

**Agreement No. CE 35/2006(CE)
Kai Tak Development Engineering Study
cum Design and Construction of Advance Works –
Investigation, Design and Construction**

**DECOMMISSIONING OF THE FORMER KAI TAK AIRPORT
OTHER THAN THE NORTH APRON
ENVIRONMENTAL IMPACT ASSESSMENT REPORT**

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3 LAND CONTAMINATION IMPACT

3.1 Introduction

3.1.1 Contaminated land refers to the land which has been polluted by hazardous substances as a result of industrial operations carried out on the site over a number of years. These contaminants if present, may pose hazardous risks or cause adverse effects to the land users and the nearby environment. The implications of land contamination associated with the former Kai Tak Airport other than the North Apron have been assessed in this section.

3.2 Environmental Legislation, Policies, Plans, Standards and Criteria

3.2.1 The Practice Note for Professional Persons ProPECC PN3/94 “*Contaminated Land Assessment and Remediation*” and “*Guidance Notes for Investigation and Remediation of Contaminated Sites of Petrol Filling Stations, Boatyards and Car Repair /Dismantling Workshop*” issued by the Environmental Protection Department (EPD) provide guidance on land contamination assessment. Further consideration of contamination issues is provided in Section 3 (Potential Contaminated Land Issues) of Annex 19 “Guidelines for Assessment of Impact on Sites of Cultural Heritage and Other Impacts” of the *Technical memorandum on Environmental Impact Assessment Process* (EIAO-TM).

Dutch Guidelines

3.2.2 The *Guidance Notes* make reference to criteria developed in the Netherlands (the “Dutch Guidelines”) which are the most comprehensive and are widely used for contaminated site assessment. The Dutch criteria consist of three levels of standards for a range of soil and groundwater contaminants, representing the following three scenarios:

- A – level implies unpolluted;
- B – level implies potential present and requires further investigation or remediation; and
- C – level implies pollution, which requires remediation.

3.2.3 The Dutch guidelines are very stringent as they are developed based on a ‘good for all uses’ philosophy. The EPD generally requires remediation for soil contamination above the Dutch ‘B’ Standards. In other words, the Dutch ‘B’ standards are the clean-up target for remediation of soil.

Risk-based Criteria for Groundwater

3.2.4 The Dutch criteria were established based on the assumption that groundwater is used as potable water. However, it is not so appropriate to be applied directly in Hong Kong where groundwater is not generally for potable use. Hence, the Dutch B levels would be only for screening out the chemicals-of-concern (COCs) for risk assessment and are not for assessing groundwater contamination in Hong Kong. A risk-based assessment would be carried out for contaminants with the concentration exceeding the Dutch B level to evaluate the risks posed to the sensitive receptors.

3.2.5 The risk-based assessment that has been adopted in U.S. Environmental Protection Agency (USEPA) takes into account concentrations of individual contaminants in groundwater, the anticipated most sensitive human receptor and the potential exposure pathways. For a worst-case scenario, the largest contaminant concentrations in the groundwater samples would be taken as the source concentration for the risk calculation.

3.2.6 Exceedance of the risk-based criteria would be qualified in two tiers. Firstly, the Total Pathway Hazard Index (TPHI) that is the sum of contaminant hazard quotients exceeds one (i.e. USEPA recommended hazard index). Secondly the largest contaminant concentration exceeds the corresponding Risk Based Screening Level (RBSL) that is derived from the recognized oral reference dose. For carcinogens, the first is the Total Carcinogenic Risk that

is the sum of contaminant carcinogenic risk exceeds 1×10^{-6} (i.e. USEPA lifetime cancer risk level). The second is the largest carcinogenic contaminant concentration exceeds the corresponding RBSL that is derived from the recognized carcinogenic oral slope factor. It should be noted that risk assessment could only be undertaken for those chemicals that have a recognized oral slope factor or oral reference dose.

3.3 Assessment Methodology

3.3.1 As shown in **Drawing 3.1**, the Project area for land contamination impact assessment has been divided into sub-areas for assessment and covered by the following studies:

- South Apron Area – Agreement No. KDO 02/2005 Assessment of Possible Land Contamination Associated with Decommissioned Fuel Pipeline and Hydrant System at South Apron of Former Kai Tak Airport conducted by Maunsell Environmental Management Consultants Ltd. (hereinafter called Agreement No. KDO 02/2005). As shown in **Drawing 3.1**, the assessment area of this study included a narrow strip of area on the southern side which is beyond the Project area of this EIA.
- Runway Area and Narrow Strip of North Apron – Agreement No. KDO 01/2006 Site Investigation and Contamination Assessment at Remaining Area of Former Kai Tak Airport and Proposed Cruise Terminal conducted by Meinhardt Infrastructure and Environmental Ltd. (hereinafter called Agreement No. KDO 01/2006).
- Ex-Government Flying Service (ex-GFS) Apron Area – Supplementary investigation was carried out in accordance with the ProPECC PN3/94 and the Guidance Notes issued by EPD. Site Appraisal was carried out by reviewing the historical aerial photographs, site inspection, consultation with relevant Government departments and interview with the existing land users. All collected information and inspection findings were analysed thoroughly to evaluate the potential impact of land contamination within the ex-GFS apron area.

3.3.2 The approved contamination assessment plans (CAPs) and site investigations prepared / conducted for the above contamination assessment studies were reviewed and evaluated to identify any potential land contamination within the Project area.

3.4 Identification of Sensitive Receivers

3.4.1 According to ProPECC PN 3/94, contaminated land usually refers to *“land which has been polluted by hazardous substances as a result of industrial operations carried out on the site over a number of years. Very often, these contaminants pose hazardous risks or cause detrimental effects to the land users, the nearby environment or even building materials, thus affecting building safety. For example, toxic chemicals used in a chemical processing plant can find their way into the ground after some time through accidental spills or leaks. These toxic chemicals can diffuse through soil and be carried by groundwater to nearby receivers polluting the environment. People using or working in these contaminated sites can also be at direct risk from, for example, direct contact with contaminated soil. It is important that potentially contaminated sites are properly managed and remediated if necessary”*.

3.4.2 Considering the environment of the Project area, construction workers are the most likely group to be exposed to the contaminated materials during excavation and remediation works. The principal exposure routes for workers include:

- Direct ingestion of contaminated soils through eating or drinking on site;
- Dermal contact with contaminated soils; and
- Inhalation of contamination if the contaminants are volatile.

3.4.3 Remedial actions will be undertaken to treat soil and groundwater found within the Project

area when necessary. Upon completion of the remediation to the agreed cleanup targets, land contamination in the Project area should not pose significant impacts to Kai Tak Development and future landusers and construction workers of the Project area.

3.5 Description of the Environment

3.5.1 The Project area is about 96 hectares and covers the former Kai Tak Airport south apron and runway areas together with the disused fuel dolphin. The locality is adjacent to Kowloon Bay, Kai Tak Approach Channel and Kwun Tong Typhoon Shelter. The east of the Project area is mainly industrial / commercial uses while the nearest residential development is at the north-western side of the Project area at To Kwa Wan and Ma Tau Kok areas.

Site History

3.5.2 The site history of the Project area was obtained by reviewing relevant historical aerial photographs. **Table 3.1** is a summary of the aerial photographs reviewed:

Table 3.1 Aerial Photographs Reviewed

Year	Ref. No	Height (ft)	Land Area		
			South Apron Area	Runway Area and the Narrow Strip of North Apron)	Ex-GFS Apron Area
1967	5571	6250	Under reclamation	In operation	Under reclamation
1972	1757	5000	Under reclamation	Under extension by reclamation	Vacant site
1984	56927	4000	Used for car parking and cargo storage	Runway extended	Used as Kai Fuk temporary housing area
1992	A30387	4000	Under construction	No apparent change in layout	Kai Fook temporary housing area decommissioned
1996	CN14346	4000	In operation	No apparent change in layout	Helicopter found in the site
1998	CN21315	4000	Vacant site with no aircraft found in the assessment area	Vacant site with no aircraft found in the assessment area	Vacant site with no aircraft / helicopter found in the assessment area

Sources of historical aerial photographs: Survey and Mapping Office, Lands Department

3.5.3 In general, during the operation of the former Kai Tak Airport, the south apron area and the ex-GFS apron area were used for aircraft loading, unloading, fuelling, parking and maintenance. The runway area was mainly used as airport runway.

3.5.4 According to the approved CAP prepared under Agreement KDO 01/2006, 2 existing fire stations are located in the runway area and the narrow strip of the north apron as summarized in **Table 3.2** below:

Table 3.2 Historical Information of Fire Stations

Fire Station	Operation Period	Landuse / Facility	Chemical/Hazardous Substances Handled
Fire Station B (end of the runway)	1974 - 1998	<ul style="list-style-type: none"> Rescue and fire-fighting operation in the former Kai Tak Airport 	<ul style="list-style-type: none"> Nil
Fire Station C (locate near the Kai Tak nullah at the narrow strip of the north apron)	1992 - 1998	<ul style="list-style-type: none"> Used for rescue and fire-fighting operation in the former Kai Tak Airport; Facilities included fire training pit, temporary vehicle maintenance workshop, refuelling facilities, underground petrol/diesel tanks; 	<ul style="list-style-type: none"> Petrol/diesel used at the petrol filling station Kerosene /diesel poured onto the fire-fighting training pit Lube oils and hydraulic fluids used by a

Fire Station	Operation Period	Landuse / Facility	Chemical/Hazardous Substances Handled
		<ul style="list-style-type: none"> Before 1992, an old Main Fire Station (in operation during 1979 – 1992) together with its associated facilities including a petrol filling station/underground storage tank, vehicle workshop, foam store and fire training pit were located around the Fire Station C. However, all of these facilities of the old Main Fire Station have probably been removed already. 	temporary vehicle maintenance workshop

3.5.5 After the closure of Kai Tak Airport, the Project area has been occupied by various temporary uses as listed in **Table 3.3** below and illustrated in **Drawing 3.2**.

Table 3.3 Existing Landuses in the Project Area after Closure of Kai Tak Airport

Land I.D.	Landuses Activity	Chemical/Hazardous Substances Handled
South Apron Area		
1	Civil Engineering and Development Department (CEDD) – Temporary stockpile area (Terminated)	• Nil
2	Kowloon Motor Bus (KMB) – Bus Parking	• Nil
3	Parking area for golf centre (Terminated)	• Nil
4	Crossroads International Ltd. – Storage of tenant's goods and container parking for non-profit making purpose	• Nil
5	Customs & Excise Department (C&ED) – Customs car detention centre	• Nil
Runway Area and Narrow Strip of North Apron		
6	Golf centre and ancillary facilities (Terminated)	<ul style="list-style-type: none"> Chemicals used including diluted bleach for floor cleaning and natural organic pesticides
7	EMSD – vehicle maintenance workshop	<ul style="list-style-type: none"> Underground tank for waste oil including diesel, lube oil and engine oil (10,000L); Break oil, hydraulic fluid, common cleaning solvent, paint, thinner, general electrical wiring, battery fluid and small amount of acids. The chemicals were handled according to legal requirements and EMS certified to ISO 14001 standards.
8	CEDD – Works Area of Development at Choi Wan and Jordan Valley	• Nil
9	CEDD – Barging points of Development at Choi Wan and Jordan Valley	• Diesel oil stored for use by dump trucks. Waste oil is disposed of by a licensed chemical waste collector
10	Hong Kong Observatory – Automatic weather station	• Nil
11	Fire Services Department (FSD) – Driving training school	• Nil
12	Architectural Services Department (ArchSD) – storage of material and pre-assemble of formwork system	• Nil

Land I.D.	Landuses Activity	Chemical/Hazardous Substances Handled
13	CEDD – Works site (Terminated)	<ul style="list-style-type: none"> Chemical used including electrical wiring
14	Hong Kong Police Force (HKPF) – Temporary storage of water barriers	<ul style="list-style-type: none"> Nil
15	Metal recycling workshop	<ul style="list-style-type: none"> Nil
Ex-GFS Apron Area		
16	C&ED – Designated areas for drums storage	<ul style="list-style-type: none"> Confidential Goods
17	GFS – Storage area for underground fuel tanks and apron area for refuelling for helicopters and aircrafts	<ul style="list-style-type: none"> Underground tanks for storage of AVTUR fuel (Kerosene) (3 x 60,000 L) and AVGAS fuel (Petrol) (2 x 6,000 L) Refuelling pits (refuelling pits 1-7 for storage of Kerosene; refuelling pits 8-9 for storage of petrol)

Records of Chemicals / Hazardous Substances Spillage

3.5.6 Historical records of chemical / hazardous substances spillage and any violations of environmental regulations are summarized in the following paragraphs:

3.5.7 For the south apron area, as provided in the approved CAP under Agreement No. KDO 02/2005 (**Appendix 3.1a**), there was no record of registered hazardous or dangerous goods installations within the south apron area. However, a total of 9 chemical / fuel spillage incidents have been recorded (as listed in **Table 3.4**) and most of the spillage cases occurred during the refuelling operations from the ground fuel hydrant system to the aircrafts. The spilled fuel leaked from the wing tanks of subject aircrafts and formed fuel patches on the ground. Therefore, the fuel pipeline and hydrant system had been identified as a possible source of land contamination.

Table 3.4 Summary of Fuel Spillage Incidents

Year	Location	Details of the Spillage	Quantity
1994	Bay 75	Leakage of fuel from supply pipe connecting to the inlet port at the wing of a Boeing 747 aircraft	5x4m of aviation fuel was emulsified by fuel refuelling staff.
1995	Bay 72	Leakage of fuel from supply pipe connecting to the inlet port at the wing of a Boeing 747 aircraft	1x2m of aviation fuel was emulsified by fuel refuelling staff.
1995	Bay 72	Leakage of fuel from the overflow vent of a wing tank on a Boeing 747 aircraft	3x3m of aviation fuel was emulsified by fuel refuelling staff.
1995	Bay 77	Leakage of fuel from the overflow vent of a wing tank on a Boeing 747 aircraft	6x6m of aviation fuel was emulsified by fuel refuelling staff.
1995	Bay 76	Leakage of fuel from the overflow vent of a wing tank on a Boeing 747 aircraft	12x5m of aviation fuel was emulsified by fuel refuelling staff.
1996	Bay 81	Leakage of fuel from the overflow vent of a wing tank on a Boeing 747 aircraft	0.5x0.5m of aviation fuel was emulsified by fuel refuelling staff.

Year	Location	Details of the Spillage	Quantity
1996	Bay 71	Leakage of fuel from the overflow vent of a wing tank on a light aircraft	1x2m of aviation fuel was emulsified by fuel refuelling staff.
1997	Bay 74	Leakage of fuel from the overflow vent of a wing tank on an Airbus 340 aircraft	2x2m of aviation fuel was emulsified by fuel refuelling staff.
1998	Bay 74	Leakage of fuel from the overflow vent of a wing tank on a Boeing 747 aircraft	10x5m of aviation fuel was emulsified by fuel refuelling staff.

3.5.8 For the runway area and the narrow strip of the north apron, as provided in the approved CAP prepared under Agreement No. KDO 01/2006 (**Appendix 3.1b**), a total of 2 accidents were identified with potential consequences of land contamination (as listed in the **Table 3.5** and shown in **Drawing 3.3**) due to fuel spillage in the period from 1978 – 1998. The accidents were occurred 13 -18 years ago and the fuel spillages were only one-off incidents. Damage of the concrete surface of the runway was not reported for both accidents and seepage of fuel into the soil under the concrete was likely to be minimal.

Table 3.5 Summary of Airplane Accidents at Former Kai Tak Airport with Potential Land Contamination

Year	Aircraft Type / Operator	Location of Plan Crash	Details of the Spillage	Other Spillage / Hazards
31-8-1998	Hawker – Siddeley Trident; Civil Aviation Administration of China	Partially fell into the sea, in the middle of the northern side of the runway	“... a layer of fuel spread over the surface of the surrounding water.” A small fire had started in the centre engine intake duct. “The fire was soon extinguished”.	None reported
4-11-1993	Boeing 747 – 409B; China Airlines	Fell into the sea at the end of the runway	“ Water pollution was largely avoided as little if any fuel was spilt.” No fire	None reported

3.5.9 For the ex-GFS apron area, as stated in the approved CAP attached in **Appendix 3.1c**, the information provided by EPD and FSD showed that no record of spillage / leakage of chemicals/ dangerous goods have been recorded in the ex-GFS apron area.

3.6 Identification of Potential Environmental Impacts

South Apron Area

3.6.1 As discussed in the approved CAP provided in **Appendix 3.1a**, potential sources of land contamination within the south apron area of the former Kai Tak Airport were likely to include: (1) leakage / spillage of the fuel from fuel pipeline and hydrant system of the South Apron; (2) migration of contaminants from the North Apron via bedding materials; and (3) migration of contaminants from the adjacent petrol filling stations located along Kai Fuk Road.

Runway Area and Narrow Strip of North Apron

3.6.2 As discussed in the approved CAP provided in **Appendix 3.1b**, potential sources of land contamination within the airport runway and the narrow strip of the north apron were likely to

include accidental spillage, mishandling or loss of spilled chemicals or fuels, leakage from underground fuel storage tanks, the “fire training pits” near the disused fire stations, and waste metal recycling activity.

Ex-GFS Apron Area

- 3.6.3 As discussed in the approved CAP provided in **Appendix 3.1c**, the information obtained from the desk study, site inspections and interview revealed that the storage area of the underground fuel tanks, the refuelling pits and their associated pipelines, and the aircraft washbay in the ex-GFS apron area were likely the potential contaminative hotspots.

3.7 Site Investigation for Land Contamination Assessment

- 3.7.1 Site investigations were conducted at the south apron area, the runway area and the narrow strip of north apron, and the ex-GFS apron area. Contamination assessment reports / remediation action plans (CARs/RAPs) have been prepared as attached in **Appendices 3.2a – 3.2c** to discuss the site investigations findings including the fieldworks and laboratory analytical results and recommend appropriate remediation plans for the identified contaminated areas.

- 3.7.2 The findings of the site investigations conducted within the Project area are summarized in the following sections.

Fieldwork and On-site Measurements

South Apron Area

- 3.7.3 Site investigation (SI) was conducted in the south apron area of the former Kai Tak Airport from 16 December 2005 to 22 January 2006. In general, a total of 16 boreholes and 20 trial pits were constructed. Groundwater sampling was conducted at 16 boreholes and 17 trial pits. The as-built locations of sampling boreholes and trial pits are shown in **Drawing 3.4**. A total of 70 soil samples and 33 groundwater samples were collected and analyzed for total petroleum hydrocarbon (TPH), benzene, toluene, ethylbenzene and xylenes (BTEX), polycyclic aromatic hydrocarbons (PAHs), chlorinated hydrocarbons and heavy metals.
- 3.7.4 Analytical results of SI in the south apron area revealed that TPH was found exceeding the Dutch B level at 3 sampling locations (BH6, BH10 and TP15), further SI was therefore proposed near these sampling locations in order to better define TPH contamination extent. The further SI was conducted from 30 June 2006 to 7 August 2006 with similar sampling methodologies in the original SI. A total of 2 boreholes and 1 trial pit were constructed as shown in **Drawing 3.4** for collecting soil and groundwater samples. A total of 7 soil samples and 2 groundwater samples were collected for TPH and/or BTEX analysis only in the further SI.
- 3.7.5 On-site measurements including Photo-ionisation Detector (PID) measurement and pressure hydrant test were undertaken during the SI. In general, the VOC levels of soil samples are low (i.e. below 20ppm), which will not pose harmful effects to site workers during decontamination. The pressure hydrant test results showed that the condition of existing pipeline was apparently intact at the time of testing and no damage, crack or signs of leakage were observed at the hydrant pits.

Runway Area and Narrow Strip of North Apron

- 3.7.6 SI was conducted in the airport runway and the narrow strip of north apron in the former Kai Tak Airport in the period from 24 January 2007 to 26 March 2007. A total of 39 boreholes (including relocated boreholes) were constructed during the SI as depicted in **Drawing 3.5**. There were 107 soil samples and 33 groundwater samples collected and analyzed for TPH, BTEX, heavy metals, PAH, halogenated and non-halogenated solvents.
- 3.7.7 During the SI, no distinctive, characteristic smell of soil and groundwater sample exhibiting

signs of contamination was noticeable.

Ex-GFS Apron Area

- 3.7.8 SI was conducted in the ex-GFS apron area from 28 May 2007 to 11 June 2007. A total of 20 boreholes (including relocated borehole) were constructed during the SI as depicted in **Drawing 3.6**. There were 65 soil samples and 20 groundwater samples collected and analyzed for TPH, BTEX, heavy metals, PAH, halogenated and non-halogenated solvents.
- 3.7.9 On-site measurements including PID and free product measurement were undertaken during the SI. In general, the VOC levels of soil samples are low (i.e. below 20ppm), which will not pose harmful effects to site workers during decontamination. Elevated PID readings were only recorded at 3 soil samples (i.e. 741ppm at B03 (1m below base of existing concrete pavement (BBC)), 386ppm at B05 (3.5BBC) and 432ppm at B06A (2.5m BBC)). Petroleum / kerosene smell was noted during soil sampling at these boreholes. It is recommended that personal protective equipment (e.g. mask) should be used by construction workers for the decontamination works of these areas. Floating oil / free product (of TPH) had been found in boreholes B02, B06 and B06A and the thickness measured by an interface probe were about 16cm, 17cm and 39cm respectively.

Laboratory Results of Soil Samples

- 3.7.10 Laboratory analytical results of collected soil samples reveal that the major contaminants in soil within the Project area are metals (lead, copper and arsenic), TPH, volatile organic chemicals (VOCs) (ethylbenzene and xylenes) and semi-volatile organic chemical (SVOC) (benzo(a)pyrene). The as-built sampling locations with contaminants exceeding Dutch B/C levels within the Project area are shown in **Drawing 3.7**.

South Apron Area

- 3.7.11 Among the 77 soil samples collected in the SI and the further SI, 9 soil samples collected within the Study Area were found with TPH and metals (arsenic and lead) exceeding Dutch B Levels. Fuel pipeline and hydrant system are likely the main potential contaminated sources within south apron area. Details of the exceedances are summarized in **Table 3.6**.

Table 3.6 Summary of Soil Samples Exceeding Dutch B/C Values in South Apron

Sampling Location	Depth (m below ground)	Contaminant	Concentration (mg/kg)	Dutch Level (mg/kg)		Dutch Level Exceeded
				B	C	
BH-10	4.00m	TPH	1309.1	1000	5000	>B
BH-6	4.10m	TPH	1590	1000	5000	>B
TP-15	2.50m	TPH	4202	1000	5000	>B
BH-10	4.00m	Lead	220	150	600	>B
BH-5	4.20m	Lead	380	150	600	>B
TP-9	2.00m	Lead	210	150	600	>B
BH-16*	0.80m	Lead	160	150	600	>B
TP-6	2.10m	Lead	530	150	600	>B
TP-17	1.10m	Lead	200	150	600	>B
TP-20	1.10m	Arsenic	38	30	100	>B

* As shown in **Drawing 3.7**, BH-16 was found outside the boundary of the former Kai Tak Airport and the Project Area, soil contamination identified in this sampling location is thus not considered further in this Project

Runway Area and Narrow Strip of North Apron

- 3.7.12 Among the 107 soil samples collected in the SI, 1 soil sample collected from the narrow

strip of the north apron near the Kai Tak Tunnel was found with SVOC (benzo(a)pyrene) exceeding Dutch B Level. The major source of soil contamination is likely due to historical activities conducted at the old vehicle workshop and foam store area in the narrow strip of north apron. No contamination was found in the airport runway area. Details of the exceedance are summarized in **Table 3.7** below.

Table 3.7 Summary of Soil Samples Exceeding Dutch B/C Values in the Narrow Strip of North Apron

Sampling Location	Depth (m below ground)	Contaminant	Concentration (mg/kg)	Dutch Level (mg/kg)		Dutch Level Exceeded
				B	C	
B30	0.00-0.75m	Benzo(a)pyrene	2.8	1	10	>B

Ex-GFS Apron Area

3.7.13 Among the 65 soil samples collected in the SI, 11 soil samples were found with TPH, heavy metals (copper and lead) and VOCs (ethylbenzene and xylenes) exceeding Dutch B/C Levels. The possible sources of elevated contaminants levels in these soil samples are likely due to possible spillage or mis-handling of fuels in the ex-GFS apron area. Details of the exceedances are summarized in **Table 3.8** below.

Table 3.8 Summary of Soil Samples Exceeding Dutch B/C Values in Ex-GFS Apron Area

Sampling Location	Depth (m below ground level)	Contaminant	Concentration (mg/kg)	Dutch Level (mg/kg)		Dutch Level Exceeded
				B	C	
B-02	5.0 – 5.45m (4.75 – 5.2m BBC)	Copper	280	100	500	>B
B-03	1.3m (1m BBC)	TPH	5112	1000	5000	>C
	2.5-2.95m (2.2 – 2.65m BBC)	TPH	2577	1000	5000	>B
B-04	2.5-2.95m (2.2 – 2.65m BBC)	TPH	1843.3	1000	5000	>B
B-05	3.5 – 3.95m (3.25 – 3.7m BBC)	TPH	1950	1000	5000	>B
B-06A	2.5-2.95m (2.3 – 2.75m BBC)	TPH	20210	1000	5000	>C
		Ethylbenzene	17	5	50	>B
		Xylenes	9.2	5	50	>B
B-09	2.5-2.95 (2.25 – 2.7m BBC)	TPH	1122	1000	5000	>B
B-11	1.25 (1 m BBC)	Lead	180	150	600	>B
	2.5-2.95 (2.25 – 2.70m BBC)	TPH	1002	1000	5000	>B
B-12	2.5-2.95 (2.2 – 2.65m BBC)	Copper	130	100	500	>B
B-13	2.5-2.95 (2.25 – 2.70m BBC)	Lead	290	150	600	>B

Remarks:

BBC = Below Base of Existing Concrete Pavement

Laboratory Results of Groundwater Samples

3.7.14 Laboratory analytical results of collected groundwater samples within the Project area revealed some exceedances in the screening criteria, which are tabulated in **Table 3.9**. The concerned test parameters include TPH, metals (including barium, cadmium, copper, molybdenum, lead, tin, zinc, thallium, vanadium, antimony, chromium, cobalt and nickel),

VOCs (benzene, ethylbenzene, xylenes) and SVOCs (benzo(a)pyrene, phenanthrene and naphthalene). As discussed in the CARs/RAPs provided in **Appendices 3.2a - 3.2c**, the major sources of groundwater contamination within the Project area are likely due to (1) possible historical leakage of contaminants from nearby local environment such as the vehicle maintenance workshops and petrol filling station/underground fuel tank; (2) possible spillage or mis-handling of chemicals seepage to groundwater; and/or (3) contamination by fill materials or from background.

Table 3.9 Summary of Groundwater Samples Exceeding Dutch B/C Values

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
South Apron Area						
BH-2	2.34	TPH	360	200	600	>B
		Barium	210	100	500	>B
		Cadmium	2.6	2.5	10	>B
		Copper	64	50	200	>B
		Lead	450	50	200	>C
		Zinc	400	200	800	>B
BH-3	2.65	TPH	900	200	600	>C
		Barium	350	100	500	>B
		Copper	300	50	200	>C
		Molybdenum	73	20	100	>B
		Lead	68	50	200	>B
BH-4	2.63	TPH	350	200	600	>B
		Barium	110	100	500	>B
BH-5	2.69	TPH	1020	200	600	>C
		Barium	110	100	500	>B
		Molybdenum	37	20	100	>B
BH-6	2.18	TPH	1920	200	600	>C
		Barium	170	100	500	>B
		Molybdenum	65	20	100	>B
		Lead	280	50	200	>C
BH-7	2.26	TPH	450	200	600	>B
		Barium	270	100	500	>B
		Copper	210	50	200	>C
		Molybdenum	71	20	100	>B
		Lead	480	50	200	>C
		Tin	34	30	150	>B
		Zinc	1700	200	800	>C
BH-8	2.82	TPH	1120	200	600	>C
		Molybdenum	64	20	100	>B
		Lead	120	50	200	>B

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
BH-9	2.86	TPH	610	200	600	>C
		Barium	110	100	500	>B
		Lead	150	50	200	>B
BH-10	2.95	TPH	270	200	600	>B
		Barium	170	100	500	>B
		Copper	53	50	200	>B
		Molybdenum	82	20	100	>B
		Lead	310	50	200	>C
		Zinc	330	200	800	>B
BH-11	2.95	TPH	890	200	600	>C
		Barium	410	100	500	>B
		Copper	150	50	200	>B
		Molybdenum	70	20	100	>B
		Lead	330	50	200	>C
		Zinc	280	200	800	>B
BH-12	3.02	TPH	360	200	600	>B
		Molybdenum	28	20	100	>B
BH-13	3.02	Barium	180	100	500	>B
		Molybdenum	160	20	100	>C
		Lead	530	50	200	>C
		Zinc	450	200	800	>B
		Antimony	21	15#		NA
BH-14	2.51	TPH	450	200	600	>B
		Barium	170	100	500	>B
		Molybdenum	35	20	100	>B
		Lead	310	50	200	>C
		Zinc	310	200	800	>B
BH-15	2.81	TPH	990	200	600	>C
		Copper	220	50	200	>C
		Lead	750	50	200	>C
BH-16	2.52	TPH	1520	200	600	>C
		Barium	160	100	500	>B
		Molybdenum	30	20	100	>B
		Lead	520	50	200	>C
		Zinc	220	200	800	>B
TP-1	2.4	TPH	440	200	600	>B
		Molybdenum	240	20	100	>C
TP-2	2.5	TPH	380	200	600	>B
		Molybdenum	27	20	100	>B
		Lead	89	50	200	>B

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
TP-3	1.4	Thallium	5.6	2.4#		NA
		Vanadium	130	36#		NA
		TPH	350	200	600	>B
		Barium	480	100	500	>B
		Molybdenum	39	20	100	>B
		Lead	940	50	200	>C
		Tin	35	30	150	>B
TP-4	1.4	Zinc	1500	200	800	>C
		TPH	1520	200	600	>C
		Barium	160	100	500	>B
TP-5	1.85	Molybdenum	24	20	100	>B
		TPH	260	200	600	>B
TP-6	2	Molybdenum	23	20	100	>B
TP-7	2.2	TPH	410	200	600	>B
TP-8	2.1	TPH	1320	200	600	>C
		Barium	330	200	600	>B
TP-9	2.2	Barium	180	100	500	>B
		TPH	370	200	600	>B
TP-10	2.3	Barium	170	100	500	>B
		TPH	770	200	600	>C
TP-11	2.2	Barium	150	100	500	>B
TP-12	2.2	Molybdenum	88	20	100	>B
		TPH	260	200	600	>B
		Barium	150	100	500	>B
		Copper	62	50	200	>B
TP-13	2.2	Molybdenum	46	20	100	>B
		Barium	110	100	500	>B
TP-14	2.3	Molybdenum	240	20	100	>C
		Barium	190	100	500	>B
		Molybdenum	59	20	100	>B
TP-16	2.2	Lead	78	50	200	>B
		Molybdenum	150	20	100	>C
TP-18	2.2	Lead	120	50	200	>B
		TPH	1000	200	600	>C
		Barium	110	100	500	>B
TP-19	2.2	Molybdenum	100	20	100	>B
		TPH	800	200	600	>C
		Molybdenum	88	20	100	>B
Runway Area and the Narrow Strip of North Apron	4.34	Lead	79	50	200	>B
		TPH	1,605	200	600	>C
B1	4.34	Lead	90	50	200	>B
		Copper	110	50	200	>B
B2	3.55	Lead	55	50	200	>B
		Copper	110	50	200	>B

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
B3	3.8	TPH	257	200	600	>B
		Lead	170	50	200	>B
		Barium	240	100	500	>B
B4	3.52	TPH	1,065	200	600	>C
		Lead	110	50	200	>B
B5A	4.67	TPH	805	200	600	>C
B6A	3.83	TPH	855	200	600	>C
		Lead	78	50	200	>B
B7A	5.1	TPH	665	200	600	>C
		Lead	80	50	200	>B
B8	3.35	Copper	63	50	200	>B
		Lead	53	50	200	>B
B9	3.55	Molybdenum	28	20	100	>B
B11	3.66	Lead	69	50	200	>B
B14	3.30	Chromium	67	50	200	>B
B15	3.45	TPH	334	200	600	>B
		Lead	130	50	200	>B
B16	3.3	TPH	457	200	600	>B
		Lead	77	50	200	>B
B17	4.07	TPH	406	200	600	>B
B18	3.55	Lead	68	50	200	>B
B19A	4.2	Lead	130	50	200	>B
B20A	3.38	TPH	258	200	600	>B
		Copper	94	50	200	>B
		Molybdenum	25	20	100	>B
B23	4.25	Lead	62	50	200	>B
B24A	1.7	TPH	462	200	600	>B
		Barium	390	100	500	>B
B25	3.05	TPH	645	200	600	>C
		Copper	70	50	200	>B
		Lead	130	50	200	>B
B26	2.83	TPH	785	200	600	>C
		Molybdenum	34	20	100	>B
B27	4.45	TPH	269	200	600	>B
		Lead	100	50	200	>B
		Barium	190	100	500	>B
		Molybdenum	44	20	100	>B
B28	5.18	TPH	228	200	600	>B
		Molybdenum	150	20	100	>C
B29	3.91	Lead	55	50	200	>B
B30	4.2	Lead	270	50	200	>C
		Barium	180	100	500	>B
B31	3.82	TPH	635	200	600	>C
		Lead	54	50	200	>B

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
B32	3.95	TPH	1,195	200	600	>C
		Lead	70	50	200	>B
		Molybdenum	25	20	100	>B
B33	3.34	TPH	1,205	200	600	>C
		Molybdenum	92	20	100	>B
Ex-GFS Apron Area						
A-01	2.64	Molybdenum	37	20	100	>B
		TPH	515	200	600	>B
		Benzene	2.2	1	5	>B
		Ethylbenzene	22	20	60	>B
A-02	2.16	Copper	110	50	200	>B
		Lead	650	50	200	>C
		Zinc	560	200	800	>B
		Barium	230	100	500	>B
A-03	2.38	TPH	460	200	600	>B
A-04	2.31	Lead	59	50	200	>B
		Zinc	450	200	800	>B
		Barium	420	100	500	>B
		TPH	465	200	600	>B
		Benzene	1.9	1	5	>B
B-01	2.31	Lead	110	50	200	>B
		Zinc	270	200	800	>B
		Barium	170	100	500	>B
		TPH	503	200	600	>B
		Benzene	4.1	1	5	>B
B-02	2.40	Lead	120	50	200	>B
		TPH	8920	200	600	>C
		Benzene	40	1	5	>C
B-03	2.41	Cadmium	5.9	2.5	10	>B
		Copper	490	50	200	>C
		Nickel	83	50	200	>B
		Lead	1200	50	200	>C
		Zinc	1200	200	800	>C
		Cobalt	67	50	200	>B
		Barium	510	100	500	>C
		TPH	421	200	600	>B
		Benzene	24	1	5	>C
		Ethylbenzene	31	20	60	>B
Xylenes	73	20	60	>C		

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
B-04	2.84	Copper	56	50	200	>B
		Lead	220	50	200	>C
		Barium	110	100	500	>B
		TPH	1270	200	600	>C
		Benzene	7.2	1	5	>C
		Xylenes	35	20	60	>B
B-05	2.50	Copper	93	50	200	>B
		Lead	780	50	200	>C
		Zinc	280	200	800	>B
		Barium	120	100	500	>B
		TPH	4100	200	600	>C
		Benzene	5.7	1	5	>C
B-06	2.62	Copper	54	50	200	>B
		Lead	540	50	200	>C
		Zinc	220	200	800	>B
		Barium	220	100	500	>B
		TPH	1434025	200	600	>C
		Naphthalene	110	7	30	>C
		Benzene	720	1	5	>C
		Ethylbenzene	1800	20	60	>C
		Xylenes	975	20	60	>C
B-06A	2.80	Copper	52	50	200	>B
		Lead	420	50	200	>C
		Zinc	230	200	800	>B
		TPH	3355325	200	600	>C
		Naphthalene	79	7	30	>C
		Phenanthrene	2.6	2	10	>B
		Benzene	3.1	1	5	>B
		Ethylbenzene	120	20	60	>C
		Xylenes	414	20	60	>C
B-07	2.29	Copper	77	50	200	>B
		Lead	860	50	200	>C
		Zinc	240	200	800	>B
B-08	2.37	Copper	330	50	200	>C
		Lead	650	50	200	>C
		Zinc	380	200	800	>B
		Molybdenum	21	20	100	>B
		Barium	400	100	500	>B
		TPH	1680	200	600	>C
		Benzene	3.5	1	5	>B

Sampling Location	GW Depth (m below ground)	Contaminant	Concentration (µg/L)	Dutch Level (µg/L)		Dutch Level Exceeded
				B	C	
B-09	2.36	Copper	79	50	200	>B
		Lead	310	50	200	>C
		Zinc	290	200	800	>B
		TPH	560	200	600	>B
		Benzene	2.1	1	5	>B
		Xylenes	54	20	60	>B
B-10	2.34	Cadmium	3.3	2.5	10	>B
		Copper	150	50	200	>B
		Lead	1800	50	200	>C
		Zinc	390	200	800	>B
		Barium	240	100	500	>B
		TPH	13148	200	600	>C
B-11	2.25	Barium	200	100	500	>B
		TPH	2870	200	600	>C
		Naphthalene	11	7	30	>B
		Benzene	38	1	5	>C
		Ethylbenzene	39	20	60	>B
B-12	2.37	Barium	220	100	500	>B
B-13	2.48	Barium	460	100	500	>B
		TPH	138020	200	600	>C
		Naphthalene	40	7	30	>C
		Benzo(a)pyrene	0.22	0.2	1	>B
		Benzene	1.6	1	5	>B
		Ethylbenzene	29	20	60	>B
B-14	2.44	Copper	74	50	200	>B
		Lead	380	50	200	>C
		TPH	21845	200	600	>C
B-15	2.37	Cadmium	14	2.5	10	>C
		Copper	190	50	200	>B
		Lead	2200	50	200	>C
		Zinc	1400	200	800	>C
		Barium	560	100	500	>C
		TPH	36445	200	600	>C

Remarks:

#: PRGs value is used since no Dutch Levels are available for thallium, vanadium and antimony. PRGs are risk-based concentrations taking into account of exposure pathway and toxicity data and are tools for evaluating and cleaning up contaminated sites in USEPA Region IX Superfund sites.

NA: Not Applicable

3.7.15 As discussed earlier, the Dutch values for groundwater would serve to indicate the chemical-of-concerns (COCs) for risk assessment. A risk-based assessment was thus carried out for parameters which exceeded the Dutch B/C levels to evaluate the risks posed to the anticipated most sensitive human receptor. It can be seen from **Table 3.10** that the risk due to ingestion of groundwater by construction workers is warranted. It should be noted that the risk due to dermal contact with groundwater by site workers is uncertain. It is because risk assessment regarding to dermal contact cannot be undertaken as the toxicity and / or chemical specific data for the chemicals of concern (COCs) do not exist. As such, it is recommended that personnel protective equipment (PPE) be used by site workers as a

mitigation measure.

Table 3.10 Evaluation of Significance of Risk Due to Groundwater Contamination

Receptor	Significance of Risk due to Groundwater Contamination	Rationale
Construction workers for decommissioning / decontamination works (by ingestion)	Significant	Existence of potential risk.
Construction workers for decommissioning / decontamination works (by inhalation)	Insignificant	Decommissioning and decontamination works would be located in the outdoor area. Also, it is recommended that personal protective equipment (PPE) should be used by site workers as a mitigation measures.
Construction workers for decommissioning / decontamination works (by dermal contact)	Uncertain	Toxicity and / or chemical specific data do not exist for the COCs for risk assessment to be undertaken. As such, it is recommended that personal protective equipment (PPE) be used by site workers as a mitigation measure.
Future land users	Insignificant	As most of the contamination in the site would be removed after the decontamination works, the soil quality would be within Dutch B level and the groundwater contamination would be much reduced. In addition, the site will be covered by filling materials / concrete. Groundwater at the site will not be used as potable water or used for recreation / irrigation purposes.
Future construction workers (including construction workers for future Kai Tak Development works as well as those employed for the concurrent projects / works as mentioned in Table 2.3)	Insignificant	Contaminated soil is considered as the major contributor for elevated COCs in the groundwater. As most of the contamination in the site would be removed after the decontamination works, the soil quality would be within Dutch B level and the contaminants in groundwater would be much reduced.

3.7.16 Compared with the future land users and future construction workers, the construction workers for carrying out decommissioning / decontamination works are regarded as the most sensitive since they would be possible to have direct contact with groundwater by incidental ingestion or dermal exposure. In addition, as discussed in **Table 3.10**, the risk for future land users / future construction workers is considered insignificant as the groundwater at the Site will not be used as potable water or used for recreation / irrigation purposed and the future ground surface of the Site should be of urban nature and to be covered by filling materials / concrete. Furthermore, the contaminated soil would have been removed so as the free product, and the sources of contamination would be removed.

3.7.17 For each parameter, the source concentration is the maximum concentration of that parameter found in the groundwater samples irrespective of their locations. Chromium was assumed to be Cr(VI) for conservative assessment. The maximum sources concentration (of groundwater samples) of the chemicals-of-concerns (COCs) (i.e. with concentration above the screening criteria) and their corresponding non-carcinogenic oral reference doses or carcinogenic slope factor are tabulated in **Table 3.11**. It should be noted that for lead, World Health Organisation's (WHO) oral reference dose (3.6×10^{-3} mg/kg-day) was adopted for the risk assessment.

Table 3.11 Maximum Source Concentrations and Non-carcinogenic Oral Reference Doses / Carcinogenic Oral Slope Factors of Chemicals of Concern

Parameter	Max. Source Concentration (of groundwater samples (mg/L)	Sample I.D. ^a	Non-carcinogenic Oral Reference Dose ^b (RfDO) (mg/kg-day)	Min. Non-carcinogenic Oral Reference Dose ^b (RfDO) (mg/kg-day)	Carcinogenic Oral Slope Factor ^c (CSDo) 1/mg/kg-day)
TPHs	3360	E-B-06A	0.03 to 5.00	0.03	Not applicable
Antimony	0.021	S-BH-13	0.0004	Not applicable	Not applicable
Barium	0.56	E-B-15	0.07	Not applicable	Not applicable
Cadmium	0.014	E-B-15	0.0005	Not applicable	Not applicable
Chromium*	0.067	R-B14	0.003	Not applicable	Not applicable
Cobalt	0.067	E-B-03	0.02	Not applicable	Not applicable
Copper	0.49	E-B-03	0.04	Not applicable	Not applicable
Lead	2.20	E-B-15	0.0036	Not applicable	Not applicable
Molybdenum	0.24	S-TP-1/ S-TP-13	0.005	Not applicable	Not applicable
Nickel	0.083	E-B-03	0.02	Not applicable	Not applicable
Thallium	0.0056	S-TP-3	0.000066	Not applicable	Not applicable
Tin	0.035	S-TP-3	0.6	Not applicable	Not applicable
Vanadium	0.13	S-TP-3	0.001	Not applicable	Not applicable
Zinc	1.70	S-BH-7	0.3	Not applicable	Not applicable
Naphthalene	0.11	E-B-06	0.02	Not applicable	Not applicable
Phenanthrene	0.0026	E-B-06A	0.04	Not applicable	Not applicable
Benzo(a)Pyrene	0.00024	E-B-13	0.03 #	Not applicable	7.30E+00
Benzene	0.72	E-B-06	0.004	Not applicable	5.50E-02
Ethylbenzene	1.80	E-B-06	0.1	Not applicable	Not applicable
Xylenes	0.975	E-B-06	0.2	Not applicable	Not applicable

Remarks:

^a Groundwater samples with suffix 'S' are groundwater samples collected from the south apron area; groundwater samples with suffix 'E' are groundwater samples collected from the ex-GFS apron area.

^b Source for TPHs : *TPH Criteria Working Group, 1999. Total Petroleum Hydrocarbons Criteria Working Group Series Volume 5 – Human Health Risk-Based Evaluation of Petroleum Release Sites: Implementing the Working Group Approach. Massachusetts, U.S.A., Amherst Scientific Publishers.*

Source for Sb, Ba, Cd, Cr,Co, Cu, Mo, Ni,Tl, Sn, V, Zn, PAHs, Benzene, Ethylbenzene & Xylenes :*USEPA Region IX Risk-based Concentration Table (revised on Oct 04), USEPA Region IX.*

Source for Pb: The value is referenced to the tolerable daily intake (TDI) from *the National Institute of Public Health and the Environment (RIVM), The Netherlands, 2001.*

^c Source for TPHs, Sb, Ba, Cd, Cr, Co, Cu, Pb, Mo, Ni, Tl, Sn, V, Zn, PAHs, Benzene, Ethylbenzene & Xylenes: *USEPA Region IX Risk-based Concentration Table (revised on Oct 04), USEPA Region IX.*

RfDo is not available for benzo(a)pyrene. With reference to the RIVM report - Re-evaluation of human-toxicological maximum permissible risk levels (March 2001) by National Institute of Public Health and the Environment, tolerable daily intake (TDI) for PAHs considered to be non-carcinogenic is 30ug/kg/day for aromatic compounds with equivalent carbon numbers of >16-35. In this assessment 30ug/kg/day takes as the non-carcinogenic oral dose for B(a)P.

* Chromium is assumed to be Cr(VI) as conservative assessment.

3.7.18 The details of risk assessment for groundwater are given in **Appendix 3.3**. According to the results of the risk assessment, the concentrations of all COCs do not exceed the calculated “allowable” concentrations (i.e. the risk-based criteria for remediation) except TPH. For the case of TPH, the maximum concentration of TPH in groundwater is 3,360mg/L and above the “allowable” concentration for TPH derived from the risk assessment (i.e. 213mg/L). In order to reduce the safety and health risk, it is proposed that free product shall be recovered.

3.8 Prediction and Evaluation of Environmental Impacts

3.8.1 Site investigations findings (including the fieldworks and laboratory analytical results) and the estimation of soil and / or groundwater contamination extent for each assessment area, have been summarized in the separate contamination assessment report / remediation action plan (CAR / RAP) as provided in **Appendices 3.2a - 3.2c**.

Soil Contamination

3.8.2 Site investigations for the land contamination assessment conducted at the Project area identified that some areas in the ex-GFS apron area and the south apron of the former Kai Tak Airport were contaminated with heavy metals, total petroleum hydrocarbons (TPH) and/or volatile organic compounds (VOCs) namely ethylbenzene and xylenes while an area in the narrow strip of the north apron near the Kai Tak Tunnel was contaminated with semi-VOC (SVOC) namely benzo(a)pyrene. No contamination was found in the former airport runway.

Estimation of Soil Contamination Extent

3.8.3 The estimated quantity of contaminated soil within the Project area is provided in **Table 3.12** below:

Table 3.12 Estimated Quantity of Contaminated Soil

Zone of Excavation	Area	Contaminant	Estimated Contamination Extent		
			Vertical (m below existing ground level)	Horizontal (m ²)	Contaminated Soil Volume (m ³)
South Apron Area					
A	BH-10	TPH, Lead	2 - 6m	28.3 ^A	113.2
B	BH-6	TPH	2 - 6m	28.3 ^A	113.2
C	TP-15	TPH	2 - 4m	28.3 ^A	56.6
D	BH-5	Lead	2 - 6m	28.3 ^A	113.2
E	TP-9	Lead	1 - 3m	28.3 ^A	56.6
F	TP-6	Lead	1.1 - 2.7m	28.3 ^A	45.3
G	TP-17	Lead	0.5 - 2.2m	28.3 ^A	48.1
H	TP-20	Arsenic	0.5 - 2.2m	28.3 ^A	48.1
Sub-total =					594.3
Narrow Strip of North Apron					
I	B-30	Benzo(a)pyrene	0 - 1.75m	28.3 ^A	49.5
Sub-total =					49.5
Ex-GFS Apron Area					
J	B03	TPH	0.8 - 2.0m (0.5 - 1.7m BBC)	1901 [*]	2,281.2

Zone of Excavation	Area	Contaminant	Estimated Contamination Extent		
			Vertical (m below existing ground level)	Horizontal (m ²)	Contaminated Soil Volume (m ³)
K	B03	TPH	2.0 - 3.5m (1.7 - 3.2m BBC)	9792*	14,688
	B04	TPH			
	B06A	TPH			
		Ethylbenzene			
		Xylenes			
B11	TPH				
L	B09	TPH	1.95 - 3.45m (1.7 - 3.2m BBC)	28.3 [^]	42.5
M	B05	TPH	3.5 - 4.45m (3.25 - 4.2m BBC)	502*	476.9
N	B11	Lead	0.75 - 1.75m (0.5 - 1.5m BBC)	28.3 [^]	28.3
O	B12	Copper	2.0 - 3.5m (1.7 - 3.2m BBC)	28.3 [^]	42.5
P	B13	Lead	1.95 - 3.45m (1.7 - 3.2m BBC)	28.3 [^]	42.5
Q	B02	Copper	4.45 - 5.95m (4.2 - 5.7m BBC)	28.3 [^]	42.5
Sub-total =					17,644.4
Total Estimated Volume of Contaminated Soil=					18288.2

Remarks:

[^] Considering the contamination found is localized and discrete, it is assumed that the extent of contamination spreads over a radius of 3m centered at the borehole location. The actual extent may be different and is subject to confirmatory sampling.

* The horizontal contamination extent has been estimated based on linear extrapolation of contamination levels between borehole locations. The actual extent may be different and is subject to confirmatory sampling.

3.8.4 On the other hand, the volumes of different types of contaminated soil at the Project area have been estimated based on the available laboratory testing results and are tabulated in **Table 3.13** below.

Table 3.13 Estimated Volume of Different Types of Contaminated Soil

Land	Metals Only	TPH/VOCs/SVOC	Metals and TPH
South Apron Area	311.3 m ³	169.8 m ³	113.2 m ³
Ex-GFS Apron Area	155.8 m ³	17488.6 m ³	NIL
Narrow Strip of North Apron	NIL	49.5 m ³	NIL
Runway Area	NIL	NIL	NIL
Total	467.1 m³	17,707.9 m³	113.2 m³

Note: The actual volume may be different and is subject to confirmatory sampling and testing to be conducted during the course of proposed remediation processes.

3.8.5 As summarized in **Tables 3.12** and **3.13** above, about 18,290m³ of contaminated soils identified within the Project area would need to be excavated and treated. There are 3 types of contaminated soil being identified based on the nature of contaminants:

- Metals contaminated soil
- TPH / VOCs / SVOC contaminated soil

- Metals and TPH contaminated soil

Consideration of Remediation Methods for Contaminated Soil

3.8.6 Soil remediation options applicable to the subject site were addressed based on the following criteria:

- Technical and cost effectiveness;
- Technology development status;
- Environmental benefits and disbenefits;
- Commercial availability;
- Experience; and
- Expertise requirement.

3.8.7 Common *in-situ* and *ex-situ* treatment technologies that were screened for the targeted soil contaminants are presented in **Table 3.14** below. The technologies are classified into biological treatment, physical / chemical treatment and removal, and grouped under *in-situ* and *ex-situ* methods.

Table 3.14 Treatment Technologies for Contaminated Soil with Metals / TPH / VOCs / SVOC

Technology	<i>In-situ</i> Treatment	<i>Ex-situ</i> Treatment
Biological Treatment	Natural Attenuation Soil Venting	Biopiling Landfarming
Physical / Chemical Treatment	Electrokinetic Separation	Solidification/Stabilization Soil washing
Removal	NA	Excavation and Landfill disposal

3.8.8 The applicability / environmental benefits and limitations / environmental dis-benefits of the above remediation techniques for metals / TPH / VOCs / SVOC contaminated soil are detailed in **Table 3.15**

Table 3.15 List of Soil Remediation Technologies for Metals / TPH / VOCs / SVOC Contaminated Soil

Remediation Option	Descriptions	Applicability / Environmental Benefits	Limitations / Environmental Dis-benefits
Biopiling	<i>Ex-situ</i> bioremediation method that bacteria grow in the piled contaminated soil and degrade the waste into harmless products.	<ul style="list-style-type: none"> Effective to TPH and other wide range of organic contaminants with some successful local case studies, e.g. decontamination works at the Cheoy Lee Shipyard at Penny's Bay, reclamation works at North Tsing Yi Shipyard site. Most cost-effective for large volumes of contaminated soil All materials and equipment are commercially available Can be designed to be a closed system; vapour emissions can be controlled 	<ul style="list-style-type: none"> Labour-intensive; require considerable maintenance Time-consuming (~1 year required) and not cost-effective for treating small volume of soil. Space required for biopile construction
Soil Venting	<i>In situ</i> bioremediation method that uses indigenous bacteria to degrade contaminants. Activity of the bacteria is enhanced by inducing air flow (using extraction or injection wells) and, if necessary, by adding nutrients.	<ul style="list-style-type: none"> Very effective to TPH Suitable for remediation in built up areas because wells can be placed between or below buildings Applicable to large sites with widespread contamination Uses readily available equipment; easy to install Vapour emissions can be controlled but not to the extent of biopiling due to underground soil in-situ properties 	<ul style="list-style-type: none"> Effectiveness is limited by underground soil features e.g. soil moisture content, permeability, etc. May induce possible air emission to the sensitive receivers Require large space for the system development

Remediation Option	Descriptions	Applicability / Environmental Benefits	Limitations / Environmental Dis-benefits
Landfarming	<i>Ex-situ</i> bioremediation method that mixes the soil with bacteria involving the spread and exposure of contaminated soil to atmosphere	<ul style="list-style-type: none"> • Very effective in treating TPH • Simple to design and implement 	<ul style="list-style-type: none"> • May induce possible dust and vapour emission to the sensitive receivers (surrounding factories and buildings) and relatively difficult to control • Require large flat space for the system development • Slow bioremediation rate and require long operation period (as long as 2years) which may affect future development schedule
Solidification /Stabilization	<i>Ex-situ</i> immobilization technique treats contaminated soil by mixing soil with binding agents, e.g. cement so that the contaminants become physically bound within stable mass.	<ul style="list-style-type: none"> • Applicable to clean-up inorganic contaminants such as heavy metals. • Solidification/stabilization has been used on certain contaminated sites in Hong Kong and demonstrated as a successful treatment method for inorganic contaminated soil, e.g. decontamination works at the Cheoy Lee Shipyard at Penny's Bay, reclamation works at North Tsing Yi Shipyard site and few isolated sites identified in the Deep Bay Link project. 	<ul style="list-style-type: none"> • The effectiveness reduces with the presence of organic contaminants • Large boulders may hinder the mixing process. Soil sorting is necessary before the treatment taken place.
Soil Washing	<i>Ex-situ</i> soil separation processes mostly based on mineral processing techniques. It is a water-based process for scrubbing soils ex-situ to remove contaminants.	<ul style="list-style-type: none"> • Applicable to clean inorganic contaminants such as heavy metals from coarse-grained soils. 	<ul style="list-style-type: none"> • The effectiveness of the treatment depends on soil particle size. Fine soil particles may require the addition of a polymer to remove them from the washing fluid. • Complex waste mixtures make formulating washing fluid difficult. • Require further treatment and disposal for residuals.

Remediation Option	Descriptions	Applicability / Environmental Benefits	Limitations / Environmental Dis-benefits
Electrokinetic Separation	<p><i>In-situ</i> remediation uses electrochemical and electrokinetic processes to desorb and remove metals and polar organics from soil. Low intensity direct current is applied to the soil to mobilize the charged species.</p>	<ul style="list-style-type: none"> • Applicable to treat low permeability soil contaminated with heavy metals. 	<ul style="list-style-type: none"> • The effectiveness depends on moisture content of soil. It decreases with moisture content less than 10%. • Require further treatment to remove the desorbed contaminants and thus increase the cost of remediation. • Presence of anomalies such as large gravels and insulating material in soil can induce variability of electrical conductivity in soil. This may reduce the effectiveness.
Excavation and Landfill Disposal	<p><i>Ex-situ</i> method whereby contaminants are removed by excavation of the contaminated soil and direct disposal to landfill</p>	<ul style="list-style-type: none"> • Most simple and quickest way to dispose of large volume of contaminated soil • Contamination is removed definitely • Higher certainty of success • Wide experience in Hong Kong • Applicable to all waste or mixture that meet land disposal restriction treatment standards. • Common practice for shallow, highly-contaminated soils. 	<ul style="list-style-type: none"> • Pre-treatment may be required for contaminated soil to meet landfill disposal criteria • Landfill space limited and valuable. • Indirect costs to the landfill management on monitoring and maintenance. • Potential long-term liabilities to landfill • Need large volume of clean backfill materials • No access to the working site until completion of backfilling • Least desirable management option.

3.8.9 In assisting the formulation of appropriate remedial measures, the *Guidance Notes* issued by EPD suggest the following factors to be taken into consideration when evaluating different available remediation methods:

- Degree and extent of the contamination;
- Anticipated future use of the site;
- Nature of the contaminants;
- Soil characteristics; and
- Time available for remediation.

Remediation Methods for Soil Contaminated with Metals

3.8.10 Among the remediation methods listed in **Table 3.15**, soil washing is considered not applicable as the complex waste mixtures (e.g. metals with organics) make formulating washing fluid difficult and extra treatment steps may be required to address hazardous levels of washing solvent remaining in the treated residuals which may increase the cost of remediation. While the effectiveness of electrokinetics depends highly on the conductivity of soil, the presence of submerged cover materials such as seashells in the layer of marine deposit in the Site reduces the removal efficiencies making electrokinetics not applicable. In addition, the lack of experience in Hong Kong for electrokinetics remediation methods may also pose difficulties in the remediation process. For the solidification / stabilization, the solid monolithic block adopted in this solidification / stabilization technique is extremely resistant to the leaching of inorganic contaminants. Additives can be added to assist in chemically binding the contaminants in a matrix that typically shows unconfined compressive strengths similar to a soil-cement mix. In addition, solidification / stabilization has been used on certain contaminated sites in Hong Kong and as a successful treatment method for inorganic contaminated soil, e.g. decontamination works at the Cheoy Lee Shipyard at Penny's Bay, reclamation works at North Tsing Yi Shipyard site and few isolated sites identified in the Deep Bay Link project. Based on the above discussion, solidification / stabilization technique is considered as the most practical and cost-effective method to treat the metals contaminated soil on site.

Remediation Methods for Soil Contaminated with TPH / VOCs / SVOC

3.8.11 Among the remediation methods listed in **Table 3.15**, biopiling is considered as the most practical and cost-effective method to treat the TPH / VOCs / SVOC contaminated soil on site. Since landfill space is very limited and valuable in Hong Kong, landfill disposal shall be considered as the last resort for TPH / VOCs / SVOC contaminated soil when other remediation methods are not applicable. Soil venting is not applicable to the contamination which is localized and discrete (e.g. for contaminated areas identified in south apron area and the narrow strip of north apron) while landfarming requires longer treatment time and may induce possible dust and vapour emission to the surrounding sensitive receivers. Therefore, biopiling is considered as remediation method for soil contaminated by TPH / VOCs / SVOC since this remediation technology is an effective technology to treat TPH / VOCs / SVOC contaminated soil with several successful local cases such as Cheoy Lee Shipyard and the North Apron of Kai Tak Airport. For example, in the North Apron of Kai Tak Airport, biopiling is capable to treat contaminated soil with TPH concentration as high as 21,728mg/kg. In fact, with reference to "Biopile Design, Operation, and Maintenance Handbook for Treating Hydrocarbon-Contaminated Soils" published by Battelle Press in 1998, biopiling is capable to treat the contaminated soil with TPH concentration less than 50,000mg/kg.

Remediation Methods for Soil Contaminated with Metals and TPH

3.8.12 Soil contaminated with metals and TPH is proposed to first be treated by biopiling and then by solidification / stabilization since organic compounds may interfere with the process of

solidification. Contaminated soil of this category shall be biopiled separately from those contaminated with TPH, which will be backfilled into the site after biopiling without solidification. During the biopiling, the contaminated soil shall be treated to below the relevant cleanup targets prior to solidification / stabilization.

Summary of Proposed Remediation Methods for Soil Contamination

- 3.8.13 Justifications for the above proposed remediation methods for the contaminated soil identified in this study are summarized **Table 3.16** below:

Table 3.16 Summary of Proposed Remediation Methods for Metals / TPH / VOCs / SVOC Contaminated Soil

Soil Contaminant(s)	Estimated Volume of Contaminated Soil (m ³)	Remediation Method	Justification
Metals	467.1	Solidification/ Stabilization	<ul style="list-style-type: none"> Well developed technology with operation experience in Hong Kong Higher certainty of success Simple operation Cost effective Treated soil is acceptable to be reused as backfill
TPH/ VOCs / SVOC	17,707.9	Biopiling	
Metals and TPH	113.2	Biopiling followed by solidification/ Stabilization	

Groundwater Contamination

- 3.8.14 Regarding groundwater contamination, the risk assessment discussed in **Section 3.7.18** concluded that the concentrations of all COCs do not exceed the risk-based criteria for remediation except TPH.

Estimation of Contaminated Groundwater (Free Product)

- 3.8.15 In general, free product is defined as the phase separated proportion of oil/water mixture present on the top of the groundwater accumulated in sufficient amount that will flow into wells or excavations. In accordance with the on-site measurement records, floating free products were recorded in the groundwater samples collected at boreholes B02, B06 and B06A in the ex-GFS apron area and the thickness measured by an interface probe were about 16cm, 17cm and 39cm respectively. The free-product was tested to be identical to petroleum hydrocarbons with resemblance to kerosene. The estimated quantity of free product is provided in **Table 3.17** below:

Table 3.17 Estimated Quantity of Contaminated Groundwater (Free Product) at Ex-GFS Apron Area

Area	Contaminant	Estimated Contamination Extent		
		Vertical (m below existing ground level)	Horizontal (m ²)	Quantity of Free Product (m ³)*
Ex-GFS Apron Area				
B-02	Free Product	0.16m (2.24 - 2.4m bgl)	28.3	1.5
B-06	Free Product	0.17m (2.43 - 2.6m bgl)	28.3	1.6
B-06A	Free Product	0.39m (2.41 - 2.8m bgl)	28.3	3.7
Total				6.8

* With reference to previous land contamination study conducted under *Agreement No. CE 42/2000(CE) South East Kowloon Development Infrastructure at North Apron Area of Kai Tak Airport*, the volume of free product for each borehole is estimated as a cone with base radius of 3m). The free product volume depends on a number of factors like soil density, porosity and capillary action, etc. It is difficult to provide an accurate estimate. The figures here are for the purpose of waste

management particularly the preparation for treatment of recovered free product.

Consideration of Remediation Methods for Free Product

- 3.8.16 In light of the presence of the floating free product, it is proposed that where free product is detected at the groundwater surface at excavated areas, free product recovery should be performed to remove the free product. Several alternatives are available for the recovery of free product. Four general techniques for recovery of free product are described in **Table 3.18** below.

Table 3.18 List of Free Product Recovery Technologies

Remediation Option	Descriptions	Applicability and Environmental Benefits	Limitations and Environmental Disbenefits
Skimming systems	Free product is recovered from a pit or trench without recovering groundwater	<ul style="list-style-type: none"> • Applicable to settings in which the amount of free product is small and exists in permeable conduits such as utility bedding or buried underground open structures. • Low cost and simple operation and maintenance. • Ideal for shallow groundwater level and soil excavation works. 	<ul style="list-style-type: none"> • Recovery rates depend on pit/trench size • Frequent media replacement • Requires manual adjustment
Free product recovery with water table depression	Free product is recovered from a well or trench along with groundwater. Groundwater is pumped to create cone of depression in water table to expand area of influence.	<ul style="list-style-type: none"> • Requires moderately permeable to permeable subsurface materials (silts, sands, and gravels). Can be used in setting with deep water tables. Often used in long term (>1year) remedial actions. Produced groundwater can be expensive to treat. • Recovered groundwater can be oxygenated and re-injected for bioremediation. 	<ul style="list-style-type: none"> • Recovered fluids usually require treatment • Product can be “smeared” across area of depression resulting in greater formation storage • Higher permeability formations may require high pumping rates • Well network design requires capture zone analysis
Vapor extraction / Groundwater extraction	Vacuum is applied to well(s) above water table to recover vapour phase and residual hydrocarbons and to help maintain high water table. Free product and / or groundwater is recovered from wells by pumps.	<ul style="list-style-type: none"> • Low to moderately permeable materials (silts and silty sands). Often used to enhance recovery of hydrocarbons. 	<ul style="list-style-type: none"> • Water and vapour treatment is typically required • Phase separation is required • Initial startup times are longer than other conventional methods • Moderate to large capital investment, medium to high operation and maintenance costs

Remediation Option	Descriptions	Applicability and Environmental Benefits	Limitations and Environmental Disbenefits
Dual phase (liquid and vapour) recovery	Both liquids and vapors are recovered from same well. Groundwater production is minimized, and water table is stabilized.	<ul style="list-style-type: none"> • Generally low permeability materials (clay, clayey silts, silts, silty / clayey sands). Requires surface seal (either naturally occurring clay or man-made) to prevent short-circuiting of vacuum. • High vacuum increases groundwater and product recovery. • Minimizes drawdown and “smearing” of product • Expedites site cleanup by recovering all hydrocarbon phases. 	<ul style="list-style-type: none"> • Usually requires vapour and groundwater treatment • Phase separation is required • Longer initial startup time • Higher capital costs

Remediation Methods for Groundwater Contamination

- 3.8.17 Among the four general techniques for free product recovery presented in **Table 3.18**, skimming system is considered as the most practical and cost-effective method for recovery of free product at the ex-GFS apron area because (1) the quantity of free product would be small and (2) skimming system has been adopted in several successful local land contamination studies such as Cheoy Lee Shipyard and North Apron of the former Kai Tak Airport.
- 3.8.18 It is proposed that the free product should be skimmed off from water surface. In general, free product skimming involves using skimming devices to remove product floating on the water table in excavations. Two types of skimming equipment are available. Mechanical skimming equipment (e.g. floating skimmer and belt skimmer) actively extracts free product from recovery initiation, whereas passive skimming equipment (e.g. filter canisters and absorbent bailers) accumulates free product over time. The selection of skimming equipment should be decided in the design stage of the Project. The skimmed free product should be drummed properly, stored in a designated drum storage area and collected by a licensed chemical waste collector for proper disposal. In general, the type, thickness of material and size of the drum to be used for storing the skimmed free product should be in line with the Waste Disposal (Chemical Waste) (General) Regulation.
- 3.8.19 Recovery of free product should continue until no free product can be measured by an interface probe (with usual detection limit of about 1.5mm). At that time, a confirmation sample of groundwater should be collected at the surface of the groundwater and analysed for TPH by a laboratory accredited by the Hong Kong Laboratory Accreditation Scheme (HOKLAS).
- 3.8.20 If TPH concentration of the groundwater sample is below the “allowable” TPH concentration derived from the risk assessment (213 mg/L), the removal of all TPH free product is considered completed. Failing this, skimming of free product shall continue and additional confirmation sample shall be collected until there is no exceedance in the “allowable” TPH concentration.
- 3.8.21 As long as the free product are removed from the water surface and the TPH concentration are below the limit derived from risk assessment, there should be no unacceptable risk for the construction workers employed for carrying out the decommissioning / decontamination works and for other concurrent projects as provided in **Section 2**, and the future construction workers and land users.

3.9 Outline Process and Operation of Remediation

Overall Remediation Arrangement

- 3.9.1 Contaminated soils will be excavated from the individual contaminated zones (i.e. the excavation zones as shown in **Drawing 3.8**) and then transported to a centralized decontamination works area for treatment by biopiling and solidification / stabilization. The overall remediation strategy for soil remediation is illustrated in **Drawing 3.9**. The decontamination works area will be located at the northern part of the South Apron, bounded by the Kai Tak Nullah to the north and Kai Fuk Road to the east. The proposed decontamination works area will have the following components:
- (i) Temporary stockpiling areas;
 - (ii) Solidification / stabilization unit;
 - (iii) Biopiling unit; and
 - (iv) Site management office.
- 3.9.2 Trucks will carry the excavated contaminated soils using the existing truck route along the

eastern shore of the Kai Tak Approach Channel and deliver to the decontamination works area for treatment.

- 3.9.3 The decontamination works area is expected to operate for about 12 months depending on the progress of treatment.
- 3.9.4 Impacts regarding noise, air and water quality generated from the decontamination works area will be addressed in the respective sections in this EIA report.

Excavation of Contaminated Soil

- 3.9.5 Contaminated soil identified within the Project area shall be excavated from the ground prior to any construction works on site. The excavation plans for the identified contaminated areas at south apron, the narrow strip of the north apron near the Kai Tak Tunnel and the ex-GFS apron area are shown in **Drawing 3.8**. Factors such as excavation areas and depths, engineering properties and stability of the soils shall be considered for safe working conditions. The excavations shall be designed in accordance with the geotechnical properties of the soils and appropriate safety factors as determined by the Engineer. All excavated areas shall be set out by an appropriate qualified and licensed land surveyor based upon the excavation plans shown in **Drawing 3.8**.
- 3.9.6 The excavation sequence would be as follows:
- Excavate the contaminated soil and properly packed until no contaminants are found (confirmed by field and laboratory tests);
 - Soils contaminated with different types of contaminants shall not be mixed to avoid the increase the volume of soil that would require treatment by different remediation methods;
 - Transport the excavated soil by roll-off trucks for on-site treatment;
 - Any free product encountered during excavation will be recovered and drummed properly and collected by licensed chemical waste collector for proper treatment;
 - Finally, backfill the excavation with clean soils.
- 3.9.7 A site closure assessment to confirm the closure/completion for the excavation of contaminated areas should be undertaken. The excavation work shall be supervised by Land Contamination Specialist. Subsequent construction activities at that particular area could only be carried out after the site closure.
- 3.9.8 Following excavation and before backfilling, confirmation sampling and testing shall be carried out at limits of excavation to confirm that all the identified contaminated soil has been excavated. Soil samples shall be collected at the limits of excavation for laboratory analysis of contaminants with exceedance of Dutch B/C levels for soil remediation. Samples shall be analysed and if the analytical results are below the relevant Dutch B levels, removal of contaminated soil shall be considered complete. If the analytical samples exceed the relevant action levels, more soil shall be excavated (either with 0.5m increment in vertical or 1m in horizontal direction depending on whether the exceeding confirmation sample is collected from a sidewall or excavation base), and additional confirmation samples shall be collected and analysed until all confirmation samples are below the relevant action levels.
- 3.9.9 For excavation areas, which are less than 100m² in size (i.e. for excavation zones A – I, L, N – Q), one confirmation sample shall be collected from the pit bottom and one from each sidewall of the excavation pit. The depth of sampling shall be based on the depth of the original SI sample result that triggered excavation in that area. If there are any visible indications of impact, extra samples shall be collected from the apparent impact zone(s).

- 3.9.10 For larger excavation areas (i.e. for excavation zones J, K and M), confirmation samples shall be collected from sidewalls of the excavation with a lateral spacing of not more than 15m. At least one confirmation sample shall be collected from each sidewall. Depth of sidewall samples shall be based on the depth of the original SI sample result that triggered excavation in that area. Confirmation samples from the bottom of larger excavation areas shall be collected on grid spacing not larger than 15m x 15m (i.e. one sample per approximately every 225m²). In all cases, if there are any visible indications of impact, samples shall be collected from the apparent impact zone(s).
- 3.9.11 Shall any *in-situ* decommissioned underground fuel tanks and /or any other underground fuel pipelines hinder any necessary excavation works, the following procedures / plans should be followed. Fire Services Department (FSD) and relevant government departments / authorities may be consulted as necessary.
- The soil / fill material from around the tank / pipeline shall be removed adequately, except for the identified contaminated material which shall be separately stockpiled on site for further decontamination treatment to be agreed by the Engineer and the Land Decontamination Specialist;
 - Appropriate heavy equipment shall be used for the underground fuel tank / pipeline removal / lifting. Relevant safety precautions should be formulated in the method statement to be prepared by the Contractor;
 - The excavated tank should be transferred to a secure area on site. The excavated tank / pipeline should be examined for structural integrity and signs of leakage if any. Contamination on the exterior surface of excavated tank, if any, should be properly washed and/or treated; and
 - The excavated tank / pipeline should then be sent for off-site disposal as general C&D waste.
- 3.9.12 In addition, for proper decommissioning of underground fuel tank / pipelines, the following fire safety advice should be adhered to:
- The gas freeing, abandoning, removing and disposal of all tanks / pipelines should be in accordance with the guidelines contained in Chapter 15 of the “Guidance for the Design, Construction, Modification, Maintenance and Decommissioning of Filling Stations”, jointly published by the APEA and Energy Institute;
 - Precautionary guidelines for hot works (as provided in **Appendix 3.4**) are to be observed at all times through the demolition process; and
 - A competent person should be assigned in writing to supervise all hot works and method statement should be submitted to FSD for scrutinizing before the commencement of the demolition works.
- 3.9.13 Spoils generated during excavation shall be placed on heavy-duty and impermeable sheeting adjacent to the excavation. The temporary stockpiles shall be properly covered by impermeable sheeting to avoid leaching out of contaminants during wet season.
- 3.9.14 As contamination with TPH within the Project area and elevated PID readings have been identified at the ex-GFS apron area, particular emphasis should be placed on contaminated soil excavation and working in areas that may contain potentially explosive and/or toxic vapours during excavation. The presence of explosive gas in the excavation pits shall be checked by using a Combustible Gas Indicator (CGI) at the ex-GFS apron area.
- 3.9.15 All construction activities related to decontamination works shall be carried out by persons appropriately trained in health and safety and appropriated personal protective equipment shall be used by the persons engaged in decontamination activities. The Occupation Safety and Health Ordinance (OSHO) (Chapter 509) and its subsidiary Regulations shall be

ollowed by all site personnel working on the site at all times:

- Temporary fencing or warning ribbons will be provided to the boundary of excavation, slope crest and temporarily stockpiled areas. Where necessary, the exposed areas will be temporarily covered with impermeable sheeting during heavy rainstorm.
- There should be a clear separation and management of “contaminated” area and “uncontaminated” area for both excavation and stockpiling. There should also be facilities for decontamination of workers and equipment.
- Workers are required to wear appropriate protective clothing and safety equipment.
- Smoking, eating, drinking and hotworks are strictly prohibited.
- Monitoring for Lower Explosive Limit in the work zone, and total VOCs (with a Photo-ionisation Detector (PID)) in the breathing zone shall be undertaken. If the PID reading in the breathing zone is greater than 100ppm, monitoring for benzene in the breathing zone shall also be undertaken.
- Relevant occupational health and safety regulations and guidelines during excavation shall be observed.

Biopiling

3.9.16 Biopiling is proposed to treat the contaminated soil with TPH, VOCs (ethylbenzene and xylenes) and SVOC (benzo(a)pyrene) in this EIA Study. In general, biopiling is a commonly accepted bioremediation method for the restoration of site contaminated with TPH and other organic contaminants. By using microorganisms to degrade contaminants in soil, biopile(s) transform hazardous / toxic materials into harmless elements such as water, carbon dioxide, and other innocuous products. The biopiling should be carried out in the proposed decontamination works area as shown in **Drawing 3.10**. The schematic layout of a typical biopile is shown in **Drawing 3.11** and the essential steps of biopiling are outlined in the following paragraphs:

Biopile Formation

- 3.9.17 The formation of a biopile should be started from one end and along the longitudinal direction. Uniform starting concentrations will facilitate the control of the bioremediation and ensure a short cleanup time (as decontamination will not be controlled by patches of soil with high initial concentrations). Compaction of the biopile by excavation machinery should be avoided in order to have uniform density of the biopile. Bulking agents are not usually added as they are hard to be compacted during backfilling. The biopile should be covered by impermeable sheeting (such that not longer than 5m of a biopile shall be exposed to open air) to avoid fugitive emissions of dust or any pollutants from the biopile affecting the surrounding environment. Adequate turning should be undertaken during biopile formation (and installation of piping) to maximize sufficient air circulation. Turning of soil may also be used during operation to enhance air circulation. Nevertheless, this should be confirmed by the cleanup progress monitoring.
- 3.9.18 Impermeable sheeting shall be placed at the bottom of the biopiles and leachate collection sump shall be constructed along the perimeter of the biopiles to prevent leachate from contaminating the underlying soil / groundwater. All leachate generated from the operation of biopiling shall be collected and recycled to the biopile.
- 3.9.19 The carbon filter system should be designed, constructed, operated and maintained to ensure adequate adsorption efficiency to prevent air pollution impact to the surrounding air sensitive receivers (ASRs). The location of the exhaust of the carbon filter should be sited as far away as possible from the nearby ASRs. The carbon adsorption system should also be monitored regularly to check the performance of the carbon filter.

- 3.9.20 The first soil samples should be taken once the construction of a biopile is completed to serve as the baseline samples. The baseline conditions should be used as the reference conditions for assessing the cleanup progress of the subsequent biopile operation.

Biopile Operation

- 3.9.21 The biopile operation involves the induction of air into each biopile resulting from the establishment of a negative pressure field within each biopile. The negative pressure encourages the “evaporation” or volatilization of part of the hydrocarbon contamination that is adsorbed to the soil particles. The inducted air collects the vapour and transports it via the extraction pipes out of the biopile. The inducted air also maintains aerobic conditions in the soil pores which encourage biodegradation of the remaining non-volatile petroleum hydrocarbons.
- 3.9.22 As a large part of the hydrocarbon contaminant is not expected to be volatilized, cleanup of the non-volatile contaminant will depend on the biodegradation process, which produces CO₂. Thus, the gas obtained from the biopile shall comprise a mixture of air, water vapour, CO₂, and vaporized hydrocarbons. Exhaust air shall be passed through the activated carbon filters prior to discharge the atmosphere to remove any contaminants.
- 3.9.23 Suitable conditions in the biopile should be maintained for the growth of microbes. Moisture would be periodically added to the soil to maintain the moisture content within 10-20%. The optimal oxygen concentration in soil gas is 15% to 20%. The soil pH should be maintained between 5 and 8 for bacteria to survive. Nutrients may be required for microbial activities in small amounts. Regular progress monitoring of the soil conditions should be conducted to ascertain these conditions have been maintained. In addition, TPH and BTEX levels in the soil should also be tested to assess the decontamination performance of the system. Bacterial numbers in soil (CFU heterotrophs or CFU degraders/gram soil) is a good indicator of the health of biopile. This parameter should be measured too whenever soil samples are collected for TPH analysis during progress monitoring.
- 3.9.24 Upon achieving the relevant cleanup targets, soil from the biopile should be reused on-site as filling material as far as practical.

Biopile Cleanup Progress Monitoring

- 3.9.25 The objective of the operation progress monitoring is twofold: i) to maintain the progress of contaminant cleanup, and ii) to ensure suitable conditions of the soil to support microbial growth. Progress monitoring would involve periodic soil gas monitoring, soil sampling, and physical parameter monitoring.
- 3.9.26 Soil gas monitoring points are installed within the biopiles. Sampling of oxygen, carbon dioxide, methane and VOC concentrations in the soil gas should be conducted once every month. Soil gas samples are taken by pulling a gas sample from the monitoring points through a vacuum pump. *In-situ* measurement of soil moisture should be included for monitoring. Soil gas sampling after placing the system in operation can establish the effectiveness of the aeration system.
- 3.9.27 It is proposed to undertake soil sampling monthly for the analysis of pH, nutrients, and bacterial number. Analyses for TPH and BTEX for soil samples shall be conducted at least once every 3 months. Monitoring should continue until the cleanup targets are achieved. Once the cleanup targets for a location have been achieved, soil sampling at that particular location may discontinue.

Biopile Closure Assessment

- 3.9.28 Biopile closure assessment should be conducted to ensure that the soil contaminant levels in the biopile are meeting the cleanup target for TPH, VOCs and SVOC.
- 3.9.29 The sampling frequency of one sample per 100 m³ for biopile closure assessment is

reference to the CAR & RAP of previous projects in Hong Kong. The biopile shall be divided into lots for sampling and testing for contaminants.

- 3.9.30 Access to the sampling locations should be through opening of heat bonded cover panels. These openings shall be closed after each access. Extracting this soil samples shall be accomplished using a hand auger or other methods approved by the Engineer.
- 3.9.31 All soil samples shall be analyzed for TPH / VOCs / SVOC. The laboratory results are considered satisfactory when the levels of TPH / VOCs / SVOC meet the cleanup target (i.e. Dutch B levels). Individual soil lot which has demonstrated meeting the cleanup target could be removed from the biopile provided the lot would not affect the operation of biopile or would not be affected by adjacent soil lots still under treatment.

Solidification / Stabilization

- 3.9.32 A treatment area for carrying out the solidification / stabilization mixing and temporary soil stockpile should be located in the proposed decontamination works area as shown in **Drawing 3.10**. Prior to solidification / stabilization, metals contaminated soils should be screened to segregate soil from debris, rock fragments and other materials and to break soil clumps into sizes allow effective mixing with solidifying agents.
- 3.9.33 During the solidification / stabilization process, portland cement (or other equivalent), water and/or other additive(s) (such as fly ash, lime, soluble silicates and clays) should be added to the contaminated soils to form a solid matrix. Uniform mixing of contaminated soils, cement, water and other additives(s) should be taken by using a skip (or other equivalent) at the designated treatment area to minimise the potential for leaching during the solidification process.
- 3.9.34 The mixture should be placed in moulds made from wooden formwork to set for approximately one week. The blocks formed should be of a suitable size to allow handling and transporting and larger blocks should be broken down into smaller sizes for transportation.
- 3.9.35 The soil mixture in the concrete blocks would be solidified within about 1 week. After setting, the samples of the blocks should be collected for testing to confirm if the contaminated materials meet the (i) Toxicity Characteristic Leaching Procedure (TCLP) and (ii) unconfined compressive strength (UCS) tests i.e. achievement of the stabilization targets.

Toxicity Characteristics Leaching Procedure Test

- 3.9.36 The sampling frequency for the TCLP test should be 1 TCLP sample per 50m³ of broken up hardened mixture after CS/S treatment. Each TCLP sample should be a composite sample collected at 5 locations throughout the 50m³ broken up hardened mixture. Same volume of sample should be collected at each of the 5 locations in order to ensure unbiased composite sample to be collected.
- 3.9.37 Any hardened samples to be submitted to laboratory for TCLP analysis should be broken up to small pieces with maximum diameter of 10cm. The sample preparation method of USEPA Method 1311 will be followed for the TCLP analysis. It is specified in USEPA Method 1311 that the maximum grain size of samples to be analyzed is 1cm. As such, the samples should be further broken up in the laboratory prior to TCLP analysis.
- 3.9.38 TCLP tests should be conducted in accordance with USEPA Method 1311 and USEPA Method 6020 for the concerned metals in this Study. "Universal Treatment Standards" (UTS) can be used for interpretation of the TCLP test results (these standards were derived from the performance of the Best Demonstrated Available Technologies (BDAT) for treating most prohibited hazardous wastes and were adopted in previous land contamination studies e.g. decontamination works at the Cheoy Lee Shipyard at Penny's Bay and reclamation works at

North Tsing Yi Shipyard site). The UTS for the concerned heavy metals are summarised in **Table 3.19**.

Table 3.19 Universal Treatment Standards (UTS) for the Concerned Heavy Metals

Parameter	Universal Treatment Standard*
Arsenic	5 mg/L as TCLP
Lead	0.75 mg/L as TCLP
Copper	7.8* mg/L as TCLP

Remarks:

* Reference to Universal Treatment Standards (UTS) of U.S. Resource Conservation and Recovery Act (RCRA) in Title 40 of the Code of Federal Regulations (CFR) Parts 268.

** It should be noted that the UTS standard for copper is unavailable. To determine the UTS for copper, a comparison has been made between Drinking Water Standards for the USEPA and the USEPA Federal Register. It was found that the 2 sets of standards differ by a factor of ~6 (for Chromium) to ~2950 (for Cyanide). Using a more conservative approach, the factor of 6 is taken. Therefore, the UTS for copper is taken to be the Drinking Water Standard value of 1.3mg/L times a factor of 6, giving a value of 7.8mg/L.

- 3.9.39 Any pile of broken up solidified mixture that meets the concerned UTS should be stockpiled on site for future reuses on-site due to their stable and inert properties.
- 3.9.40 Any pile of broken up solidified mixture that does not meet the concerned UTS should be crushed and re-treated by solidification / stabilization. The re-treated pile should be tested again for TCLP to confirm if it can be reused on site.

Unconfined Compressive Strength (UCS)

- 3.9.41 The treated material should be allowed to set to achieve the unconfined compressive strength (UCS) of not less than 1mPa with reference to the USEPA guidelines (1986) – Handbook of Stabilization/ Solidification of Hazardous Wastes, EPA/540/2-86-00. The test procedure of UCS test should be based on BS 1377.
- 3.9.42 The solidified materials should then be broken into mass with maximum size of 250mm for backfilling or reuse on-site. Whenever the treated soil is to be reused as filling materials, it should be put below 1m of clean fill.
- 3.9.43 It is recommended that compliance check on soil / groundwater samples by a third party (independent HOKLAS) should be carried out during the decontamination works.

3.10 Remediation Report

- 3.10.1 A Remediation Report shall be prepared by the Land Contamination Specialist and submitted to EPD to report on the remediation process and demonstrate that contaminated soils and groundwater are all treated to meet the relevant standards or properly handled. All relevant information, including details of closure assessment, sampling results, photographs and certification of independent checker, the quantities of treated soil and recovered free product, final backfill site of treated soil and disposal site of free product shall be included in the remediation report.

3.11 Environmental Mitigation Measures and Safety Measures

- 3.11.1 In order to minimise the potentially adverse environmental impacts arising from the handling of potentially contaminated materials, the following environmental mitigation measures are proposed during the course of the site remediation:

Free Product Recovery

- The skimmed free product should be drummed properly, stored in a designated drum storage area with containment and collected by a licensed chemical waste collector for proper disposal. In general, the type, thickness of material and size of the drum to be used for storing the skimmed free product should be in line with the Waste Disposal (Chemical Waste) (General) Regulation.

Excavation and Transportation

- Excavation profiles must be properly designed and executed.
- Stockpiling site(s) shall be lined with impermeable sheeting and bunded. Stockpiles shall be properly covered by impermeable sheeting to reduce dust emission. If this is not practicable due to frequent usage, regular misting shall be applied. Watering shall be avoided on stockpiles of contaminated soil to minimise contaminated runoff.
- Stockpiles of contaminated soil shall be properly covered by impermeable sheeting to minimize contaminated runoff from the stockpiles.
- Excavation and stockpiling shall be carried out during dry season as far as possible to minimise contaminated runoff from contaminated soils.
- Supply of suitable clean backfill material is needed after excavation.
- Vehicles containing any excavated materials should be suitably covered to limit potential dust emissions or contaminated wastewater run-off, and truck bodies and tailgates should be sealed to prevent any discharge during transport or during wet conditions.
- Speed control for the trucks carrying contaminated materials should be enforced;
- Vehicle wheel and body washing facilities at the site's exist points shall be established and used.

Biopiling

- To avoid fugitive emissions of dust or any air pollutants from the biopile(s) and to minimise runoff from the stockpiled soils, the stockpiled soils at the biopiles shall be covered by impermeable sheeting such that not longer than 5m of the biopile is exposed to open air.
- Impermeable sheeting shall be placed at the bottom of the biopiles and leachate collection sump shall be constructed along the perimeter of the biopiles to prevent leachate from contaminating the underlying soil / groundwater. All leachate generated from the operation of biopiling shall be collected and recycled to the biopile.
- The vented air from the biopile(s) shall be connected to blower and carbon adsorption system for treatment before release to the atmosphere. Exhaust air from the blower and carbon adsorption system shall be monitored for VOCs regularly.
- Spend activated carbon of the carbon adsorption system shall be replaced at appropriate intervals such that the VOC emission rate from the system is acceptable.
- Silencers shall be installed at the biopile blowers to minimise noise impact.
- Contaminated runoff from biopile(s) shall be prevented by constructing a concrete bund along the perimeter of the biopiles.

Solidification / Stabilization

- Mixing process and other associated material handling activities should be properly scheduled to minimise potential noise impact.
- Mixing of contaminated soils and cement / water / other additive(s) should be undertaken at a solidification plant to minimise the potential for leaching.
- Runoff from the solidification / stabilization area should be prevented by constructing a concrete bund along the perimeter of the solidification / stabilization area.

3.11.2 In order to minimise the potentially adverse effects on health and safety of construction workers during the course of site remediation, the Occupation Safety and Health Ordinance (OSHO) (Chapter 509) and its subsidiary Regulations shall be followed by all site personnel working on the site at all times. In addition, the following basic health and safety measures should be implemented as far as possible:

- Set up a list of safety measures for site workers;
- Provide written information and training on safety for site workers;
- Keep a log-book and plan showing the contaminated zones and clean zones;
- Maintain a hygienic working environment;
- Avoid dust generation;
- Provide face and respiratory protection gear to site workers;
- Provide personal protective clothing (e.g. chemical resistant jackboot, liquid tight gloves) to site workers; and
- Provide first aid training and materials to site workers.

3.12 Interaction with other Concurrent Projects

3.12.1 There would be no adverse impacts identified for airport runway to be developed in parallel with the proposed decontamination works considering there is no contamination impacts identified and the airport runway is physically separated from contaminated areas identified at the south apron, narrow strip of the north apron and the ex-GFS apron area by the Kai Tak Approach Channel (KTAC). Therefore, construction activities in the airport runway could be proceeded upon the approval of the EIA report in concurrent with the decontamination work.

3.12.2 All the contaminated soils identified in the ex-GFS apron area, the south apron and the narrow strip of north apron, would be excavated and transported to the proposed decontamination works area for remediation treatment. In addition, any free product encountered during excavation will be recovered. As a result, no adverse impacts would be anticipated after the closure of excavation zones and construction works in these sites would be carried out immediately. No adverse impacts would also be anticipated on the commencement of permanent construction in the ex-GFS apron area upon completion of free product recovery and excavation of contaminated soil in this site.

3.12.3 Potential impacts arising from the proposed decontamination works area would be controlled by environmental mitigation measures (on water, air and noise as suggested in **Sections 5, 6 and 7**, respectively). As a results, no adverse impacts would be anticipated for the adjacent concurrent projects.

3.12.4 In summary, given that the site cleanup is completed, no adverse impacts would be

anticipated for construction workers employed for other concurrent projects as identified in **Section 2**.

3.13 Evaluation of Residual Impacts

- 3.13.1 After completion of groundwater remediation by free product recovery and removal of contaminated soil, risk of petroleum hydrocarbons in groundwater would be acceptable and no adverse impact to the construction workers for carrying out decontamination works (which is regarded as the most sensitive receptor due to groundwater contamination) would be envisaged. The future landusers / future construction workers of the Kai Tak Development are considered less sensitive than the construction workers of the decontamination works and adverse impact would not be anticipated. In addition, groundwater at the Project area will not be used as potable water or used for recreation / irrigation purposes and the future ground surface of the Project area should be of urban nature and to be covered by filling materials / concrete, residual impacts in respect of groundwater contamination on future landusers / future construction workers should therefore be insignificant.
- 3.13.2 In terms of soil contamination, the proposed remediation methods would remove contaminated soils from the site through excavation followed by degradation of the contaminants to non-toxic substances by biopiling or immobilizing the contaminants by solidification / stabilization. After completion of soil remediation, residual impact in respect of land contamination on the future users and construction workers should not be expected.

3.14 Environmental Monitoring and Audit

- 3.14.1 Details of the environmental monitoring and audit requirements are provided in Chapter 10 of this EIA and a stand-alone EM&A Manual.

3.15 Conclusion

- 3.15.1 The land contamination assessment has been carried out in the following three steps: preparation of contamination assessment plans, carrying out the site investigations, reporting in the contamination assessment reports and remediation action plans. Results of sub-areas: south apron area, ex-Government Flying Service (ex-GFS) apron area, and runway area and the narrow strip of north apron have been reviewed and assessed in this section of the EIA study.
- 3.15.2 Based on the investigation results, some individual areas in the south apron were identified with metals and/or petroleum hydrocarbons (in terms of TPH) contamination. In addition, a small area in the narrow strip of the north apron near the Kai Tak Tunnel was also found contaminated with benzo(a)pyrene. Furthermore, the supplementary investigation undertaken at the ex-GFS apron area revealed that the site was contaminated with metals, TPH, ethylbenzene and xylenes. No contamination was found in the runway area and therefore construction works for any future development in the runway area could be proceeded accordingly without the need of prior decontamination.
- 3.15.3 There would be no adverse impacts identified for airport runway to be developed in parallel with the proposed decontamination works considering there is no contamination found and the physical separation between the airport runway and the identified contamination areas (at the south apron area, the ex-GFS apron area and the narrow strip of the north apron) by Kai Tak Approach Channel (KTAC). In addition, there would be no adverse impacts for the commencement of permanent construction in the ex-GFS apron area upon completion of free product recovery and excavation of contaminated soil.
- 3.15.4 While groundwater in the area is not used as potable water nor irrigation, Dutch B standard is considered not directly applicable. Results of the groundwater risk assessment indicate that the concentrations of the chemical-of-concerns (COCs) in the groundwater, including metals (including barium, cadmium, copper, molybdenum, lead, tin, zinc, thallium, vanadium, antimony, chromium, cobalt and nickel), VOCs (benzene, ethylbenzene, xylenes) and

SVOCs (benzo(a)pyrene, phenanthrene and naphthalene) do not exceed risk-based criteria for remediation except TPH. Based on the site investigation findings, floating free products were recorded at some of the groundwater monitoring wells in the ex-GFS apron area and the estimated quantity of free product is about 6.8m³. In order to reduce the safety and health risk, it is proposed that free product shall be skimmed off from water surface. The skimmed free product shall be drummed properly, stored in a designated drum storage area with containment and collected by a licensed waste collector for proper disposal.

- 3.15.5 Based on the site investigations findings, the estimated soil volumes by different soil contaminant types are (1) metals only: 467.1m³; (2) TPH / VOCs / SVOC only: 17,707.9m³ and (3) both TPH and metals: 113.2m³. After review of various remediation methods, biopiling is proposed to treat TPH / VOCs / SVOC contaminated soil. Biopile cleanup progress monitoring and closure assessment are proposed for biopiling to ensure a satisfactory cleanup progress and that all the target contaminants have been treated to below the cleanup targets. Solidification / stabilization is proposed to treat the soil contaminated with metals. For soil contaminated with metals and TPH, it is suggested to treat the contaminated soil by biopiling first and followed by solidification / stabilization.
- 3.15.6 No adverse impacts would be anticipated from the decontamination works, including free product recovery, excavation, biopiling and solidification / stabilization with the implementation of the recommended mitigation measures.
- 3.15.7 The soil treated by biopiling should be reused on-site as fill material as far as practical. For soil treated by solidification / stabilization, the treated soil should be backfilled on-site and then covered by 1m of clean fill.
- 3.15.8 After necessary remediation actions are carried out at the contaminated areas, no adverse residual environmental impact in respect of land contamination is anticipated.