8 Land Contamination Impacts

8.1 Overview

This section presents the assessment of land contamination impacts which may arise during the construction phase. The assessment has covered the entire LMC Loop as well as the contamination assessment area including footprint of associated infrastructure, working space and works area for the associated infrastructure outside the LMC Loop. Details of the assessment can be referred to their respective Contamination Assessment Plans (CAPs) given in **Appendix 8-1** and **Appendix 8-3** respectively.

This section presents the assessment of land contamination impacts which may arise during the construction phase. The assessment has covered the entire Lok Ma Chau Loop (Area A) as shown in **Figure 1.1** (hereby refers to LMC Loop) as well as the contamination assessment area including footprint of associated infrastructure, working space and works area for the associated infrastructure outside the LMC Loop. The location of the contamination assessment area for the associated infrastructure in adjacent area in Hong Kong outside the LMC Loop can be referred to Figure 1.4 in the Contamination Assessment Plan (CAP) for Associated Infrastructure outside Lok Ma Chau Loop given in **Appendix 8-3**. Details of the assessment can be referred to their respective CAPs given in Appendix 8-1 and Appendix 8-3 respectively.

Environmental site investigation has been conducted for the Project within the LMC Loop. The concentration of the metal "Arsenic (As)" from 6 soil samples collected at 5 boreholes marginally exceeded the Risk-Based Remediation Goals (RBRGs) of Rural Residential and Urban Residential land uses. With the implementation of Remediation Action Plan, all contaminated soils would be remediated during the construction phase. No groundwater contamination was detected.

No potentially contaminated site was identified within the contamination assessment area for the associated infrastructure outside the LMC Loop as shown in the plan of Superimposition of Study Area and Assessment Area i.e. Figure 1.4 of **Appendix 8-3**. It is also confirmed that there will not be any works/development outside the contamination assessment area under the present EIA study.

The land contamination assessment has been conducted in accordance with the requirements of Annexes 19 of the TM-EIAO as well as the requirements set out under Clause 3.4.9 of the EIA Study Brief.

8.2 Environmental Legislation, Standards and Guidelines

The relevant legislations, standards and guidelines applicable to the present study for the assessment of land contamination include:

- Annex 19 of the TM-EIAO, Guidelines for Assessment of Impact On Sites of Cultural Heritage and Other Impacts (Section 3 : Potential Contaminated Land Issues), EPD, 1997;

- Guidance Manual for Use of Risk-Based Remediation Goals (RBRGs) for Contaminated Land Management, EPD, 2007.
- Guidance Notes for Contaminated Land Assessment and Remediation EPD, 2007 ; and
- Practice Guide for Investigation and Remediation of Contaminated Land, EPD, 2011.

8.2.1 Environmental Impact Assessment Ordinance (EIAO) (Cap. 499), Technical Memorandum on Environmental Impact Assessment Process (TM-EIAO)

Under Annex 19 of the TM-EIAO, a number of potentially contaminating historical land uses should be considered, including oil installations, gas works, metal workshops, car repair and dismantling workshops, which have the potential to cause or have caused land contamination.

8.2.2 Guidance Manual for Use of Risk-Based Remediation Goals (RBRGs) for Contaminated Land Management

The Guidance Manual introduces the risk based approach in land contamination assessment and present instructions for comparison of soil and groundwater data to the Risk-based Remediation Goals (RBRGs) for 54 chemicals of concern commonly found in Hong Kong. The RBRGs were derived to suit Hong Kong conditions by following the international practice of adopting a risk-based methodology for contaminated land assessment and remediation and were designed to protect the health of people who could potentially be exposed to land impacted by chemicals under four broad post restoration land use categories. The RBRGs also serve as the remediation targets if remediation is necessary. The RBRGs for soil and groundwater are given in **Table 8.1** and **Table 8.2** respectively.

Table 8.1 Risk-Based Remediation Goals (RBRGs) for Soil & Soil Saturation Limit

Chemical	Risk-Based Remediation Goals (RBRGs) for Soil				Soil Saturation Limit (C_{sat})
	Urban Residential (mg/kg)	Rural Residential (mg/kg)	Industrial (mg/kg)	Public Park (mg/kg)	(mg/kg)
VOCs					
Acetone	9,590	4,260	10,000	10,000	***
Benzene	0.704	0.279	9.21	42.2	336
Bromodichloromethane	0.317	0.129	2.85	13.40	1,030
2-Butanone	10,000	10,000	10,000	10,000	***
Chloroform	0.132	0.0529	1.54	253	1,100
Ethylbenzene	709	298	8,240	10,000	138
Methyl tert-Butyl Ether	6.88	2.80	70.1	505	2,380
Methylene Chloride	1.30	0.529	13.9	128	921
Styrene	3,220	1,540	10,000	10,000	497
Tetrachloroethene	0.101	0.0444	0.78	1.84	97.1
Toluene	1,440	705	10,000	10,000	235

Chemical	Risk-Based Remediation Goals (RBRGs) for Soil				Soil Saturation Limit (C_{sat})
	Urban Residential (mg/kg)	Rural Residential (mg/kg)	Industrial (mg/kg)	Public Park (mg/kg)	(mg/kg)
Trichloroethene	0.523	0.211	5.68	69.4	488
Xylenes (Total)	95.0	36.8	1,230	10,000	150
SVOCs					
Acenaphthene	3,510	3,280	10,000	10,000	60.2
Acenaphthylene	2,340	1,510	10,000	10,000	19.8
Anthracene	10,000	10,000	10,000	10,000	2.56
Benzo(a)anthracene	12.0	11.4	91.8	38.3	
Benzo(a)pyrene	1.20	1.14	9.18	3.83	
Benzo(b)fluoranthene	9.88	10.1	17.8	20.4	
Benzo(g,h,i)perylene	1,800	1,710	10,000	5,740	
Benzo(k)fluoranthene	120	114	918	383	
Bis-(2-Ethylhexyl)phthalate	30.0	28.0	91.8	94.2	
Chrysene	871	919	1,140	1,540	
Dibenzo(a,h)anthracene	1.20	1.14	9.18	3.83	
Fluoranthene	2,400	2,270	10,000	7,620	
Fluorene	2,380	2,250	10,000	7,450	54.7
Hexachlorobenzene	0.243	0.220	0.582	0.713	
Indeno(1,2,3-cd)pyrene	12.0	11.4	91.8	38.3	
Naphthalene	182	85.6	453	914	125
Phenanthrene	10,000	10,000	10,000	10,000	28.0
Phenol	10,000	10,000	10,000	10,000	7,260
Pyrene	1,800	1,710	10,000	5,720	
Metals					
Antimony	29.5	29.1	261	97.9	
Arsenic	22.1	21.8	196	73.5	
Barium	10,000	10,000	10,000	10,000	
Cadmium	73.8	72.8	653	245	
Chromium III	10,000	10,000	10,000	10,000	
Chromium VI	221	218	1,960	735	
Cobalt	1,480	1,460	10,000	4,900	
Copper	2,950	2,910	10,000	9,790	
Lead	258	255	2,290	857	
Manganese	10,000	10,000	10,000	10,000	
Mercury	11.0	6.52	38.4	45.6	
Molybdenum	369	364	3,260	1,220	
Nickel	1,480	1,460	10,000	4,900	
Tin	10,000	10,000	10,000	10,000	
Zinc	10,000	10,000	10,000	10,000	
Dioxins / PCBs					
Dioxins (I-TEQ)	0.001	0.001	0.005	0.001	
PCBs	0.236	0.223	0.748	0.756	

Chemical	Risk-Based Remediation Goals (RBRGs) for Soil				Soil Saturation Limit (C_{sat}) (mg/kg)
	Urban Residential (mg/kg)	Rural Residential (mg/kg)	Industrial (mg/kg)	Public Park (mg/kg)	
Petroleum Carbon Ranges					
C6 - C8	1,410	545	10,000	10,000	1,000
C9 - C16	2,240	1,330	10,000	10,000	3,000
C17 - C35	10,000	10,000	10,000	10,000	5,000
Other Inorganic Compounds					
Cyanide, free	1,480	1,460	10,000	4,900	
Organometallics					
TBTO	22.1	21.8	196	73.5	

Note:

(1) For Dioxins, the cleanup levels in USEPA Office of Solid Waste and Emergency Response (OSWER) Directive of 1998 have been adopted. The OSWER Directive value of 1 ppb for residential use has been applied to the scenarios of "Urban Residential", "Rural Residential", and "Public Parks", while the low end of the range of values for industrial, 5 ppb, has been applied to the scenario of "industrial".

(2) Soil saturation limits for petroleum carbon ranges taken from the Canada-Wide Standards for Petroleum Hydrocarbons in Soil, CCME 2000.

(3) * indicates a 'ceiling limit' concentration.

(4) *** indicates that the C_{sat} value exceeds the 'ceiling limit' therefore the RBRG applies.

Table 8.2 Risk-Based Remediation Goals (RBRGs) for Groundwater and Solubility Limit

Chemical	Risk-Based Remediation Goals (RBRGs) for Groundwater			Solubility Limit (mg/L)
	Urban Residential (mg/L)	Rural Residential (mg/L)	Industrial (mg/L)	
VOCs				
Acetone	9,590	4,260	10,000	***
Benzene	0.704	0.279	9.21	336
Bromodichloromethane	0.317	0.129	2.85	1,030
2-Butanone	10,000	10,000	10,000	***
Chloroform	0.132	0.0529	1.54	1,100
Ethylbenzene	709	298	8,240	138
Methyl tert-Butyl Ether	6.88	2.80	70.1	2,380
Methylene Chloride	1.30	0.529	13.9	921
Styrene	3,220	1,540	10,000	497
Tetrachloroethene	0.101	0.0444	0.78	97.1
Toluene	1,440	705	10,000	235
Trichloroethene	0.523	0.211	5.68	488
Xylenes (Total)	95.0	36.8	1,230	150
SVOCs				
Acenaphthene	10,000	7,090	10,000	4.24
Acenaphthylene	1,410	542	10,000	3.93

Chemical	Risk-Based Remediation Goals (RBRGs) for Groundwater			Solubility Limit (mg/L)
	Urban Residential (mg/L)	Rural Residential (mg/L)	Industrial (mg/L)	
Anthracene	10,000	10,000	10,000	0.0434
Benzo(a)anthracene				
Benzo(a)pyrene				
Benzo(b)fluoranthene	0.539	0.203	7.53	0.0015
Benzo(g,h,i)perylene				
Benzo(k)fluoranthene				
Bis-(2-Ethylhexyl)phthalate				
Chrysene	58.1	21.9	812	0.0016
Dibenzo(a,h)anthracene				
Fluoranthene	10,000	10,000	10,000	0.206
Fluorene	10,000	10,000	10,000	1.98
Hexachlorobenzene	0.0589	0.0234	0.695	6.20
Indeno(1,2,3-cd)pyrene				
Naphthalene	61.7	23.7	862	31.0
Phenanthrene	10,000	10,000	10,000	1.00
Phenol				
Pyrene	10,000	10,000	10,000	0.135
Metals				
Antimony				
Arsenic				
Barium				
Cadmium				
Chromium III				
Chromium VI				
Cobalt				
Copper				
Lead				
Manganese				
Mercury	0.486	0.184	6.79	
Molybdenum				
Nickel				
Tin				
Zinc				
PCBs				
Dioxins (I-TEQ)				
PCBs	0.433	0.171	5.11	0.031
Petroleum Carbon Ranges				
C6 - C8	1,410	545	10,000	1,000
C9 - C16	2,240	1,330	10,000	3,000
C17 - C35	10,000	10,000	10,000	5,000
Other Inorganic Compounds				

Chemical	Risk-Based Remediation Goals (RBRGs) for Groundwater			Solubility Limit (mg/L)
	Urban Residential (mg/L)	Rural Residential (mg/L)	Industrial (mg/L)	
Cyanide, free				
Organometallics				
TBTO				

Note:
(1) Blank indicates that RBRG could not be calculated because the toxicity or physical/chemical values were unavailable, or the condition of Henry's Law Constant>0.00005 was not met for the inhalation pathway.
(2) Where solubilities for Petroleum Carbon Range aliphatic C9-C16 and greater than C16 generally are considered to be effectively zero and therefore the aromatic solubility for C9-C16 is used.
(3) * indicates a 'ceiling limit' concentration.
(4) *** indicates that the solubility limit exceeds the 'ceiling limit' therefore the RBRG applies.

8.2.3 Guidance Note for Contamination Land Assessment and Remediation

In accordance with EPD's *Guidance Note for Contamination Land Assessment and Remediation*, a contamination assessment evaluation should:

- provide a clear and detailed account of the present land-use and the relevant past land history in relation to possible land contamination;
- identify areas of potential contamination and associated impacts, risks or hazards; and
- submit a plan to evaluate the actual contamination conditions for soil and/or groundwater, if required.

8.2.4 Practice Guide for Investigation and Remediation of Contaminated Land

The EPD's *Practice Guide for Investigation and Remediation of Contaminated Land* includes a summary of the general steps to be followed in conducting a contamination assessment study.

8.3 Assessment Methodology

Land contamination assessment has been conducted according to the following procedures:

- Desktop review of site history;
- Site survey to identify the potentially contaminated sites;
- Prepare Contamination Assessment Plan for EPD's agreement;
- Site Investigation for soil and groundwater sampling and testing;
- Interpret the laboratory test results and evaluate the contamination level:

- Prepare Contamination Assessment Report to summarize the assessment findings for EPD's agreement;
- If contamination is confirmed, propose remediation method and prepare Remediation Action Plan for EPD's agreement.

8.3.1 Desktop Review of Site History

The following information have been collated for the desktop review of site history:

- Hong Kong Ordinance Survey Maps from various years;
- Relevant Outline Zoning Plans (OZPs) in the vicinity of LMC Loop;
- Hong Kong Geological Survey Map;
- Relevant aerial photos from 1973;
- "Mapping Hong Kong, A Historical Atlas", Government Information Services, 1992;
- Environmental Impact Assessment Study on Shenzhen River Regulation Project - Study Report for Stage 1 Works; Nov., 1994;
- Environmental Impact Assessment Study on Shenzhen River Regulation Project - Final EIA Study Report; Nov., 1995;
- 落馬洲河套地區-土壤污染評估報告-安社亞洲(香港)有限公司, 二零零七年六月; (Translate: Lok Ma Chau Loop-Soil Contamination Assessment Report; AECOM Asia Co. Ltd; Jun., 2007);
- 港深落馬洲河套地區聯合開發項目環境影響評價大綱 (送審稿) - 深圳市環境科學研究所, 北京大學, 二零零七年八月; (Translate: Hong Kong Shenzhen Joint Study on Development of Lok Ma Chau Loop - Environmental Impact Assessment Summary (Draft); Shenzhen Institute of Environmental Science, Peking University; Aug., 2007)
- "Sheung Shui to Lok Ma Chau Spur Line Contaminated Land Assessment, Contamination Assessment Report (CAR) and Remediation Action Plan (RAP) Final (May 2002) with Addendum (August 2002) (2141/913)", MTR, 2002; and
- Information related to potential land contamination from Environmental Compliance Division of Environmental Protection Department (EPD) and Fire Services Department (FSD).

8.3.2 Site Survey

Site surveys were conducted subsequently to ground truth the findings of desktop review and to identify any other land uses within the Project area which may have the potential for causing soil and groundwater contaminants. Possible contaminants were identified in accordance with Table 2.3 of EPD's *Practice Guide for Investigation and Remediation of Contaminated Land.*

8.3.3 Preparation of Contamination Assessment Plan

According to the findings of desktop study and site surveys, the CAPs for the entire LMC Loop and that for the associated infrastructure outside the LMC Loop

as given in **Appendix 8-1** and **Appendix 8-3** were prepared and submitted to EPD. Sampling locations and sampling depths for soil and groundwater within the LMC Loop have been proposed for the site investigation (SI) works in its respective CAP. The CAP for LMC Loop also specified the sampling and testing requirements for the SI works.

Since no potentially contaminated site was identified in the contamination assessment area for the associated infrastructure outside the LMC Loop, no SI work was proposed in this area.

8.3.4 Site Investigation and Data Interpretation

After completion of the SI works (i.e. boreholes drilling, soil and groundwater sampling and testing) within LMC Loop, the analytical results of the soil and groundwater were interpreted using RBRGs. The nature, level and extent of the land contamination within LMC Loop were evaluated.

According to the findings of desktop study and site survey, no potentially contaminated site was identified in the contamination assessment area for the associated infrastructure outside the LMC Loop and therefore SI work was not required.

8.3.5 Preparation of Contamination Assessment Report and Remediation Action Plan for LMC Loop

The findings of laboratory test results were documented in the Contamination Assessment Report (CAR) and Supplementary CAR for LMC Loop. Options of remedial works for contaminated soil have been reviewed and evaluated, and appropriate remediation option has been recommended. Details are presented in the Remediation Action Plan (RAP) and Supplementary RAP. Copies of the CAR/RAP and Supplementary CAR/RAP are given in **Appendix 8-2**.

8.4 Description of the Environment

8.4.1 Existing Environment of LMC Loop

The LMC Loop is a flat land with grasses and shrubs. No temporary structure was found in this restricted area. No special land use or activity was observed that may have the potential for causing soil and groundwater contamination.

8.4.1.1 Potentially Contaminated Site within LMC Loop

Historically, the LMC Loop (i.e. former agricultural land and fish ponds in 1980s and early 1990s) was used as a dumping ground for mud extracted from Shenzhen River Training Works Stages 1 and 2. Approximately 1Mm^3 contaminated mud and 3Mm^3 uncontaminated mud were dredged and disposed of within the LMC Loop from year 1995 to 2000. The depth of the disposed mud within the LMC Loop was approximately 5m (which include about 1m to 1.5m thick top layer of uncontaminated mud for capping). However, the disposal pattern, e.g. the disposal location and area of contaminated mud within the LMC Loop is unknown. Therefore, the entire LMC Loop is considered as a potentially contaminated site,

namely "Site A" (**Table 8.3**). The location of Site A and the proposed boreholes are shown in **Figure 8.1** and **Figure 8.2** respectively.

Table 8.3 Potentially contaminated landuse within the LMC Loop

Site ID	Location	Current Land Use	Potential Sources of Contamination	Approximate Area (m^2)	Recommended No. of Boreholes[(i)]
A	Entire LMC Loop	Flat land with Grasses and Shrubs	Approx. 1Mm^3 contaminated mud and 3Mm^3 uncontaminated mud were dredged from the Shenzhen River and disposed of within the LMC Loop from year 1995 to 2000. Total filling depth within the LMC Loop is about 5m, which include 1m to 1.5m thick top layer of uncontaminated mud for capping.	870,000 (87ha)	35

Note

(1) The recommendation in 港深落馬洲河套地區聯合開發項目環境影響評價大綱(送審稿) [Hong Kong Shenzhen Joint Study on Development of Lok Ma Chau Loop - Environmental Impact Assessment Summary (Draft)] under the Law of the People's Republic of China on Environmental Impact Assessment has been taken into account for the determination of the number of boreholes.

8.4.2 Existing Environment of Contamination Assessment Area for the Associated Infrastructure outside LMC Loop

Details of the existing surrounding environment of contamination assessment area for the associated infrastructure outside the LMC Loop are described below.

Direct Link to Lok Ma Chau Station

The contamination assessment area mainly consisted of fish ponds and agricultural lands, intersecting with San Sham Road and the nullah. The area extends westward towards Lok Ma Chau Station with no industrial activity identified.

Western Connection Road

The upper section of the contamination assessment area comprised of fish ponds along Ha Wan Tsuen and Lok Ma Chau Road. For the lower section, Lok Ma Chau Public Transport Interchange, a taxi chit waiting area, and a fenced government land were observed. The contamination assessment area also includes part of the Fanling Highway, San Tin Highway and San Tin Interchange. No industrial activity with land contamination potential was identified.

Eastern Connection Road

The contamination assessment area mainly consisted of fish ponds, agricultural land and natural terrain. Only Lok Ma Chau Police Station was identified and thus no industrial activity was observed.

Flushing Water Service Reservoir

The contamination assessment area consisted of natural terrain only and no industrial activity was identified.

8.4.2.1 Potentially Contaminated Site within Contamination Assessment Area for the Associated Infrastructure outside LMC Loop

Based on the information collected from site survey and review of available historical records e.g. historical aerial photos, no potentially contaminated site was identified in the contamination assessment area for the associated infrastructure outside the LMC Loop. Hence, SI work was not required.

8.4.2.2 Site Re-appraisal

As the construction of the associated infrastructures would only commence a few years later, the entire contamination assessment area for the associated infrastructure outside the LMC Loop, which are currently road structure and natural terrain, should be re-appraised. The objective of re-appraisal of this area is to ensure any potential contamination activities from land use changes after the approval of this land contamination assessment study is subject to a proper updating review prior to commencement of the construction works.

8.5 Site Investigation

8.5.1 LMC Loop

A total of 35 boreholes (3 soil samples per borehole) were drilled for soil and groundwater sampling in accordance with the CAP for the LMC Loop. The laboratory testing results showed that the Arsenic levels from 6 soil samples at 5 boreholes marginally exceeded the RBRGs for both Rural and Urban Residential land uses. In order to determine the extent of the contamination at these 5 locations, 3 additional boreholes near each of the 5 contaminated boreholes were drillled (i.e. a total of 15 additional boreholes were drilled) for additional soil sampling and testing. The laboratory testing results of the additional soil samples show compliance with the RBRG for Rural Residential (i.e. the stringent set of RBRGs).

In order to further confine the horizontal extent of the contamination, 3 further additional boreholes were drilled roughly mid-way in-between the pairs of contaminated and uncontaminated boreholes (i.e. a total of 15 further additional boreholes were drilled). The estimation of final horizontal extent of the contaminated zones in LMC Loop is detailed in **Section 8.6**.

The entire SI programme was supervised by the on-site Land Contamination Specialist. All soil and groundwater samples were analysed by a HOKLAS accredited laboratory for all parameters listed in the **Appendix 8-1**.

Re-appraisal on the LMC Loop will be required to ensure any potential contamination activities from land use changes after the approval of this land contamination assessment study, subject to a proper updating review prior to commencement of the construction works. Where re-appraisal or re-assessment is required, the PP would prepare and submit the Supplementary CAP to EPD prior to the commencement of SI works. Following on from the submission of Supplementary CAP and completion of additional SI, the PP would prepare CAR, RAP and RR and submit to EPD for agreement prior to commencement of the development works.

8.5.2 Contamination Assessment Area for the Associated Infrastructure outside LMC Loop

Re-appraisal on the entire contamination assessment area for the associated infrastructure outside LMC Loop will be required to ensure any potential contamination activities from land use changes after the approval of this land contamination assessment study, subject to a proper updating review prior to commencement of the construction works. Where re-appraisal or re-assessment is required, the PP would prepare and submit the Supplementary CAP to EPD prior to the commencement of SI works. Following on from the submission of CAP and completion of SI, the PP would prepare CAR, RAP and RR and submit to EPD for agreement prior to commencement of the development works.

8.6 Identification and Evaluation of Land Contamination

8.6.1 LMC Loop

The laboratory test results of soil, groundwater and elutriate samples have been reviewed and they are summarized in the CAR/RAP for LMC Loop and Supplementary CAR/RAP for LMC Loop (**Appendix 8-2**).

8.6.1.1 Soil Contamination

A total of 105 soil samples were collected from 35 boreholes (i.e. 3 soil samples per borehole) from November 2009 to January 2010. The test results indicated that all but 6 of the soil samples collected from 5 boreholes were below RBRG for Rural Residential (i.e. the most stringent set of RBRGs for SVOCs, Metals, Dioxins, PCBs and Cyanide) and Intervention Value (i.e. for Chlorinated Pesticides). In these 6 samples, the concentrations of metal “Arsenic (As)” have marginally exceeded the RBRGs for Rural Residential and Urban Residential land uses. The results are presented **Table 8.4** and their respective 5 borehole locations are shown in **Figure 8.3**.

Table 8.4 Summary of soil samples exceeding RBRGs

Borehole No.	Depth of Soil Sampling (mbgl)	Contaminant	Concentration (mg/kg dry soil)	RBRGs of Arsenic (mg/kg dry soil)
A-S01	3.0 – 3.45	Arsenic	22.2	Rural Residential RBRG : **21.8** Urban Residential RBRG : **22.1** Public Parks RBRG : **73.5** Industrial RBRG : **196**
	4.5 – 4.95	Arsenic	24.0	
A-S03	3.0 – 3.45	Arsenic	26.8	
A-S20	3.0 – 3.45	Arsenic	23.0	
A-S24	3.0 – 3.45	Arsenic	27.7	
A-SG10	4.5 – 4.95	Arsenic	27.3	

In order to determine the extent of contamination at these 5 locations, 3 additional boreholes near each of the 5 contaminated boreholes were drillled (i.e. a total of 15 additional boreholes were drilled) from January 2010 to February 2010 for additional soil sampling and testing. The locations of these 15 additional boreholes were chosen roughly mid-way in between the pairs of contaminated and uncontaminated boreholes, as shown in **Figure 8.4** and depicted in **Figures 8.5** to **8.9**. All laboratory testing results at these 15 additional boreholes show compliance with the RBRG for Rural Residential (i.e. the stringent set of RBRGs).

As the 5 contaminated boreholes have exceeded only marginally of the RBRGs and the laboratory testing results of the 15 additional boreholes has complied, there is scope to further confine the horizontal extent of contamination estimation. Therefore, 3 further additional boreholes were drilled roughly mid-way in-between the pairs of contaminated and uncontaminated boreholes (i.e. a total of 15 further additional boreholes were drilled) from May 2011 – July 2011. The locations of the 15 further additional boreholes are shown in **Figure 8.10** and depicted in **Figures 8.11** to **8.15.**

8.6.1.2 Possible Soil Contamination Extent in LMC Loop

The estimated quantity of contaminated soil within LMC Loop is summarized in **Table 8.5**. The extents of which the 5 contaminated zones lie are depicted in **Figures 8.16** to **8.21**. Calculations of the contaminated soil quantity are detailed in **Appendix 8-2**. The respective soil remediation method and disposal criteria are described in **Section 8.8**.

8.6.1.3 Groundwater Contamination

Groundwater samples were taken from 10 boreholes. The test results indicated that none of the groundwater samples have exceeded the RBRG levels for Rural Residential land use. Chlorinated Pesticides were not detected in the groundwater samples.

8.6.1.4 Elutriate Test

The objective of the Elutriate Test is to assess the potential of contaminants release from the sediment filled mud during excavation within LMC Loop.

Elutriate test was conducted on the deepest soil samples (i.e. 4.5mbgl) collected from 10 boreholes. Groundwater samples from the same boreholes were used for preparation of elutriate. The test results have shown non-detectable level, which indicated that the potential of contaminants release is insignificant.

8.6.2 Contamination Assessment Area for the Associated Infrastructure outside LMC Loop

No potentially contaminated site was identified in the contamination assessment area for the associated infrastructure outside LMC Loop and hence, no SI was conducted.

Table 8.5 Initial estimate of contaminated soil quantity

Contaminated Borehole (Concerned Zone) ID	Borehole ID	Estimated Distance from Contaminated Borehole (m)	Estimated Vertical Extent of Contamination (m)	Estimated Contaminated Area (m^2)	Estimated Quantity of Contaminated Materials (m^3)
A-S01	A-S01a1	45	3.0 (2.5m-5.5m)	5,576	16,728
	A-S01b1	35			
	A-S01c1	44			
A-S03	A-S03a1	43	1.5 (2.5m-4.0m)	4,580	6,870
	A-S03b1	27			
	A-S03c1	51			
A-S20	A-S20a1	23	1.5 (2.5m-4.0m)	4,989	7,484
	A-S20b1	50			
	A-S20c1	41			
A-S24	A-S24a1	32	1.5 (2.5m-4.0m)	4,001	6,002
	A-S24b1	46			
	A-S24c1	34			
A-SG10	A-SG10a1	31	1.5 (4.0m-5.5m)	3,520	5,280
	A-SG10b1	43			
	A-SG10c1	34			
			Sub-Total:	22,666	42,364
Estimated Quantity of Contaminated Materials at A-S03a1 & A-S03c1					
Contaminated Borehole (Concerned Zone) ID	**Borehole ID**	**Estimated Distance from Contaminated Borehole (m)**	**Estimated Vertical Extent of Contamination (m)**	**Estimated Contaminated Area (m^2)**	**Estimated Quantity of Contaminated Materials (m^3)**
A-S03a1	A-S03a	48	1.5 (4.0-5.5m)	4,452	6,678
	A-S03b1	51			
	A-S03	43			
A-S03c1	A-S03c	50	1.5 (1.0-2.5m)	5,601	8,402
	A-S03b1	41			
	A-S03	51			
			Sub-Total:	10,053	15,080
			Total:		57,444

8.7 Remediation Action Plan for LMC Loop

8.7.1 Remediation Strategy

According to the Recommended Outline Development Plan (RODP), the 5 contaminated zones are located within the RBRG land use categories of "Public Park" and "Industrial". Subject to confirmation of these planned land uses, their exceedances against with the RBRGs are given in **Table 8.6**.

Table 8.6 Possible future land uses of the contaminated zones

Contaminated Zone	Proposed Future Land Uses	Corresponding RBRGs	Exceed the Corresponding RBRGs
A-S01	• Amenity/ Activity Corridor • Commercial • Open Space	• Urban Residential • Public Park	Yes (Urban Residential)
A-S03	• Sewage Treatment Works • Open Space	• Industrial • Public Park	No
A-S20	• Ecological Area	• Public Park	No
A-S24	▪ Amenity/ Activity Corridor ▪ District Cooling System ▪ Open Space	• Industrial • Public Park	No
A-SG10	• Ecological Area	• Public Park	No

Regardless of the test results evaluation against the RBRGs land use categories, excavation at the 5 contaminated zones is expected for the proposed land uses during construction. Therefore, the chance of construction workers and other site staff having contact with the contaminated soil cannot be ruled out. In view of the safety concerns about human contact with the contaminated soil, it is recommended to remediate all the contaminated soil. This decision can also benefit to providing flexibility for any future adaptation of land use changes.

8.7.2 Remediation Method

After review of various remediation methods, "Solidification/Stabilization" (S/S) treatment method was proposed for the remediation of arsenic-contaminated soil. Toxicity Characteristic Leaching Procedure (TCLP) test should be undertaken after S/S in order to ensure that the contaminant will not leach to the environment. Unconfined Compressive Strength (UCS) test should be conducted, and not less than 1MPa should be met prior to the backfilling or stockpiled for future reuse

within the study area. Off-site disposal or reuse of the solidified material is not allowed.

8.7.2.1 Toxicity Characteristic Leaching Procedure (TCLP) Test

The sampling frequency for the TCLP test should be 1 TCLP sample per 100m^3 of broken up hardened mixture after S/S treatment. Each TCLP sample should be a composite sample collected at 5 locations throughout the 100m^3 broken up hardened mixture. Same volume of sample should be collected at each of the 5 locations in order to facilitate unbiased sample compositing.

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 analysed is 1cm. As such, the samples should be further broken up in the laboratory prior to TCLP analysis.

TCLP tests should be conducted in accordance with USEPA Method 1311 and USEPA Method 6020 for metal arsenic. The EPD's TCLP limits as specified in *EPD's Guidance Notes for Investigation and Remediation of Contaminated Sites of Petrol Filling Stations, Boatyards, and Car Repairing/Dismantling Workshops* are standard leachability test standards. However, this set of standards is only applicable to disposal to landfill. For on-site reuse, these standards are not applicable.

"Universal Treatment Standards" (UTS) could be used for interpretation of the TCLP testing results in this Study. The UTS were derived from the performance of the Best Demonstrated Available Technologies (BDAT) for treating most prohibited hazardous wastes and were adopted in pervious local 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 metal arsenic is given in **Table 8.7**.

Table 8.7 Universal Treatment Standards (UTS) for metal arsenic

Parameter	Universal Treatment Standard (1)
Arsenic	5 mg/L as TCLP

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

Any pile of broken up solidified mixture that does not meet the UTS of arsenic should be crushed and re-treated by S/S. The re-treated pile should be tested again for TCLP to confirm if it could be reused on site.

8.7.2.2 Unconfined Compressive Strength (UCS)

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 guideline (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 - Methods of test for soils for civil engineering purposes.

For complete removal of contaminated soil, a closure assessment in the form of confirmatory test should be conducted after excavation to confirm complete clean-up of the contaminated zones/concerned areas. A Remediation Report (RR) will be submitted to EPD for agreement before starting of any development works within the LMC Loop, should remediation is deemed as necessary after the site investigations and site re-appraisals.

The detail requirements of the proposed remediation work are given in the RAP (**Appendix 8-2**). In any case, reference will be made to the RAP for remediation works. As the remediated soil would be fully reused within the LMC Loop and off-site disposal or reuse is not allowed, the remediation work would not increase the amount of waste disposal to the landfill or other disposal sites.

8.7.3 Environmental Mitigation Measures

In order to minimise the potential environmental impacts arising from the handling of contaminated materials, the following environmental mitigation measures are recommended during the course of the site remediation:

8.7.3.1 Excavation and Transportation

- Excavation profiles must be properly designed and executed with attention to the relevant requirements for environment, health and safety;
- In case the soil to be excavated is situated beneath the groundwater table, it may be necessary to lower the groundwater table by installing well points or similar means;
- Excavation should be carried out during dry season as far as possible to minimise contaminated runoff from contaminated soils;
- Stockpiling site(s) should be lined with impermeable sheeting and bunded. Stockpiles should be properly covered by impermeable sheeting to reduce dust emission during dry season or contaminated run-off during rainy season. Watering should be avoided on stockpiles of contaminated soil to minimise contaminated runoff;
- Supply of suitable clean backfill material after excavation, if required;
- Vehicles containing any excavated materials should be suitably covered to limit potential dust emissions or contaminated run-off, and truck bodies and tailgates should be sealed to prevent any discharge during transport or during wet season;
- Speed control for the trucks carrying contaminated materials should be enforced; and
- Vehicle wheel washing facilities at the site's exit points should be established and used.

8.7.3.2 Solidification / Stabilization

- The loading, unloading, handling, transfer or storage of cement should be carried out in an enclosed system;

- Mixing process and other associated material handling activities should be properly scheduled to minimise potential noise impact and dust emission;
- The mixing facilities should be sited as far apart as practicable from the nearby noise sensitive receivers;
- Mixing of contaminated soil 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;
- The run-off contained in the concrete bund area along the perimeter of the paved solidification / stabilization area, if any, will be collected, stored and used for the mixing process of cement / contaminated soil;
- If stockpile of treated soil is required, the stockpiling site(s) should be lined with impermeable sheeting and bunded. Stockpiles should be properly covered by impermeable sheeting to reduce dust emission during dry season or site run-off during rainy season; and
- If necessary, there should be clear and separated areas for stockpiling of untreated and treated materials.

8.7.4 Safety Measures

In order to minimize the potential adverse effects on health and safety of construction workers during the course of site remediation, the Occupation Safety and Health Ordinance (OSHO) (Charter 509) and its subsidiary Regulations should be followed by all site personnel working on the site at all times. In addition, basic health and safety measures should be implemented, including but not limited to the following:

- 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 if necessary;
- Provide personal protective clothing (e.g. chemical resistant jackboot, liquid tight gloves) to site workers, if necessary;
- Provide first aid training and materials to site worker;
- Bulk earth moving equipment should be utilized as much as possible to minimize workers' handling and contact of the contaminated materials; and
- Eating, drinking and smoking should not be allowed in contaminated areas to avoid inadvertent ingestion of contaminant.

8.8 Conclusion

This land contamination assessment has examined the potential contaminative landuses within the project area and their potential impacts to future use. The assessment involved site appraisal, site investigation, assessment of contamination extent and where necessary formulation of remedial actions.

5 zones within LMC Loop were identified as contaminated by metal Arsenic. The volume of contaminated soil is tentatively estimated as 57,444m^3.

Remediation by Solidification/Stabilization is recommended. Mitigation measures are proposed during excavation and remediation of the contaminated soil in order to safeguard the general environmental, health and safety on site during the construction phase.

In addition, re-appraisal on the LMC Loop and the entire contamination assessment area for the associated infrastructure outside LMC Loop would be required to ensure any potential contamination activities from land use changes after the approval of this land contamination assessment study, subject to a proper updating review prior to commencement of the construction works. Where re-appraisal or re-assessment is required, the PP would prepare and submit the Supplementary CAP to EPD prior to the commencement of SI works. Following on from the submission of CAP and completion of SI, the PP would prepare a CAR, a RAP and a RR and submit to EPD for agreement prior to commencement of the works on the development.