1 INTRODUCTION

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1.1 Background to Pilot Test

In December 1997, Maunsell Environmental Management Consultants Ltd (MEMCL, formerly CES (Asia) Ltd), acting as environmental sub-consultants to Maunsell Consultants Asia Ltd (MCAL), (MEMCL and MCAL hereafter referred to as "the Consultants") were appointed by Territory Development Department (TDD) to prepare a detailed design for the remediation of soil/groundwater contaminated with hydrocarbon at the Kai Tak International Airport (KTA). Early remediation of the site is critical to allow redevelopment of the KTA site in line with the South East Kowloon Development Statement (SEKDS) which indicates that the north apron of the Kai Tak Airport will be primarily developed for housing and housing related uses by 2009.

The remediation design has been founded on a series of site investigations conducted while the airport was still operational[1,2,3]. Although some information has been gathered and exploited in the design, the scope of investigation work completed in April 1998 was constrained by the necessity to maintain uninterrupted airport operations. As a result, the nature and extent of permitted investigation works were restricted to some degree, particularly with respect to more sensitive airport areas (taxiways, aircraft parking bays etc).

In the remedial feasibility studies, the Consultants have evaluated various options for clean up and concluded the soil vapour extraction (SVE) and air sparging (AS) are the most cost-effective methods with the least secondary environmental effects for cleaning up of the Hot Spot area B (near the airport tunnel, refer to Figure 1.2). Due to the time constraint of the redevelopment programme, it was decided that the fastest route to clean up the site was to conduct a detailed design using limited site data and experience from similar sites and to invite tenders for the decontamination works (Contract No. KL 31/98 South East Kowloon Development at Kai Tak Airport Decontamination and Site Preparation). The tender was invited in July 1998 and awarded in October 1998. As a requirement of the Environmental Impact Assessment Ordinance (EIAO), an EIA Report was prepared in parallel specifically for this project[4]. The EIA report was approved in August 1998 with conditions attached to the Environmental Permit. One of the conditions is to verify the feasibility of the proposed decontamination technology (SVE and AS) by pilot tests.

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[1] MCAL (in association with CES) (July 1997) *Technical Report No. RA16 Kai Tak Airport Contamination Assessment Phase 1 - Final Report.*

[2] MCAL (in association with CES) (Jan 1998) *Technical Report No. RA24 Kai Tak Airport Contamination Assessment Phase 2 - Final Report.*

[3] MCAL (in association with CES) (Sept 1998) *Decontamination and Site Preparation at Kai Tak Airport Design and Site Investigation Phases: Further Site Investigation Report.*

[4] MCAL (in association with CES) (June 1998) *Kai Tak Airport North Apron Decommissioning Environmental Impact assessment Report (amended version).*

The objectives of the present pilot test were therefore to study the effectiveness of the recommended technology under the site conditions of KTA, and to gather additional data for the detailed design. The Consultants recognised that for a site of this extensive area (>12 hectare (1.2×10^5 m^2) of contaminated area), some heterogeneity is bound to occur. In the EIA report, a 'fall back plan' was proposed to address any area showing undesirable response of the SVE/AS system using an excavation and biopile method. Therefore if the pilot test identifies potential difficulties, the present design can be modified at an early stage or another means of remediation can be selected.

The EIA Report proposes the following aspects to be evaluated:

1) the Radius of Influence (ROI)
2) the Volatile Organic Chemicals (VOC) removal rate to achieve clean up
3) the potential lateral migration of free product
4) the existence of preferential pathways
5) the presence of microbial degradation

It should be pointed out that some of the above criteria should ideally be based on tests lasting for months. Due to the tight schedule and the need to run pilot test in various locations, however, only a maximum of 5 days were allowed for each test. It was decided that while the data obtained in this manner necessitate more subjective judgement and prediction, overall it is more cost-effective to dedicate more time to operational phase of the actual system, which can be optimised during the commissioning phase.

The present pilot test investigated the effects of SVE/AS technology only and therefore only focused on the soil characteristics of Hot Spot B.

In August 1998, the Consultants were appointed by TDD to design, supervise and interpret the results of the pilot test. The Consultants prepared the scope of work for the pilot test. It was reviewed and commented by the Environmental Protection Department (EPD) and Oil Companies Tank Farm (OCTF), the party responsible for the oil supply, storage and distribution pipeline facility. Suggestions were added to the scope and reviewed by the EPD. It was formally approved by EPD in September 1998.

Teemway Engineering Ltd was appointed as the contractor to provide the equipment, conduct the test, and collect data for the pilot test. An international expert[5], who was involved in the main design of the clean up work, reviewed the test scope, visited Hong Kong on two occasions to oversee the work, assisted in data interpretation and recommendation. During the same period, OCTF and their consultants (XDD, EHS) visited the site and gave comments. A demonstration was made to the OCTF's consultants. Data were transferred to OCTF for concurrent review during and after the test periods.

5 Symmes F. of Roy F. Weston Incorporated, New Hampshire, USA.

The preparatory phase (i.e. drilling) of the pilot test commenced on 18 August 1998 and the last test was completed on 26 November 1998. The programme of the work was presented in Figure 1.1.

1.2 Review of Previous Findings

1.2.1 Contamination Hot spots

Three Hot Spots of Total Petroleum Hydrocarbons (TPH) contamination (Figure 1.2) were identified in the previous Phase 2 Kai Tak Airport Contamination Assessment[2]. The contours of TPH level in soil at 1m above and 1m below water table, as delineated in the Phase 2 Contamination Assessment, are shown on Figure 1.3 and Figure 1.4 respectively. The contours show that the highest TPH levels were found near the north-west and south-east parts of the Hot Spot B.

It was also found that the majority of the TPH found existed in the light and medium volatility range. The nature of contaminant, which resembled jet fuel, is amenable to SVE/AS treatment (see Figure 1.5).

Some free product (apparent thickness ~ 1 ft (0.305m)) was found in 3 locations within Hot Spot B, which were in the vicinity of the previous OCTF's jet fuel leak locations.

1.2.2 Laboratory Test of Hydraulic Conductivity of Soil Samples Collected in Hot Spot B

Some residual soil samples from the Phase 2 Contamination Assessment were taken to an accredited laboratory to test for hydraulic conductivity (by constant-head test) in March 1998 to obtain the preliminary information about the feasibility of employing soil vapour extraction (SVE)/air sparging (AS) as the site remediation method.

The test results show that the hydraulic conductivity of the soil samples collected at 1 m above water table in Hot Spot B range from 5.75×10^{-8} to 1.36×10^{-5} ms^{-1}. The range of values of hydraulic conductivity and permeability for a wide range of geological materials is shown on Figure 1.6. It should be noted that in contrast to permeability, which is a function only of the medium, hydraulic conductivity is a function of the medium, the density and viscosity of the fluid[6]. If these geological materials are divided into three broad categories (of high, medium, and low permeability respectively), then the soil samples collected in Hot Spot B (with permeability range from 10^{-3} to 1 darcy) are considered to be of medium permeability.

The sampling locations (relative to Hot Spot B) and the corresponding hydraulic conductivity values are shown on Figure 1.7. The contours of the hydraulic conductivity values (on log-scale) are shown on Figure 1.8.

[6] Freeze, R. A. and Cherry, J. A. (1979) *Groundwater*, p 604. Prentice Hall, New Jersey.

1.2.3 Field-Based Permeability Test Outside of Hot Spot B

A further site investigation was undertaken in April 1998 to obtain information about soil particle size distribution and contaminant characteristics, and preliminary data on soil vapour extraction (SVE) test. The locations that were investigated are shown on Figure 1.9. Due to the Civil Aviation Department's safety requirements, no pilot test could be conducted within Hot Spot B. The results of this site investigation suggested that the hydraulic conductivity of soil formation at Sites S2 (near OCTF) and S3 (near HAECO) are moderately high whereas that at Sites S4, S5 and VP (all near HACTL) are medium; and in the vicinity of the testing location (VP), the Radius of Influence (ROI) of SVE is greater than 20m with extracted air flow rate of 76 cfm to 137 cfm (127.68 m^3h^{-1} to 230.16 m^3h^{-1}) and corresponding vacuum pressure of 14 to 26 inches water column (3.486 x 10^3 to 6.474 x 10^3 Pa).

A table of conversion factors for units of several physical quantities relevant to this report, namely, length, area, volume, flow rate, and pressure, is given in Appendix A for information.

The above results suggested the initial applicability of SVE/ AS on the present site. However, more field-based tests were considered necessary to conclude the feasibility of this technology. A pilot test was then proposed to be conducted in various locations at Hot Spot B in order to gather more information to confirm the design for the full-scale remediation system.

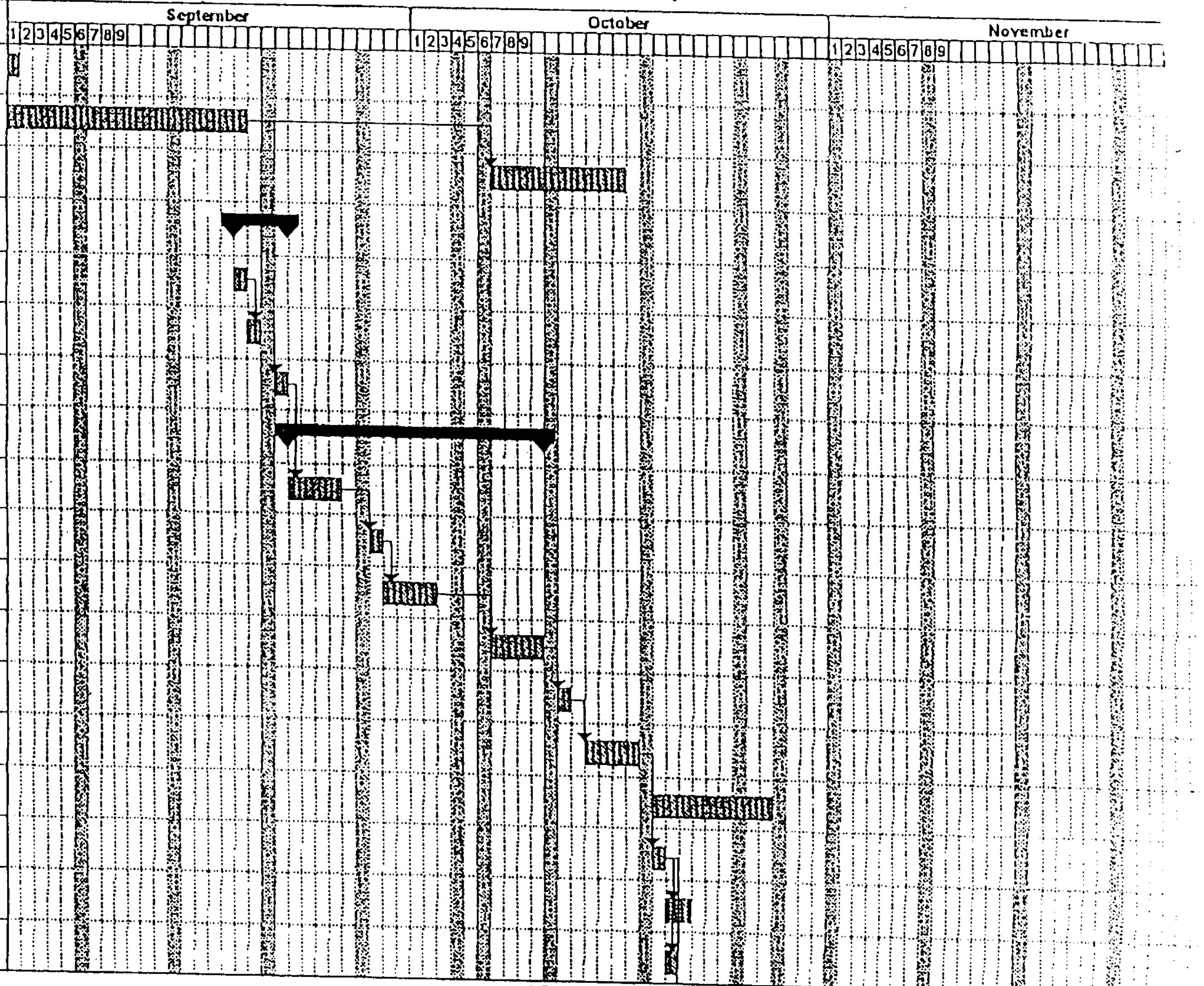
1.3 Design of Pilot Test

The general scope of the pilot test (Appendix B) defines the proposed test points, describes the requirements of utility survey/setting out and the construction of test wells and monitoring points. The equipment and the general procedures (including the measurement schedule) of the pilot test are also covered in the general scope.

Before this scope was agreed by EPD, OCTF had commented on the draft version. MEMCL then replied to EPD regarding the OCTF's comments. Finally, the scope of work was approved by EPD. All correspondence is attached in Appendix C for reference.

Working Programme for SVE & AS Pilot Test at Kai Tak Airport

ID	Task Name	Duration
1	Mobilization & Setting Up	1d
2	Drilling Work & Installation of Pipes	16d
3	Additional Drilling Work & Installation of Pipes at VT4	9d
4	SVE Short-term Test	3d
5	VT1	1d
6	VT2	1d
7	VT4	1d
8	SVE Long-term Test	16d
9	VT4	4d
10	VT1	1d
11	VT2	4d
12	VT1	4d
13	SVE Short-term Test at VT3	1d
14	SVE Long-term Test at VT3	4d
15	OCTF & MEMCL Site Visit (with their own expert)	8d
16	Demonstration of SVE Short-term Test at VT4	1d
17	AS Test at VT4	2d
18	Helium Test at VT4 (1)	1d



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Project : SVE & AS Pilot Test at KTA

Date : 11/12/98

Maunsell

TITLE

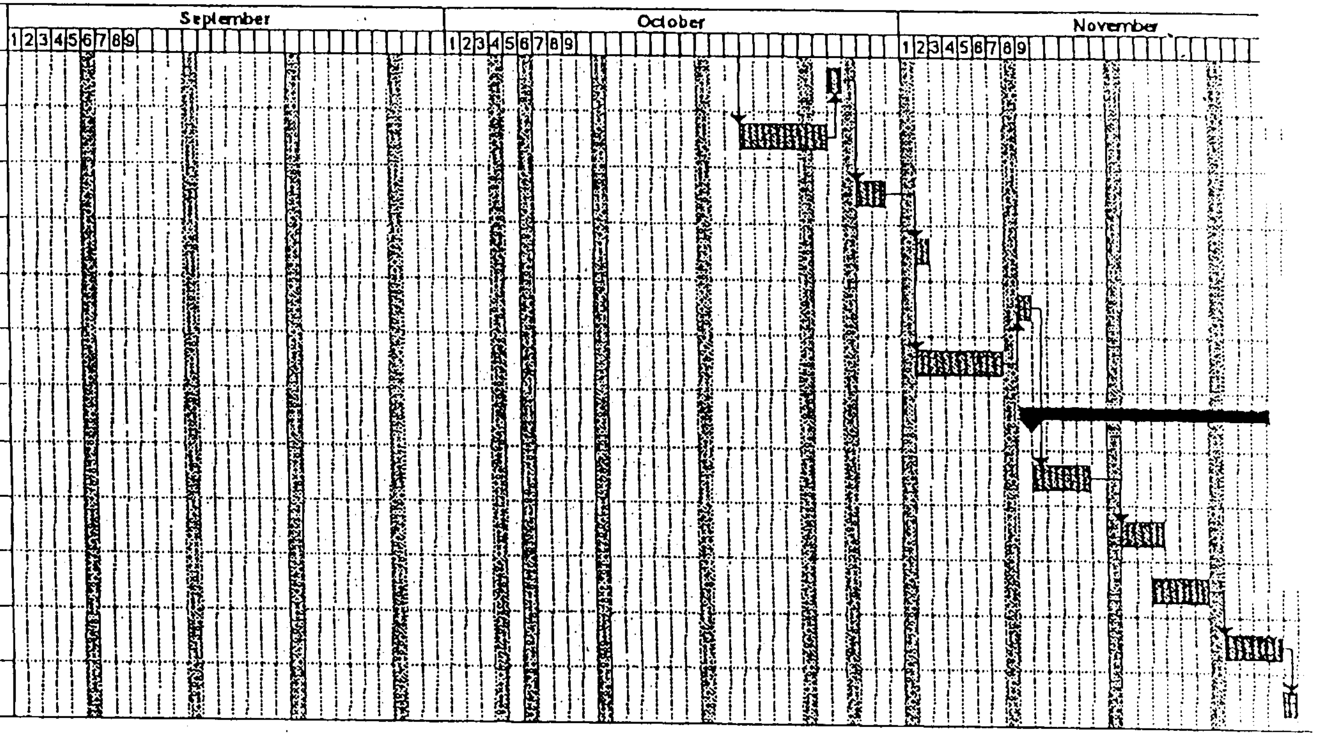
Programme of Pilot Test

MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD

PROJECT NO	C418	FIGURE NO.	Figure 1.1
DESIGNED/ CHECKED	Eric Lai	DATE	Dec 1998

Working Programme for SVE & AS Pilot Test at Kai Tak Airport

ID	Task Name	Duration
19	Helium Test at VT4 (2)	1d
20	SVE/AS Combined Test at VT4	5d
21	AS Test at VT3	2d
22	Helium Test at VT3 (1)	1d
23	Helium Test at VT3 (2)	1d
24	SVE/AS Combined Test at VT3	6d
25	SVE Long-term Re-test	15d
26	VT1	4d
27	VT2	3d
28	VT4	4d
29	VT3	4d
30	Dismantling Work & Handover of Site	1d



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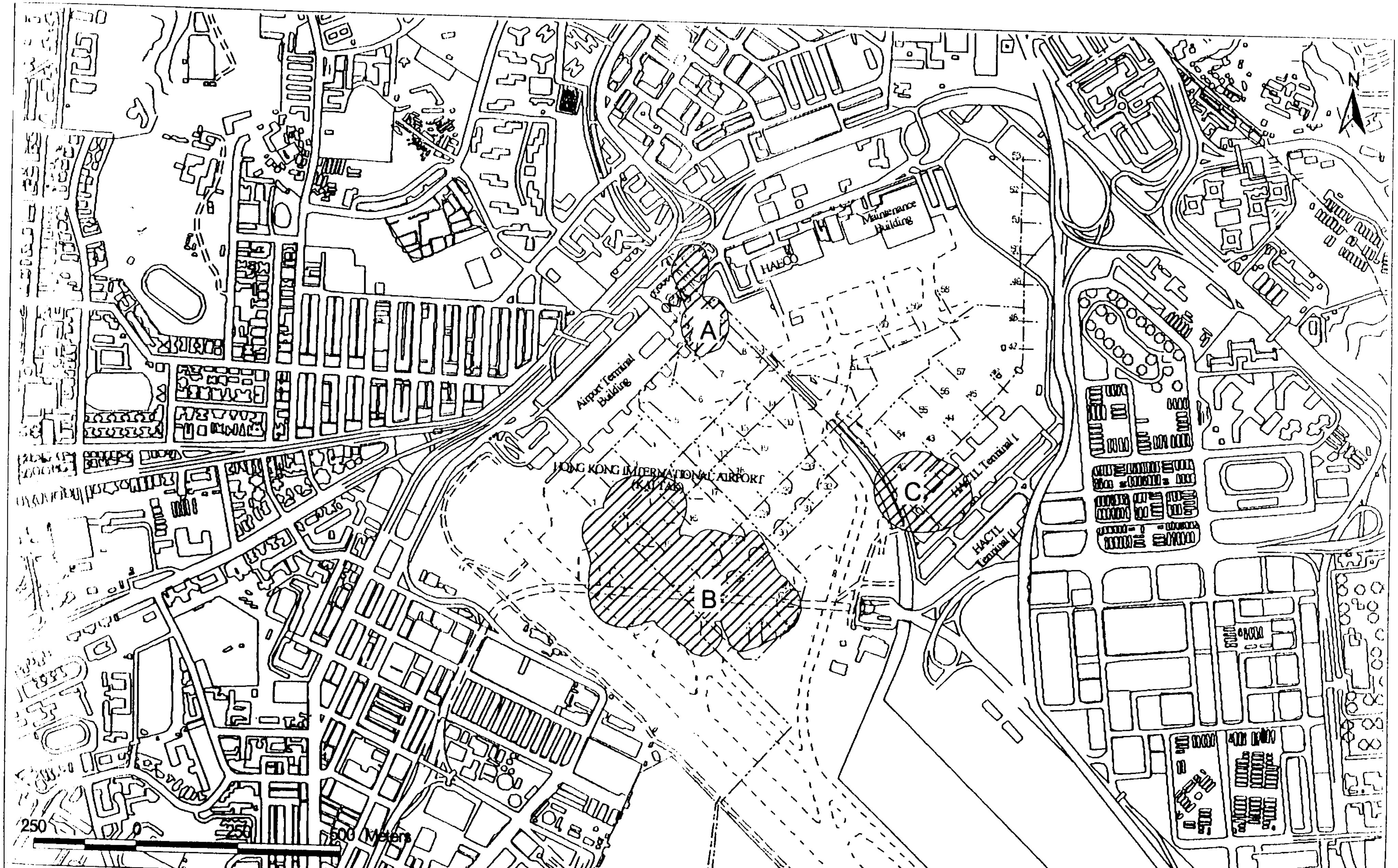
TITLE

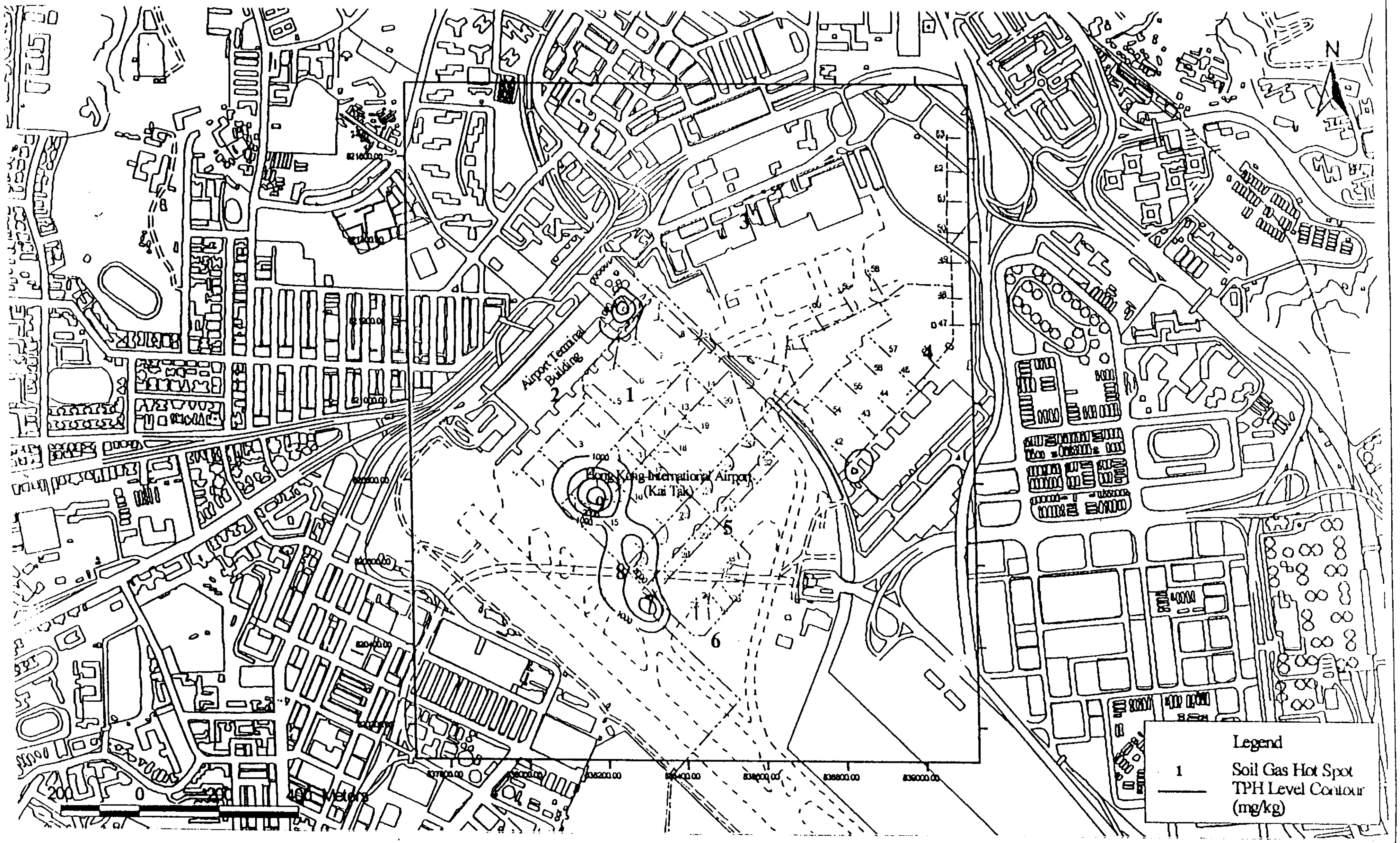
Programme of Pilot Test

MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD

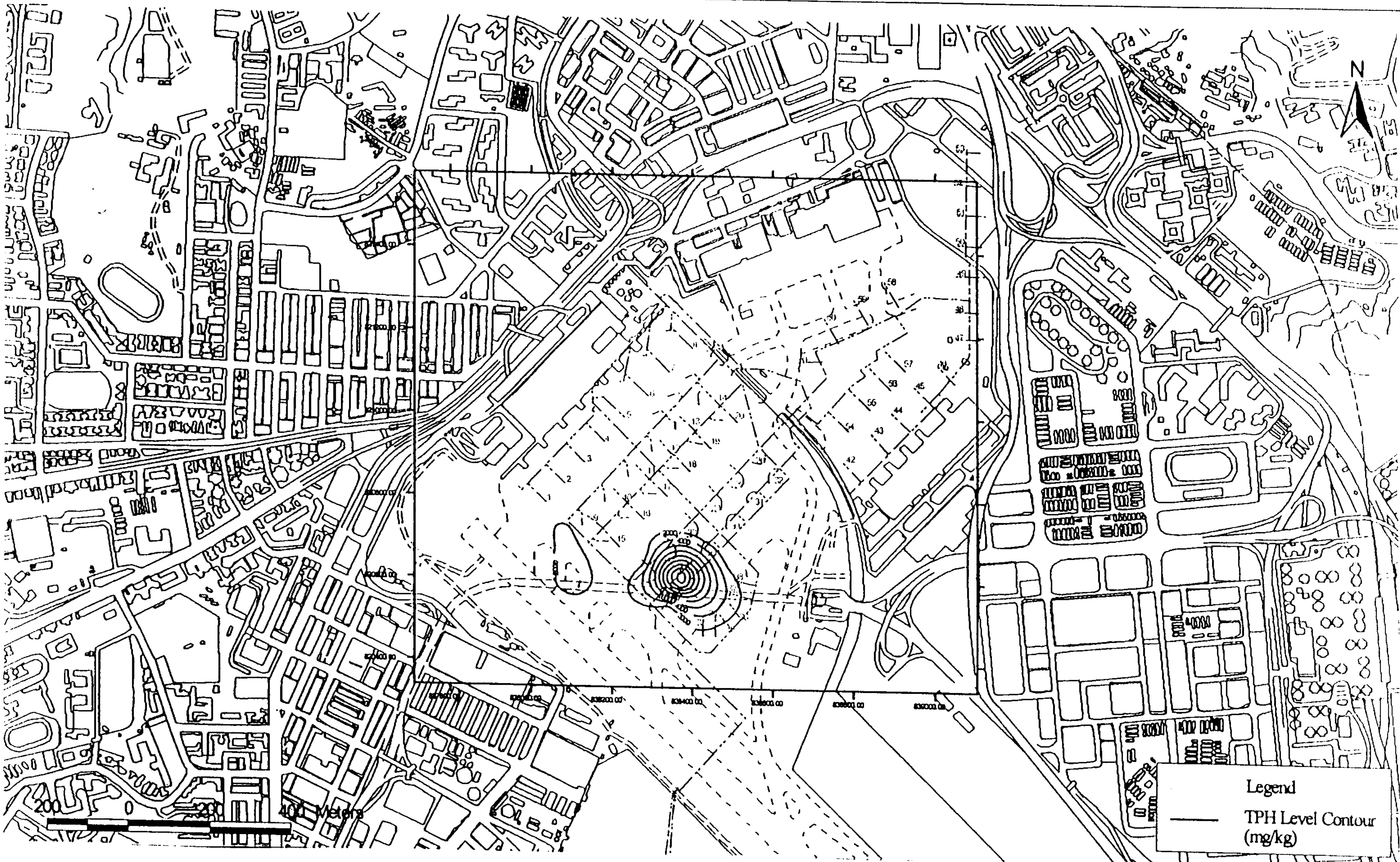
PROJECT NO	C418	FIGURE NO	Figure 1.1
DESIGNED/ CHECKED	Eric Lai	DATE	Dec 1998



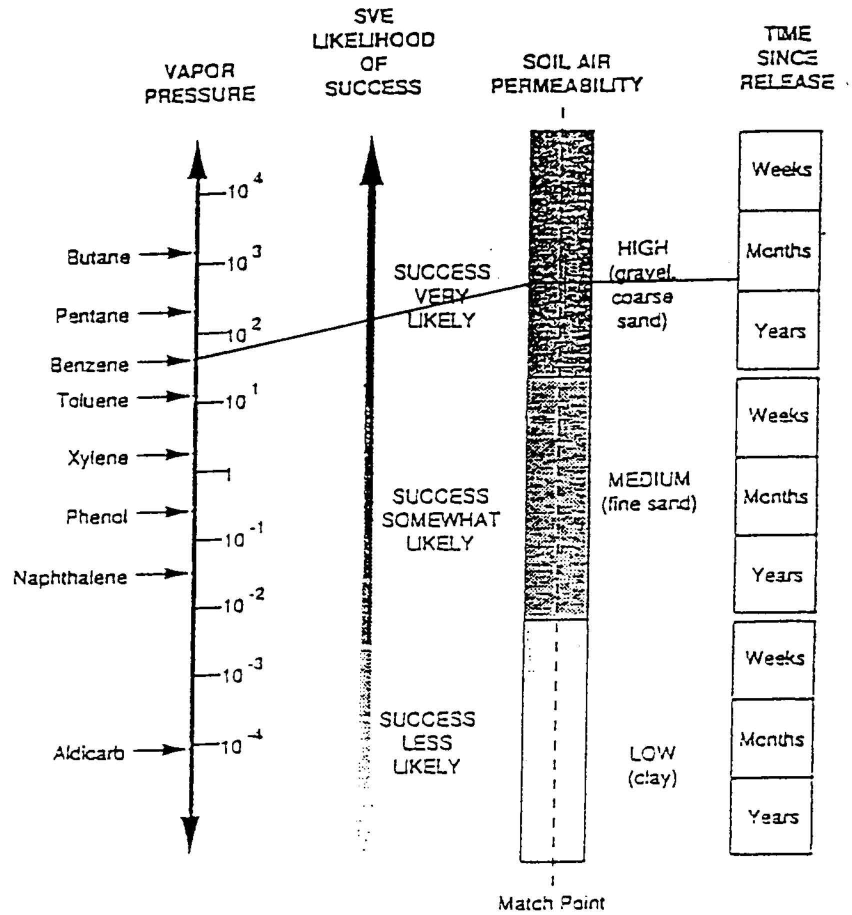
Maunsell	TITLE Three Hot Spots of TPH Contamination	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD			
		PROJECT NO.	C418	DATE	Dec. 1998
		DESIGNED	Eric Lai	DRAWING NO.	Figure 1.2



Maunsell	TITLE: TPH Level for Soil at 1m above Groundwater Level	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD		
		PROJECT NO	C418	FIGURE NO. Figure 1.3
		DESIGNED/CHECKED	Bernard Wong	DATE Dec. 1998



Maunsell	TITLE TPH Level for Soil at 1m below Groundwater Level	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD		
		PROJECT NO	C418	FIGURE NO: Figure 1.4
		DESIGNED/ CHECKED		DATE: Dec. 1998



(with line adjusted to show the KTA case)

Source: Suthersan, S. S. (1996) *Remediation Engineering: Design Concept*, p 362. CRC-Lewis, Boca Raton Fla.

Maunsell	TITLE **Applicability of SVE Treatment**	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD			
		PROJECT NO	C418	FIGURE NO.	Figure 1.5
		DESIGNED/ CHECKED		DATE	Dec 1998

Table 2.2 Range of Values of Hydraulic Conductivity and Permeability

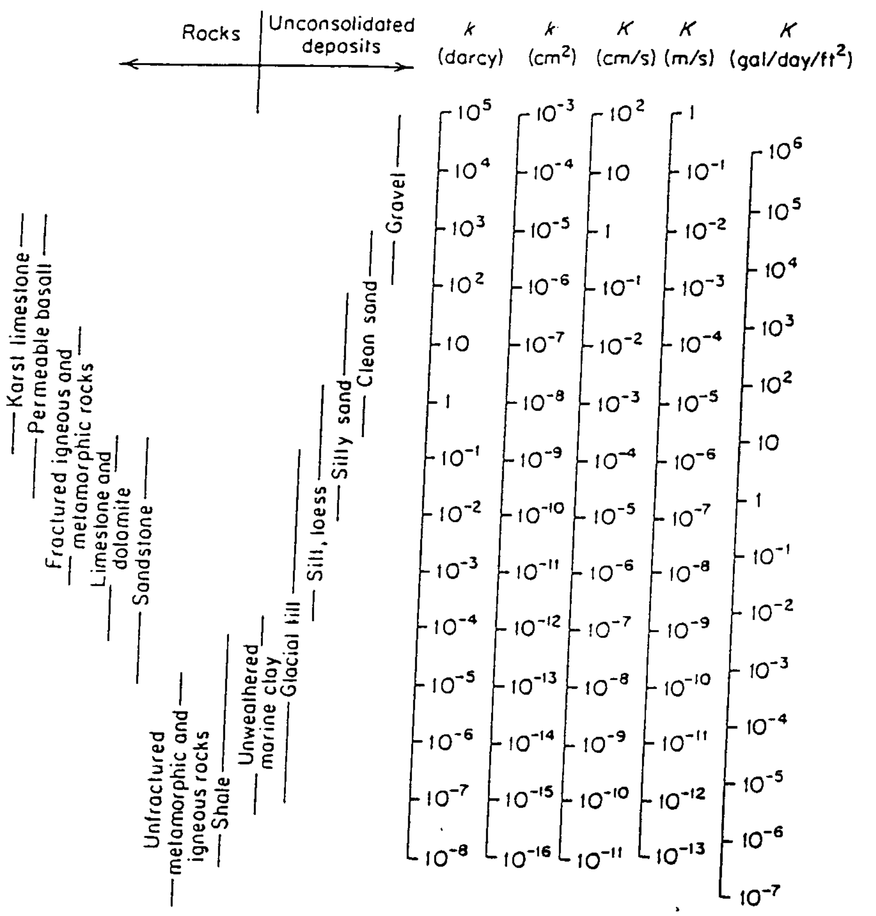


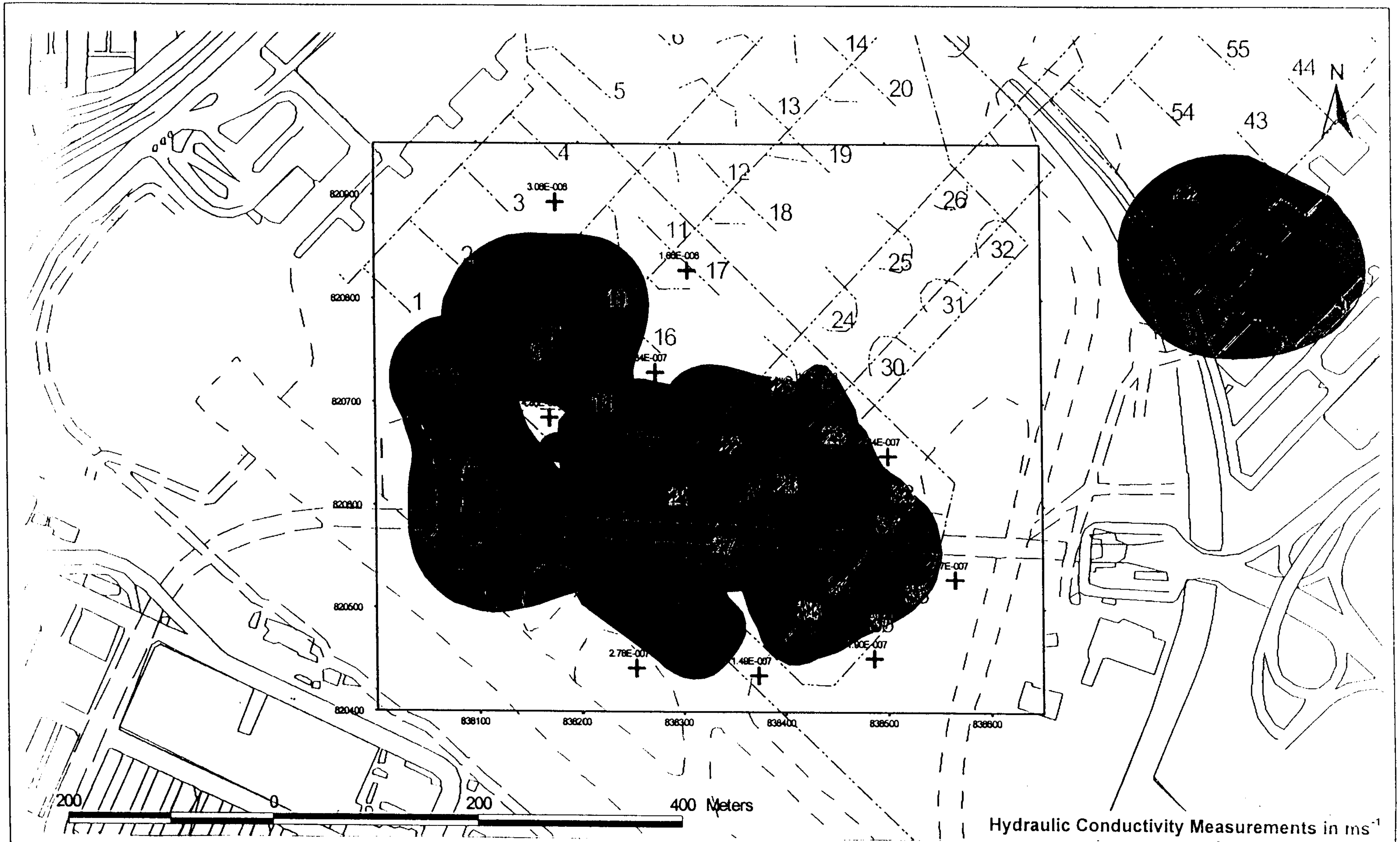
Table 2.3 Conversion Factors for Permeability and Hydraulic Conductivity Units

	Permeability, k*			Hydraulic conductivity, K		
	cm^2	ft^2	darcy	m/s	ft/s	U.S. gal/day/ft^2
cm^2	1	1.08×10^{-3}	1.01×10^{8}	9.80×10^{2}	3.22×10^{3}	1.85×10^{9}
ft^2	9.29×10^{2}	1	9.42×10^{10}	9.11×10^{5}	2.99×10^{6}	1.71×10^{12}
darcy	9.87×10^{-9}	1.06×10^{-11}	1	9.66×10^{-6}	3.17×10^{-5}	1.82×10^{1}
m/s	1.02×10^{-3}	1.10×10^{-6}	1.04×10^{5}	1	3.28	2.12×10^{6}
ft/s	3.11×10^{-4}	3.35×10^{-7}	3.15×10^{4}	3.05×10^{-1}	1	6.46×10^{5}
U.S. gal/day/ft^2	5.42×10^{-10}	5.83×10^{-13}	5.49×10^{-2}	4.72×10^{-7}	1.55×10^{-6}	1

*To obtain k in ft^2, multiply k in cm^2 by 1.08×10^{-3}.

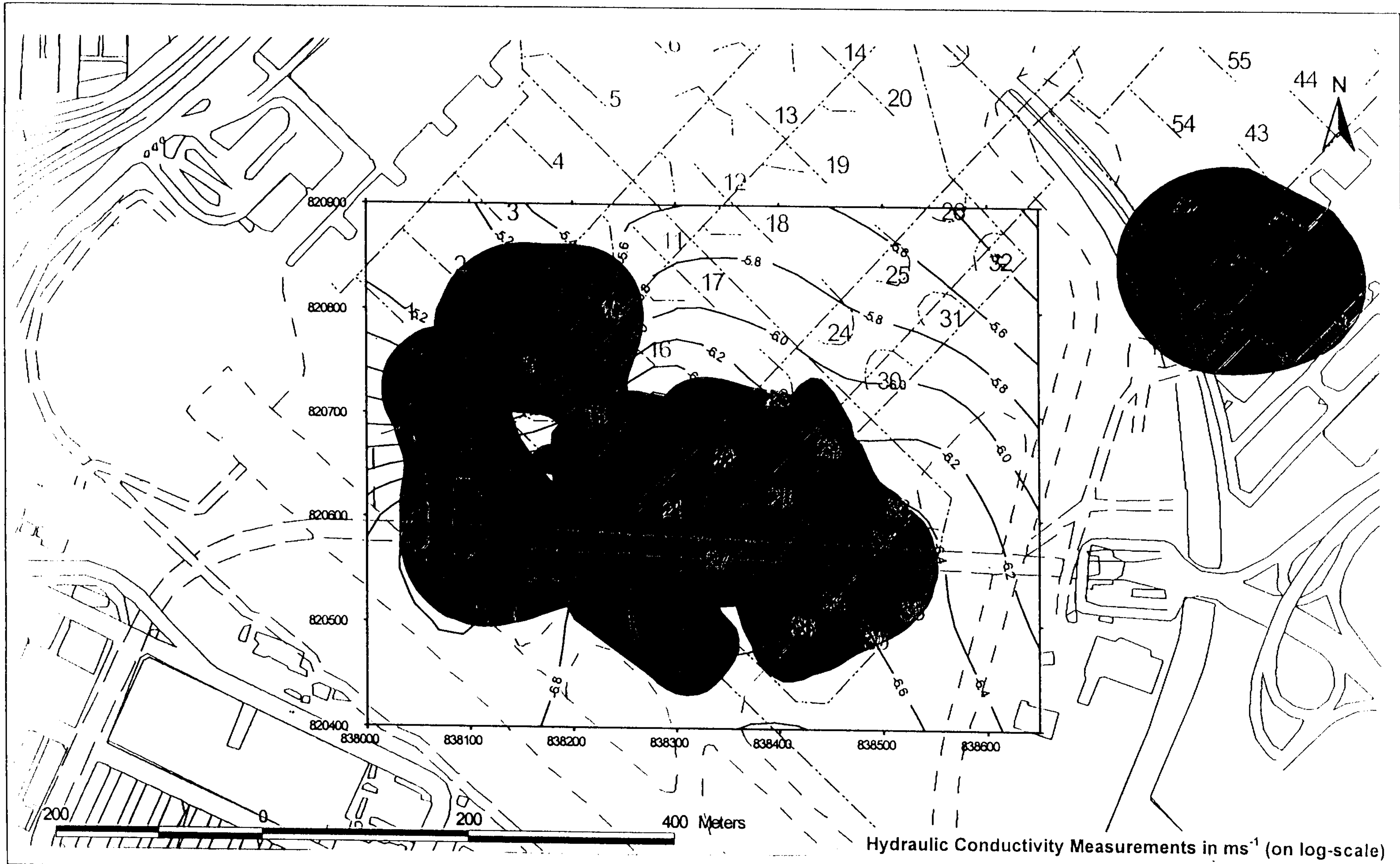
Source: Freeze, R. A. and Cherry, J. A. (1979) *Groundwater*, p 604. Prentice Hall, New Jersey.

Maunsell	TITLE Range of Values of Hydraulic Conductivity and Permeability for Geological Materials	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD			
		PROJECT NO	C418	FIGURE NO	Figure 1.6
		DESIGNED/ CHECKED		DATE	Dec 1998



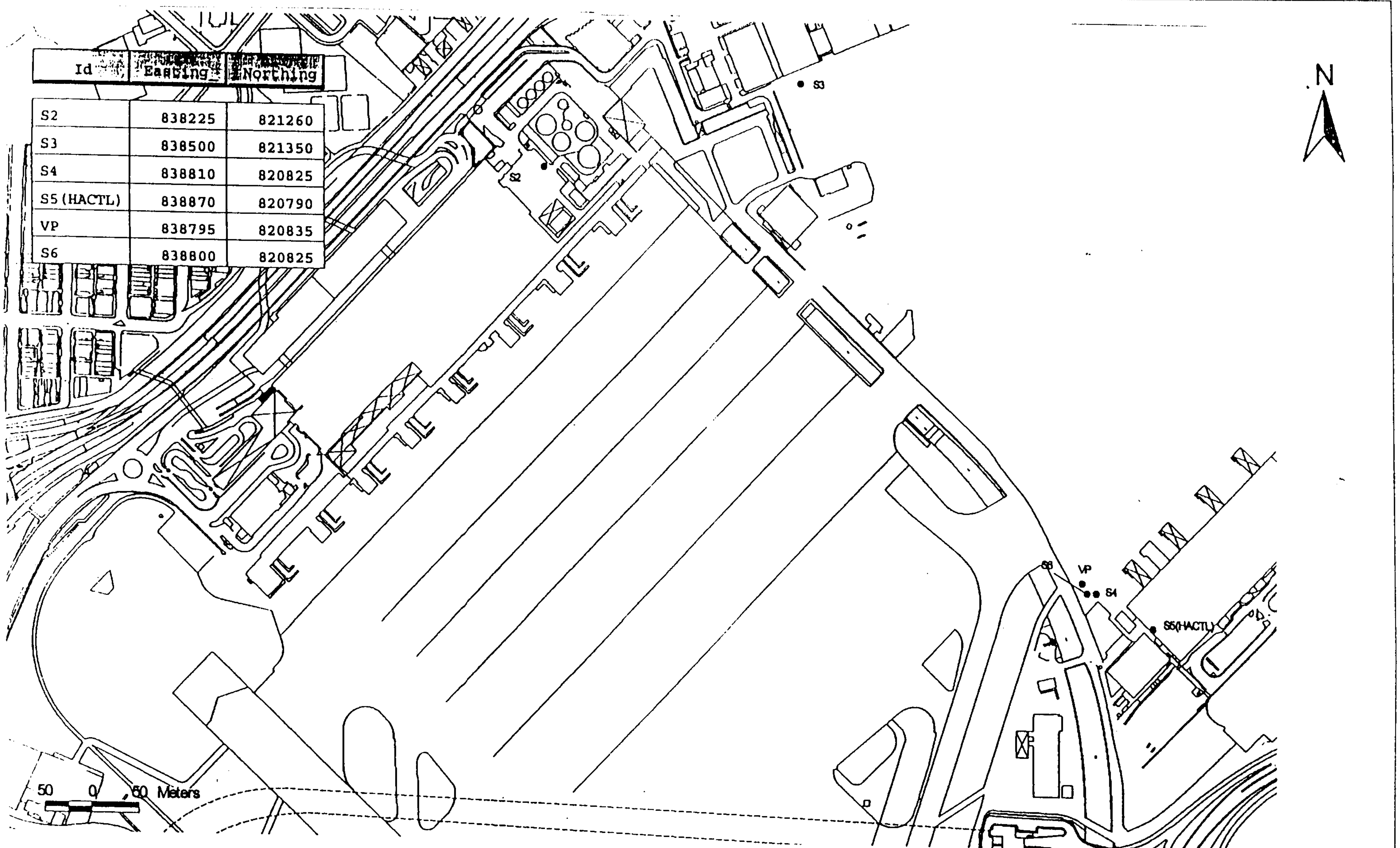
Maunsell	TITLE **Hydraulic Conductivity of Soil Samples Taken at Hot Spot B**	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD

PROJECT NO	C418	FIGURE NO.	Figure 1.7
DESIGNED/ CHECKED	Bernard Wong	DATE	Dec. 1998



Maunsell	TITLE Contours of Hydraulic Conductivity of Soil Across Hot Spot B	MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD		
		PROJECT NO	C418	FIGURE NO. Figure 1.8
		DESIGNED/ CHECKED	Bernard Wong	DATE Dec. 1998

Id	Easting	Northing
S2	838225	821260
S3	838500	821350
S4	838810	820825
S5 (HACTL)	838870	820790
VP	838795	820835
S6	838800	820825



Maunsell

TITLE

Testing Locations of the Previous Further Site Investigation

MAUNSELL ENVIRONMENTAL MANAGEMENT CONSULTANTS LTD

PROJECT NO	C418	FIGURE NO	Figure 1.9
DESIGNED/ CHECKED	Bernard Wong	DATE	Dec. 1998