Demand Sdn Bhd, and Design and Build Contract was signed on August 13th, 2003.

Following the commencement of the project, as part of the deliverables, the contractor prepared and submitted the project implementation schedule as shown in **Figure 6.4.1**.

The detailed design was completed and approved by the Study Team within one month from the project commencement date. Samples of the design drawings are shown in **Table 6.4.2** and **Table 6.4.3**. The final As-built drawings are provided in Volume 4, Chapter 9. The photographic records of the progress of the work and the main facilities are shown in **Plate 6.4.1**, **Plate 6.4.2** and **Plate 6.4.3** respectively.

The brief description and Bill-of-Quantities (BQ) of the Pilot Project is summarised in **Table 6.4.4**.

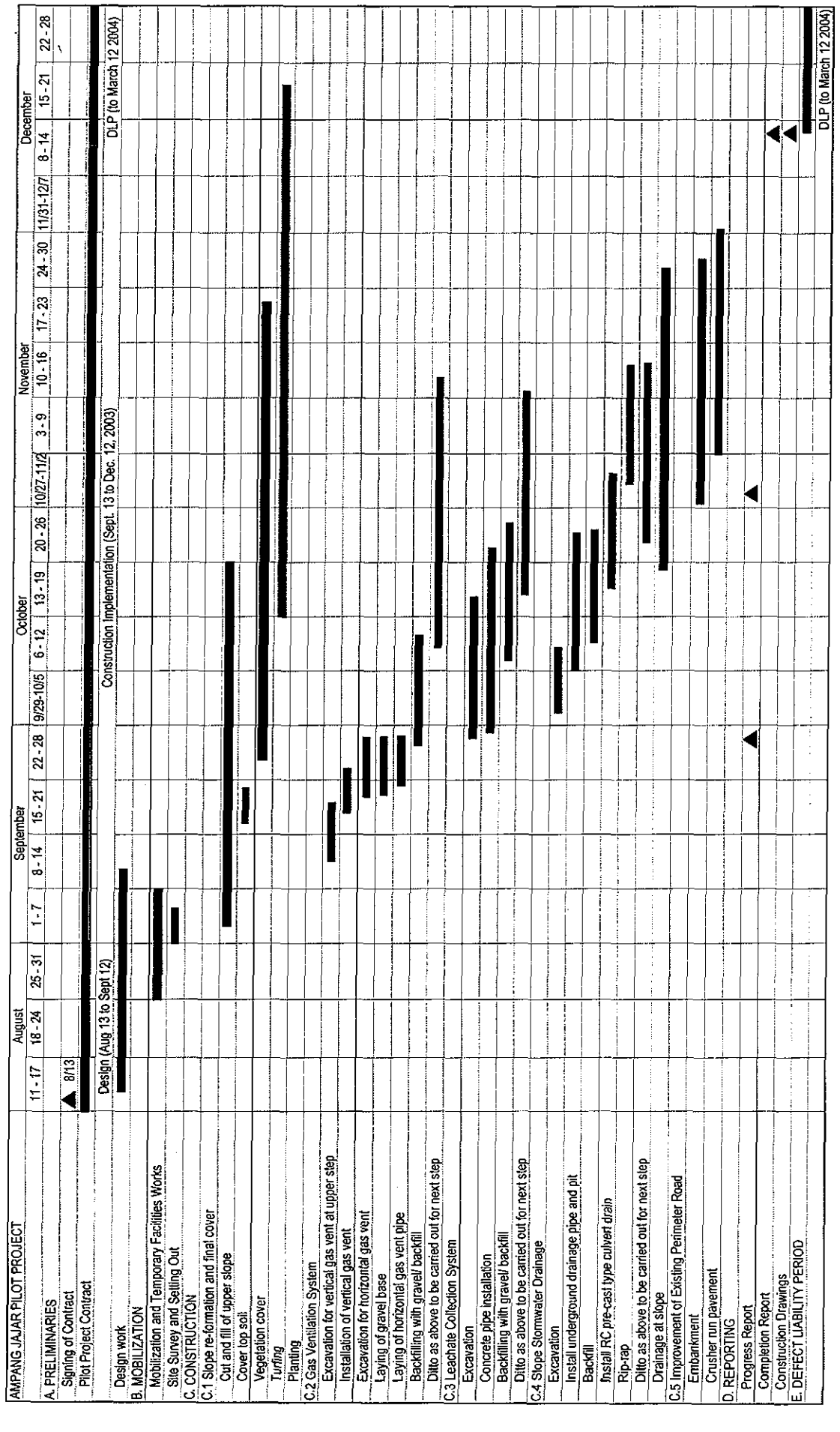
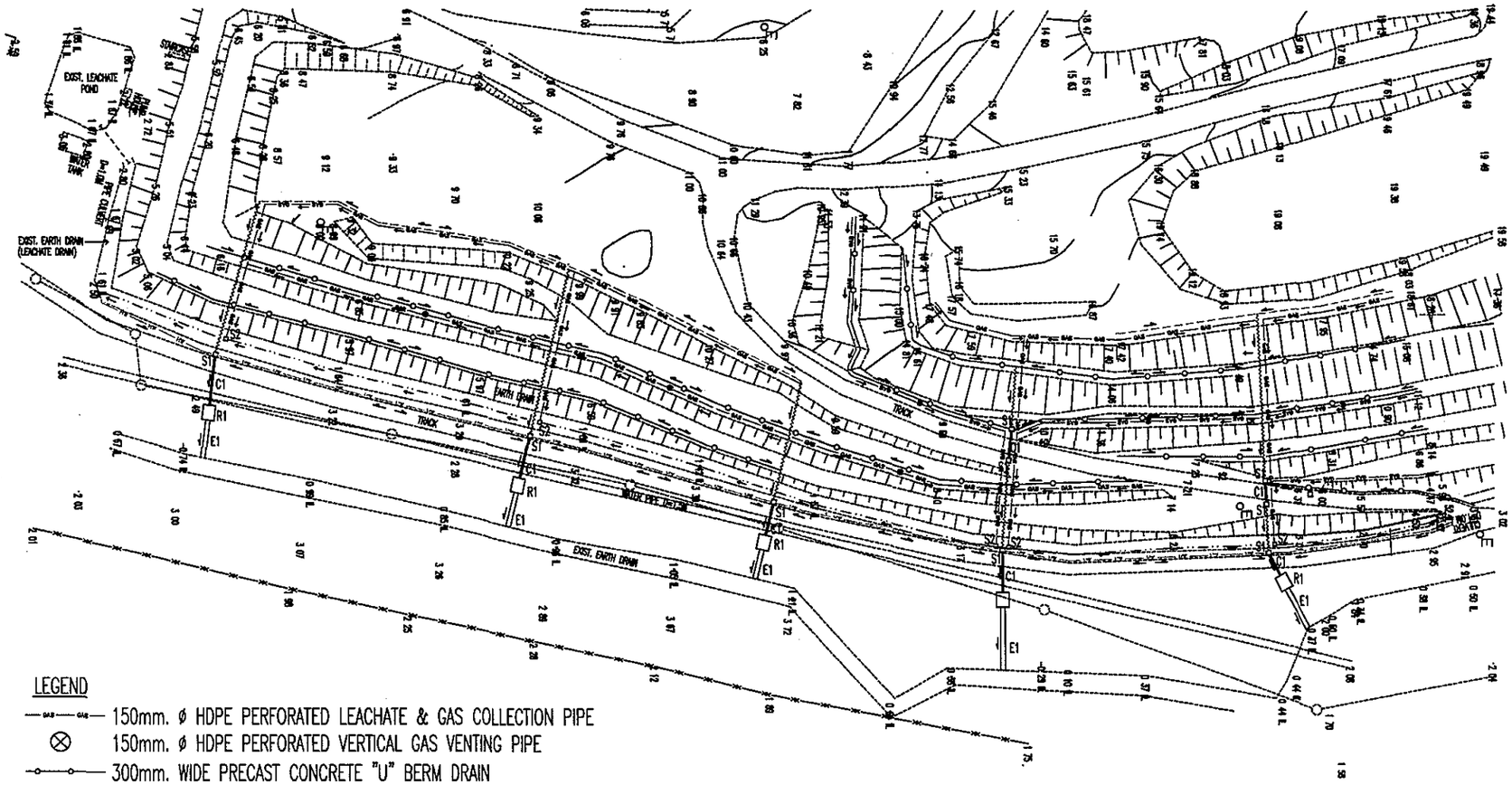


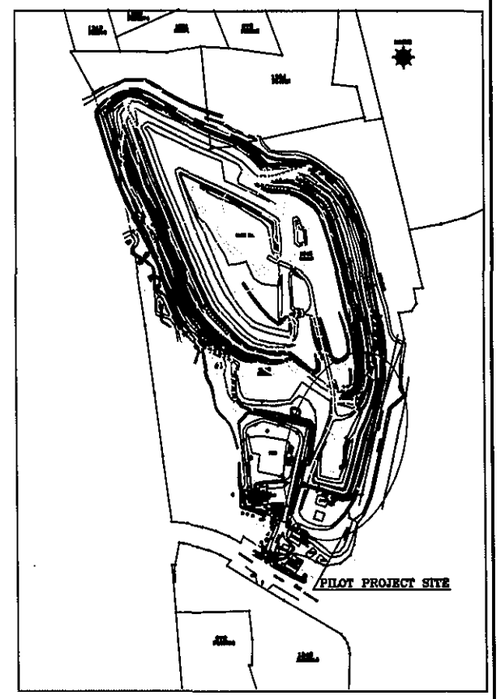
Figure 6.4.1 Project Implementation Schedule for Ampang Jajar PP

Table 6.4.4 Ampang Jajar PP Description

No.	Item/Description	Quantity
1	Slope Re-formation and Final Cover	
	Re-formation of the 1st Step Slope and final cover *Improvement of the lowest slope to 1:2, and supply and compaction of impermeable clayey soil on the slope. Height of the step varies from 3.2 to 7.1m.*	1,580m^3
	Application of cover soil on the upper layer of the 2nd Step Slope (t = 300mm) *Supply and compaction of clayey soil on the slope and steps with a thickness of 300mm to improve the existing slope. Number of steps above the first step range from 2 to 5 steps.*	8,000m^2
	Vegetation cover (t = 150mm) *Application of rich organic field soil.*	11,385m^2
	Turfing (slope protection) *Spot turfing for protection of the slope.*	11,385m^2
	Planting (1 tree/25m^2) *Selected tree type should be able to grow under the landfill conditions*	240 trees
2	Leachate collection system (Main Pipe)	
	Blind (buried) leachate collection pipe (dia. 450mm) *Supply and installation of perforated spun concrete pipe class H, of nominal diameter 450mm including placing of gravel around the pipe, partial excavation and laying with crusher-run of 200mm thickness, on wooden sleeper/wedge.*	275m
3	Gas venting system	
	Vertical gas venting pipe (150mm) *Supply and installation of vertical gas venting perforated HDPE pipe, of diameter 150mm in pits surrounded by gravel (50 to 150mm), to a depth of 3.5m penetrating the solid waste. Locations were selected mostly midway of the slope. Connecting pipes were installed at heights of about 1.5m above ground*	6 units
	Gas at slope (HDPE, 150mm) *Supply and installation of inclined vents (perforated 150mm HDPE) to vent the gas and collect leachate. Pipes are located at four (4) sections along the slope and connect with vertical and horizontal pipes for leachate and gas. Pipes are laid below ground in trenches of 50 x 50cm and surrounded by gravel.*	185m
	Horizontal gas and leachate collection branch pipes (150mm) *Supply and installation of horizontal gas venting perforated HDPE pipe, diameter 150mm buried in trenches of 500mm x 500mm and surrounded by gravel of size 25mm. These pipes are laid along the upper two steps.*	600m
4	Improvement of existing perimeter roads	
	Crusher-run pavement (t = 200mm) *Supply, level and compaction of the crusher-run for pavement of width 3.5m and thickness of t=200mm, including bed grading, along the road running adjacent to the foot of the slope.*	192.5m^3
5	Slope storm water drainage	
	Drainage at steps *Supply and place RC pre-cast type drainage ducts of dimensions 300 x 300mm along the steps.*	700m
	Drainage at slope (sloping part) *Supply and placement of RC pre-cast type cascading drainage ducts of dimensions 600 x 600 mm, at 5 locations along the slope.*	190m
	Drainage pipes at step crossings and under perimeter road (dia. 300mm) *Supply and installation of pipe culvers of spun concrete, diameter 300mm under the steps and the perimeter road.*	50m
	Earth drain (300 & 900 wide) *Earth drain of 300 x 300mm shall also be laid along the top of the slope.*	214m
	Drainage pits at steps and perimeter road. *Square brick drainage pits of base dimensions S1=750x750mm and S2=900x900mm are installed at the intersections of leachate main and branch pipes and at the intersections of horizontal and cascading drains and the main drainage pipe.*	14 units

No.	Item/Description	Quantity
	Rip Rap (3000mm x 2500mm x 900mm depth) with cement mortar *Riprap is installed at the 5 locations where the concrete drainage pipe connects with the wide earth drain to drain the collected storm water to the existing earth drain.*	5 units
	Drainage at toe (600 x 450 pieces U Drain) *RC pre-cast drains of dimensions 600 x 450mm are laid along the foot of the slope to receive.*	275m





KEY PLAN

NORTH

SCALE

0 10 20 30 40 50m

LEGEND

- 150mm. ø HDPE PERFORATED LEACHATE & GAS COLLECTION PIPE
- ⊗ 150mm. ø HDPE PERFORATED VERTICAL GAS VENTING PIPE
- 300mm. WIDE PRECAST CONCRETE "U" BERM DRAIN
- 600mm. WIDE EARTH DRAIN
- 600mm. WIDE PRECAST CONCRETE "U" DRAIN
- CASCADING DRAIN @ ±50M CENTRES
- 450mm. ø PERFORATED SPUN CONCRETE CLASS "H" LEACHATE COLLECTION PIPE
- → DIRECTION OF FLOW FOR LEACHATE AND GAS COLLECTION PIPE
- → DIRECTION OF FLOW FOR DRAINAGE
- S1 900mm. SQ. x 750mm. DEEP BRICK SUMP
- C1 300mm. ø HEAVY DUTY CONCRETE PIPE CULVERT
- R1 2500mm. x 3000mm. x 900mm. DEEP RIPRAP
- E1 900mm. WIDE EARTH DRAIN
- S2 750mm. SQ. BRICK SUMP

Figure 6.4.2 Layout Plan (Ampang Jajar Pilot Project)

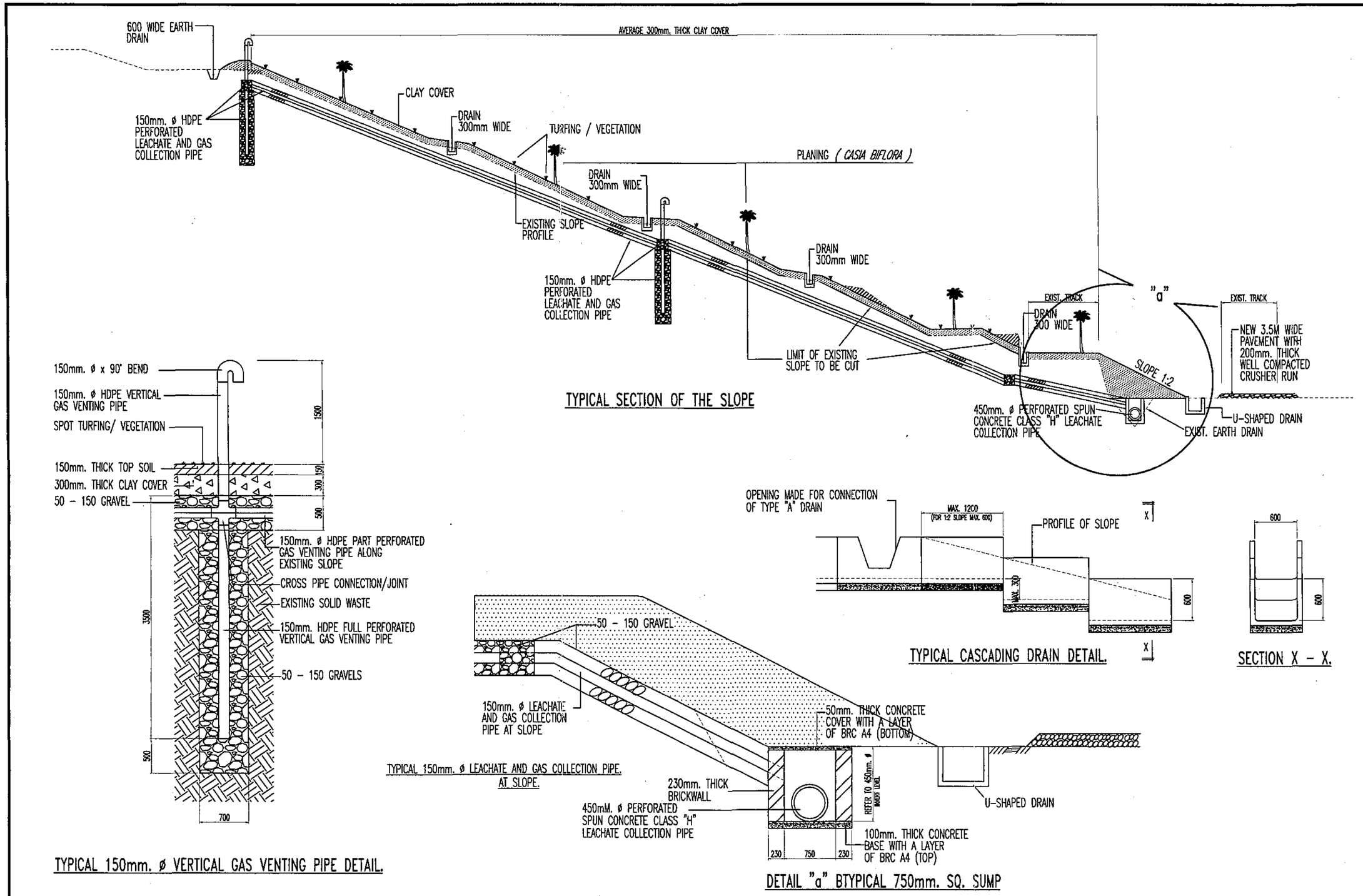


Figure 6.4.3 Typical Sections (Ampang Jajar Pilot Project)

Plate 6.4.1 Ampang Jajar Pilot Project 1

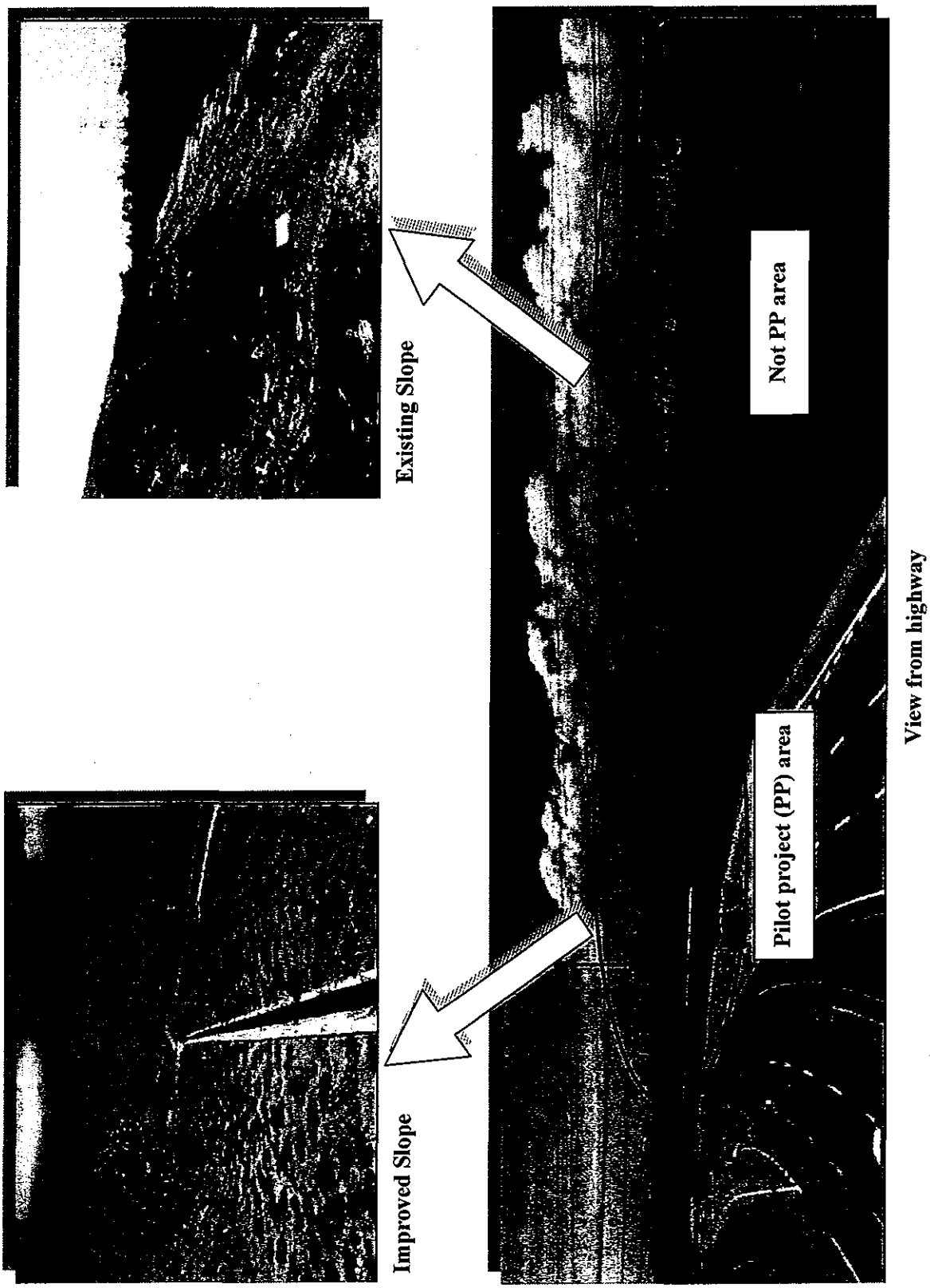
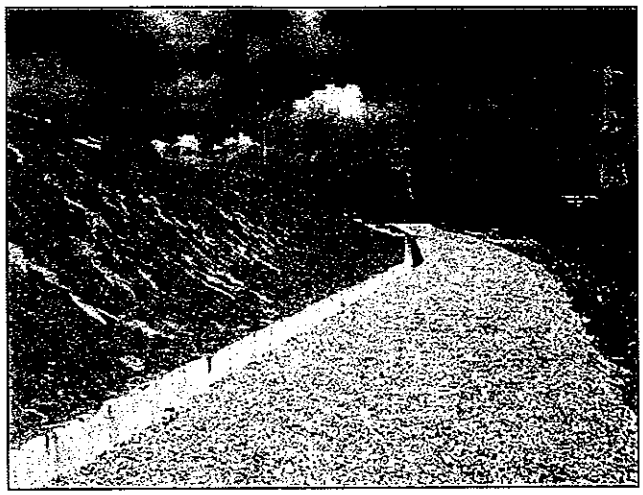


Plate 6.4.2 Ampang Jajar Pilot Project 2

Before pilot project (PP)

During PP

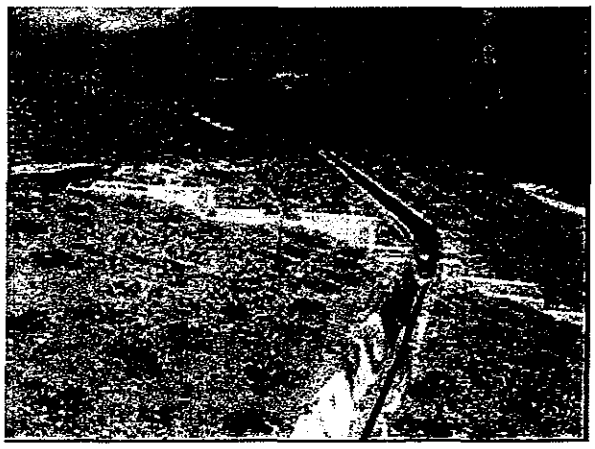


After PP
(Improved slope, drainage, leachate collection (not visible) and access road)

Plate 6.4.3 Ampang Jajar Pilot Project 3

Installation of leachate pipe/drain

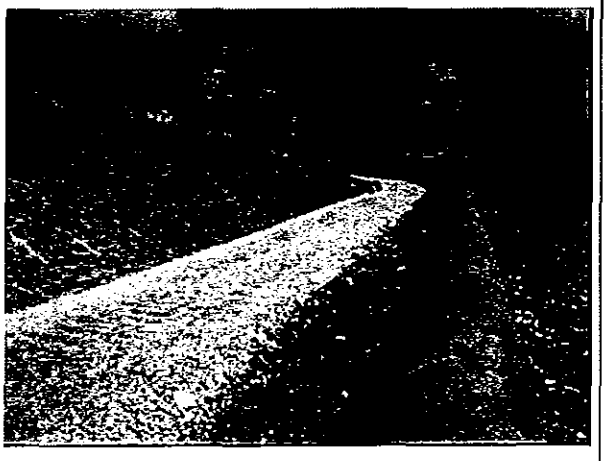
Installation of gas pipe



Storm water drainage - 1

Storm water drainage - 2

Gas ventilation pipe



PP Site and water pipeline

6.4.5 Environmental Monitoring – Ampang Jajar PP

(1) Monitoring programme

1) Sampling Quantity, Schedule and Locations

The following **Table 6.4.5** summarizes the sampling quantity of monitoring for Ampang Jajar pilot project site.

Table 6.4.5 Sample Number at Ampang Jajar Pilot Project Site

Sample type	Ampang Jajar (Number of locations)
Surface water	2
Leachate	2
Groundwater	3
Gas	2

For each location, samples will be taken four times (once before the pilot project improvement and three times after the project) according to the schedule shown in the previous **Table 6.3.2**.

Table 6.4.4 shows the location of monitoring for each sample type.

2) Geological setting and Installation of monitoring well

The water monitoring wells are installed at the base of slope, while the gas monitoring well is installed at the hill top. The elevation of the present ground level varies from approximately RL+2m to RL+20m.

(2) Geological Background

The site is located in an area of Quaternary Deposits. The granitic rock and Phylite/Schist/Slate crop out at the east of the site. The Quaternary Deposits comprise of beach sand, high and low terrace deposits, laterite, gravel, sand, silt and clay. The base rock at the site is considered to be granite. The orientation of the soil profile is indicated in **Figure 6.4.5**.

(3) Laboratory analysis

The results of laboratory analysis of physical and basic parameters and gas composition for both the sampling exercises are shown in **Table 6.4.6** and **Table 6.4.7**.

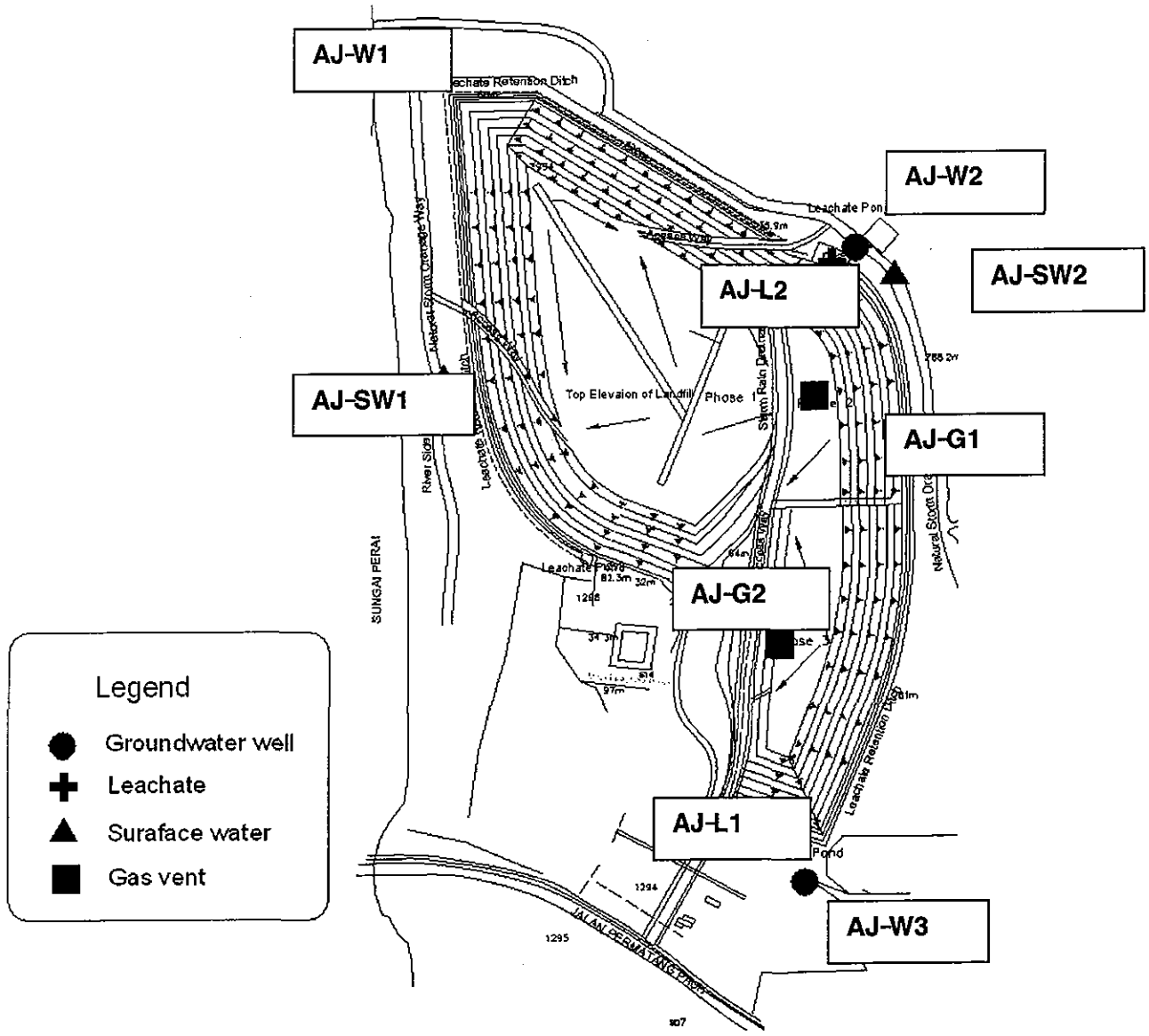


Figure 6.4.4 Map of Sampling Location for Monitoring, Ampang Jajar

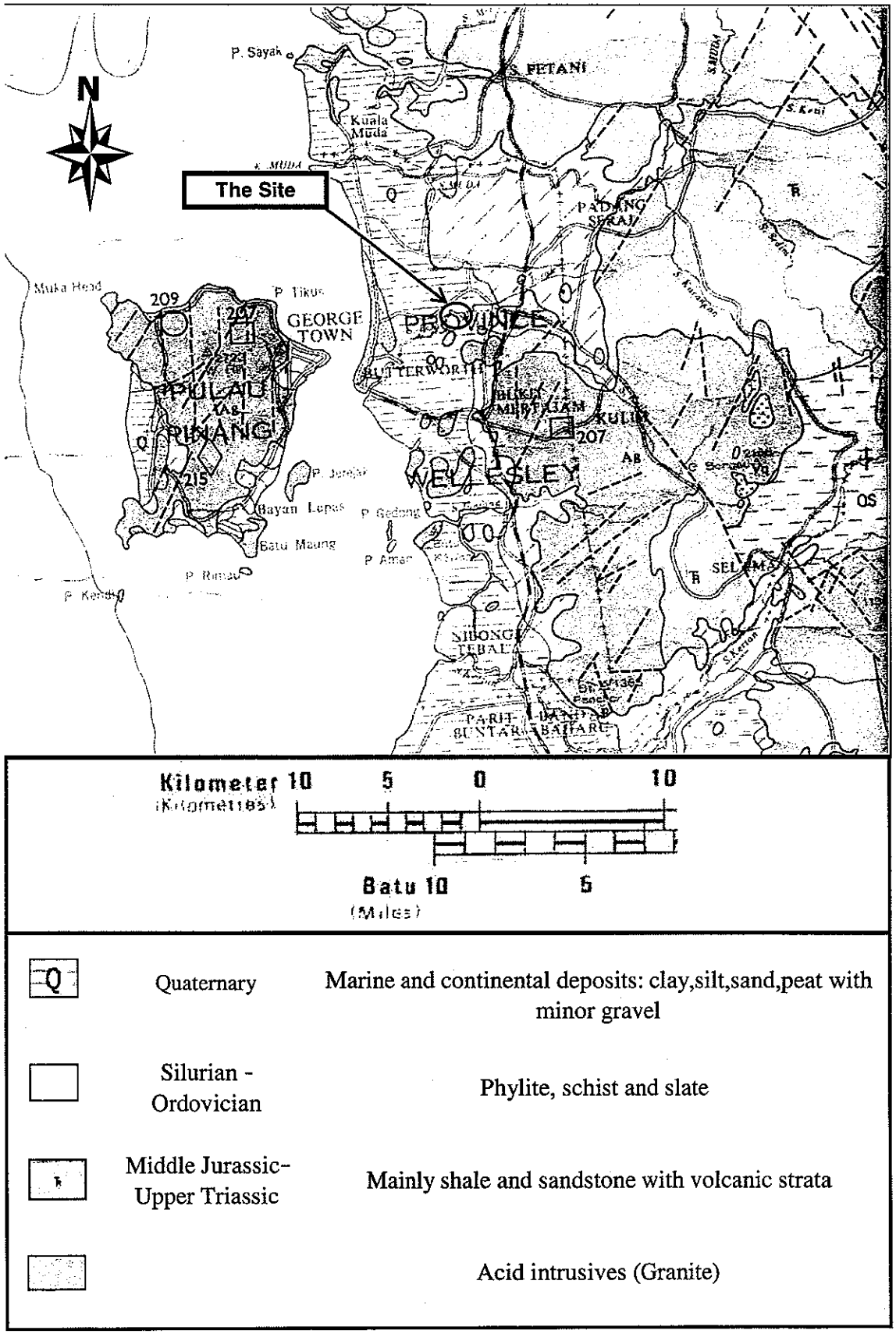


Figure 6.4.5 Map of Geological Setting, Ampang Jajar (reproduced from geological map published by Geological Survey Malaysia, 1985)

Table 6.4.6 Summary of Results - Physical Parameters

Samples taken on		*29/8/03*						
Test Parameters	Units	W1 10:10hrs	W2 11:30hrs	W3 12:45hrs	L1 11:50hrs	L2 11:15hrs	SW1 09:15hrs	SW2 09:45hrs
pH (*in-situ*)	-	7.1	6.9	6.1	7.7	8.1	7.5	7.8
Temperature (*in-situ*)	^{0}C	30.5	30.2	31.3	32.5	31.4	27.9	28.2
ORP	mV	-145	-108	-79	62	86	116	75
Conductivity	mS/cm	22.9	20.1	20.3	59.3	37.3	22.3	38.5
Turbidity	NTU	108	126	500	63.3	130	25.9	43.4
DO	mg/l	1.07	1.18	1.48	0.29	0.16	1.61	2.40
BOD_5 at 20^{0}C	mg/l	14	4	3	52	48	14	17
COD	mg/l	71	63	64	450	374	93	189
Total suspended solid	mg/l	22	56	343	23	94	26	28
Samples taken on		*04/2/04*						
Test Parameters	Units	W1 09:05hrs	W2 10:15hrs	W3 11:30hrs	L1 09:45hrs	L2 11:10hrs	SW1 08:35hrs	SW2 10:05hrs
pH	-	7.8	7.0	6.6	8.8	8.6	6.7	7.4
Temperature	°C	29	28	28	29	28	26	28
ORP	mV	-336	-215	-154	-32	-94	240	50
Conductivity	mS/cm	6.42	19.1	20.3	14.5	10.1	7.12	1.82
Turbidity	NTU	7.73	13.7	3.94	24.6	46.6	13.7	24.3
DO	mg/l	0.89	0.92	0.76	0.41	1.54	4.79	2.30
BOD_5	mg/l	29	6	7	77	68	12	16
COD	mg/l	40	86	72	1705	670	60	94
Suspended Solids	mg/l	3	10	15	23	42	14	18
Samples taken on		*21/5/04*						
Test Parameters	Units	W1 15:30hrs	W2 14:45hrs	W3 13:45hrs	L1 16:45hrs	L2 14:10hrs	SW1 07:45hrs	SW2 08:35hrs
pH	-	7.5	6.8	6.3	8.0	8.0	7.2	7.4
Temperature	°C	31	30	30	33	31	27	27
ORP	mV	-255	-128	-89	-32	-49	-32	17
Conductivity	mS/cm	28.7	21.5	20.2	7.7	10.7	4.84	4.19
Turbidity	NTU	1.37	1.90	144	91.1	24.6	11.1	18.2
DO	mg/l	0.4	0.98	3.4	3.34	0.5	3.30	2.52
BOD_5	mg/l	3	5	7	100	187	10	4
COD	mg/l	123	110	93	1190	2460	70	64
Suspended Solids	mg/l	60	46	134	107	26	2	6
Samples taken on		*04/2/04*						
Test Parameters	Units	W1 16:00hrs	W2 16:20hrs	W3 15:00hrs	L1 17:10hrs	L2 16:40hrs	SW1 18:20hrs	SW2 18:45hrs
pH	-	7.0	6.7	6.4	8.0	8.0	6.8	6.9
Temperature	°C	30	30	30	35	35	30	32
ORP	mV	-154	-142	-101	44	-32	-51	24
Conductivity	mS/cm	25.6	19.4	18.0	4.5	3.9	2.3	1.3
Turbidity	NTU	3.41	2.97	12.6	43.4	33.4	40.3	62.7
DO	mg/l	0.64	0.87	0.69	2.39	1.51	2.04	1.11
BOD_5	mg/l	6	6	3	66	46	15	17
COD	mg/l	114	89	67	447	484	74	80
Suspended Solids	mg/l	14	24	84	20	12	13	22

Table 6.4.7 Summary of Results - Landfill Gases

Samples taken on		*25/8/03*	
Test Parameters	Units	AJ-G1 12:35hrs	AJ-G2 12:40hrs
Methane (CH_4)	%	67.8 (*1)	30.9
Carbon Dioxide (CO_2)	%	39.2 (*2)	17.7
Oxygen (O_2)	%	Not Detectable	11.7
Nitrogen (N_2)	%	Not Detectable	40.6
Hydrogen Sulphide (H_2S)	ppm	50	3
Carbon Monoxide (CO)	ppm	42	11

Note: *1 *2 = Reason for why the sum of the percentage of all the parameters exceed 100 may be due to the anomalies in the results and measurement error.

Samples taken on		*04/2/04*	
Test Parameters	Units	AJ-G1 11:55hrs	AJ-G2 12:15hrs
Methane (CH_4)	%	54.5	18.1
Carbon Dioxide (CO_2)	%	36.2	11.4
Oxygen (O_2)	%	2.27	13.2
Nitrogen (N_2)	%	5.03	54.6
Hydrogen Sulphide (H_2S)	ppm	22	1
Carbon Monoxide (CO)	ppm	28	12.7
Samples taken on		*21/5/04*	
Test Parameters	Units	AJ-G1 16:00hrs	AJ-G2 16:20hrs
Methane (CH_4)	%	61.2	35.1
Carbon Dioxide (CO_2)	%	38.7	21.5
Oxygen (O_2)	%	1.3	8.4
Nitrogen (N_2)	%	4.4	34.9
Hydrogen Sulphide (H_2S)	ppm	29	1.0
Carbon Monoxide (CO)	ppm	35.7	16.7
Samples taken on		*01/7/04(24/8/2004)*	
Test Parameters	Units	AJ-G1 17:30hrs	AJ-G2 17:40hrs
Methane (CH_4)	%	6.0(16.7)	3.4(41.1)
Carbon Dioxide (CO_2)	%	2.1(7.1)	1.1(25.1)
Oxygen (O_2)	%	16.6(13.8)	17.3(6.8)
Nitrogen (N_2)	%	75.2(62.2)	78.2(26.0)
Hydrogen Sulphide (H_2S)	ppm	12	Not detectable
Carbon Monoxide (CO)	ppm	7.0	7.5

Note: Landfill gas in AJ-G1 and G2 were re-tested again in August 24, 2004 because of significant change in measured gas composition in July 1, 2004.

6.4.6 Considerations

(1) Consideration - Baseline

The monitoring data taken in August 2003 represent the baseline data.

1) Groundwater Quality

The monitoring wells were installed to a depth below the near surface layer of the marine clay layer of over 5m thick. In principle, the 5m thick marine clay layer provides a good barrier as clay has very low permeability. The contamination of the groundwater

at the site should minimal. However, based on the analysis results, the water quality at the 3 monitoring well were rather poor. For instance, points W1, W2 and W3 all showed fairly high conductivity and turbidity. The COD value exceeded 50mg/l and iron and manganese concentration also exceeded the benchmark value for groundwater quality set by DOE. Furthermore, the ammonia concentrations are over 10mg/l. Generally, these results indicated that the groundwater is not suitable for consumption. How the contaminant pass through the thick layer of clay is not clear at this moment. Probably there were breakings of clay layer in some part of the land filled area. In spite of the long distance between the monitoring wells, water quality of the three wells is somewhat similar range. It indicates that contamination of groundwater is not taking place in small spot but in wide area around the landfill sites.

2) Groundwater Flow

The groundwater levels measured during the sampling exercise are shown in **Table 6.4.8**.

Table 6.4.8 Groundwater Levels at Ampang Jajar PP Site

Monitoring Well	Elevation (MSL m)	Groundwater level from the top of the well (m)	Groundwater level (MSL m)
AJ-W1	2.37	1.63	0.74
AJ-W2	2.06	1.51	0 55
AJ-W3	2.09	2.01	0 08
AJ-G1	18.22	11 5	6 72

With the groundwater levels, the contour map for the groundwater was generated and shown in **Figure 6.4.6**. The general direction of the groundwater flow can be deduced by considering its flow perpendicular to the contour lines, from the higher elevation to the lower elevation. Thus, from the contour map, the groundwater flow was deduced to be from the north to the south and similar to the direction of flow of the nearby river. However, it should be noted that leachate flows from the landfill layers to into surrounding area in all directions. The leachate may have infiltrated into the groundwater at AJ-W1 even though its location is in upstream of groundwater flow.

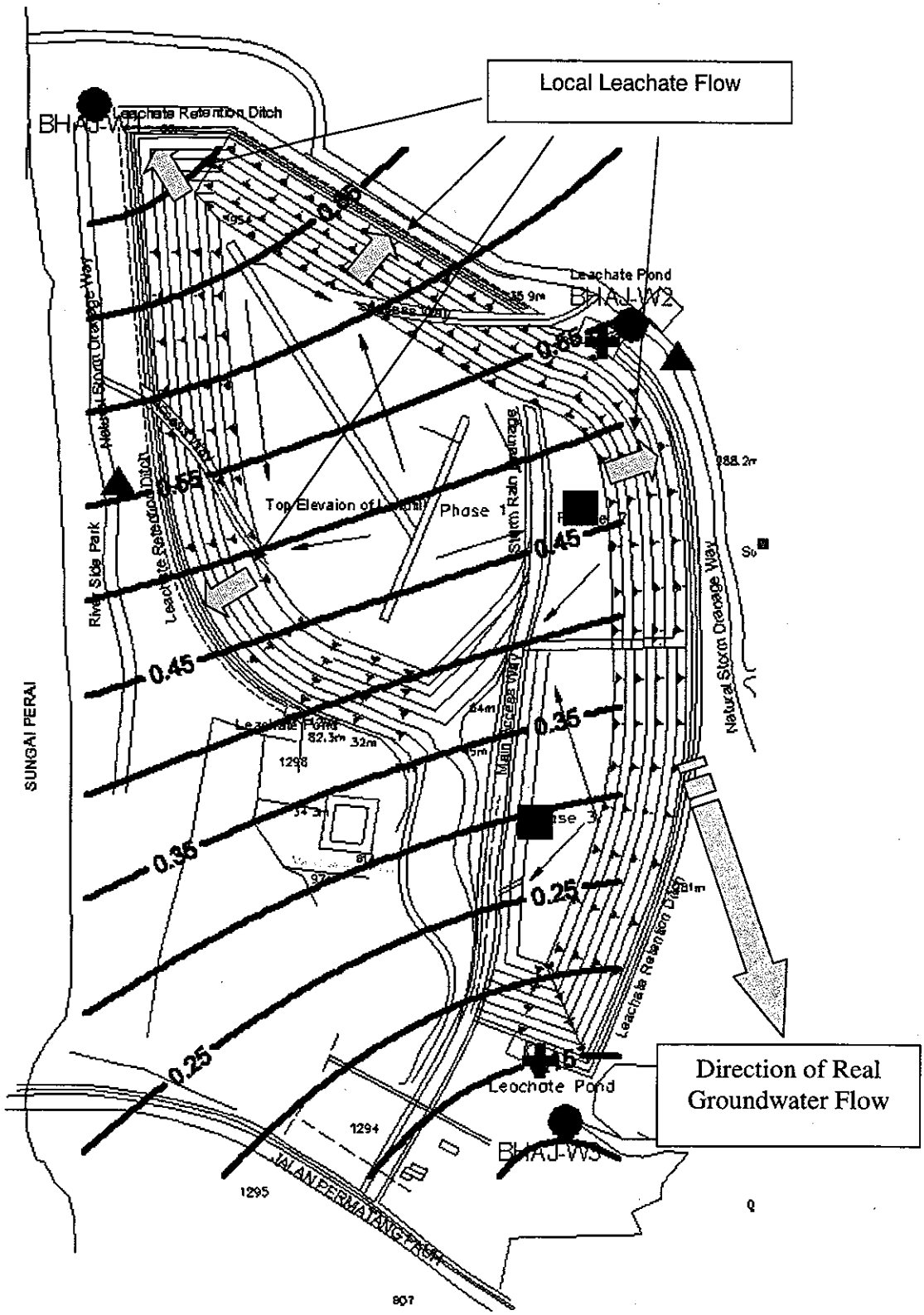


Figure 6.4.6 Groundwater Level Contour Map - Ampang Jajar PP

3) Leachate and Surface water quality

Inline with the EQA effluent quality standards, the results for the water quality are shown in **Table 6.4.9**. Since there is no water intake point downstream of the Ampang Jajar site the Standard B limits were applied.

Table 6.4.9 Leachate and Water Quality

	Standard B	L1	L2	SW1	SW2
BOD_5 at 20° C	50	***52***	48	14	17
COD	100	***450***	***374***	93	***189***
Boron	4.0	***4.0***	1.5	0.6	1.1
Iron	5.0	***6.19***	1.34	2.25	***7.62***

From the above table above, it shows that for sampling point L1 the results exceeded the Standards. Generally, it was noticed that the COD of the samples tend exceed the prescribed limit.

4) Landfill gas

The results for AJ-G1 gas sampling show a high Methane (CH_4) concentration of over 65%. No oxygen and nitrogen were detected. As for AJ-G2, the results show lower Methane concentration of just over 30% with 18% CO_2 18%. The oxygen and nitrogen were detected at 1:4 ratio thus indicating they may be due to atmospheric air contribution.

(2) *Considerations - After the PP improvements*

As evaluation of the PP improvement will be discussed in the later section (Chapter 6-9), brief result of environmental monitoring is discussed for three aspects, i.e., environmental impact, safety and stabilization process.

1) Environmental impact

For surface water and leachate, their water quality were compared with effluent standard B. As noted in **Table 6.4.9**, four parameters, i.e., BOD_5, COD, Boron and Iron exceeds in some points during baseline sampling before PP improvement. **Table 6.4.10** summarises the result of monitoring for those parameters exceeding the effluent standard B. Though leachate samples often exceeded the standard for various parameters, surface water samples did not except Iron and Manganese for SW" in June 2004 sampling. It is noted that high arsenic were found at leachate L1 samples at February and May, 2004 sampling. Arsenic in leachate requires special attention for future monitoring.

In legally speaking, the leachate at the site, which exceed standard in various parameters, should not be discharged without treatment. However from the scientific view point, considering the large volume flow of the Perai River, and the fact that there is no water intake point around, environmental impact by the inflow of those surface water SW1 and SW2 may not be serious.

Table 6.4.10 Monitoring Value Exceeding Effluent Standard B

	Sampling point	BOD_5 (mg/l)	COD (mg/l)	Boron (mg/l)	Iron (mg/l)	Manganese (mg/l)	Arsenic (mg/l)
Effluent standard B		50	100	5.0	5.0	1.0	0.1
Feb/04	L1	***77***	***1705***	***5.6***	***6.03***	0.1	***0.61***
	L2	***68***	***670***	3.5	4.34	0.07	<0.05
	SW1	12	60	0.7	0.18	0.27	<0.05
	SW2	16	94	0.5	1.28	0.19	<0.05
May/04	L1	***100***	***1190***	4.7	2.91	0.07	***0.64***
	L2	***187***	***2460***	***6.9***	7	0.1	<0.05
	SW1	10	70	0.7	0.61	0.45	<0.05
	SW2	4	64	0.7	0.69	0.2	<0.05
June/04	L1	***66***	***447***	2.6	1.26	0.33	<0.05
	L2	***46***	***484***	1.7	0.79	0.26	***0.06***
	SW1	15	74	0.5	***5.89***	***1.79***	<0.05
	SW2	17	80	0.3	3.76	0.38	<0.05

Groundwater quality of the monitored samples was not suitable for drinking purpose. As the flow of groundwater is to southern direction, it is recommended to make additional monitoring well at the down gradient (south direction). According to the baseline survey, hydraulic gradient of the area is approx. 1/1,000 and permeability ranged between 6.4 x 10^{-6} to 5.8 x 10^{-5} m/sec. Assuming effective porosity at 10%, approx. velocity of groundwater flow will be 2.0-20 m/year. The velocity estimated is not significant. However this is preliminary estimate by limited data. Any use of groundwater at the southern direction of the site within approx. 500m shall be strictly supervised to avoid any health effect.

2) Safety

For landfill gas, methane has been generated at the concentration over 5% at the wells. Any use of fire around such methane generation should be controlled.

Slope improvement at the PP site reduced the risk of collapse at the south-eastern side of the site. However, other areas of the site still have risk of slope collapse. Caution is required for the work under the slope as well as the top.

3) Stabilization process

The leachate composition showed relatively lower BOD_5 value than COD. This implies the progress of organic degradation within the landfill site. On the other hand, landfill gas composition indicated active aerobic and anaerobic degradation of organic matter inside the landfill. As long as high concentration of methane and CO_2 were observed, stabilization can not be reached.

6.4.7 Continuous Operations & Maintenance and Monitoring

(1) Operation and maintenance of landfill facilities

All the facilities provided and installed at the landfill site, such as the final cover, leachate collection and treatment systems, gas ventilation systems, surface drainage etc, should be operated and maintained properly, up until the closed landfill site has stabilised.

It is highly recommended that the Local Authority or the operator of the site should carry out the regular inspection and maintenance work at the site, and to ensure that the facilities are in good working conditions. The types of work required are as follows;

a. Leachate collection and treatment facilities

The proper operation and maintenance of the leachate collection and treatment facilities is essential for the treatment of the leachate prior to discharging the effluent into the drains. The equipments such as the aerators, pumps and filtration system must be maintained and serviced regularly and should be in good working conditions. Filter media should be replaced where necessary.

b. Gas ventilation pipes

The gas ventilation pipes act as the gas vents and also air supply pipes to supply oxygen to the waste layers and accelerate the waste degradation process. The gas ventilation pipes should be maintained over the long term and new ventilation pipes be installed where necessary.

c. Top cover

For the PP, only the top cover at the slopes and steps were provided. Some subsidence and erosion of the slopes may occur over a period of time. Nevertheless it is necessary to maintain the top cover for the entire site to prevent the percolation of rainwater into the waste layers and to protect the landfill site.

d. Surface drainage

The surface drainage system should be inspected and maintained regularly, and cleared of any debris and blockages. Drains may also be damages as a result of uneven ground settlements. In such cases, all damaged section should be maintained or replaced.

e. Other supporting facilities

Other supporting facilities like the access road and the vegetation growth on the top/slopes should be maintained where necessary for a long period of time.

The typical example of the maintenance items of the landfill facilities, method and scale/frequency are shown in **Table 6.4.11**.

Table 6.4.11 Summary of Maintenance Items

Facilities	Items	Methods	Scale/ Frequency
Top cover & dykes	Cracks, pools and soil erosion on the surface, State of plants	Periodic visual inspections	The entire site, weekly
Surface drainage on the top cover	Clogging by soil/leaves, Damage by sedimentation	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Cut-off drainage around the site	Clogging by soil/leaves, Damage by traffic	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Gas ventilation pipes	Clogging, damage to pipes, corrosion	Periodical visual inspections	all pipes, weekly
Leachate collection pipes	Clogging, damage to pipes, corrosion	Periodical inspections & comparison of the effluent quantity data	daily

Leachate treatment facility	Quality of treated effluent	Daily inspections (colour of effluent) Periodical effluent analysis	daily monitoring frequency
Monitoring facility	Conditions of the monitoring wells	Periodical inspections	all wells, weekly

In accordance with the Guideline, for the Post Closure Management for Ampang Jajar, the following monitoring programme has been recommended, as shown in **Table 6.4.12**.

Table 6.4.12 Monitoring Programme

Monitoring media/parameters	Item and parameters	Frequency	Location
Leachate	• pH • BOD • COD • Nitrogen (Ammonia, Nitrate, Nitrite) • ORP • EC • TOC	4 times / year	1 point/ leachate pond
Landfill gas	• Oxygen (O_2) • Nitrogen (N_2) • Methane (CH_4) • Carbon Dioxide (CO_2) • Hydrogen Sulfide • Temperature	2 times/ year	2 points/ site
Land subsidence	Topographic height of the top of the landfill	Once a year	1 point/ landfill block
Groundwater	Groundwater benchmark parameters	Once a year	3 points/ site
Surface water	Effluent standard parameters	Once a year	2 points/ stream

The site specific recommendations are as follows.

1) Leachate

For the Pilot Project, only 2 samples from the 2 leachate ponds were monitored. As there are four leachate ponds at the site, it is recommended that samples should be taken at all the four ponds. Also it is recommended to analyze for the presence of Arsenic, as several high concentration levels were observed during the Pilot Project.

2) Landfill gas

Continuous monitoring of the gas composition is recommended.

3) Land subsidence

Under the Pilot Project, settlement plates to determine the rate of land subsidence were provided. The level of the settlement plates should be measured once a year as the good indicator of the stabilisation process.

4) Groundwater

All the groundwater samples exhibited deteriorating water quality that is not suitable for human consumption. It is recommended to that additional monitoring well be provided at the south direction, at about 200-300 m south of well W3.

5) Surface water

Surface water should be monitored regularly in accordance to the guideline.

6.5 PILOT PROJECT - PEKAN NENASI LANDFILL SITE (PAHANG)

6.5.1 Outline of the Site

(1) General

The Pekan Nenasi landfill site is situated on a wetland, south of Pekan Town and by the side of the East-Coast trunk road. The plan of the site is shown in **Figure 6.7.1**.

The landfill started operations in 1988 and was operated by Majlis Daerah Pekan. At present, the landfill is operated and managed by Alam Flora Sdn Bhd, under an interim concession agreement prior to the privatisation of the Solid Waste Management services. About 30 tonnes of waste per day is disposed at the site.

The site consists of two parts; i.e. the eastern front part nearest to the truck road and the western inner part, separated by the stream. The front part is about 2.8 ha and the back part is about 19 ha. Adjacent to the site is the 1.5 ha sewage sludge disposal site belonging to the sewerage services company, Indah Water Konsortium Sdn Bhd. Since April 2003, with the closure of the eastern front part, the waste is now being disposed at the new cells at the western back part.

In 2002, with the financial subsidy from MHLG, the Majlis Daerah Pekan with the assistance of Alam Flora Sdn Bhd carried out some upgrading work at the site to include the preparation of the western part, installation of the weighbridge, construction of the office building, and the vehicle maintenance workshop and yard. In 2003, further upgrading of the access road was carried out including the installation of the perimeter fence to prevent stray animals from entering the site. By the end of 2003, additional subsidy from MHLG provided for the installation of the leachate collection system in line with the JICA PP at the western part, on the second cell, and the provision of final cover for the eastern front part that was closed.

The brief description of the landfill operations and site characteristics are summarised in **Table 6.5.1**.

Table 6.5.1 Pekan Nenasi Landfill Operations and Site Characteristics

Operational Characteristics	Site Characteristics
⇒ Started operations in 1988 ⇒ About 30 tonnes of waste are disposed at the landfill daily ⇒ In 2002, upgrading work was carried out to provide the control building and workshop, weighbridge station and opening of the Phase I at the western part ⇒ The site expected to be used for a long period phased expansion	⇒ Located south of Pekan town, by the side of the east coast trunk road ⇒ Located on a wetland area ⇒ The site occupied an area of about 22ha

6.5.2 Development plan and closure plan

(1) Development plan of the western part

The landfill is situated on a wetland that is not suitable and not recommended for use as a landfill site. Careful consideration and countermeasures, especially on the drainage and leachate collection aspects are required to prevent excessive environmental pollution and damage. However, from the soil investigation, it was discovered that there are thick marine clay layers under the site and possesses low permeability and hence groundwater contamination may be minimal. Nevertheless, continuous monitoring should be carried out. The summary of the conceptual development plan for the western part of Pekan Nenasi Landfill site is shown in **Table 6.5.2**.

Table 6.5.2 Conceptual Development Plan for the Western Part of Pekan Nenasi Landfill Site

Items	Plan
Basic policy	• The site should be used for a long time • The eastern front part has been closed • The western back part is to be used for landfill disposal in phases, cell by cell • The target level is set at level 3
Waste quantity	The amount of waste disposed at the site is about 30 tonnes/day (11,000 ton/year). This amount will increase annually due to population growth,
Available capacity	The maximum available capacity of the entire site depends on the final height and/or depth of the waste. Assuming the final height of the waste is 10m, the estimated available capacity should be about 666,000 m^3. On the estimation based on the availability of land, the site should be able to be in operations for more than 40 years.
Final shape/profile of the landfill	The present ground level is about 3 m and the final height should be about 10 m. The slope should be less than 1:3 gradient (33 %). First waste layer3.0 m Intermediate cover 0.5 m Second waste layer 3.0 m Intermediate cover 0.5 m Final cover / barrier layer 0.6 m Top soil 0.3 m (Settlement approximately 10% of waste layer) Total 7.3 m
Landfill level	Targeted to Level 3, semi-aerobic landfill site with leachate re-circulation
Leachate management	Leachate should be collected and treated before discharge. The target for BOD will be less than 50 mg/l (Standard B)

	Leachate collection system, leachate aeration pond, re-circulation system, should be provided.
Landfill gas management	Vertical gas ventilation pipes connecting to the leachate collection pipes should be provided. Horizontal gas collection and ventilation system will have to be provided for the final stages of the landfill.
Surfacewater drainage	A ditch should be provided around the site and The surface water drainage system should also be provided and discharge to the ditch.
Control l facility	*Weighbridge, control room, perimeter fencing and gate*
Monitoring facility	Groundwater monitoring well, gas monitoring well, etc.
Others	Access road
Ultimate land use	Proposed to develop into a park or left as an open space

a) Rehabilitation of Cell I of Phase I landfill site

The Phase I of the landfill site shall be upgraded to a semi-aerobic, Level 3, landfill site with leachate re-circulation system. As the surrounding bund has already been constructed, the rehabilitation works will include the construction of the leachate collection system, gas discharge pipes, leachate aeration pond and monitoring facilities. The summary of the PP works are as follows;

- Planned height : Elevation 10 m (2 waste layers)
- Area : 0.9 ha
- Landfill structure : Semi-aerobic landfill site

6.5.3 Pekan Nenasi Pilot Project Implementation

Subsequent to the PP tender and evaluation exercise, the Pekan Nenasi Pilot Project was eventually awarded to the successful contracting company, S.S. Selenggara Padu, and the Design and Build Contract was signed on August 13th, 2003.

Following the commencement of the project, as part of the deliverables, the contractor prepared and submitted the project implementation schedule as shown in **Figure 6.5.1**.

The detailed design was completed and approved by the Study Team within one month from the project commencement date. Samples of the design drawings are shown in **Figure 6.5.2** and **Figure 6.5.3**. The final As-built drawings are provided Volume 4, Chapter 8. The photographs records of the progress of the work and the main facilities are shown in **Plate 6.5.1** and **Plate 6.5.2** respectively.

The brief description and Bill-of-Quantities (BQ) of the Pilot Project is summarised in **Table 6.5.3**.

Figure 6.5.1 Project Implementation Schedule for Pekan Nenasi PP

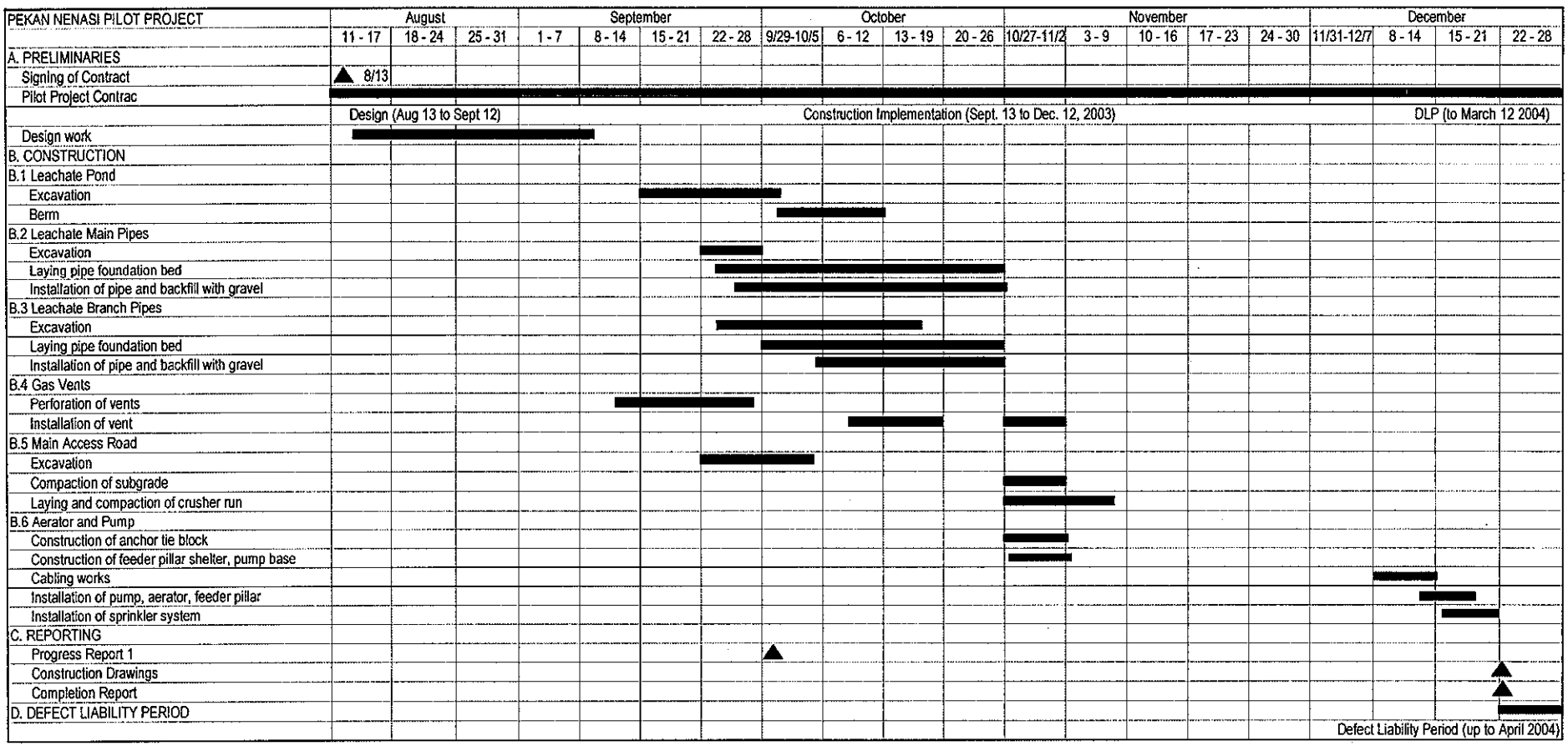


Table 6.5.3 Pekan Nenasi PP Description

No.	Item/Description	Quantity
1	Leachate Collection System	
	Excavation of solid waste *Excavation of the solid waste in the existing operation area in order to install the leachate collection system. The excavated waste was placed in the adjacent active cell.*	500m^3
	Main leachate collection pipe (dia. = 450mm) installed in two lines *Non-perforated spun concrete pipe, Class H, of nominal diameter 450mm laid under the berm and road, with a length of 12m x 2 lines. Perforated spun concrete pipe, Class H of nominal diameter 450mm including placing of gravel around the pipe and preparation of pipe bed with crusher-run of 200mm, over wooden sleeper/wedge of length 30m x 2 lines.*	84m
	Branch leachate collection pipe (dia. = 225mm) installed in 4 lines *Supply and install perforated spun concrete pipe of nominal diameter 225mm with minimum slope of 1:200 and total length of 290m. Pipes laid on compacted crusher run and surrounded by gravel.*	331m
2	Gas venting system	
	Vertical gas venting pipe *Supply and install 4 gas collection pipes, uPVC class D, diameter 160mm with a height of 2.5m. Installation at square pits of brick walls of outer dimensions of 1.65 x 1.65m and clear height of 0.9m. These pits also serve intersection points between the main and branch pipes.*	4 units
3	Leachate pond	
	Excavation for leachate pond *Leachate pond dimensions are 100m length x 10m bottom width x 2m depth and the pond is excavated at the location of the present pond so only part of the required excavation volume of 2,600m^3 is required.*	1,400m^3
	Earth berm along the leachate pond (h = 1.0m, L = 145m) *Supply impermeable clayey soil to form 1m high berm from the existing ground level, with slope of 1:2 and 1m width at the top. Top level of the berm is 3.20m from the ground level.*	145m
	Access road embankment (t = 200mm) between dike and leachate pond *Levelling, subgrade and fill the soil material with average thickness of 200mm crusher run. Access road constructed on existing berm with a minimum width of 3m.*	2,250m^2
	Crusher-run pavement for access road *Supply, level and compact the crusher run with a thickness of 300mm.*	180m^3
	Aerator (7.5 kw) *Supply and installation of low speed surface aerator, vertically mounted geared motor, with electrical accessories and wiring of 300m extensions. Aerator installed at approximately centre point of the pond length.*	1 set
	Re-circulation pump (5 kw) *Supply and installation of suction pump with discharge outlet of diameter 80mm including all accessories and wiring of 300m extensions. Pump is installed near the access road between the waste disposal operations area and the pond. Rubber hoses are connected from the pump to 4 sprinklers installed at the top of each gas vent.*	1 set

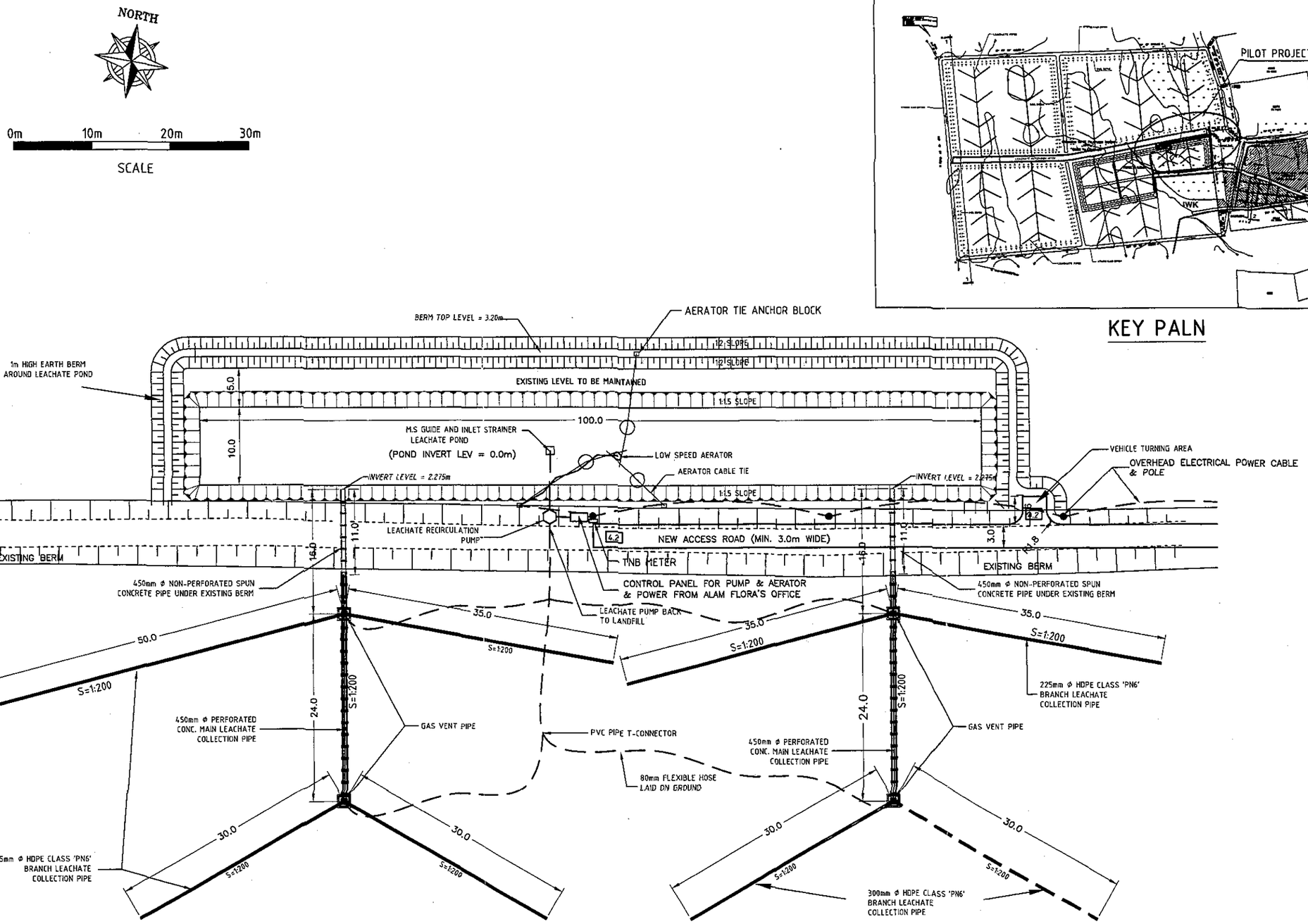
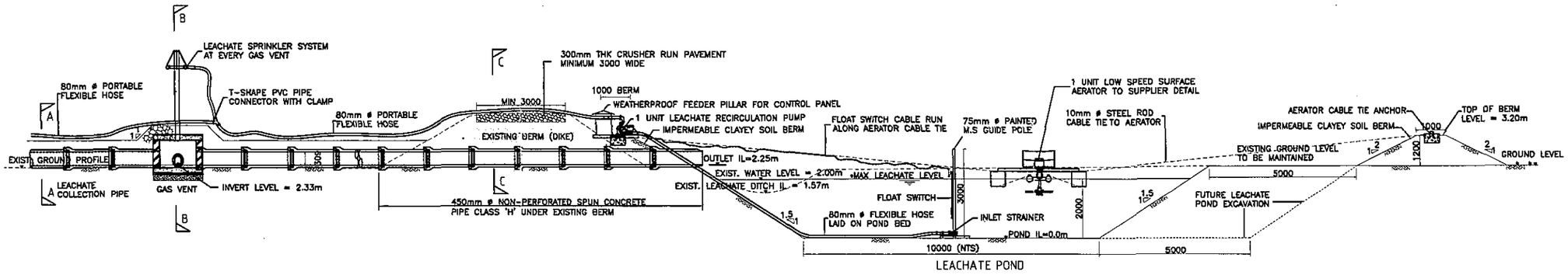
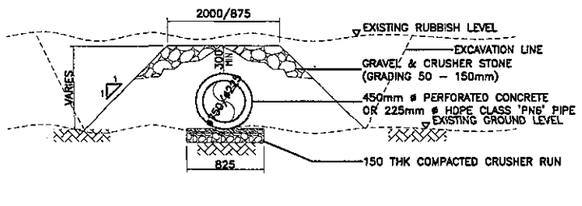


Figure 6.5.2 Layout Plan (Pekan Nenasi Pilot Project)



LEACHATE COLLECTION PIPE LONG-SECTION

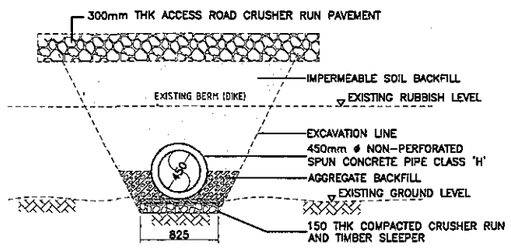
100 250 500
SCALE (mm)



SECTION A-A

PIPE ABOVE EXIST. GROUND LEVEL

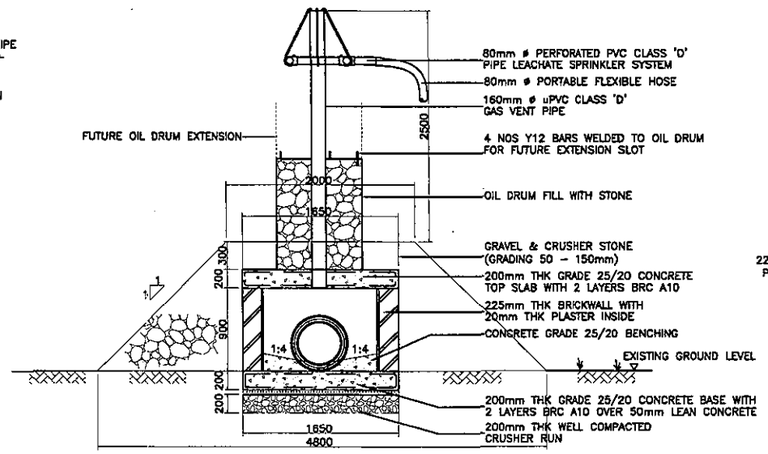
100 500 1000
SCALE (mm)



SECTION C-C

PIPE BELOW ACCESS ROAD & BERM

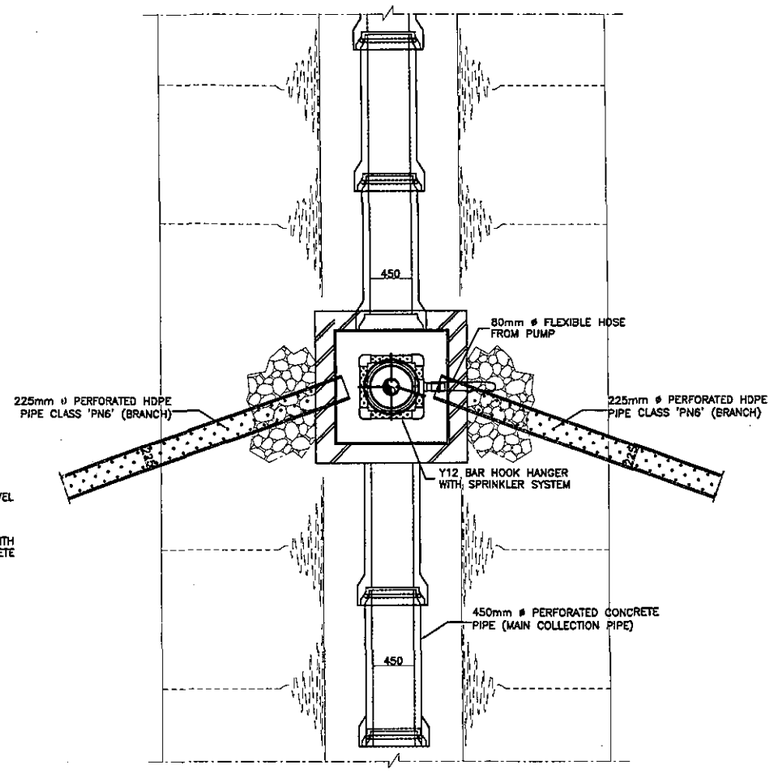
100 500 1000
SCALE (mm)



SECTION B-B

GAS VENT SYSTEM

100 500 1000
SCALE (mm)



GAS VENT PLAN

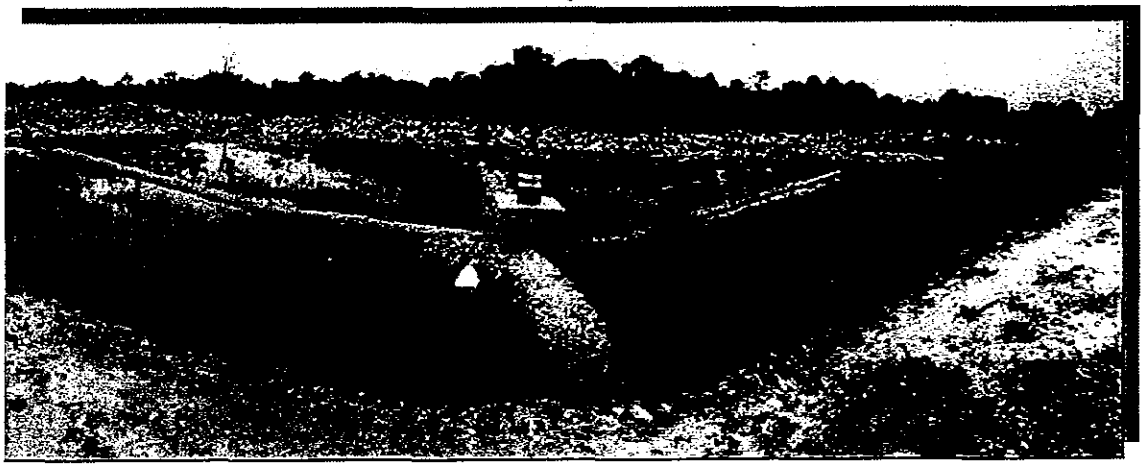
100 500 1000
SCALE (mm)

Figure 6.5.3 Typical Sections (Pekan Nenasi Pilot Project)

Plate 6.5.1 Pekan Nenasi Pilot Project 1

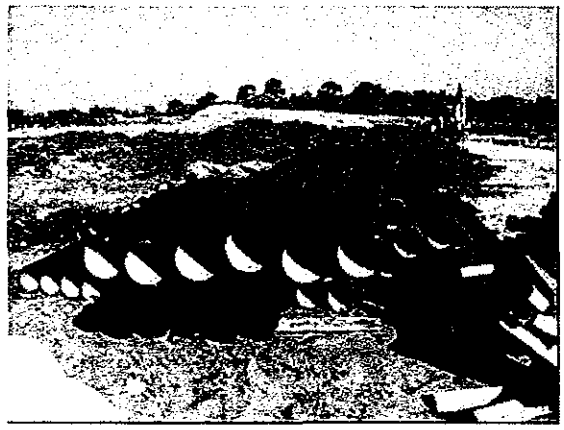
Before pilot project (PP)

During PP



After PP
(Installation of leachate pipe & gas vent)

Plate 6.5.2 Pekan Nenasi Pilot Project 2



Leachate collection pipe
(Brunch pipe)

Leachate collection pipe
(Main Pipe)

Aerator

Leachate collection & gas venting System Installed by the LA
(After pilot project works)

6.5.4 Environmental Monitoring – Pekan Nenasi PP

(1) Monitoring programme

1) Sampling Quantity, Schedule and Locations

The following **Table 6.5.4** summarizes the sampling quantity of monitoring for Pekan Nenasi pilot project site.

Table 6.5.4 Sample Number at Pekan Nenasi Pilot Project Site

Sample type	Pekan Nenasi (Number of locations)
Surface water	2
Leachate	1
Groundwater	3
Gas	2

Sampling schedule and specific consideration is same as that applied for Ampang Jajar site. **Figure 6.5.4** shows the location of monitoring for each sample type.

2) Geological setting and Installation of monitoring well

The site is an active landfill, which is located along the coastal area. The site is relatively flat with the present ground level varies from RL+3.2m to RL+4.2m.

(2) Geological Background

The site is located in an area of Quaternary Deposits. The Quaternary Deposits are also found prominently along the coastal area. The Quaternary Deposits comprise of beach sand, high and low terrace deposits, laterite, gravel, sand, silt and clay. The orientation of the soil profile is indicated in **Figure 6.5.5**.

(3) Laboratory analysis

The results of the laboratory analysis for both the sampling exercise are shown in and **Table 6.5.6**.

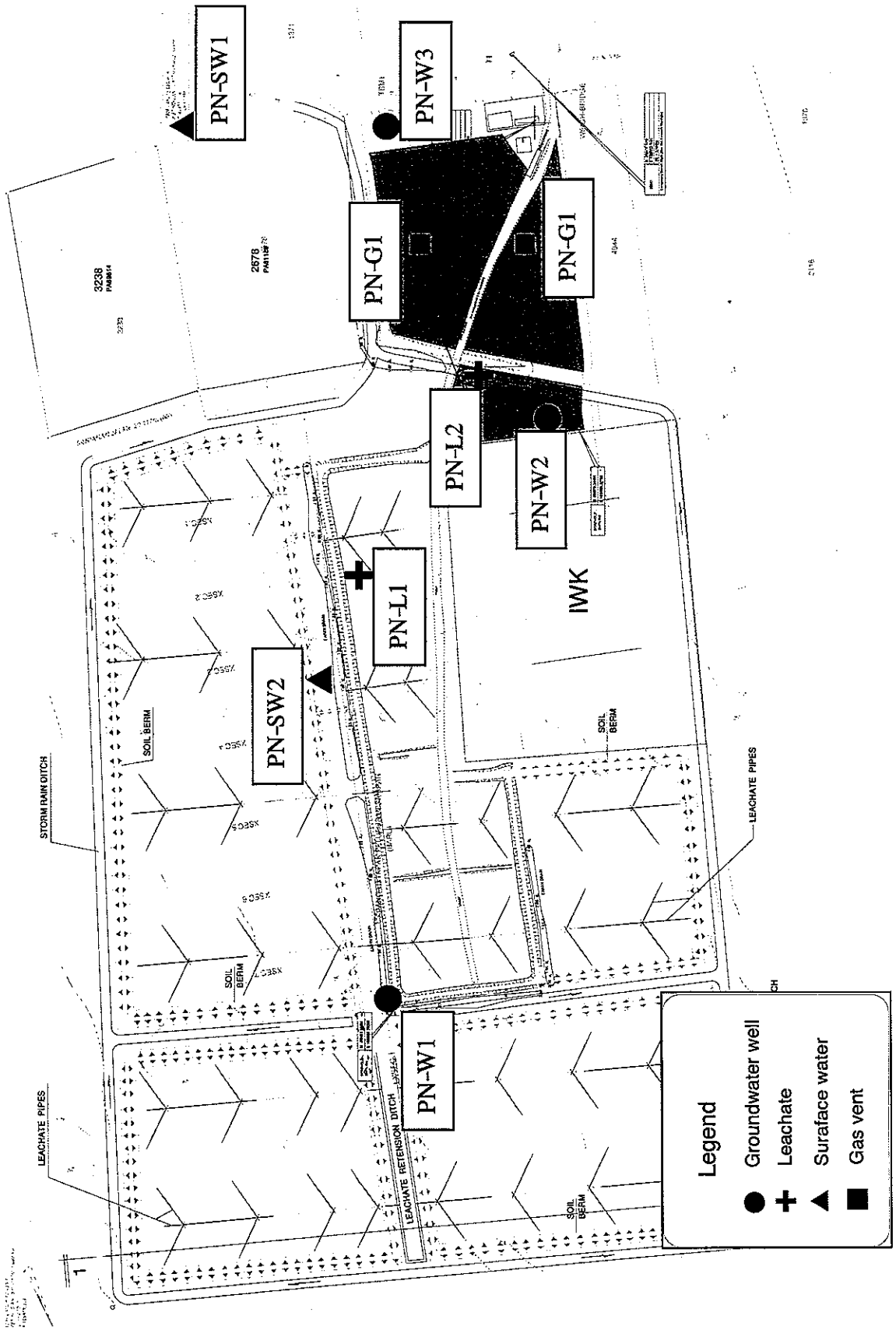


Figure 6.5.4 Sampling Location for Monitoring, Pekan Nenasi

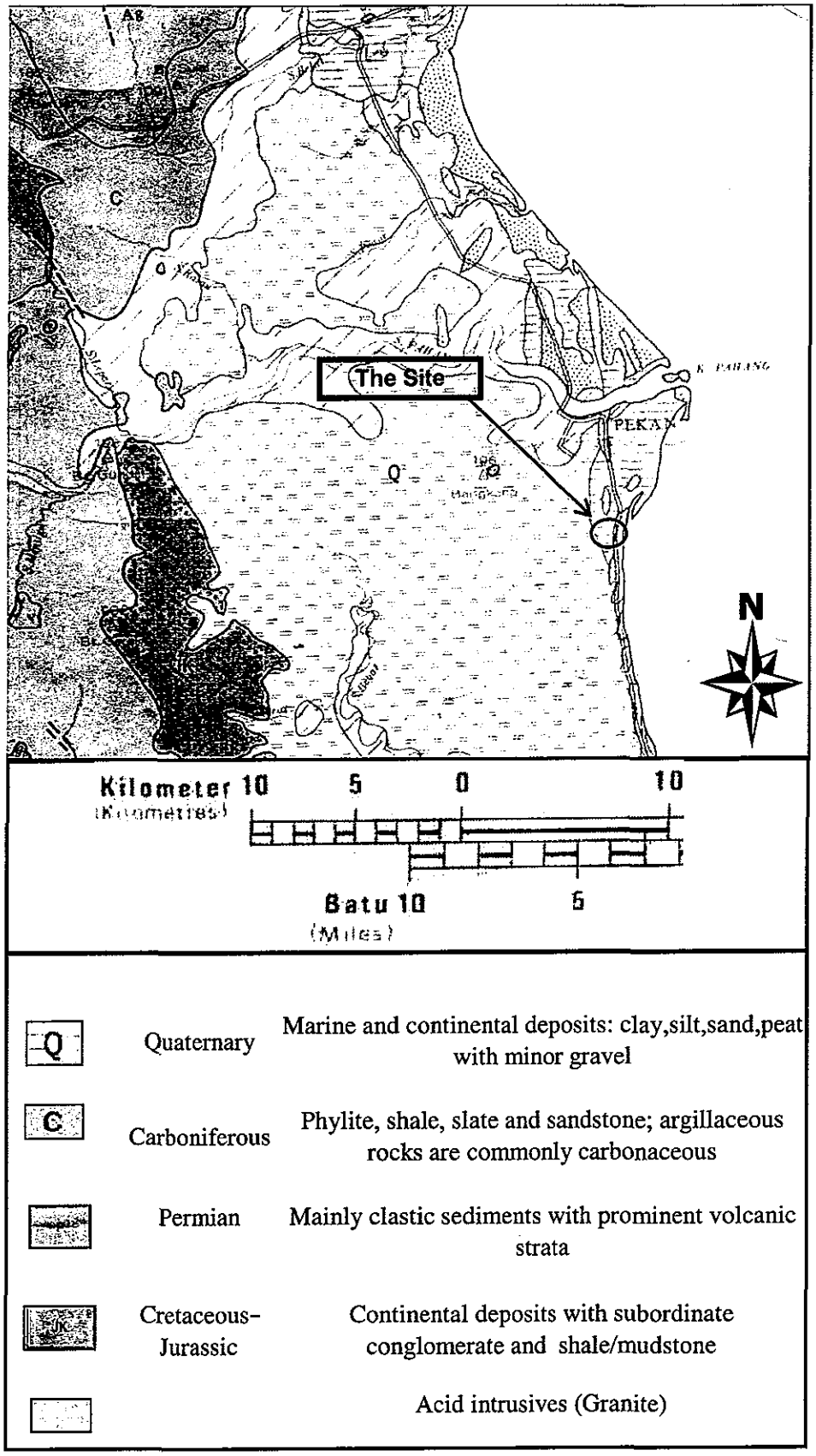


Figure 6.5.5 Map of Geological Setting Pekan Nenasi (reproduced from geological map published by Geological Survey Malaysia, 1985)

Table 6.5.5 Summary of Results - Physical Parameters

Samples taken on		*10/10/03*		*27/8/03*			
Test Parameters	Units	W1 11:30hrs	W3 12:15hrs	W2 13:00hrs	L1 11:45hrs	SW1 15:00hrs	SW2 11:15hrs
pH (*in-situ*)	-	6.9	7.0	6.4	7.4	7.3	4.1
Temperature (*in-situ*)	^{0}C	30	30	32	34	29	32
ORP	mV	-45	-132	-113	56	41	353
Conductivity	mS/cm	1.41	3.95	1.16	4.35	0.236	0.348
Turbidity	NTU	18.4	27.6	60.8	56.1	13.8	6.28
DO	mg/l	4.6	4.7	1.31	0.3	1.05	2.81
BOD_5 at 20^{0}C	mg/l	4	21	25	47	5	1
COD	mg/l	28	38	86	653	87	17
Total suspended solid	mg/l	24	15	146	35	6	7
Samples taken on		*08/02/04*					
Test Parameters	Units	W1 10:30hrs	W2 13:00hrs	W3 12:30hrs	L1 11:30hrs	SW1 13:30hrs	SW2 11:00hrs
pH	-	6.8	6.0	7.1	7.8	6.2	6.0
Temperature	°C	28	30	30	28	30	27
ORP	mV	-301	-74	-162	-58	53	-132
Conductivity	mS/cm	4.45	1.26	3.65	1.20	0.082	0.281
Turbidity	NTU	7.89	7.59	7.00	32.3	26.6	18.3
DO	mg/l	1.35	1.62	0.75	2.50	0.85	4.48
BOD_5	mg/l	22	6	12	90	4	1
COD	mg/l	105	79	75	161	38	15
Suspended Solids	mg/l	4	11	1	52	25	8
Samples taken on		*20/05/04*					
Test Parameters	Units	W1 09:45hrs	W2 13:30hrs	W3 12:55hrs	L1 11:00hrs	SW1 11:20hrs	SW2 10:30hrs
pH	-	6.9	6.4	6.4	7.5	7.4	3.7
Temperature	°C	29	31	30	31	30	31
ORP	mV	-217	-118	-173	106	378	279
Conductivity	MS/cm	6.95	1.70	4.06	1.13	3.52	1.09
Turbidity	NTU	46.6	4.50	3.85	56.40	14.7	3.04
DO	mg/l	0.64	1.70	0.96	3.00	1.99	6.16
BOD_5	mg/l	29	31	46	24	5	2
COD	mg/l	96	56	109	159	20	10
Suspended Solids	mg/l	12	4	11	47	10	1
Samples taken on		*30/06/04*					
Test Parameters	Units	W1 13:20hrs	W2 12:25hrs	W3 10:55hrs	L1 09:40hrs	SW1 12:10hrs	SW2 9:20hrs
pH	-	7.0	6.0	6.9	7.2	5.8	3.6
Temperature	°C	30	31	29	30	28	29
ORP	mV	-85	-93	-176	55	-15	364
Conductivity	MS/cm	6.43	1.37	3.26	1.6	0.1	0.52
Turbidity	NTU	41.7	5.67	6.13	125	19.4	5.73
DO	mg/l	1.91	1.13	1.04	2.68	2.49	3.89
BOD_5	mg/l	30	12	15	85	9	1
COD	mg/l	125	74	95	340	66	7
Suspended Solids	mg/l	36	2	9	62	20	2

Table 6.5.6 Summary of results - landfill gases

Samples taken on		*27/8/03*	
Test Parameters	Units	PN-G1 13:45hrs	PN-G2 14:00hrs
Methane (CH_4)	%	0.2	0.2
Carbon Dioxide (CO_2)	%	<0.03	<0.03
Oxygen (O_2)	%	21.5	21.4
Nitrogen (N_2)	%	78.4	78.5
Hydrogen Sulphide (H_2S)	ppm	Not Detectable	Not Detectable
Carbon Monoxide (CO)	ppm	4.0	2.0
Samples taken on		*08/02/04*	
Test Parameters	Units	PN-G1 12:15hrs	PN-G2 12:00hrs
Methane (CH_4)	%	0.06	0.2
Carbon Dioxide (CO_2)	%	<0.03	2.9
Oxygen (O_2)	%	20.5	17.8
Nitrogen (N_2)	%	79.4	79.2
Hydrogen Sulphide (H_2S)	ppm	Not Detectable	Not Detectable
Carbon Monoxide (CO)	ppm	2.3	2.7
Samples taken on		*20/05/04*	
Test Parameters	Units	PN-G1 14:20hrs	PN-G2 14:00hrs
Methane (CH_4)	%	0.5	0.4
Carbon Dioxide (CO_2)	%	1.4	<0.03
Oxygen (O_2)	%	16.8	18.3
Nitrogen (N_2)	%	81.0	81.3
Hydrogen Sulphide (H_2S)	ppm	Not Detectable	Not Detectable
Carbon Monoxide (CO)	ppm	4.0	1.5
Samples taken on		*30/06/04*	
Test Parameters	Units	PN-G1 11:35hrs	PN-G2 11:45hrs
Methane (CH_4)	%	0.6	0.7
Carbon Dioxide (CO_2)	%	1.1	<0.03
Oxygen (O_2)	%	16.6	17.2
Nitrogen (N_2)	%	81.7	82.0
Hydrogen Sulphide (H_2S)	ppm	Not Detectable	Not Detectable
Carbon Monoxide (CO)	ppm	3.3	4.0

6.5.5 Considerations

(1) Consideration - Baseline

The monitoring data taken in August 2003 represent the baseline data.

1) Groundwater quality

The monitoring wells PN-W1 and PN-W3 were installed to the depth below the soft clay layer of over 5-10m thick. The depth of PN-W2 was set at the sand layer near the surface. The results roughly indicated that the iron and manganese values exceeded the permitted benchmarked limits. Generally, iron and manganese are present in the groundwater from the dissociation of iron and manganese hydroxide in the soil and thus their detection may be insignificant and may not be due to the influence of the landfill

contaminant. However, the results also show relatively high levels of ammonia and electric conductivity that are caused by contamination. The contamination may have originated from the landfilled waste and may have also come from the adjacent sewage sludge disposal site. The sampling point PN-W1 that is the furthest from the landfilled area of the site showed the least contamination.

2) Groundwater Flow

The groundwater levels measured during the sampling exercise are shown in **Table 6.5.7**.

Table 6.5.7 Groundwater Levels at Pekan Nenasi PP Site

Monitoring Well	Elevation (MSL m)	Groundwater level from the top of the well (m)	Groundwater level (MSL m)
PN-W1	4.2	2.04	2.16
PN-W2	3.2	1.3	1.9
PN-W3	3.3	1.77	1.53

With the groundwater levels, the contour map for groundwater was generated and shown in **Figure 6.5.6**. The general direction of the groundwater flow can be deduced by considering its flow as perpendicular to the contour line. Thus, from the contour map, the groundwater flow was deduced to flow from the west to the east. The relatively equally spaced contour lines indicate the homogeneous permeability of the aquifer and this may imply that the aquifer crossing the monitoring wells may be interconnected despite their difference in the depths.

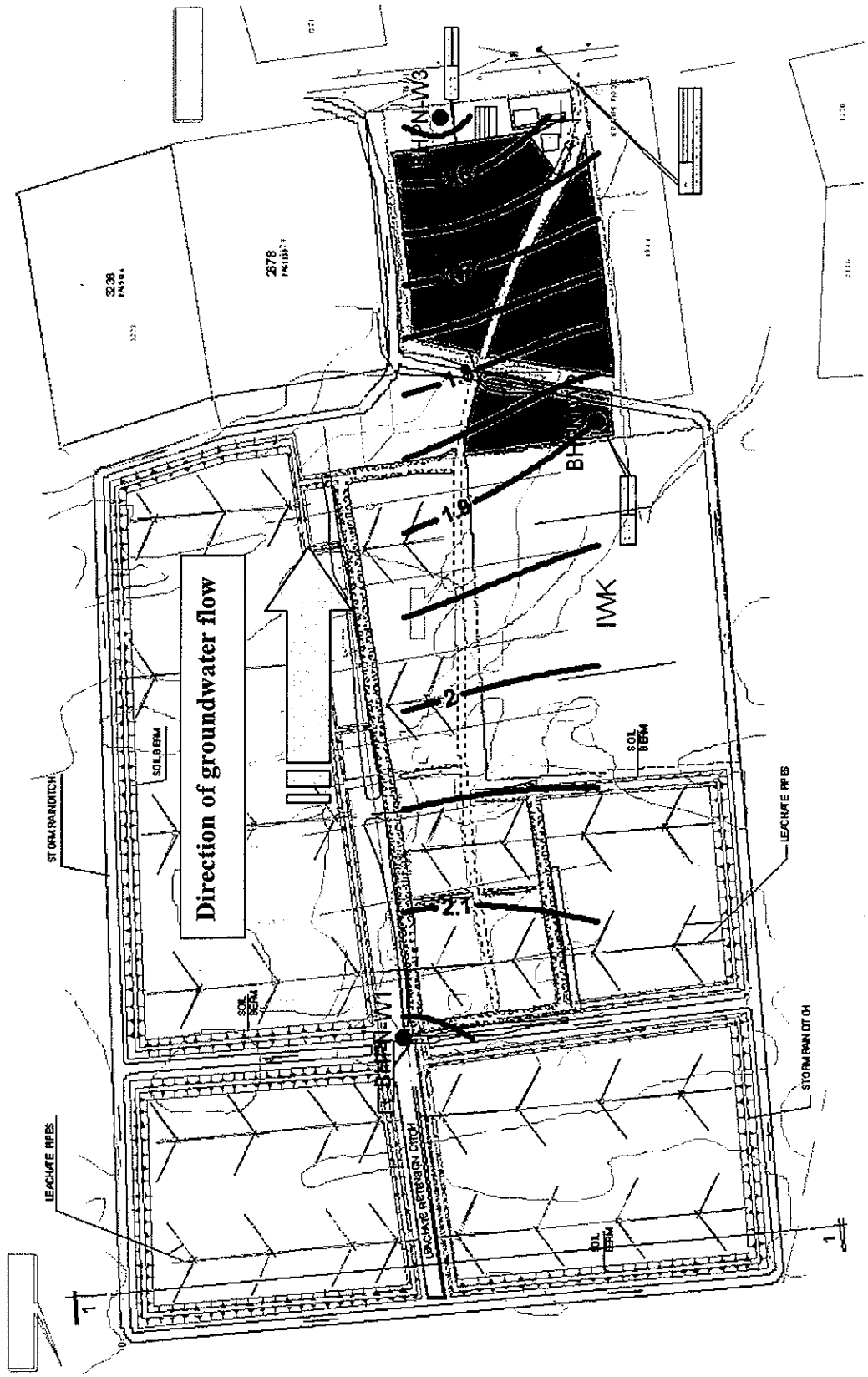


Figure 6.5.6 Groundwater Level Contour Map - Pekan Nenasi PP

3) Leachate and Surface water quality

Similarly, with the Ampang Jajar PP, the Pekan Nenasi Landfill site is situated downstream of water intake points and hence the EQA effluent quality Standard B is applied. The results for the water quality parameters are shown in **Table 6.5.8**.

Table 6.5.8 Leachate and Water Quality

	Standard B	L1	SW1	SW2
BOD_5 at 20° C	50	47	5	1
COD	100	***653***	87	17

From the above table, it shows that the result for COD for PN-L1 exceeded the permitted standard limits. The results for the other monitoring points were within the limits of Standard B. Surface water around site is within the standard B though they are vulnerable for contamination because of stagnation.

4) Landfill gas

The Pekan Nenasi site is relatively new and the waste layer at the closed site is fairly thin, thus there is no significant landfill gas detected at the gas vents.

(2) Considerations after the PP improvements

As evaluation of the PP improvement will be discussed in the later section (Chapter 6-9), brief result of environmental monitoring is discussed for three aspects, i.e., environmental impact, safety and stabilisation process.

1) Environmental impact

For surface water and leachate, their water quality were compared with effluent standard B. As noted in **Table 6.5.8**, BOD_5, COD in L1 point exceeded the effluent standard B during baseline sampling before PP improvement. **Table 6.5.9** summarises the result of monitoring for those parameters exceeding the effluent standard B.

Leachate L1 exceeded the BOD_5 and COD in most cases, surface water SW1 and SW2 were well below the standard. As the site is flat, flow of the surface water is almost negligible, and leachate outflow is minimum. Environmental impact by high BOD_5 and COD to the surrounding area is not serious. On the other hand high Iron and Manganese were observed in surface water. As leachate sample showed low concentration for Iron and Manganes, these high value for surface water might be come from other sources, most likely naturally from soil.

Table 6.5.9 Monitoring Value Exceeding Effluent Standard B

	Sampling point	BOD_5 (mg/l)	COD (mg/l)	Iron (mg/l)	Manganese (mg/l)
Effluent standard B		50	100	5.0	1.0
Feb/04	L1	***90***	***161***	0.32	0.2
	SW1	4	38	2.75	0.09
	SW2	1	15	0.78	0.19

May/04	L1	24	***159***	0.84	0.18
	SW1	5	20	***5.16***	0.59
	SW2	2	10	0.28	***1.1***
June/04	L1	***85***	***340***	1.29	0.31
	SW1	9	66	***7.02***	0.13
	SW2	1	7	0.5	***1.16***

Groundwater quality of the monitored samples was not suitable for drinking purpose, mainly because of high ammonia over 10mg/l. Also high Iron and Manganese were observed. The flow of groundwater estimated to eastern direction. According to the baseline survey, hydraulic gradient of the area is approx. 1/1,000 and permeability ranged between 1.5 x 10^{-4} to 1.7 x 10^{-4} m/sec. Assuming effective porosity at 10%, approx. velocity of groundwater flow will be 50 m/year. This is preliminary estimate by limited data. Any use of groundwater at the eastern direction of the site within approx. 500 m shall be strictly supervised to avoid any health effect.

2) Safety

For landfill gas, the thickness of the waste is not much to generate landfill gas.

Risk of slope collapse is not concern for the site.

3) Stabilisation process

As the landfill is just started as noted above, it is premature to discuss about the stabilization process.

6.5.6 Continuous Operations & Maintenance and Monitoring

(1) Operation and maintenance of landfill facilities

All the facilities provided and installed at the landfill site, such as the leachate collection and treatment systems, leachate pond and gas ventilation systems should be operated and maintained properly throughout the entire life of the landfill and including the post closure period.

It is highly recommended that the Local Authority or the operator of the site should carry out the regular inspection and maintenance work at the site, and to ensure that the facilities are in good working conditions. The types of work required are as follows;

a. Leachate collection and treatment facilities

The proper operation and maintenance of the leachate collection and treatment facilities is essential for the treatment of the leachate prior to discharging the effluent into the drains. The equipments such as the aerator and the recirculation pump must be maintained and serviced regularly and should be in good working conditions. The control panel should be inspected regularly and maintained.

b. Gas ventilation pipes

The gas ventilation pipes act as the gas vents and also air supply pipes to supply oxygen to the waste layers and accelerate the waste degradation process. The gas ventilation pipes should be maintained over the long term and new ventilation pipes be installed where necessary.

c. Top cover

Since the Pekan Nenasi landfill site is still in operations, top cover is not necessary however, intermediate soil cover should be provided and compacted for the active cells. Nevertheless, for the closed section of the site, i.e. in the eastern front area, the top cover should be inspected regularly and any cracks on the surface should be repaired where necessary.

d. Surface drainage

Surface drains were not included in the PP but however the existing surface drainage system and stream should be inspected and maintained regularly, and cleared of any debris and blockages. Since the area is on a low lying swamp land, it is crucial to ensure that the surface water or floor water does not flow into the landfill cells, and should be diverted to the main discharge drains.

e. Other supporting facilities

Other supporting facilities like the access road, bund walls and power supply pylons and cables should be maintained where necessary for a long period of time.

The typical example of the maintenance items of the landfill facilities, method and scale/frequency are shown in **Table 6.5.10**.

Table 6.5.10 Summary of Maintenance Items

Facilities	Items	Methods	Scale/ Frequency
Top cover & dykes	Cracks, pools and soil erosion on the surface, State of plants	Periodic visual inspections	The entire site, weekly
Surface drainage on the top cover	Clogging by soil/leaves, Damage by sedimentation	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Cut-off drainage around the site	Clogging by soil/leaves, Damage by traffic	Periodical visual inspections	The entire site, weekly (more frequent during the rain season)
Gas ventilation pipes	Clogging, damage to pipes, corrosion	Periodical visual inspections	all pipes, weekly
Leachate collection pipes	Clogging, damage to pipes, corrosion	Periodical inspections & comparison of the effluent quantity data	daily
Leachate treatment facility	Quality of treated effluent	Daily inspections (colour of effluent) Periodical effluent analysis	daily monitoring frequency
Monitoring facility	Conditions of the monitoring wells	Periodical inspections	all wells, weekly