Environmental Protection Department
The Government of the Hong Kong Special Administrative Region

August 2011

Practice Guide for Investigation and Remediation of Contaminated Land

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Environmental Protection Department
The Government of the Hong Kong Special Administrative Region

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ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CAP	Contamination Assessment Plan
CAR	Contamination Assessment Report
COC	Chemical of Concern
C_{sat}	Soil Saturation Limit
CSM	Conceptual Site Model
DQOs	Data Quality Objectives
EPD	Environmental Protection Department
ETWB	Environment, Transport and Works Bureau
FEP	Fluorinated Ethylene Propylene
HOKLAS	Hong Kong Laboratory Accreditation Scheme
MTBE	Methyl Tert-Butyl Ether
mg/kg	Milligram per Kilogram
mg/L	Milligram per Litre
NAPL	Non-Aqueous Phase Liquid
PAH	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCRs	Petroleum Carbon Ranges
PFA	Perfluoroalkoxy
PG	Practice Guide for Investigation and Remediation of Contaminated Land
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl Chloride
PVDF	Polyvinylidene Fluoride
RAP	Remediation Action Plan
QA	Quality Assurance
QC	Quality Control
RBRGs	Risk-Based Remediation Goals
$RBRG_{soil}$	Risk-Based Remediation Goal for soil
$RBRG_{gw}$	Risk-Based Remediation Goal for groundwater
RR	Remediation Report
SS	Stainless Steel
S/S	Stabilisation / Solidification
SVE	Soil Vapour Extraction
SVOCs	Semi-Volatile Organic Chemicals
TBTO	Tributyltin Oxide
TCLP	Toxicity Characteristic Leaching Procedure
TFE	Tetrafluoroethylene
USEPA	United States Environmental Protection Agency
UTS	Universal Treatment Standards
VOCs	Volatile Organic Chemicals

1 Introduction

1.1 Background

In view of the development pressure on the scarce land resources in Hong Kong, many areas (e.g. former industrial sites) may have to be re-developed for other purposes (e.g. commercial and residential uses). These areas may have been contaminated due to their former uses for anthropogenic activities and hence may pose a risk to future users and the surrounding environment. As such, a potentially contaminated site must be properly assessed and, if necessary, remediated by the project proponent before re-development so as to prevent unacceptable risks from arising in the future.

There has been significant development of contaminated land management practices in both Hong Kong and overseas since the publication of the *Guidance Notes for Investigation and Remediation of Contaminated Sites of: Petrol Filling Stations, Boatyards and Car Repair / Dismantling Workshops* (Guidance Notes) by the Environmental Protection Department (EPD) in 1999. Hence, there is a need to develop updated guidance on the practices for the investigation and remediation of contaminated sites in Hong Kong.

This *Practice Guide for Investigation and Remediation of Contaminated Land* (PG) is to replace the 1999 Guidance Notes and presents the standard investigation methods and remediation strategies for the range of potential contaminated sites and contaminants typically encountered in Hong Kong.

1.2 Purpose of this Practice Guide (PG)

The PG outlines the process for conducting land contamination assessment and remediation in Hong Kong. The PG sets out the requirements for:

- planning and implementation of the contaminated land investigation;
- interpretation of the investigation results using the Risk-Based Remediation Goals (RBRGs);
- reporting the contaminated land assessment;
- planning and implementation of remediation actions; and
- reporting the remediation works.

The PG should be used in conjunction with the following documents:

- Guidance Manual for *Use of Risk-Based Remediation Goals for Contaminated Land Management* (RBRGs Guidance Manual) (December 2007); and
- *Guidance Note for Contaminated Land Assessment and Remediation* (August 2007).

The RBRGs Guidance Manual introduces the background to the RBRGs and presents instructions for comparison of soil and groundwater data to the RBRGs. The Guidance Note for Contaminated Land Assessment and Remediation sets out requirements for assessment and management of contaminated sites, including the process of site assessment and remediation methods.

The PG focuses on providing guidance on soil and groundwater contamination investigation, assessment and remediation. Issues related to other environmental issues (e.g. disposal of marine sediments, wastewater sludge and contaminated wastewater) that are not accounted for in the RBRGs Guidance Manual and the PG should be managed by reference to the relevant legislation, including but not limited to those listed in ***Annex A***.

1.3 List of Submissions to EPD for Land Contamination Assessment of Typical Sites

The assessment, investigation and, if necessary, remediation of contaminated land are covered by a series of submissions made to the EPD.

After completion of a site appraisal and prior to the commencement of land contamination site investigation works, the project proponent shall prepare a Contamination Assessment Plan (CAP) for submission to the EPD for approval.

Based on the approved CAP, the project proponent shall conduct the site investigation and prepare a Contamination Assessment Report (CAR) documenting the findings of the site investigation for submission to the EPD for approval.

If contamination has been confirmed at levels in excess of the appropriate RBRG values and remediation is deemed necessary, the project proponent shall prepare a Remediation Action Plan (RAP) for submission to the EPD for approval. The CAR and RAP may be submitted as a combined report.

Based on the approved RAP, the project proponent shall conduct the remediation of the site and prepare a Remediation Report (RR) documenting the remediation programme for submission to the EPD for endorsement.

The list of submissions to EPD through the various stages of the land contamination assessment is summarised in ***Table 1.1***.

Table 1.1 : *List of Submissions to the EPD*

Report Title	Content	When to Submit?
Contamination Assessment Plan (CAP)	• Site description and site setting • Proposed land use and applicable RBRGs for the land use scenario • Past and present activities • Historical information • Potential sources of contamination (historic and present, on-site and off-site) • Contamination site investigation programme	• After site appraisal, prior to commencement of land contamination site investigation
Contamination Assessment Report (CAR)	• Procedure of land contamination investigation • Field observations • Laboratory analytical results • Interpretation of results • Site map showing locations of contamination • Contamination impacts assessment	• After completion of land contamination site investigation.
Remediation Action Plan (RAP)	• Background information from the CAR • Objectives of remediation action • Evaluation of remediation alternatives • Design and operation of remediation • Implementation and monitoring programme	• After completion of land contamination site investigation, prior to commencement of remediation.
Remediation Report (RR)	• Background information from the RAP • Remediation programme • Monitoring results • Conclusion and recommendations	• After completion of remediation.

1 Introduction

1.4 Limitation on the Use of PG

The PG is intended to be used in conjunction with the RBRGs Guidance Manual. The RBRGs have been developed to cater for the majority of contaminated sites in Hong Kong with typical environmental conditions, activities and building designs. Assumptions have been made as to the degree of exposures that can occur to the residents, workers and the public and only the typical exposure pathways to future users of the site. Separate sets of RBRGs have been developed for four land use scenarios and users of this PG must familiarise themselves with the assumptions behind each of these land use scenarios before adopting them for the particular site of concern. In particular, they must satisfy themselves that all exposure pathways and receptors for their site have been considered. If through the site appraisal, additional contamination pathways/receptors other than those listed in the RBRGs conceptual site models are identified, a separate risk assessment shall be prepared. Please refer to the RBRGs Guidance Manual for further details on the limitations on the use of the RBRGs.

It should be noted that this PG is intended to address arrangement for decontamination of a site, found to be contaminated due to previous anthropogenic activities. If a site contains naturally occurring chemicals of concerns at elevated level, before the site is suitable for other intended uses, it may also require the adoption of mitigation measures to reduce the risk of public health due to possible exposure pathways of the concerned chemicals.

1.5 Structure of the PG

The structure of the PG follows the stages of the contamination assessment and remediation process as summarised in the flow diagram in ***Figure 1.1***. The steps involved in the process are as follows:

(1) Site appraisal;

(2) Design site investigation and prepare CAP for EPD's approval;

(3) Site investigation;

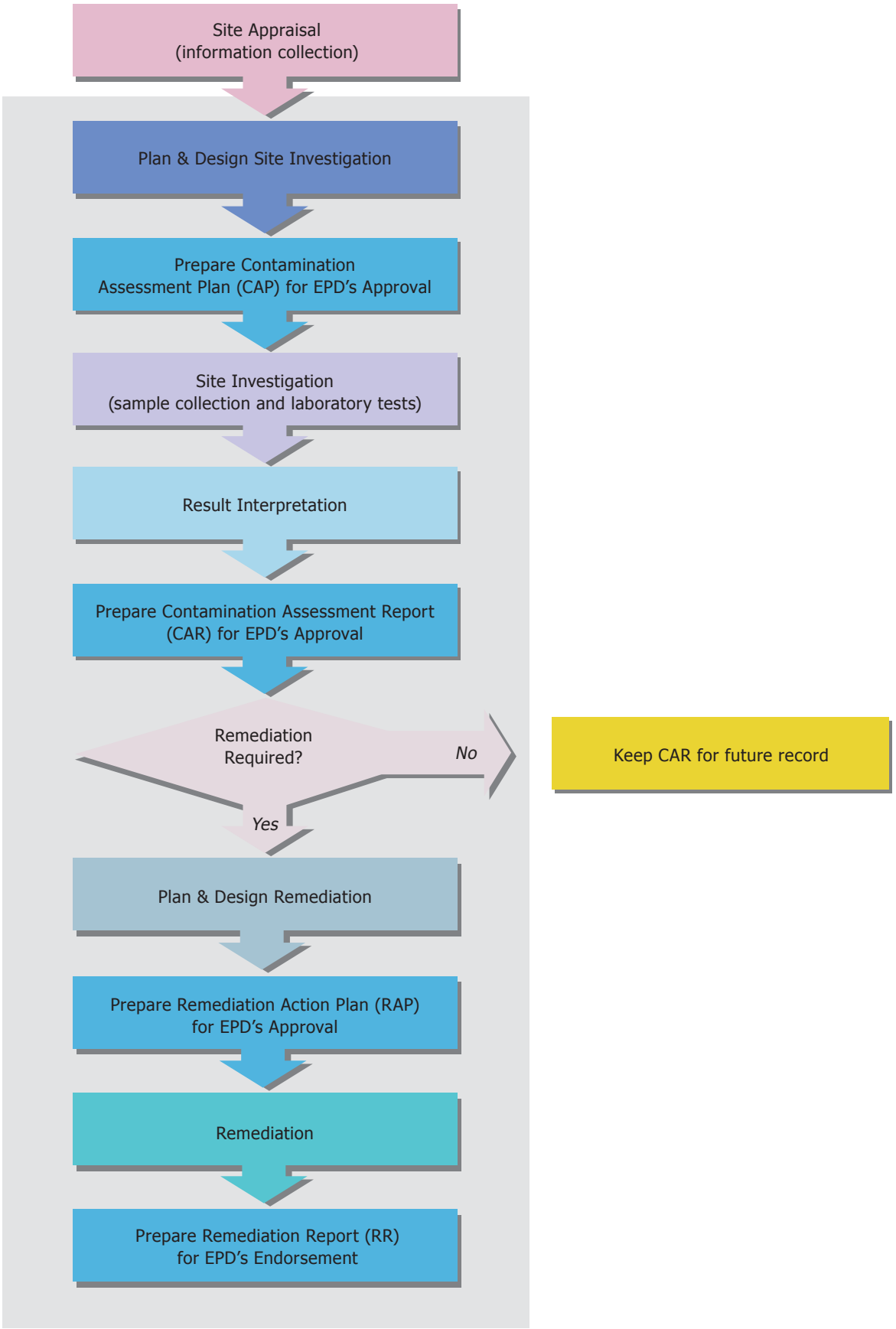
(4) Interpret results and prepare CAR for EPD's approval;

(5) Plan, design remediation and prepare RAP for EPD's approval;

(6) Remediation works; and

(7) Prepare RR for EPD's endorsement.

Figure 1.1 : *Flow Diagram of Contamination Assessment and Remediation Process*



2 Site Appraisal

2.1 Schematic Flow Diagram for Site Appraisal

A comprehensive site appraisal should be undertaken to identify the potential contamination sources that may have impacted the site. The site appraisal process is summarised in the flow diagram in ***Figure 2.1***.

2.2 Identification of Site's Future Land Use

Prior to the site appraisal, the project proponent shall determine the site's future land use and clearly identify the appropriate set of RBRGs corresponding to the land use scenario. For any future land uses falling outside the four land use scenarios, the project proponent needs to compare the exposure characteristics of the site with those described for the four land use scenarios and identify a scenario that most closely matches the exposure characteristics of the site. If the future land use is unknown, the most stringent set of RBRGs (i.e. rural residential) should be adopted. The four RBRGs land use scenarios are as follows:

- urban residential;
- rural residential;
- industrial; and
- public parks.

The project proponent may refer to Step 1 of ***Section 3.1*** of the RBRGs Guidance Manual for the detailed definitions of the applicable RBRGs for the land use scenarios.

2.2.1 Selection of Conceptual Site Model (CSM)

A conceptual site model (CSM) comprises the sources of contamination, the potential receptors and the pathways by which the contamination may reach the receptors. Based upon the land use scenario identified for the site, the project proponent shall select a corresponding CSM from those provided in ***Annex B***. The assumptions that have been made on the degree of exposure that can occur to residents, workers and the public for each of the land use scenarios are summarised in the ***Figure 2.2***, and are described in detail in the RBRGs Guidance Manual. The selected CSM will serve as a reference during the site appraisal to identify contamination sources, exposure pathways and receptors for the site to ensure that no additional pathways or receptors exist for the site and that the selected RBRGs can be applied. In the rare cases where additional exposure pathways or receptors are identified, the project proponent shall conduct a separate risk assessment. Under the typical scenario, the project proponent will not be required to include a CSM in the CAP.

Figure 2.1 : *Flow Diagram of Site Appraisal Process*

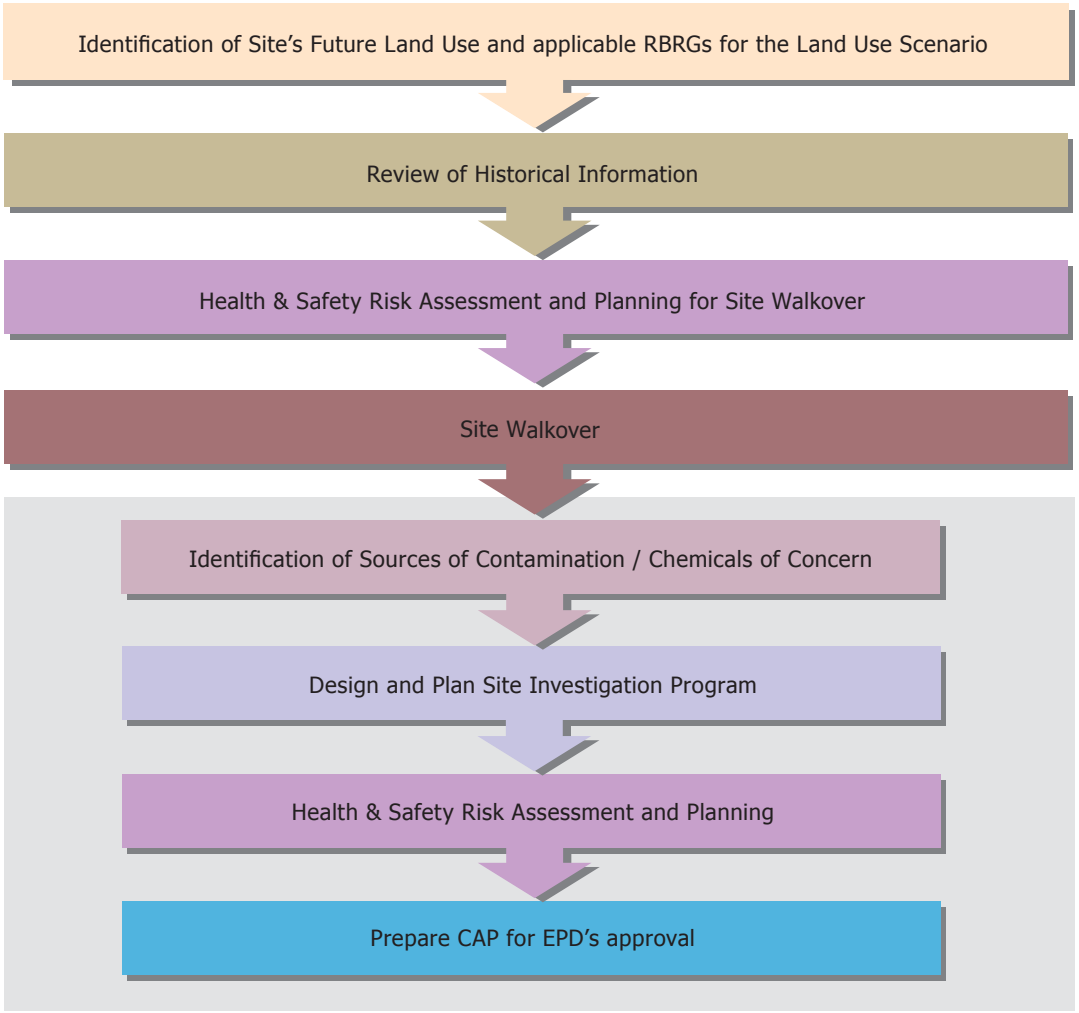


Figure 2.2 : *Exposure Pathways of RBRGs under various Land Use Scenarios*

	Type of RBRG	**Soil**					**Groundwater**
Land Use Scenario	*Pathway*	*Ingestion of surface soil*	*Dermal Contact with surface soil*	*Volatiles from surface soil*	*Particulates from surface soil*	*Volatiles from sub-surface soil (Indoor)*	*Volatiles from groundwater (Indoor)*
	Urban Residential	✓	✓	✓	✓	✓	✓
	Rural Residential	✓	✓	✓	✓	✓	✓
	Industrial	✓	✓	✓	✓	✓	✓
	Public Parks	✓	✓	✓	✓		

2 Site Appraisal

2.3 Site Walkover

The PG site walkover checklist is designed to ensure that the walkover records important facts about a site, such as potential sources and signs of contamination (e.g. chemicals, oils and hazardous waste handling and storage locations, bulk storage tanks, sumps, pipelines, staining, decolouration, distressed vegetation, etc.) and the surrounding environment (e.g. neighbours, surface water, groundwater abstraction wells, etc.).

This information will form the basis for identifying potential sources of contamination, what may be at risk from this contamination and the potential pathways linking the two.

A competent scientist, engineer or consultant shall complete the various sections as appropriate and add comments where information is not available or is not relevant. Any sources of information (e.g. on past land uses that are different from current uses) that forms part of the basis of the site investigation must be fully documented and explained. The checklist, attached as ***Annex C1***, should be completed and included as an Annex to the CAP.

Prior to commencement of site walkover, the project proponent shall identify potential health and safety risks during the site walkover and determine the necessary health and safety control measures (refer to ***Annex D***).

2.3.1 Site Information

Information including site history and other available information regarding the site shall be reviewed during the site appraisal to identify potential current and historical, on and off-site activities that could result in contamination of the site. These may include, but are not limited to the following:

- Potentially contaminating activities that have occurred at the site such as storage and handling of chemicals, oils and/or hazardous waste, on-site waste disposal, burn pits, etc. There may have been different activities over time which may have caused contamination, all of which should be noted.
- Storage facilities, pipelines, collection sumps for chemicals, oils and/or hazardous wastewater/ waste that are or were present on the site.
- Accidents, fires, explosions, spillages and any pollution incidents attributed to the site and any remediation that has occurred at the site or neighbouring areas.
- Other site information should include geological and hydrogeological characteristics of the site.

A competent professional shall oversee the review of site information and full references and justifications of any assumptions made will be required in the CAP. The checklist of suggested sources of information that could be referenced for a particular site is attached in ***Annex C2***.

2.4 Site Investigation Planning

The design of the site investigation should aim to determine the presence and extent of contamination on site. The CAP will contain a site investigation programme that is justified based on the site appraisal. The method by which the site is investigated should be fully explained in the CAP. Some guidance on some of the available methods is contained in ***Section 2.4.5***.

2.4.1 Sampling Strategy

Sampling Locations and Numbers

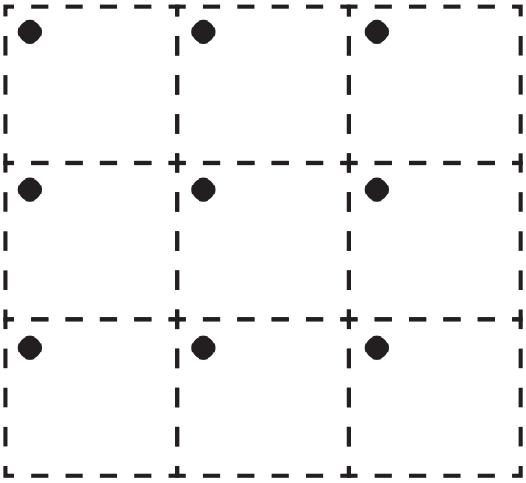
Samples shall be taken following a regular grid pattern to provide a representation of the extent and nature of contamination at the site. Extra sampling points shall also be located at or near potential sources of contamination (i.e. hot spot) such as near underground storage tanks, staining and burn pits.

The regular grid element of the sampling pattern should be a systematic, grid based design. The sampling points should be located in a regular grid, which may be a regular square grid or an off-set square grid, known as a herringbone pattern (CLR4 1994). The patterns are presented in ***Figure 2.3***. The first sampling location should be chosen at random to lessen bias, but because all sites are not uniform the positioning of the grid should allow a reasonable coverage of the site when the grid pattern is overlain onto the site.

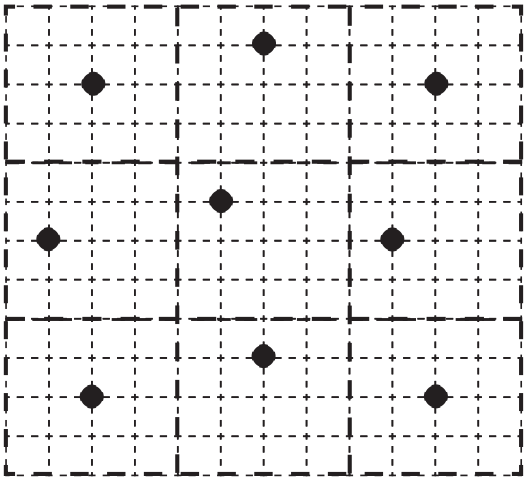
In order to calculate the number of sampling locations required for a suitable level of contamination detection, a formula should be applied that allows 95% confidence in detecting contamination of a certain size. For example, a formula of a similar form is used in both the UK (CLR4 1994)[1] and New Zealand (MfE 2004)[2].

The minimum number of sampling points derived using these equations are provided in ***Table 2.1***. It would be necessary for the project proponent to propose the final sampling design in the CAP.

Figure 2.3 *: Regular Square Grid Pattern and Offset Square Grid Pattern (Herringbone Pattern) Sampling Design*



Regular Square Grid Pattern



Offset Square Grid Pattern
(note the herringbone pattern with 1/4 grid offset)

(1) Department of the Environment: Contaminated Land Research Report: *Sampling Strategies for Contaminated Land*. Department for Environment, Food & Rural Affairs (DEFRA) (CLR4 1994)

(2) Ministry for the Environment. *Site Investigation and Analysis of Soils Contaminated Land Management Guidelines No. 5*. Wellington, New Zealand (2004)

Table 2.1 : *Minimum Number of Grid Sampling Points*

Area of site (m^2)	Square grid size (m)	Minimum number of sampling points
100	6	3
500	13	3
1,000	13	6
2,000	13	12
4,000	17	14
5,000	17	17
8,000	17	28
10,000	19	29
30,000	31	32
90,000	51	35

Notes:

1. For an area of site greater than 90,000m^2, project proponent should propose the number of grid sampling points for EPD's agreement. In any case, the square grid size should not be greater than 100m.
2. Apart from grid sampling, soil samples should also be taken from any identified hot spots.

Simplified Site Investigation

Subject to the agreement of the EPD, a simplified site investigation may be carried out for some special cases. These would include re-development of sites previously used for very small scale operations, such as small car repair workshops or metal workshops with localized source of contamination such as waste collection area or fuel/oil storage, or for very short term operations. In such cases, a simplified site investigation for the site would be acceptable, which would involve sampling only at potential hot spots together with analyses for a few essential parameters. ***Table 2.2*** provides a list of criteria that should be considered for evaluating the applicability of a simplified site investigation to a site. Justification should be provided for criterion that is not relevant or applicable to the site. If the answers to all the applicable criteria are "Yes", a simplified site investigation may suffice.

Table 2.2 : *Criteria for Adopting Simplified Site Investigation*

Criteria	Yes / No / Not Applicable
• There are well defined, small, localised sources of contamination on site.	
• Length of operation of potential contaminating activities on site is less than 2 years.	
• There are evidences of previous investigation indicating that the remaining areas of the site are not contaminated.	
• There are records of previous spill incidents indicating the exact areas impacted.	
• Waste disposal is carried out in accordance with Government requirements.	

• Absence of on-site evidences indicating contamination, including:
  • Staining
  • Abnormal odours
  • Distressed vegetation	

• Absence of potential sources of contamination in remaining areas of the site, including:
  • Underground / aboveground storage tanks, pipe works
  • Abandoned pipes, bulk storage tanks, pumps
  • Improper management of drum storages
  • Waste disposal facilities
  • Damaged pavements, drainage facilities that may result in release of contaminants	

Soil Sampling Intervals

In order to determine the vertical spread of contamination, soil samples shall be taken at various vertical depths at different locations on the site. Three soil samples or more should be taken at each sampling point to determine vertical distribution of contaminants. For an investigation that focus on a narrow soil strata, for example surface soil strata of less than 1.5m depth, the project proponent may propose to sample at less than 3 sampling depths per sampling location subject to an approval by the EPD. The soil samples may be taken at the surface, at above and below the soil and groundwater interface, below the potential sources of contamination (e.g. underground structures), and where signs of contamination are identified. Onsite screening (see methods listed in ***Section 3.4***) may be used to assist in the identification of potentially contaminated soil strata and selection of samples for laboratory analysis. The project proponent may propose a combination of sampling methods where some locations include samples taken at various depths and others target at the surface layer. Soil samples should be taken to the anticipated full depth of contamination or as required based on the proposed development at the site.

2.4.2 Hydrogeological Investigation

The site investigation programme should aim to determine the subsurface geology and hydrogeology (including groundwater depth and flow direction) of the site. Determination of local groundwater flows will aid the assessment of the presence and extent of groundwater contamination on site, on-site movement of contamination through groundwater, and potential for migration of contamination onto site or off-site. The selection of remediation methods also depends on subsurface hydrogeology in some circumstances.

Subsurface geological conditions shall be recorded during the site investigation(3). Experienced field personnel should be employed to record the geological strata logs and the depth of groundwater tables.

Three or more groundwater monitoring wells are recommended as the minimum number to indicate local groundwater flows on site. The groundwater monitoring wells shall be positioned up and down-stream of the anticipated location of the contamination sources, as well as along site boundaries to determine if potential concentrations are coming from off-site sources (if any).

2.4.3 Choice of Parameters

Parameters for chemical analysis during the site investigation shall be determined based on the potential sources of contamination identified and their associated chemicals of concern (COCs). Reference may be made to ***Table 2.3*** on typical COCs for different types of activities.

Where potential COCs identified on site are not covered by the list of RBRGs, the project proponent shall identify and propose with justification available numerical standards for the particular COCs for comparison of investigation results and remediation goals. The applicability of the proposed standards is subject to EPD's agreement.

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(3) Reference should be made to *Geoguide 2: Guide to Site Investigation and Geoguide 3: Guide to Rock and Soil Descriptions* published by the Geotechnical Engineering Office of Civil Engineering and Development Department on how to prepare a geotechnical description of soil profiles.

Table 2.3 : *Contaminated Land Types and Key Chemicals of Concern (COCs)*

Land Use Types[x]	Potentially Polluting Activities	Key COCs[+]
• Boat / ship building or repairing	Storage, handling and use of fuels and solvents (e.g. for thinning paints, cleaning and degreasing metal parts of equipment) for ship building, repair and maintenance activities. Transfer and disposal of scrap metal, metal shaving dust and paint chips.	Metals^ (e.g. arsenic, chromium, copper, lead, nickel and zinc), free cyanide, VOCs (e.g. BTEX, 2-butanone), SVOCs, PCRs, TBTO, dioxins and furans.
• Chemical manufacturing / processing plants, dangerous goods stores	Spillages and accidents related to storage of chemicals, manufacturing process, equipment maintenance and cleaning, storage, treatment and disposal of wastes.	[#] Dependent on the materials handled, stored, used and produced on site.
• Concrete and asphalt production	Storage and transfer of residues from physical conversion of earthen materials by sorting, mixing, and grinding.	VOCs (e.g. BTEX), SVOCs and PCRs.
• Golf courses	Application of chemicals (pesticides and herbicides) for maintaining the golf courses, on-site power generation, vehicle, machinery and equipment fuelling and maintenance.	Metals (e.g. arsenic), PCRs, PCBs. pesticides[a] and herbicides[a].
• Motor vehicle / equipment depot, repairing, service centres	Release of oils and fuels and lubricants from vehicles, vehicle and equipment maintenance and refuelling. Use of chemicals and solvents in maintenance activities. Motor vehicle painting and storage and disposal of wastes.	Metals^ (e.g. chromium, copper, lead, manganese, nickel, zinc), PCRs, VOCs (e.g. acetone, BTEX, MTBE, and trichloroethene) and PAHs^^^.
• Open area storage	Loading, unloading and storage of goods, fuel storage and transfer, maintenance of equipment and vehicles.	Metals^^, PCRs, VOCs and SVOCs.
• Petrol filling stations	Leaks from pipework, tanks and offset fill pipes. Spills during customer refuelling, filling underground storage tanks and over filling of portable containers.	Metals^ (e.g. lead), PCRs, VOCs (e.g. BTEX and MTBE), and PAHs^^^.
• Petroleum Products and coal industrial operations (including oil depots and gas works)	Storage and handling of hydrocarbons and/or coal, manufacture, storage and transfer of refined hydrocarbon products.	Metals^ (e.g. arsenic, cadmium, chromium, copper, lead, manganese, mercury, nickel and zinc), free cyanide, VOCs (e.g. BTEX and MTBE), SVOCs (e.g. PAHs^^^ and phenol) and PCRs.
• Power plants, individual power generation units	Storage, transfer and use of fuels, oils and chemicals, equipment and vehicle maintenance activities, storage, treatment and disposal of combustion residues, dielectric fluid spillage/leakage from transformers and other equipment and waste disposal.	Metals^ (e.g. arsenic, cadmium, chromium, mercury, nickel related to coal/ash metal composition and lead related to petroleum products, other trace metals may also be present), PCRs, VOCs (e.g. BTEX), SVOCs (e.g. phenol, naphthalene) and PCBs.
• Scrap yards	Waste oils and fuels and lubricants from scrap vehicles, transformers, scrap metals, vehicle and equipment maintenance and refuelling. Storage and disposal of wastes.	Metals^^, VOCs (e.g. acetone, BTEX, MTBE and trichloroethene), SVOCs (e.g. PAHs ^^^), PCBs and PCRs.

Land Use Types[x]	Potentially Polluting Activities	Key COCs[+]
• Steel mills / metal workshops	Use of metals and chemicals for manufacturing, equipment maintenance and cleaning, storage, treatment and disposal of wastes.	Metals^^, PCRs, VOCs (e.g. BTEX), SVOCs (e.g. phenol, and PAHs^^^).
• Waste recycling workshops	Storage and processing of waste materials, storage and transfer of chemicals and fuels. Storage and disposal of wastes.	Metals^^, VOCs, SVOCs and PCRs. Depending on the waste types and operations on site, PCB and dioxins may be present.

Notes:

1. The key COCs listed in this table may not reflect all those that may be present at a specific site and consideration should be given to particular process, materials used at an individual site when identifying potential COCs and planning the site investigation. This table is not intended to be exhaustive. Other polluting activities may be present in Hong Kong but not listed here. Users would need to exercise judgment to determine the COCs to be analysed on the subject site.
2. [x] **Reference:** Lands Administration Office's Technical Circular No. 735A and Environmental Protection Department's Guidance Note for Contaminated Land Assessment and Remediation.
3. [#] Sources of contaminants could be present depending onsite activities, but could include RBRGs metals, petroleum carbon ranges (PCRs) - in the RBRGs the PCRs include C_6-C_8, C_9-C_{16} and C_{17}-C_{35}, volatile organic chemicals (VOCs), semi-volatile organic chemicals (SVOCs). The desktop study will need to carefully record such items and justify the COCs to be tested for.
4. [+] The key COCs listed against each of the contaminated land types do not take into account the potential for the use of emergency power generators (such as fuel storage and transfer facilities and transformers) and associated contaminants.
5. [^] The metals listed in brackets are those that are typically present; however, the Project Proponent shall use professional judgment and historical information to determine potential COCs for an individual site.
6. [^^] It is recommended that a full suite of metals are analysed for these industries unless a specific list of metals could be confirmed based on historical information or previous investigations.
7. [^^^] Polyaromatic hydrocarbons (PAHs) in the RBRGs include, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene and pyrene.
8. [a] These chemicals are not included in the RBRGs lists. The UK standard for pesticides and herbicides is very stringent at 0.1 micrograms per litre (0.1 parts per billion) for individual pesticides or 0.5 micrograms per litre for total pesticides.
9. **Reference:** US EPA Compliance Assistance http://www.epa.gov/Compliance/resources/publications/assistance/sectors/notebooks/index.html

2.4.4 Determination of Background Arsenic Concentrations

Arsenic is generally the only known toxic element where background concentrations in certain geographical areas of Hong Kong may be found above RBRG concentrations as a result of natural processes. Therefore, with the EPD's approval, the project proponent may collect background soil samples from off-site areas and test them for arsenic.

Where background arsenic is considered to be an issue, the project proponent may:

- review published literatures (e.g. Geochemical Atlas of Hong Kong) to confirm that the site in question is within an area which may have naturally elevated background arsenic levels;
- clarify with the EPD that background sampling is acceptable for the site in question;
- determine a minimum of six suitable off-site sampling locations, the locations should be free of potential impacts from contaminations at the site or from other sources;
- clearly demonstrate the similarity of soil types being sampled off-site to those on-site;
- statistically analyse the off-site arsenic data to calculate a mean value and standard deviation; and
- provide a report that describes the soil horizon of concern on-site and calculates the mean arsenic value within this horizon and then compares this to the soil horizon sampled off-site and the mean arsenic concentration off-site and the arsenic levels in the area obtained from published literatures.

Two examples of different situations are provided in ***Table 2.4***.

Table 2.4 : *Background Sampling Example Cases*

Results of Soil Arsenic Analysis (mg/kg)				
	Example 1		***Example 2***	
	Background Site	**Site**	**Background Site**	**Site**
	Soil: Yellow silty SAND	*Soil: Yellow silty SAND*	*Soil: Grey SAND*	*Soil: Grey SAND with inclusions of WASTE MATERIALS*
Soil description from engineer's logs	50	51	5	33
	80	44	4	25
	60	66	3	18
	53	54	10	23
	28	22	1	33
	45	60	2	1
		33		2
		28		50
		21		15
		54		25
Mean	52.7	43.3	4.2	22.5
Standard Deviation	17.2	16.2	3.2	14.7
Maximum	80.0	66.0	10.0	50.0
Natural Concentration*	48-64		3-11	
Conclusion	Site 1 is background arsenic.		Site 2 is contaminated with arsenic.	

Note: *Natural background concentration in the site area from published literatures for comparison.

In Example 1 it is clear that there is broad similarity between the background site data set and the investigated site data set: the means are close and the standard deviations are similar. Concentrations of arsenic in both background site and investigated site in Example 1 are similar to those natural concentrations indicated in published literatures.

In Example 2 there is a more than twofold difference in the means and the standard deviations, indicating that levels measured on-site do not represent background arsenic concentrations. Concentrations of arsenic at background site in Example 2 are within the natural background concentrations indicated in published literatures but the concentrations at the investigated site are mostly above these. When other evidence from engineer's logs is considered, it is clear that the soil in Example 2 site has been influenced by waste disposal and is different from the soil from the chosen background area.

Example 1 shows that the site has elevated level of arsenic and is in the same order and concentration range of the natural background arsenic. Therefore, the existing site owner, before returning the site to the government or handing it over to the new site owner, may not be required to clean up the land since the high arsenic level is not due to previous anthropogenic activities. Notwithstanding this, if the site is intended for new uses such as residential purpose, and that the elevated arsenic level is above the corresponding RBRG values, appropriate mitigation measures may still have to be adopted from health risk consideration.

2.4.5 Investigation Methods

The PG is not intended to provide detailed guidance on any particular investigation technique. It is expected that the contractor undertaking the investigation is competent in such activities. The following techniques are for guidance purposes only and are intended to assist in the design of the site investigation to be proposed in the CAP.

Boreholes

There are a variety of methods of drilling boreholes and the technique chosen should be suitable for the expected ground conditions and the required samples. In general, rotary drilling is the most common method of drilling a borehole and obtaining soil samples from specified depths and is suitable for most soil conditions, except very dense materials or rock. Dry rotary drilling method without the need of using any flushing medium is preferable in order to avoid potential cross-contamination. Soil samples can be taken at required depths by means of sample tubes such as thin-walled volumetric (Shelby tube) or split barrel samplers. Typical drill rigs are presented in ***Figure E1*, *Annex E***. Examples of borehole drilling and sampling equipment are shown in ***Figure E2*, *Annex E***.

Installation of Groundwater Monitoring Wells

Boreholes to be used for groundwater monitoring should generally be drilled to a minimum depth of two metres below the water table and/or to suspected contamination depth and installed with well materials to allow for groundwater sampling.

The project proponent shall select suitable well casing and screen materials for the site. The most frequently evaluated site characteristics that directly influence the performance of casing and screen materials in groundwater monitoring applications are strength and chemical resistance/interference. Well casing and screen materials should maintain their structural integrity and durability in the environment in which they are used over their operating life. The monitoring wells should be resistant

to chemical and microbiological corrosion and degradation in contaminated and uncontaminated waters. Wells should also not react and interfere with the chemical characteristics of the groundwater. General recommendations for selecting the well materials related to expected contaminants are provided in ***Table 2.5***.

Table 2.5 *: Recommendations Regarding Chemical Reactions with Well Materials*

COCs	Well materials#		
	Recommended	***Acceptable***	***To be avoided***
Metals	PTFE	PVC	SS*
Organics	SS	PVC	Galvanised steel and PTFE**
Metals and Organics	-	PVC and PTFE	SS*

Notes:

1. # Materials widely available for use in ground-water monitoring wells can be divided into three categories:
   - Fluoropolymer materials, including PTFE, TFE, FEP, PFA, and PVDF;
   - Metallic materials, including carbon steel, low-carbon steel, galvanized steel, and stainless steel (304 and 316); and
   - Thermoplastic materials, including PVC and ABS. Fluoropolymer materials including PTFE, FEP, PFA, PVDF may be used depending on types of contaminants.
2. * Substantial concentrations of metals can be leached from SS if the contact time is 2 hours or longer.
3. ** Do not use PTFE for monitoring of tetrachloroethene. PTFE tends to adsorb organics more than PVC. Hydrophobic organics (i.e. Log of Octanol-Water Partition Coefficient (Log K_{ow}) ≥~2) are most readily adsorbed.

Reference: RCRA Ground-Water Monitoring: Draft Technical Guidance, Office of Solid Waste, U.S. Environmental Protection Agency, 1992.

Well materials should be decontaminated prior to installation. Well sections should be connected together using appropriate methods such as pre-fabricated threaded joints or rivets and not connected using solvent based glues. Empty voids between the well pipe and the borehole may be packed with clean gravels and sand. Wells should be secured to prevent contamination from the surface, typically bentonite and cement are used to fill the top of the void and well caps are used to close the pipe. A typical configuration of a groundwater monitoring well is shown in ***Figure E3, Annex E***.

Trial Pits

Trial pits or trenches can be used in conjunction with boreholes or on their own. The use of trial pits offers a quick method of investigating and inspecting a site. Trial pits can be excavated, by hand or mechanical excavator; however, trial pits should not be entered by anyone once the depth has equalled or exceeded 1.2 m unless appropriate safety precautions (i.e. shoring, stepping and/or sloping of sides) are taken. Excavated trenches can also be used to visually establish the extent of contamination. The depth of the pit or trench is dependent on site conditions and soil stability. Trial pits should be designed to ensure safety and to prevent the pits from collapsing. Typical trial pit configurations are presented in ***Figure E4, Annex E***.

Window Sampling

Window sampling is carried out by drilling small diameter boreholes into the ground. The window sampler tubes are driven into the ground by hand held equipment or small rig. The maximum depth is usually around 5 metres. Slots in the tube enable soils to be extracted for sampling. It is possible to install groundwater/gas monitoring points in the window sampling holes if required. Typical window sampling method is presented in ***Figure E5, Annex E***.

Other Methods

Soil Probe - Another common method of obtaining soil samples is by means of a soil probe. Direct push probes are inserted into the ground by means of hydraulic machinery. Soil samples can be taken at specific depths by means of a reliable piston system. Sensors can be installed at the point of a probe for on-going groundwater/gas monitoring.

Hand Augering - This method can be used to take soil samples from shallow depths. There are a number of types of auger, but it is typically a corkscrew spiral that is screwed into the ground. Samples can be taken at targeted soil depths and conveyed to the surface. A typical hand auger is presented in ***Figure E5, Annex E***.

Sampling for Volatiles - Samples collected for volatile parameters (e.g. solvents, BTEX) must be collected quickly, with as little disturbance as possible. Samples should be taken so as to minimise the loss of volatile compounds. This may involve using:

- zero headspace sampler, which is sealed and transported to the laboratory, where it can be interfaced directly to the analytical instrumentation (this is an expensive technique and requires special laboratory set-up);
- solvent extraction sampling with a coring device and transfer to a pre-weighed vial containing methanol; and
- direct filling of a glass container with no headspace (this will be sub-sampled in the laboratory using a corer).

The site investigation can include a variety of investigation techniques to suit the site conditions and time requirements. A site layout plan of the proposed investigation with clearly defined symbols for each particular method of investigation should be included in the CAP.

2.4.6 Sample Size and Handling Procedure

Sample size and preservation procedures required for each chemical analysis should be confirmed with the laboratory prior to the commencement of site investigation. Sample containers should be laboratory cleaned, sealable, water-tight, made of suitable materials to prevent cross contamination, reaction or adsorption of contaminants with the container surface. Samples should be placed in appropriate decontaminated containers with gas-tight, non-absorptive seals, allowing no headspace (for volatile compounds), and kept chilled until arrival at the laboratory. Samples should not be frozen because glass sample jars can crack or break. For samples containing relatively volatile contaminants, immediately store at a temperature range within 0°C to 4°C in order to achieve proper sample preservation. Where field screening is required (e.g. head-space testing), a separate sample must be collected. Arrangements should be made to ensure delivery of chilled samples to the laboratory as soon as possible to allow analysis to commence within the time limitations which apply for the parameters and laboratory methods. Samples must remain preserved until they are analysed.

Chain-of-Custody

Chain-of-custody documentation shall be prepared to document sample handling and transport procedures from the point of collection at the site to the laboratory.

An example of a chain-of-custody document is attached in ***Annex F***.

2.4.7 Data Quality Objectives

As discussed in the RBRGs Guidance Manual, the Data Quality Objectives (DQOs) process is used to define the type, quantity and quality of data needed to meet the objectives of the contamination assessment. The DQOs define the approach for data collection to ensure robust, usable and repeatable data are collected. Criteria that DQOs help to determine include: how, when, where, and how many samples should be collected. Project proponents should make reference to the DQO process when planning for the collection of site investigation data.

Guidance on the DQO process is provided by the USEPA in the *Guidance for the Data Quality Objectives Process, USEPA 1994 and Data Quality Objectives Process for Hazardous Waste Site Investigations, USEPA 2000*.

2.4.8 Quality Assurance / Quality Control (QA/QC)

To ensure representation and integrity of samples and accuracy and reliability of analysis results, proper QA/QC procedures should be implemented throughout the investigation process from field works to laboratory analysis of samples. A QA/QC programme should be included in the CAP with clear data quality objectives. It is recommended that as a minimum, the following procedures should be implemented.

Sample Handling and Storage – appropriate sample handling and storage, transport accompanied with chain-of-custody documentation should be implemented.

Equipment Decontamination – field equipment such as drilling rigs, excavators, should be thoroughly decontaminated prior to commencement of site investigation, preferably prior to mobilisation to the site. Sampling tools that come into contact with the samples shall be decontaminated prior to and between each sample. Decontamination procedures shall follow international standard protocols (e.g. USEPA's Standards[4]).

Field QA/QC Samples – This may include checking of sampling equipment cleanliness by keeping rinsate for analysis (i.e. "equipment blanks"), cross-checking of sample identities by taking "duplicate samples", and checking of sample contamination during handling by taking "trip blanks" and "field blanks".

Laboratory QA/QC Procedures – The laboratory should have HOKLAS[5] (or one of its Mutual Recognition Arrangement partners) accreditation for the specific chemicals and analytical methods proposed for the site investigation programme. The laboratory should have QA/QC procedures with proper documentation and recording of results.

The project proponent should confirm with the laboratory that the analytical methods used are acceptable and that the detection limits of the accredited methods (see ***Section 3.7***) are below their respective RBRGs for the COCs.

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(4) USEPA Region 9. *Sampling Equipment Decontamination* (SOP No. 1230, Rev 1. September 1999)

(5) In Hong Kong, the Hong Kong Accreditation Service is responsible for the implementation and accreditation of the Hong Kong Laboratory Accreditation Scheme (HOKLAS). The scheme is open to voluntary participation from any Hong Kong laboratory that performs objective testing and calibration falling within the scope of the Scheme and meets the HOKLAS criteria of competence.

2.5 Contamination Assessment Plan (CAP)

A CAP shall be prepared for submission to the EPD and an approval obtained prior to the commencement of the site investigation.

The content of the CAP should include the following:

- Background, including background of the project, regulatory and other requirements, site future land use and land use scenarios;
- Site appraisal findings, including sources of information, site description, site setting (including neighbouring environment), description of site history, site walkover observations (the completed checklist should be attached as an annex of the CAP), potential sources of contamination identified and potential COCs;
- Proposed site investigation programme, including proposed sampling locations, sampling depths, groundwater monitoring programme, laboratory analytical parameters, test methods, reporting limits of corresponding test methods, equipment decontamination procedure and QA/QC programme; and
- Health and safety for site investigation including risks identification and control measures required during the investigation.

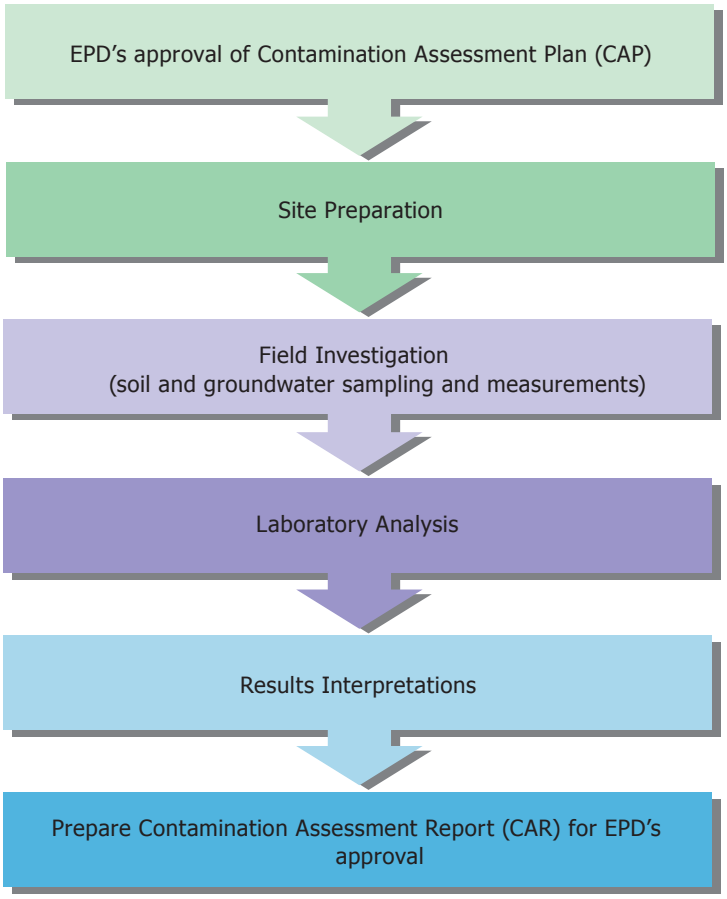
Site photographs/maps and other referenced documents can be attached as annexes of the CAP.

3 Site Investigation

3.1 Schematic Flow Diagram For Site Investigation

The site investigation process is summarised in the flow diagram in ***Figure 3.1***.

Figure 3.1 : *Flow Diagram of Site Investigation*



3.2 Site Preparation

Prior to commencement of site investigation, the project proponent shall prepare to address possible site constraints, potential disturbance of neighbouring properties and facilities (e.g. water supply), health, safety and environmental issues (refer to ***Annex D***).

3.3 Sampling

3.3.1 Sampling of Soils

Soil sampling shall be carried out in accordance with the approved CAP. The person supervising the work should be competent in taking field notes, recording information, such as logging the soil profiles,

signs of contamination such as decolouration, odour, recording levels from which the soil samples were taken and taking photographs. An experienced person is required to oversee the decontamination of equipment and the taking of samples. Care should be taken to prevent cross contamination between samples and contamination of samples from the environment or equipment. Examples of soil sampling techniques are listed in ***Section 2.4.5***.

Soil samples collected should be placed in laboratory supplied containers appropriate for the target contaminants. The laboratory (see ***Section 3.7*** for the requirements for test laboratory used) should be consulted on which preservation methods are required prior to delivery to the laboratory. Appropriate sample handling, storage and transport accompanied with chain-of-custody documentation should be implemented.

3.3.2 Sampling of Groundwater

Groundwater monitoring wells should be developed after completion of installation to remove debris from the water. The wells should be purged with at least three times the well volume or until dry prior to each sampling event. Groundwater samples should be taken within 24 hours of the wells being purged. Prior to purging and sampling, groundwater levels should be measured and recorded. Presence of non-aqueous phase liquid (NAPL) should also be recorded (see also ***Section 3.4***). The type of sampler or sampling system selected for groundwater sampling varies, depending on type of well, depth to water from ground surface, physical characteristics of the well, groundwater chemistry, and the parameters targeted for study should be recorded. Groundwater sampling methods may include:

- *Grab sampling* – groundwater samples may be taken from open pits or trenches using clean containers. Sampling from open pits is not generally recommended as the content and the environment of the pits are not controlled. The test results may be used for initial screening or to provide an indication of the suspect contaminants;
- *Bailer* – bailers are commonly used to take groundwater samples from wells and can be used at greater sample depths. A bailer is lowered and raised repeatedly in the well to collect a sample which disturbs the water column and can result in stirring up or mobilizing particulates, including colloidal matter or mineral precipitates arising from well construction, which are not part of the ambient groundwater flow. This, in turn, can result in substantially greater than ambient concentrations of trace elements and hydrophobic organic compound(s). Either disposable or reusable bailers can be used. Reusable bailers should be thoroughly decontaminated between samples. Use of a bottom-emptying device through which the rate of sample flow can be controlled is recommended;
- *Submersible pump* – submersible pumps (positive pressure or other types of positive-displacement pumps) are placed under the static water level and send water through tubing to the surface for collection. Submersible pumps designed specifically for collection of water samples do not create a vacuum; and
- *Suction-lift pump* – suction-lift pumps or peristaltic pumps create a vacuum in the intake line that draws the sample up to the land surface. There is a limitation on the depths of the water from the ground that such pumps can be used. The vacuum can result in the loss of dissolved gases and VOCs and the intake tubing could diffuse atmospheric gases. Suction-lift pumps have few moving parts, are easy to clean, have easily replaceable heads, and are portable.

Schematic drawing of groundwater sampling equipment is shown in ***Figure E6, Annex E***. Groundwater samples collected should be transferred directly to laboratory supplied containers appropriate for the target contaminants. The laboratory should be consulted on whether the samples are required to be filtered on-site, and which preservation methods are required prior to delivery to the laboratory. Appropriate sample handling, storage and transport accompanied with chain of custody documentation should be implemented.

3.4 Field Testing

A variety of field tests/measurements may be used as a limited contribution to the screening of samples on contaminated sites to provide real-time data. The field results need to be augmented by chemical analysis and their use as the sole source of analytical data in the assessment of potentially contaminated sites is inappropriate as they may give falsely high or low results. In determining field tests/measurements the project proponent shall consider the parameters/characteristics that need to be measured, the equipment limitations and site conditions that may affect the results and calibration requirements for the substances being measured.

Typical field tests/measurements include an oil/water interface meter for the measurement of free-floating products, photoionisation detectors, flame ionisation detectors, gas detectors and field portable x-ray fluorescence spectrum analysers, field gas chromatography, test kits and field water probes/meters.

3.5 Equipment Decontamination Procedures

Decontamination procedures include the process of washing, rinsing and removing material from exposed surfaces of equipment and clothing that can, or has, come into contact with the sample. Any decontamination must be undertaken in a manner that avoids contaminating areas to be sampled, or the spread of contamination around or off the site. The level of decontamination adopted should be practical and appropriate for the tasks and site conditions. Large sampling equipment, such as excavators and drilling rigs that come into contact with the soil, should be cleaned between sampling locations on a dedicated area.

3.6 Field Reporting

3.6.1 Soil Profiling

It is important that the underlying geology is accurately recorded(1). Photographs and descriptive field notes should be taken and information included in the CAR. Borehole/trial pit logs should be included as an annex to the CAR.

(1) Reference should be made to *Geoguide 2: Guide to Site Investigation and Geoguide 3: Guide to Rock and Soil Descriptions* published by the Geotechnical Engineering Office of Civil Engineering and Development Department on how to prepare a geotechnical description of soil profiles.

3.6.2 Groundwater Levels

Groundwater levels should be recorded in the borehole logs if water is detected. If water is visible during trial pitting then the water level should be recorded.

It is recommended that water levels are monitored after monitoring well installation to allow for levels to settle after the drilling works.

In order to determine groundwater flow, if deemed necessary, the relative levels of the groundwater well tops must be surveyed in order for a hydrogeologist or a suitable professional to establish the water levels across the investigation area and to determine the local groundwater flow direction(s).

3.6.3 Non-Aqueous Phase Liquid (NAPL)

As required in ***Section 3.1*** of the RBRGs Guidance Manual, evidence of NAPL should be recorded and reported in the CAR. Examples of field conditions indicating presence of NAPL include:

- Stained, unnaturally colored, or wet soil above the water table. The presence of NAPL may be obvious based on visual evidence of liquids in the soil, especially if the appearance is of a colored (or opaque) liquid or of a viscous liquid.
- Petroleum or solvent odour in soil or groundwater samples.
- Presence of sheen on water samples or bailer, or oily residual on soil samples or split spoon sampler.

Examples of signs of hydrocarbons contamination are shown in ***Figure E7, Annex E***.

3.6.4 Other Information

Other relevant on-site observations should also be reported in the CAR. This information may include signs of contamination such as decolouration, odour, waste materials, records of soil sampling depths and photographs.

Field testing data should be reported as necessary.

3.7 ▶ Laboratory Analysis

All laboratory test methods must be accredited by the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or one of its Mutual Recognition Arrangement partners (See ***Section 2.4.8***).

3.8 Interpretation of Site Investigation Results

3.8.1 Sample Analytical Results

Following site investigation, detected concentrations of contaminants in the samples shall be compared against their respective RBRGs. A point-by-point comparison should include tabulation of all sample numbers, concentrations, locations, and depths of all samples, comparison against the RBRGs and soil saturation limit (for soil samples) or RBRGs and solubility limit (for groundwater).

If the detected chemical concentrations in soil exceed the soil saturation limit (C_{sat}), or the detected chemical concentrations in groundwater exceed the solubility limit, additional assessment is required to determine whether NAPL may be present. The decision on whether or not the soil or groundwater at a site contains NAPL or other non-natural free liquids will likely require professional judgement and a weight-of-evidence approach to balance out potentially conflicting information. The evidence may include information on the historical land-use activities at the site, soil boring logs (visual evidence and/or hydrocarbon vapour readings), as well as soil, groundwater and soil vapour concentrations of the COCs.

The laboratory analytical results should be summarized using Standard Forms (or forms in similar formats) as provided in the RBRGs Guidance Manual. A site figure is to be prepared indicating the distribution of contamination for samples that exceed an RBRG or NAPL trigger criterion.

Based upon the investigation results and field observations, the need for site remediation should be identified. The assessment process is summarised below and in the schematic flow diagram presented in ***Figure 3.2***.

- Where sample concentrations are greater than the RBRGs and the field assessment indicates no trace of NAPL then the remediation goal will be the RBRGs.
- Where sample concentrations are greater than RBRGs and field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat}/solubility limit will be the clean-up criterion.
- Where sample concentrations are less than RBRGs and the field assessment indicates no trace of NAPL then remediation is not required.
- Where sample concentrations are less than RBRGs and the field assessment indicates NAPL as present, then NAPL removal will be necessary and the lower of the RBRG or C_{sat}/solubility limit will be the clean-up criterion. If site concentration is less than both the RBRG and C_{sat}/solubility limit, only removal of NAPL is necessary.

3.8.2 QA/QC Documentation

Supporting documentations, including Chain-of-Custody Procedures, Data Quality Objectives and Quality Assurance/Quality Control, should be maintained by the project proponents and it should be submitted to EPD when required.

3.9 Contamination Assessment Report (CAR)

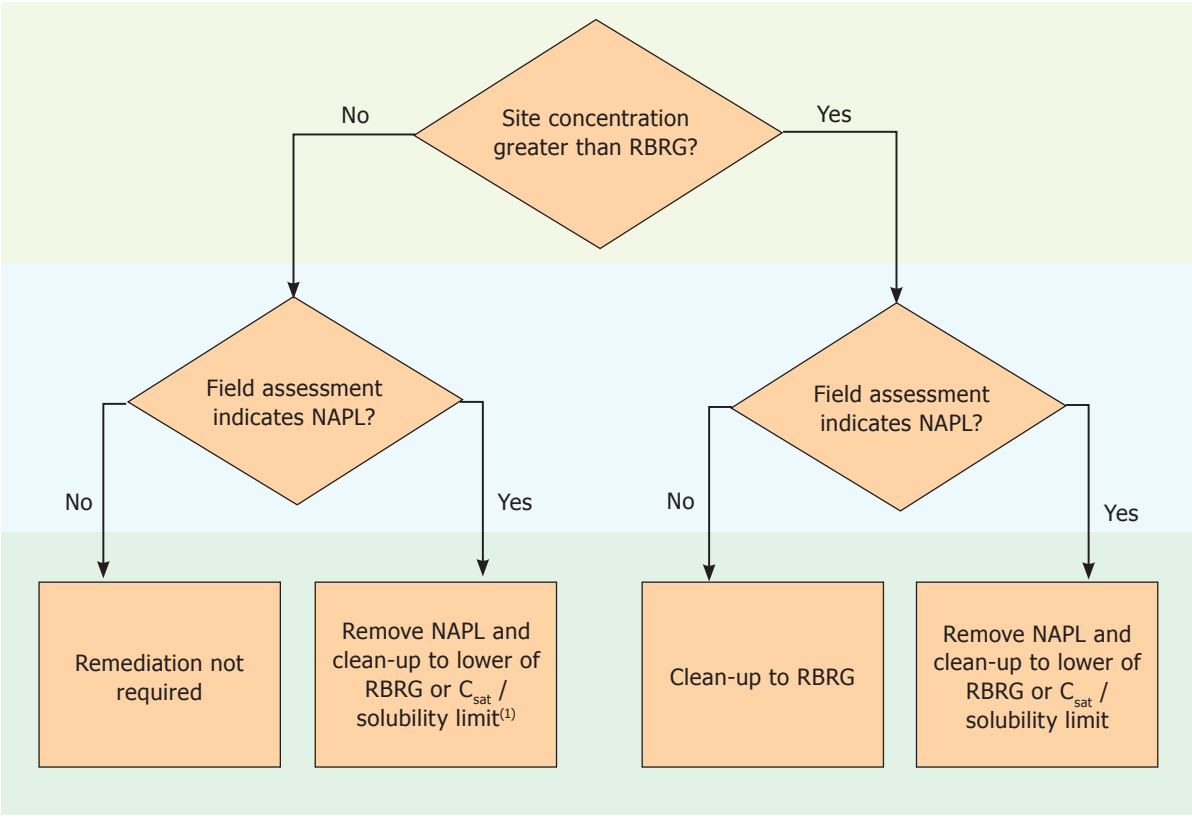
A CAR shall be prepared for submission to EPD and an approval obtained upon completion of the site investigation.

The content of the CAR should include:

- Background information, including background of the project, regulatory and other requirements, site future land use and land use scenarios, site appraisal findings, including sources of information;
- Description of site investigation programme carried out including field measurements, sampling and analysis, QA/QC results and decontamination programme;
- Site investigation results including field measurements and observations, laboratory test results, presence of NAPL and QA/QC results; and
- Results interpretation and recommendations (if applicable) for further investigation or remediation.

Laboratory analytical results, compliance with data quality objectives, chain-of-custody, site photographs/maps and other referenced documents can be attached as annexes to the CAR.

***Figure 3.2**: NAPL Assessment Flowchart*



Note:

1. If site concentration is less than both the RBRG and C_{sat}/solubility limit, only removal of NAPL is necessary.

4 Remediation Action Plan

4.1 Selection of Remediation Method

Based on the findings of the site investigation, the need to remediate the site will be determined. The project proponent shall identify appropriate remediation methods suitable for the site conditions and the contaminants requiring remediation. The following factors should be considered when evaluating different remediation methods:

- nature and level of contamination;
- extent of contamination;
- site characteristics (such as site hydrogeology, soil and groundwater chemical characteristics);
- site constraints (such as available space, surrounding areas); and
- time available for remediation.

Table 4.1 summarises the remediation methods historically applied in Hong Kong. ***Table 4.2*** presents selected overseas remediation methods that may be applicable to Hong Kong. The general applicability and effectiveness of these remediation methods on COCs are summarised in ***Table 4.3***. Typical setup and schematic diagrams of some remediation methods are attached in ***Annex G***. The list of methods provided is not intended to be exhaustive and other methods may also be applicable on a site-by-site basis. Remediation methods shall be agreed upon with the EPD.

It is important that experienced professionals are engaged for the design, implementation and monitoring of remediation works. The possibility of carrying out in situ remediation and recycling and reuse of remediated materials should be explored first. Ex situ remedial measures could then be considered if the in situ remediation is not considered to be practical. Off-site disposal of contaminated materials to landfills should be adopted only as a last resort. Acceptance of contaminated soil at a landfill requires an approval from the EPD. Permission for disposal via an admission ticket system needs to be obtained from the EPD prior to the delivery of contaminated soil to a landfill. Waste for disposal to landfills is required to meet the Landfill Disposal Criteria for Contaminated Soil, in terms of Toxicity Characteristic Leaching Procedure (TCLP) limits, as shown in ***Table 4.4***. Acceptance of disposal of contaminated soil at landfill also depends on the degree of contamination of the soil and the nature of the contamination. In some cases, contaminated soil must be pretreated or stabilized before landfill disposal. If excavated soil contains other contaminants in addition to the parameters specified in the landfill TCLP limits, approval for disposal will be assessed on a case by case basis. ***Table 4.5*** summarizes the appropriate action at each stage of assessment and remediation.

Criteria for treated soil from cement stabilisation/solidification (CS/S) remediation method which is intended to be reused as fill material on-site should be agreed upon with EPD in advance, for example the Universal Treatment Standards (UTS), as shown in ***Table 4.6***, may be proposed. The treated material should comply with other applicable standards, for example Unconfined Compressive Strength (UCS) standard [(1)].

(1) Unconfined compressive strength requirement is described in the USEPA guidelines (1986) – Handbook for Stabilisation/Solidification of Hazardous Wastes, EPA/540/2-86/001. The acceptance criteria for UCS previously recommended in Hong Kong was 1000 kPa.

Table 4.1 *: Remediation Methods Applied in Hong Kong since the Commencement of the Environmental Impact Assessment Ordinance*

Remedial Option	Media	Clean-Up Goal	Comments/Limitations
Air Sparging	Groundwater	$RBRG_{gw}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{gw}$ or solubility limit.[1]	Most effective for VOCs and PCRs. Should ensure that there is no uncontrolled movement of potentially dangerous vapours. Less effective in fine-grain/low permeability soil with restricted air flow and also where depth of contaminated groundwater is shallow. If free-floating products are present underneath, it should be removed before air sparging.
Biopile	Soil	$RBRG_{soil}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Effective for treatment of soil contaminated with non-halogenated VOCs and fuel hydrocarbons. Halogenated VOCs, SVOCs, and pesticides can also be treated, but the process effectiveness will vary and may be applicable only to some compounds within these contaminant groups. Biopile may not be effective for high levels of contamination.
Recovery Trenches or Wells	Groundwater	$RBRG_{gw}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{gw}$ or solubility limit.[1]	To be used for free products recovery from plume. Works well for high permeability soil. Treatment/disposal of recovered liquids required. The method does not treat residual contamination in saturated soils. The method is not applicable to contaminants with high residual saturation, contaminants with high sorption capabilities, and homogeneous aquifers with hydraulic conductivity less than 10^{-5} cm/second. Biofouling of the extraction wells and associated treatment stream is a common problem.

Remedial Option	Media	Clean-Up Goal	Comments/Limitations
Soil Vapour Extraction (SVE)	Soil	$RBRG_{soil}$ or C_{sat} if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Very effective at removing VOCs from unsaturated zone. With the addition of an air sparging system, contaminants can be removed from saturated zone as well. Treatment/disposal of residual liquids required. Also, regeneration or disposal of the spent activated carbon will be required. To eliminate possible harm to the public and the environment, exhaust air from in situ SVE system may require treatment. Soil with high organic content or is extremely dry has a high sorption capacity of VOCs, which results in reduced removal rates. Fine-grained soil or soil with a high degree of saturation will require higher vacuums (increasing costs) and/or hindering the operation of the in situ SVE system.
Stabilisation / Solidification (S/S)	Soil	For disposal at landfill, TCLP limits as landfill disposal criteria for contaminated soil. For on-site or off-site reuse, the treated materials should also comply with UTS (***Table 4.6***) and UCS.	Organics are generally not immobilized. Long-term effectiveness has not been demonstrated for many contaminant/ process combinations. If VOCs/SVOCs is present underneath, it should be removed before stabilisation/soil solidification.
Thermal Desorption	Soil	$RBRG_{soil}$ or C_{sat} if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Thermal desorption have varying degrees of effectiveness against the full spectrum of organic contaminants. Clay, silty soils and high humic content soils increase reaction time as a result of binding of contaminants. Highly abrasive feed potentially can damage the processor unit.

Notes:

1. Please refer to **Figure 3.2** for NAPL assessment.
2. The project proponents are required to identify remediation methods most appropriate for their individual sites in the RAP and obtain EPD's approval on a case by case basis. If the project proponents intend to adopt a remedial method not previously used in Hong Kong, thorough analysis for feasibility of the selected method in local context should be undertaken.

Table 4.2 : *Remediation Methods Applied in Overseas Cases*

Remedial Option	Media	Clean-Up Goal	Comments/Limitations
Bioventing	Soil	$RBRG_{soil}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Proven successful in remediating soils contaminated by petroleum hydrocarbons, non-chlorinated solvents, some pesticides and other organic chemicals. The effectiveness of the process may be affected by the soil moisture content. Soil with low permeability will reduce bioventing performance.
Chemical methods including: chemical oxidation, dehalogenation, soil flushing, solvent extraction and surface amendments	Soil, Ground-water	$RBRG_{soil}$/$RBRG_{gw}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$/$RBRG_{gw}$ or C_{sat}/ solubility limit.[1]	Site specific - depends on the contaminant present. Very specialised contractors required. Chemical methods require the handling of large quantity of hazardous oxidising chemicals. Some COCs are resistant to oxidation. Effectiveness less certain when applied to sites with low-permeability soil or stratified soils.
Incineration	Soil	$RBRG_{soil}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Ash residues produced. Volatile heavy metals, including lead, cadmium, mercury, and arsenic, leave the combustion unit with the flue gases and require gas treatment system. Metals can react with other elements in the feed stream, such as chlorine or sulphur, forming more volatile and toxic compounds. Such compounds can be destroyed in a caustic quench.
In Ground Containment / Capping	Soil, Ground-water		Can be used for containing contamination in soils and groundwater in place, avoids need for excavation and disposal. The method does not lessen toxicity, mobility, or volume of hazardous wastes, but does mitigate migration. Long-term monitoring and maintenance required. Treatment in the future cannot be ruled out.

Remedial Option	Media	Clean-Up Goal	Comments/ Limitations
Permeable Reactive Barriers	Groundwater	$RBRG_{gw}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{gw}$ or solubility limit.[1]	Water flows through reactive material to reduce contamination levels and risk to receptors down stream of site. The method applies to relatively shallow aquifers. The effectiveness of the treatment is influenced by groundwater chemistry/flow rate, ground geochemistry, site topography, seasonal changes in hydrogeological conditions.
Soil Washing	Soil	$RBRG_{soil}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Requires large site for equipment. Soils can be reused except small residue which requires disposal. High humic content in soil may require pre-treatment and it may be difficult to remove organics adsorbed onto clay-size particles.
Windrows	Soil	$RBRG_{soil}$ if field assessment does not indicate NAPL. If field assessment indicates NAPL, should remove NAPL and clean-up to lower of $RBRG_{soil}$ or C_{sat}.[1]	Require frequent turning to oxygenate the materials and accelerate treatment. Sufficient space is required. Conditions affecting biological degradation of contaminants (e.g. temperature, rainfall) are largely uncontrolled, which increases the length of time to complete remediation.

Notes:

1. Please refer to ***Figure 3.2*** for NAPL assessment.
2. The project proponents are required to identify remediation methods most appropriate for their individual sites in the RAP and obtain EPD's approval on a case by case basis. If the project proponents intend to adopt a remedial method not previously used in Hong Kong, thorough analysis for feasibility of the selected method in local context should be undertaken.

Table 4.3 : *Applicability and Effectiveness of Remediation Methods on COCs*

Remedial Option	Remediation Effectiveness on COCs							
	Metals	PCRs	PAHs	PCBs	Dioxins	Free Cyanide	VOCs	SVOCs
Remediation Methods Applied in Hong Kong since the Commencement of the EIAO								
Air Sparging	N	Y	N	N	N	N	Y	Y
Biopile	N	Y	Y	N	N	N	Y	Y
Recovery Trenches or Wells	N	Y	N	N	N	N	N	N
Soil Vapour Extraction (SVE)	N	Y	N	N	N	N	Y	Y
Stabilisation / Solidification (S/S)	Y	N	N	N	N	N	N	N
Thermal Desorption	N	Y	Y	Y	Y	N	Y	Y
Remediation Methods Applied in Overseas Cases								
Bioventing	N	Y	Y	N	N	N	Y	Y
Chemical Methods	D	D	D	D	D	N	D	D
Incineration	N	Y	Y	Y	Y	Y	Y	Y
In Ground Containment / Capping	Y	N	N	N	N	N	N	N
Permeable Reactive Barriers	Y	Y	Y	Y	Y	Y	Y	Y
Soil Washing	Y	Y	Y	Y	N	Y	N	Y
Windrows	N	Y	Y	N	N	N	Y	Y

Notes:

1. Y – Yes, N – No and D – Depends on contaminant and method chosen.
2. The table is intended for use as a reference only. The remediation methods may also be used for treatment of other contaminants.
3. The project proponents are required to identify remediation methods most appropriate for their individual sites in the RAP and obtain EPD's approval on a case by case basis. If the project proponents intend to adopt a remedial method not previously used in Hong Kong, thorough analysis for feasibility of the selected method in local context should be undertaken.
4. The remediation industry is highly diversified and there are many contractors who promote other techniques to those listed above which may be suitable for use in Hong Kong.

Table 4.4 : *Landfill Disposal Criteria for Contaminated Soil*

Parameters	TCLP Limit (mg/L)
Antimony	150
Arsenic	50
Barium	1000
Beryllium	10
Cadmium	10
Chromium	50
Copper	250
Lead	50
Mercury	1
Nickel	250
Selenium	1
Silver	50
Thallium	50
Tin	250
Vanadium	250
Zinc	250

Notes:
Soil sample should be stored at 0 – 4°C. The allowable storage time for mercury in soil samples is 8 days while the storage time for the rest of the parameters (in ***Table 4.4***) in soil samples can be up to 6 months. Soil samples, if stored beyond the allowable time, are not considered representative of the actual site conditions.

Table 4.5 : *Contaminated Soil Disposal Procedure*

Stage	Action
Preparation of CAP	a. If exceedance of the relevant land contamination standards is likely, and excavation and disposal is envisaged to be the only suitable cleanup method during site appraisal, then the investigation plan should include TCLP or other relevant tests on every soil sample that will be analysed for land contamination standards. Furthermore, TCLP or other relevant screening tests must be done on at least 3 samples from the most contaminated areas. A screening test is one that analyses for the full suite of parameters in **Table 4.4** irrespective of whether a parameter has been identified as a contaminant of concern during site appraisal. b. If the most suitable cleanup method has not been identified during site appraisal, extra soil samples should be collected and stored for TCLP or other relevant tests in the future (except the parameter of mercury, see note to **Table 4.4**), should exceedance of land contamination standards be confirmed and excavation and disposal be selected as the cleanup method. This approach may save the costs of unnecessary TCLP or other relevant tests during the CAP stage, but would require extra time in the project programme if TCLP or other relevant tests become necessary during CAR and RAP preparation.
Preparation of CAR and RAP	If any TCLP or other relevant test results exceed the disposal criteria, the "non-complying" part of contaminated soil must first be pretreated or stabilized before disposal. The RAP should propose the most suitable method of pretreatment or stabilization.
After approval of CAR and RAP	A copy of the approved CAR and RAP must be submitted together with an application to Waste Facilities Group (WFG) of EPD 3 months before disposal. WFG may limit the daily disposal quantity and require additional testing to confirm that other pollutants of concern are not present.
Implementation of RAP	The authorized person or resident engineer on site will be required to certify on an admission ticket that excavation, segregation and delivery of soil for disposal is done according to the approved RAP. For soils requiring pretreatment or stabilization, typically one sample per 400 tonnes of treated or stabilized soil is to be taken and subjected to TCLP or other relevant tests to confirm that the soil can be accepted at landfills according to the criteria in **Table 4.4** or other relevant criteria. Only those parameters with concentrations exceeding the criteria during the initial testing need to be included in the confirmatory test. Every load of contaminated soil to be disposed of at landfills should be accompanied by an admission ticket and if applicable, confirmatory test results.

Table 4.6 : *Universal Treatment Standards for On-site Reuse of Cement Stabilisation/ Solidification Treated Soil*

Parameters [1][2]	TCLP Limit (mg/L)
Antimony	1.15
Arsenic	5
Barium	21
Cadmium	0.11
Total Chromium	0.6
Lead	0.75
Mercury - All Others	0.025
Nickel	11
Zinc	4.3

Notes:

1. Universal Treatment Standard - US 40 CFR 268.48
2. For other RBRGs metal contaminants Cobalt, Copper, Manganese, Molybdenum and Tin, they must be reduced by at least 90 percent in mobility for respective metals through Cement Stabilisation/solidification remedial treatment. The reduction of mobility of metal contaminants (leachable metals contaminants) should be confirmed through TCLP tests (i.e. to carry out TCLP test for the untreated soil and for the soil after treatment and to compare the concentrations of the metals in the leachates).

4.2 REMEDIATION ACTION PLAN (RAP)

Where a need for remediation has been identified, a RAP shall be prepared for submission to the EPD and an approval obtained prior to the commencement of the remediation works.

The objectives of the RAP are to:

- set remediation objectives and goals;
- formulate optimal and cost-effective mitigation and remedial measures for the contaminated material identified in the contamination assessment;
- specify remediation monitoring and measurements to monitor remediation progress and to confirm completion of the remediation; and
- propose good handling practices for the contaminated materials during all stages of the remediation works and appropriate disposal measures.

The content of the RAP should include:

- Background information, including background of the project, regulatory and other requirements, summary of site history, contamination sources;
- A summary of site investigation findings, nature, levels and extent of contamination on site;
- The objectives of the remediation action plan, goals and remediation targets;
- The proposed remediation actions, including outlines of the methods for remediation, treatment and handling, equipment, verification and confirmation sampling and testing and other monitoring and audit requirements and equipment decontamination procedure;

- An implementation schedule for remediation with appropriate actions and milestones. The criteria to be used to assess the effectiveness of the remediation activities should be included; and
- A health and safety section that includes health and safety risks identification and control measures required during the remediation, monitoring and measurements activities.

Drawings, maps and other referenced documents can be attached as annexes to the RAP.

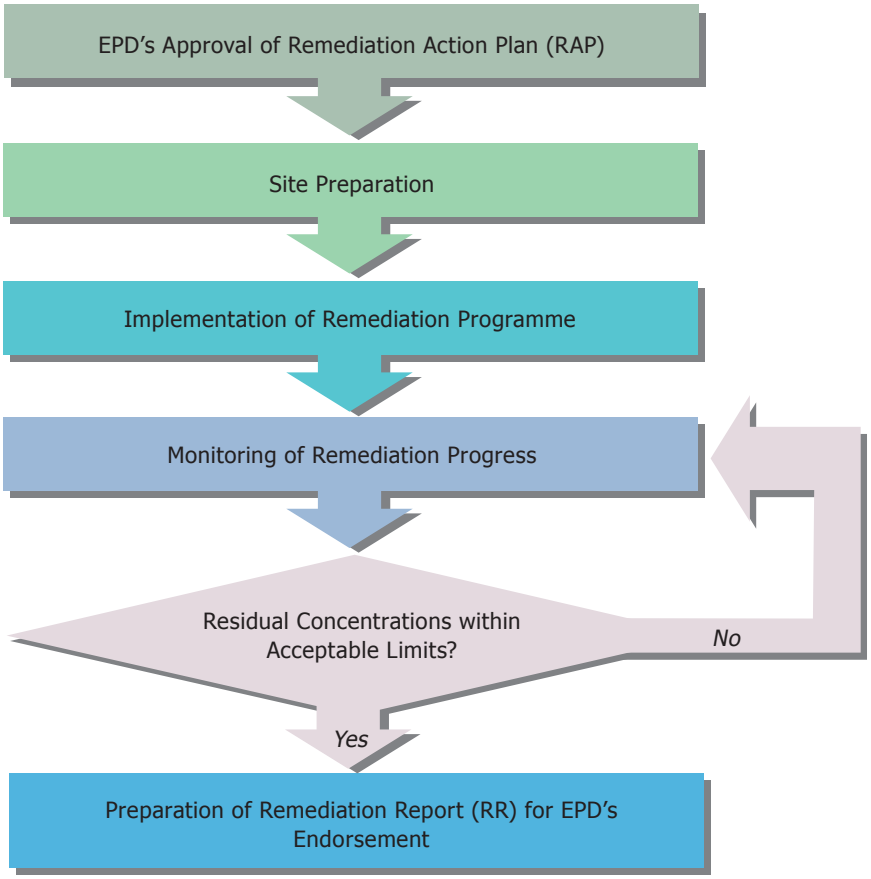
Where remediation for a site is required, the project proponent may choose to submit a combined CAR/ RAP for EPD's approval.

5 Remediation

5.1 Schematic Flow Diagram for Site Remediation

The remediation process is summarised in ***Figure 5.1***.

Figure 5.1 : *Flow Diagram of Site Remediation*



5.2 Site Preparation

Prior to the commencement of the remediation programme, the project proponent shall prepare to address possible site constraints, potential disturbance of neighbouring properties and facilities (e.g. water supply), health, safety and environmental issues (refer to ***Annex D***).

5.3 Remediation Action Implementation

5.3.1 Pilot Testing

Depending on the type of remedial methods chosen, pilot tests should be conducted prior to the full scale implementation of the remediation programme to determine whether the chosen method(s) can reliably generate the targeted results.

Pilot testing usually involves small scale trials for determining the optimal conditions required to generate the desired results within the timeframe allowed. Once the pilot test has been proven to be effective, the chosen method can be implemented at the full scale.

5.3.2 Monitoring of Remediation

To confirm that the remedial actions implemented at the site have been successful, a verification and confirmation sampling programme needs to be implemented.

Samples should be taken at locations where remediation has taken place. Samples should be analysed by a HOKLAS accredited laboratory, following the procedures outlined in ***Section 2.4.8***.

Should the concentrations of the chemical of concerns still exist above the RBRG limits, further remediation is required. However, should the verification and confirmation samples indicate that they are within the acceptable RBRG limits, then, further remediation will not be necessary.

All verification and confirmation samples and their results should be compiled into the RR and submitted to the EPD for endorsement.

5.4 ▶ Remediation Report (RR)

Upon completion of the remediation, a RR shall be prepared for submission to EPD and an approval obtained. The project proponent should note that no construction works or development of site should be carried out prior to the approval of the RR.

The content of the RR should include:

- Background information, including background of the project, regulatory and other requirements, site future land use and land use scenarios, summary of on-site contamination;
- Description of remediation programme carried out including additional investigation, pilot testing, remediation, monitoring and measurements, decommissioning of plants and equipment;
- Remediation monitoring results including field measurements and observations, samples laboratory test results, QA/QC results;
- Soil disposal records and certification by the Independent Checker (if applicable); and
- Conclusions and recommendations (if applicable).

Laboratory analytical results, chain-of-custody, site photographs/maps and other referenced documents can be attached as annexes of the RR.

6 General Reference

GEO (Geotechnical Engineering Office) 2000, *Geoguide 2: Guide to Site Investigation*.

GEO (Geotechnical Engineering Office) 2000, *Geoguide 3: Guide to Rock and Soil Description*.

Department for Environment, Food & Rural Affairs (DEFRA), UK 1994, *Sampling Strategies for Contaminated Land*.

Ministry for the Environment, New Zealand 2004, *Contaminated Land Management Guidelines No. 5: Site Investigation and Analysis of Soils*.

U.S. Environmental Protection Agency 1992, *RCRA Ground-Water Monitoring: Draft Technical Guidance*.

U.S. Environmental Protection Agency 1994, *Guidance for the Data Quality Objectives Process*.

U.S. Environmental Protection Agency 2000, *Data Quality Objectives Process for Hazardous Waste Site Investigations.*

Annex A

List of Relevant Legislation, Codes of Practice, Guidance Notes and Publications

Legislation

a. Air Pollution Control Ordinance
b. Building (Oil Storage Installations) Regulations
c. Environmental Impact Assessment Ordinance
d. Factories and Industrial Undertakings Ordinance
e. Hazardous Chemicals Control Ordinance
f. Occupational Safety and Health Ordinance
g. Town Planning Ordinance
h. Waste Disposal Ordinance
i. Waste Disposal (Charges for Disposal of Construction Waste) Regulation
j. Waste Disposal (Chemical Waste) (General) Regulation
k. Waste Disposal (Designated Waste Disposal Facility) Regulation
l. Water Pollution Control Ordinance, in particular Part III on Prohibited Discharges and Deposits

Codes of Practice

m. Code of Practice on the Handling, Transportation and Disposal of Polychlorinated Biphenyl (PCB) Waste (EPD)
n. Code of Practice on the Packaging, Labelling and Storage of Chemical Wastes (EPD)

Technical Circular

o. ETWB Technical Circular (Works) No. 19/2005 "Environmental Management on Construction Sites" (DEVB)

Technical Memorandum

p. Technical Memorandum on Environmental Impact Assessment Process (EPD)
q. Technical Memorandum – Standards for Effluents Discharged into Drainage and Sewerage Systems, Inland and Coastal Waters (EPD)

Guidance Notes

r. A Guide to the Chemical Waste Control Scheme (EPD)
s. A Guide to the Registration of Chemical Waste Producers (EPD)
t. A Guide to the Water Pollution Control Ordinance (EPD)
u. Guidance Manual for Use of Risk-Based Remediation Goals for Contaminated Land Management (EPD)
v. Guidance Note for Contaminated Land Assessment and Remediation (EPD)
w. Guidelines for Admission Ticket System (EPD)
x. Geoguide 2 - Guide to Site Investigation (GEO of CEDD)
y. Geoguide 3 - Guide to Rock and Soil Descriptions (GEO of CEDD)

Publications

z. Geochemical Atlas of Hong Kong, Civil Engineering Department, 1999

The majority of above reference materials can be downloaded from the websites of the Department of Justice: Bilingual Law Information System (http://www.elegislation.gov.hk/)[1] or Environmental Protection Department (http://www.epd.gov.hk/) or Development Bureau (Works Branch) (http://www.devb-wb.gov.hk/) or Civil Engineering and Development Department (http://www.cedd.gov.hk/).

[1] The link was updated in February 2017.

Annex B

RBRGs Conceptual Site Models Under Various Land Use Scenarios

Figure B1

Conceptual Site Model - Urban Residential

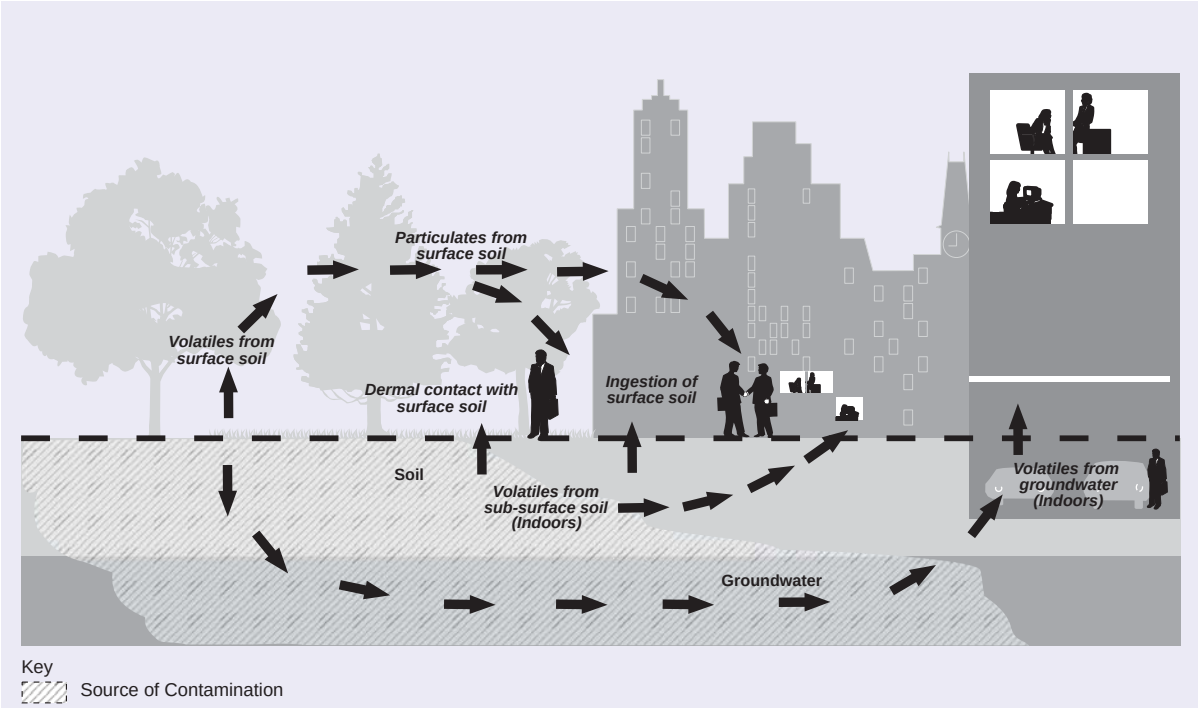


Figure B2

Conceptual Site Model - Rural Residential

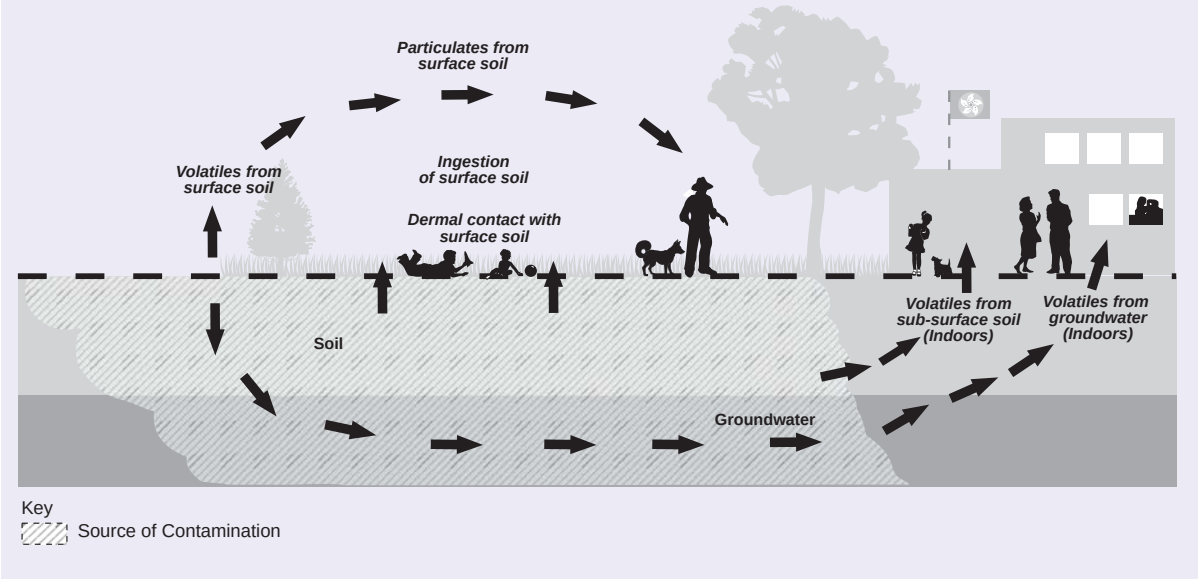


Figure B3
Conceptual Site Model - Industrial

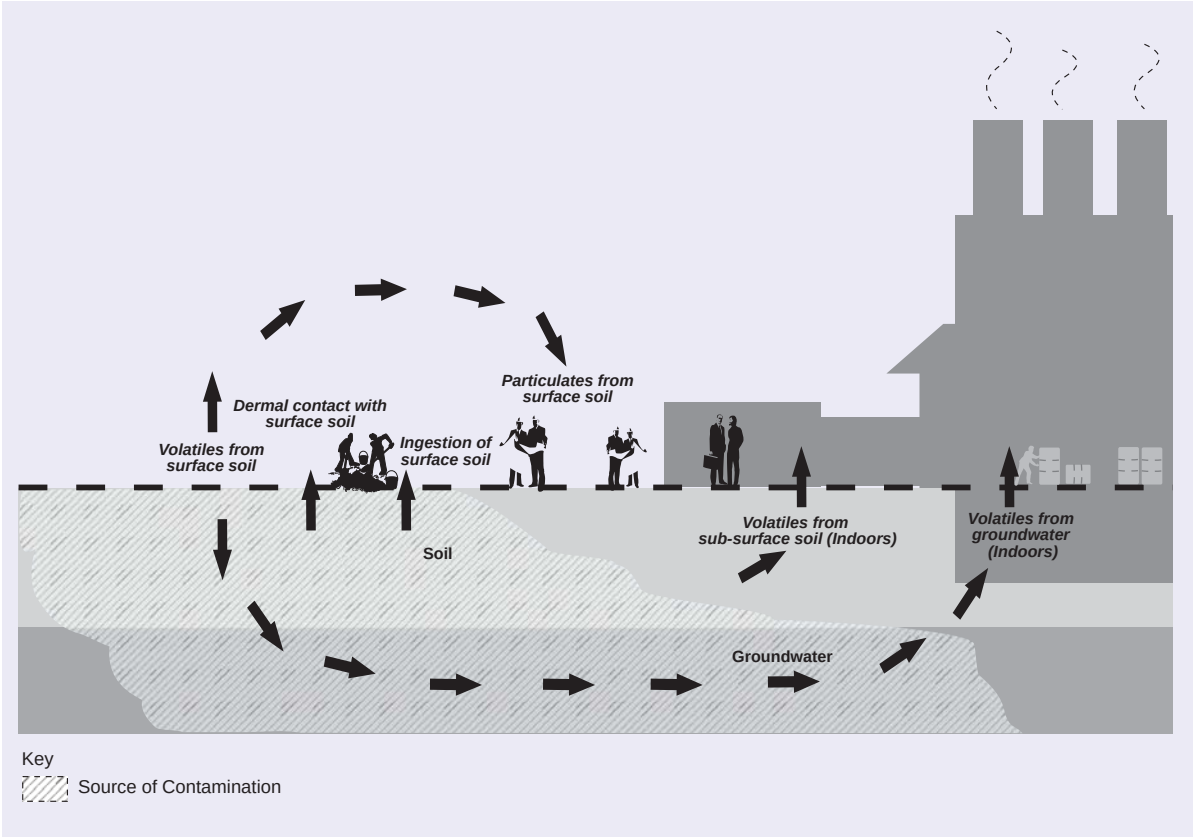
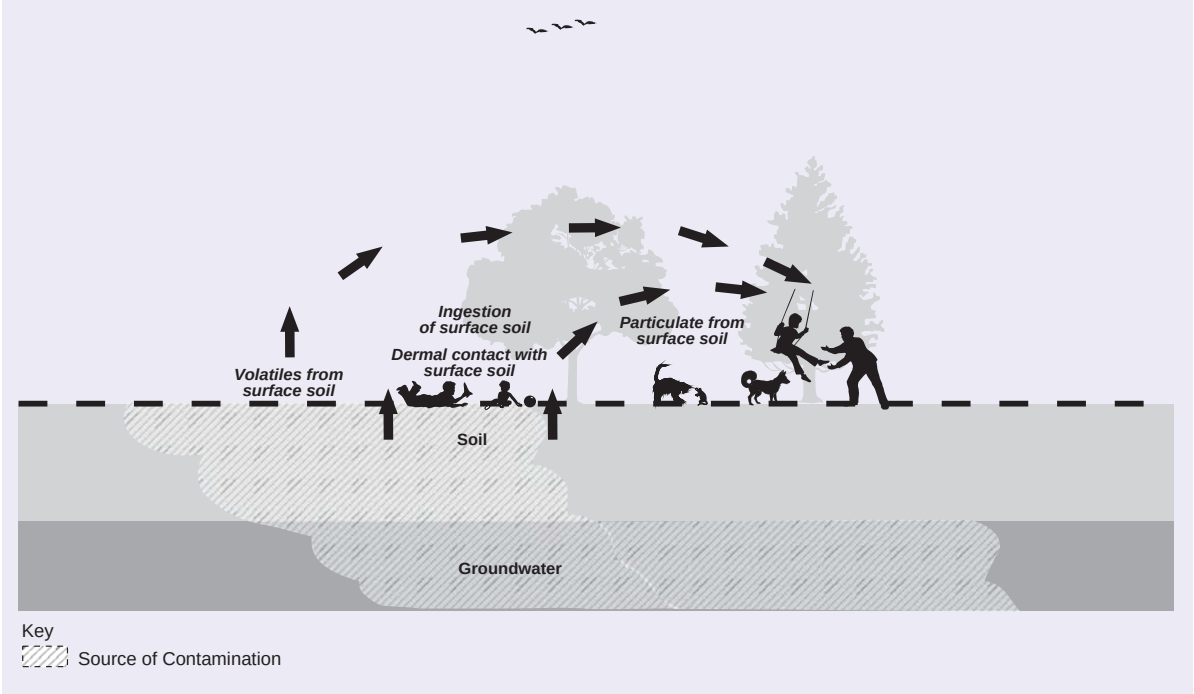


Figure B4
Conceptual Site Model - Public Parks



Annex C1
Site Walkover Checklist

GENERAL SITE DETAILS

SITE OWNER/CLIENT _____

_____

PROPERTY ADDRESS _____

_____

_____

PERSON CONDUCTING THE QUESTIONNAIRE

NAME _____

POSITION _____

AUTHORIZED OWNER/CLIENT REPRESENTATIVE (IF APPLICABLE)

NAME _____

POSITION _____

TELEPHONE _____

SITE ACTIVITIES

Briefly describe activities carried out on site, including types of products/chemicals/materials handled. **Obtain a flow schematic if possible.**

Number of employees: Full-time: _____

Part-time: _____

Temporary/Seasonal: _____

Maximum no. of people on site at any time: _____

Typical hours of operation: _____

Number of shifts: _____

Days per week: _____

Weeks per year: _____

Scheduled plant shut-down: _____

Detail the main sources of energy at the site:

Gas	Yes/No
Electricity	Yes/No
Coal	Yes/No
Oil	Yes/No
Other	Yes/No

SITE DESCRIPTION

This section is intended to gather information on site setting and environmental receptors on, adjacent or close to the site.

What is the total site area: _____

What area of the site is covered by buildings (%): _____

Please list all current and previous owners/occupiers if possible. _____

_____

Is a site plan available? If yes, please attach. Yes/No

Are there any other parties on site as tenants or sub-tenants? Yes/No

If yes, identify those parties: _____

Describe surrounding land use (residential, industrial, rural, etc.) and identify neighbouring facilities and types of industry.

North: _____

_____

South: _____

_____

East: _____

_____

West: _____

_____

Annex C1
Site Walkover Checklist

Describe the topography of the area (flat terrain, rolling hills, mountains, by a large body of water, vegetation, etc.).

State the size and location of the nearest residential communities.

Are there any sensitive habitats nearby, such as nature reserves, parks, wetlands or sites of special scientific interest?

Questionnaire with Existing/Previous Site Owner or Occupier

		Yes/No	Notes
1.	What are the main activities/operations at the above address?		
2.	How long have you been occupying the site?		
3.	Were you the first occupant on site? (If yes, what was the usage of the site prior to occupancy.)		
4.	Prior to your occupancy, who occupied the site?		
5.	What were the main activities/operations during their occupancy?		
6.	Have there been any major changes in operations carried out at the site in the last 10 years?		
7.	Have any polluting activities been carried out in the vicinity of the site in the past?		
8.	To the best of your knowledge, has the site ever been used as a petrol filling station/car service garage?		
9.	Are there any boreholes/wells or natural springs either on the site or in the surrounding area?		
10.	Do you have any registered hazardous installations as defined under relevant ordinances? (If yes, please provide details.)		
11.	Are any chemicals used in your daily operations? (If yes, please provide details.)		
	• Where do you store these chemicals?		
12.	Material inventory lists, including quantities and locations available? (If yes, how often are these inventories updated?)		
13.	Has the facility produced a separate hazardous substance inventory?		
14.	Have there ever been any incidents or accidents (e.g. spills, fires, injuries, etc.) involving any of these materials? (If yes, please provide details.)		

		Yes/No	Notes
15.	How are materials received (e.g. rail, truck, etc.) and stored on site (e.g. drums, tanks, carboys, bags, silos, cisterns, vaults and cylinders)?		
16.	Do you have any underground storage tanks? (If yes, please provide details.)		
	• How many underground storage tanks do you have on site?		
	• What are the tanks constructed of?		
	• What are the contents of these tanks?		
	• Are the pipelines above or below ground?		
	• If the pipelines are below ground, has any leak and integrity testing been performed?		
	• Have there been any spills associated with these tanks?		
17.	Are there any disused underground storage tanks?		
18.	Do you have regular check for any spillage and monitoring of chemicals handled? (If yes, please provide details.)		
19.	How are the wastes disposed of?		
20.	Have you ever received any notices of violation of environmental regulations or received public complaints? (If yes, please provide details.)		
21.	Have any spills occurred on site? (If yes, please provide details.)		
	• When did the spill occur?		
	• What were the substances spilled?		
	• What was the quantity of material spilled?		
	• Did you notify the relevant departments of the spill?		
	• What were the actions taken to clean up the spill?		
	• What were the areas affected?		
22.	Do you have any records of major renovation of your site or re-arrangement of underground utilities, pipe work/underground tanks (If yes, please provide details.)		
23.	Have disused underground tanks been removed or otherwise secured (e.g. concrete, sand, etc.)?		
24.	Are there any known contaminations on site? (If yes, please provide details.)		
25.	Has the site ever been remediated? (If yes, please provide details.)		

Annex C1
Site Walkover Checklist

Observations

		Yes/No	Notes
1.	Are chemical storage areas provided with secondary containment (i.e. bund walls and floors)?		
2.	What are the conditions of the bund walls and floors?		
3.	Are any surface water drains located near to drum storage and unloading areas?		
4.	Are any solid or liquid waste (other than wastewater) generated at the site? (If yes, please provide details.)		
5.	Is there a storage site for the wastes?		
6.	Is there an on-site landfill?		
7.	Were any stressed vegetation noted on site during the site reconnaissance? (If yes, please indicate location and approximate size.)		
8.	Were any stained surfaces noted on-site during the site reconnaissance? (If yes, please provide details.)		
9.	Are there any potential off-site sources of contamination?		
10.	Does the site have any equipment which might contain polychlorinated biphenyls (PCBs)?		
11.	Are there any sumps, effluent pits, interceptors or lagoons on site?		
12.	Any noticeable odours during site walkover?		
13.	Are any of the following chemicals used on site: fuels, lubricating oils, hydraulic fluids, cleaning solvents, used chemical solutions, acids, anti-corrosive paints, thinners, coal, ash, oily tanks and bilge sludge, metal wastes, wood preservatives and polyurethane foam?		

Annex C2

Potential Information Sources for Site Appraisal

1. Aerial photographs from the Lands Department of Hong Kong
2. Public Records Office – For obtaining old maps and photos
3. Local Libraries – Public libraries and/or Universities Libraries
4. Antiquities and Monuments Office – For obtaining old maps and historical information
5. Topographic Maps from the Survey and Mapping Office – Lands Department
6. Land title searches from the Land Registry
7. Site plans obtained from site contacts
8. Building layout drawings from current and previous site owners
9. Previous assessments completed by site owners
10. Consultation with authorities for obtaining information such as underground utilities, sensitive areas, previous site investigation, zoning and spill records:
    a. Planning Department
    b. Agriculture, Fisheries and Conservation Department
    c. Lands Department
    d. Buildings Department
    e. Environmental Protection Department
    f. Fire Services Department
    g. Drainage Services Department
    h. Civil Engineering and Development Department
    i. Geotechnical Engineering Office, Civil Engineering and Development Department

Annex D

Health, Safety and Environmental Controls during Site Appraisal, Site Investigation and Remediation

	Site Appraisal	Site Investigation	Remediation
Health and Safety (H&S)			
Identify potential health and safety risks and determine control measures	✓	✓	✓
Potential Risks			
• Exposure to hazardous materials on site	✓	✓	✓
• Exposure to contaminated soil & groundwater		✓	✓
• Exposure to volatile / toxic vapours	✓	✓	✓
• Exposure to sample preservative chemicals		✓	✓
• Exposure to chemicals used in remediation			✓
• Possible presence of underground services and utilities		✓	✓
• Machines / equipment on site	✓	✓	✓
• Machines / equipment used in site investigation and remediation		✓	✓
• Manual handling and repetitive motions		✓	✓
• Confined space		✓	✓
• Moving vehicles	✓	✓	✓
• Falling and flying objects	✓	✓	✓
• Dust	✓	✓	✓
• Noise	✓	✓	✓
• Slip and trip	✓	✓	✓
• Fall from height	✓	✓	✓
• Fire and explosion	✓	✓	✓
• Poisonous plants and animals	✓	✓	✓
• Heat stress	✓	✓	✓
H&S Control Measures			
• Prepare site H&S plan		✓	✓
• Appoint site safety personnel		✓	✓
• Works designed and supervised by competent persons		✓	✓
• Personal protective equipment (PPE), for example:			
◦ Safety shoes	✓	✓	✓
◦ Helmet	✓	✓	✓
◦ Respiratory protection	✓	✓	✓
◦ Breathing apparatus			✓
◦ Hearing protection	✓	✓	✓
◦ Goggles	✓	✓	✓
◦ Face mask		✓	✓

	Site Appraisal	Site Investigation	Remediation
• Gloves		✓	✓
• Coverall		✓	✓
• Barricade the site		✓	✓
• Communicate with other working on site		✓	✓
• Check for explosive/flammable gases		✓	✓
• Confined space entry procedure		✓	✓
• Subsurface utility survey		✓	✓
• Compressed gas procedure		✓	✓
• Chemical handling procedure		✓	✓
• Provide decontamination facilities		✓	✓
• Use mechanical tools to reduce manual handling		✓	✓
Environment			
• Identify potential environmental impacts and determine control measures		✓	✓
Potential Environmental Impacts			
• Handling and storage of potentially contaminated soil and groundwater		✓	✓
• Disposal of contaminated wastes arising from the on-site activities		✓	✓
• Discharge of potentially contaminated wastewater		✓	✓
Environmental Control Measures			
• Segregate potentially contaminated soil and groundwater		✓	✓
• Stockpile of potentially contaminated materials should be contained and covered		✓	✓
• Collect potentially contaminated water recovered for appropriate treatment and disposal		✓	✓
• Segregate contaminated waste for disposal in accordance with the requirements of the Waste Disposal Ordinance		✓	✓
• Discharge to the storm water drainage, sewer or surface water shall comply with the requirements of the Water Pollution Control Ordinance		✓	✓
• Comply with noise and vibration limits		✓	✓
• Comply with Air Pollution Control Ordinance		✓	✓

Notes: This table is provided as a guide for identification of potential health, safety and environmental risks and control measures associated with site appraisal, site investigation and remediation activities. Potential risks and control measures listed here are those typically found and implemented in Hong Kong. Risks should be reviewed for each individual site and site-specific control measures should be identified and implemented accordingly. Reference should be made to relevant legislation and guidelines relating to the protection of H&S of personnel such as the *Factories and Industrial Undertakings Ordinance* and the *Occupational Safety and Health Ordinance* and their associated regulations and relevant environmental legislations.

Annex E
Site Investigation Methods

Figure E1
Types of Drill Rigs Commonly Used in Hong Kong

Track Mounted Rotary Drill Rig

Skid Mounted Rotary Drill Rig

Figure E2
Borehole Drilling and Sampling Equipment

Cable Percussive Drill

Shelby Tube Sampler

Split Barrel Sampler

Figure E3
Schematic Drawing of Groundwater Monitoring Well

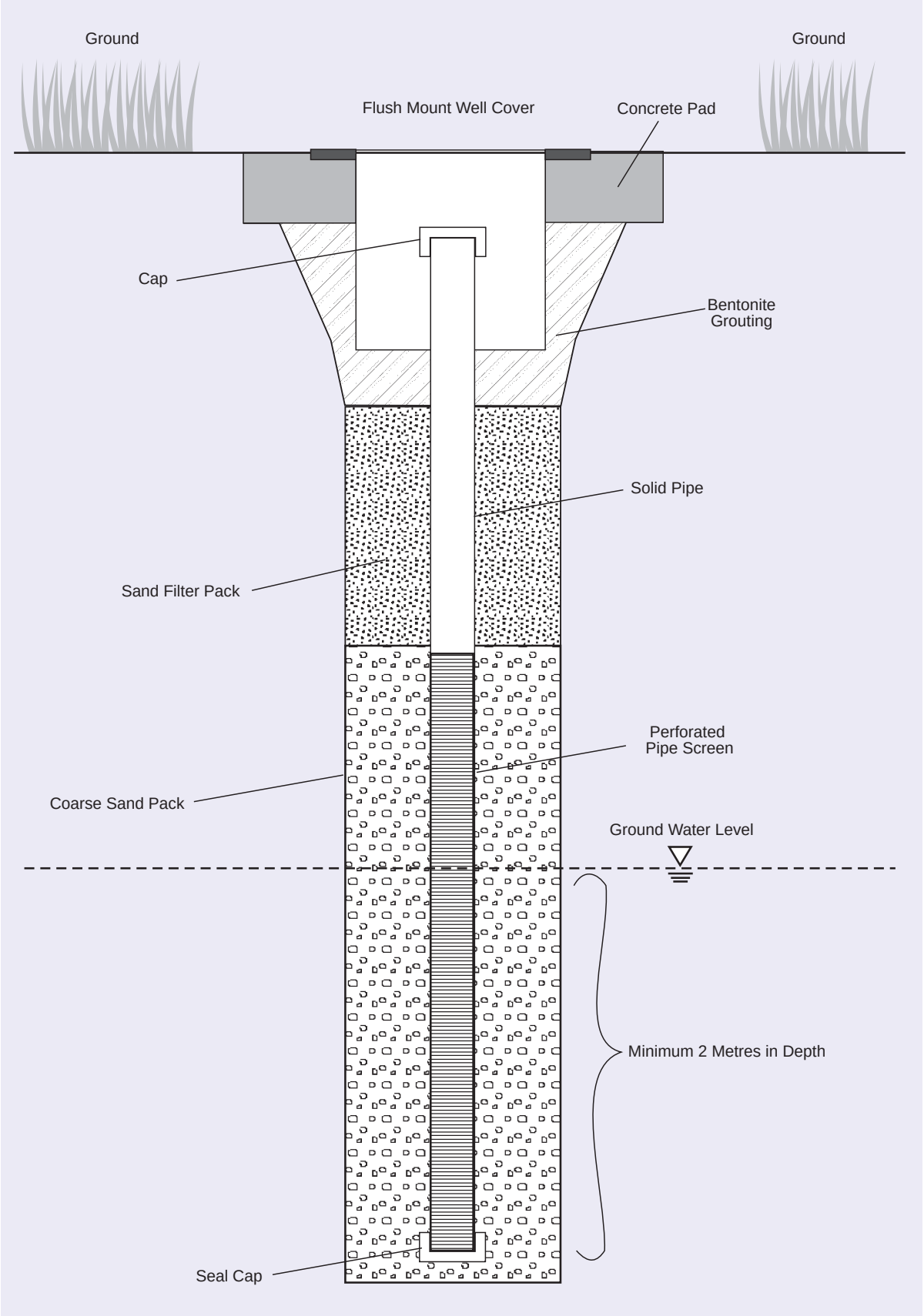
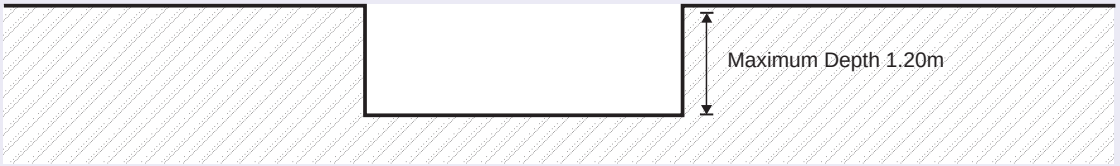
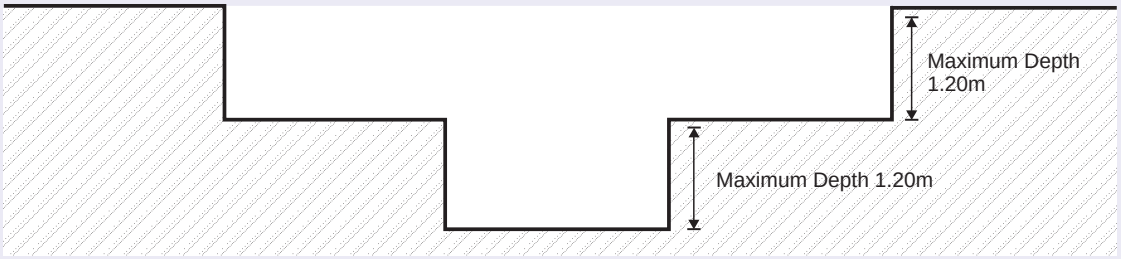


Figure E4
Schematic Drawing of Trial Pit

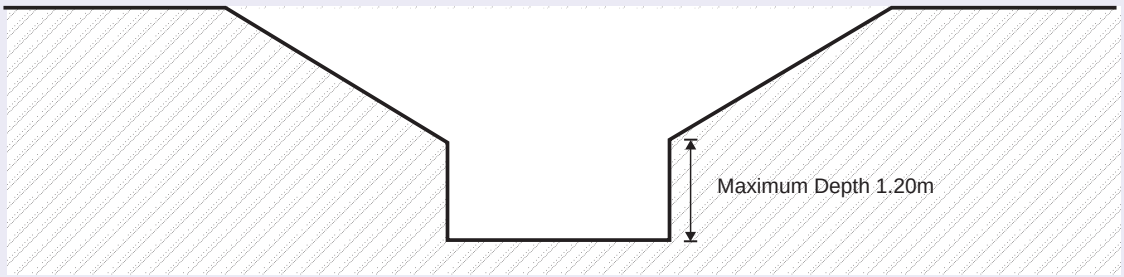
(A) Typical Shallow Trial Tit



(B) Stepped Trial Pit



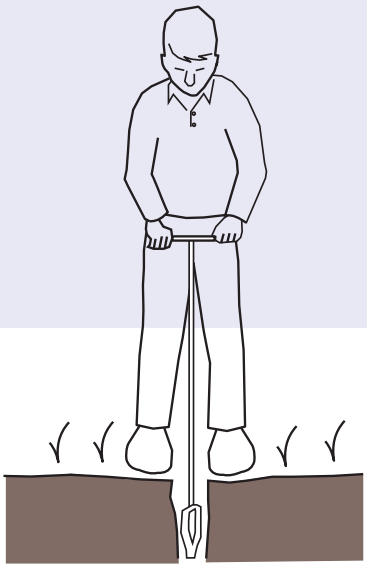
(C) Slope and Stepped Trial Pit



Annex E
Site Investigation Methods

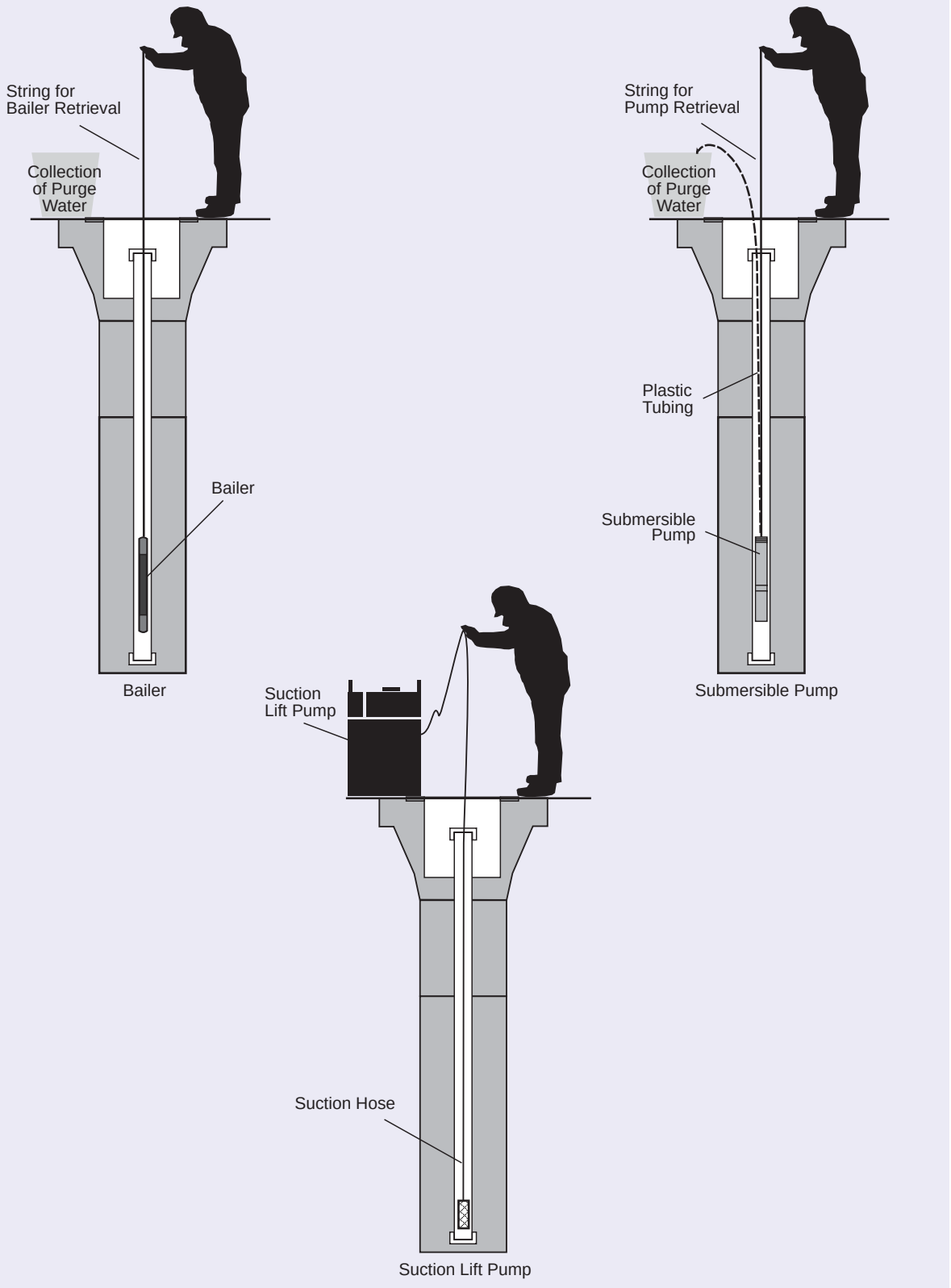
Figure E5
Schematic Drawing of Window Sampling and Hand Augering

Tube Sampler



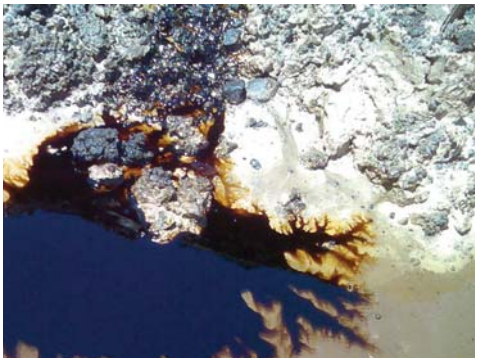
Hand Auger

Figure E6
Schematic Drawing of Groundwater Sampling Equipment

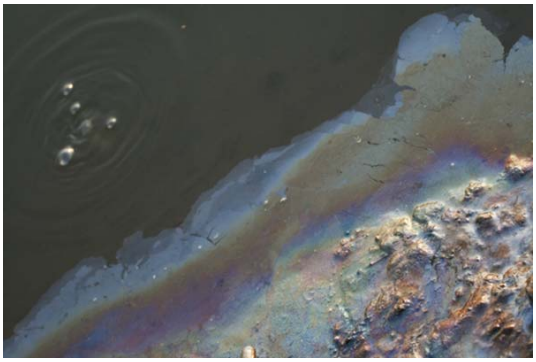


Annex E
Site Investigation Methods

Figure E7
Example of Hydrocarbons Contamination



Oil Staining Dispersing from Soil to Nearby Surface Water Body



Oil Sheen on Top of Surface Water

Surface Staining

Non-aqueous Phase Liquid

Hydrocarbons in Soil Samples

Annex F
Example of Chain-of-Custody Documentation

CHAIN-OF-CUSTODY DOCUMENTATION

Reference No:

Project:	Laboratory Batch No:
Address:	Samplers:
Site ID:	Analysis Required
Project No:	
Client:	
Contact:	
Reporting to:	
For Lab Use Only	Comments / Special Handling / Storage / Disposal
Cooler Seal Yes ..... No ..... Broken ..... Intact ..... Cooler Temp C	

Sample ID	Matrix	Date	Time	Container Type & Preservative																Notes

Submitted By		Received By		Method of Shipment
Name: Of:	Date: Time:	Name: Of:	Date: Time:	Consignment Note #
Name: Of:	Date: Time:	Name: Of:	Date: Time:	Transport Co. Name

Page ___ of ___

Annex G1

Remediation Methods - Applied in Hong Kong since the commencement of the Environmental Impact Assessment Ordinance

Figure G1
Typical Setup of Air Sparging System

Air Sparging
Air sparging is the process of injecting air directly into groundwater. Air sparging remediates groundwater by the injection of contaminant-free air into the subsurface saturated zone, enabling a phase transfer of hydrocarbons from a dissolved state to a vapour phase (volatilisation).

Example of Air Injection System

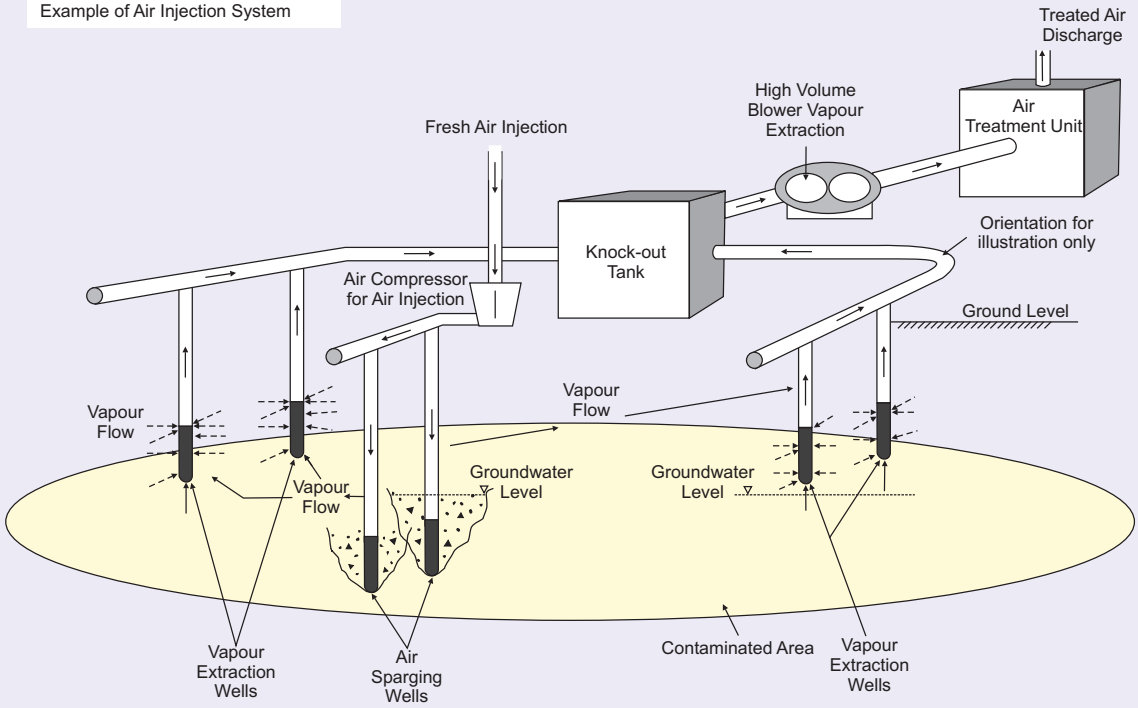


Figure G2
Typical Setup of a Biopile

Biopile
Engineered soil pile designed to enhance biodegradation. It allows natural processes to breakdown harmful chemicals. The microorganisms that live in soil can transform certain harmful chemicals, such as those found in gasoline and oil spills, eventually into water and carbon dioxide.

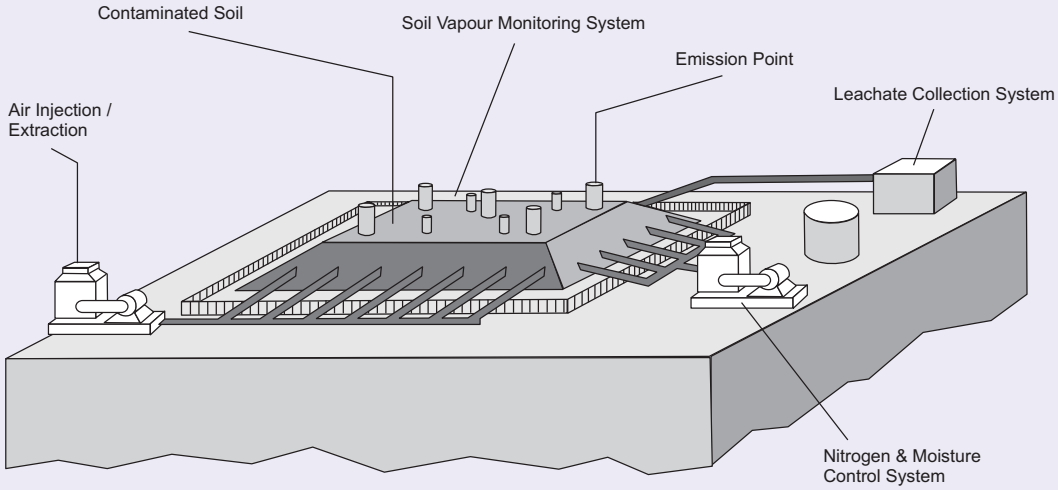
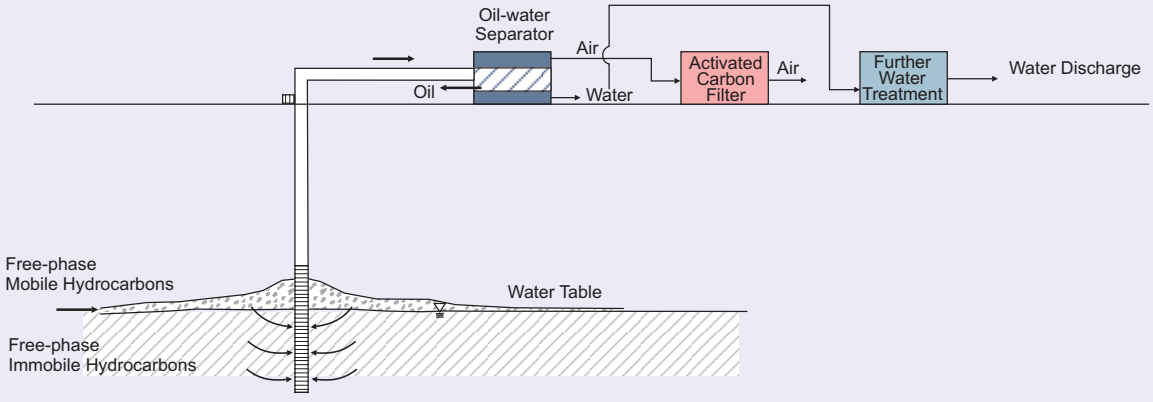


Figure G3
Typical Setup of a Groundwater Recovery Well System

Recovery Trenches or Wells
Engineered pumping or recovering of free floating products from a plume. Installation of trench or well within the plume and pump the groundwater out for recovering of products prior to recharging into the ground.



Annex G1

Remediation Methods - Applied in Hong Kong since the commencement of the Environmental Impact Assessment Ordinance

Figure G4

Typical Setup of a Soil Vapour Extraction System

Soil Vapour Extraction (SVE)

In situ treatment of soils by removal of NAPL or contaminants by suction/volatilization, in the form of vapours, from the soil above the water table. The vapours are extracted from the ground by applying a vacuum to pull the vapours out. Extracted vapours are separated and treated prior to discharging into the atmosphere.

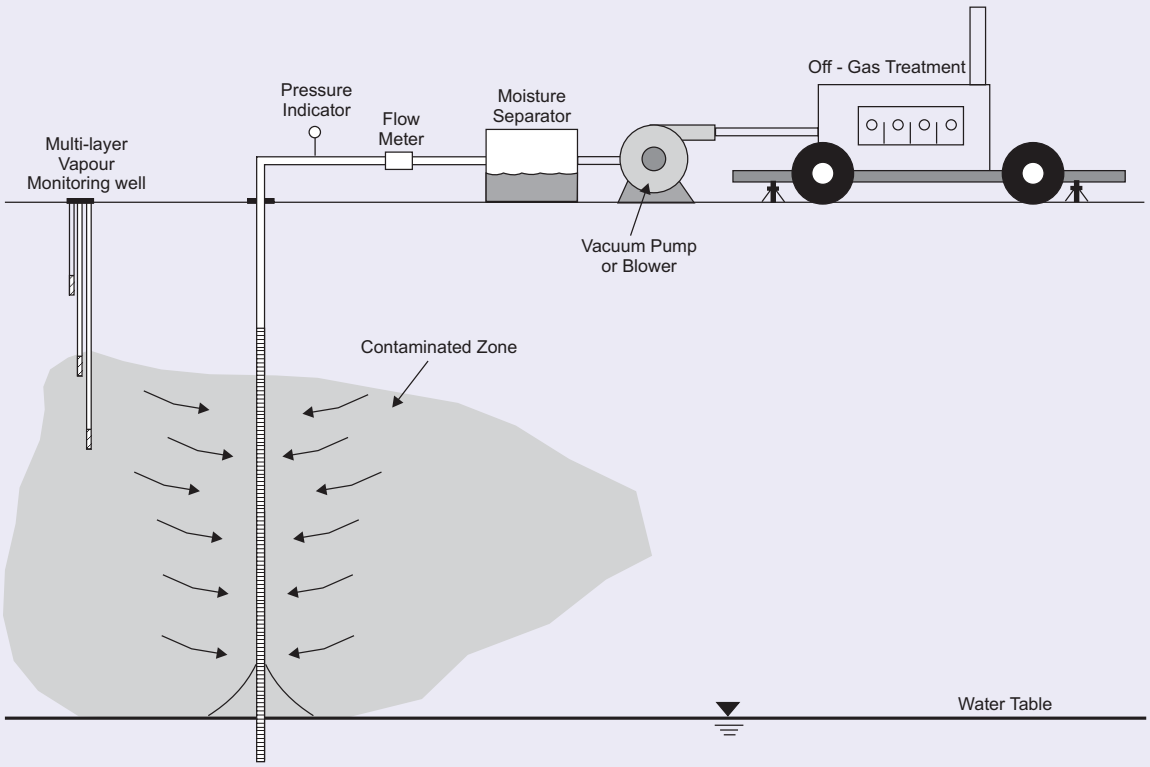
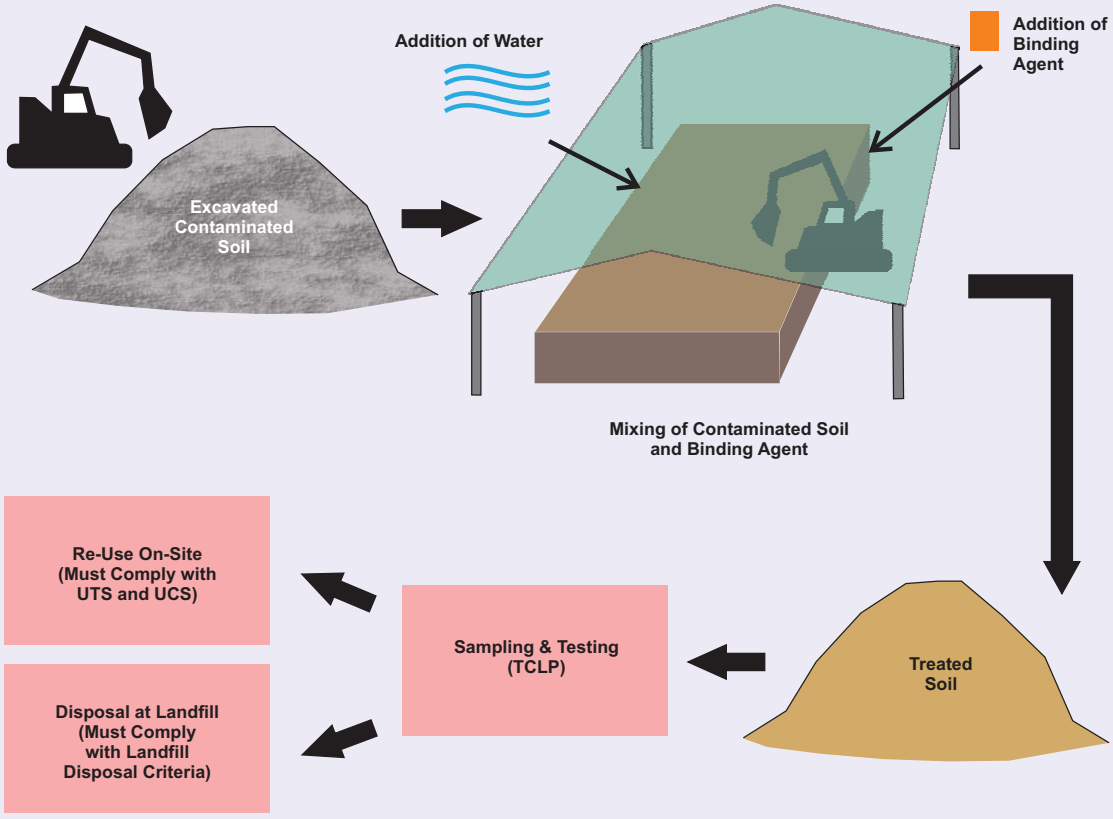


Figure G5
Typical Setup of a Solidification / Stabilisation System

Stabilisation / Solidification (S/S)
The most common form of S/S is a cement process, which simply involves the addition of cement or a cement-based mixture, to limit the solubility or mobility of the contaminants. S/S can be accomplished either in situ, by injecting a cement-based agent into the contaminated materials or ex situ, by excavating the materials, machine-mixing them with a cement-based agent, and depositing the solidified mass in a designated area.



Annex G1

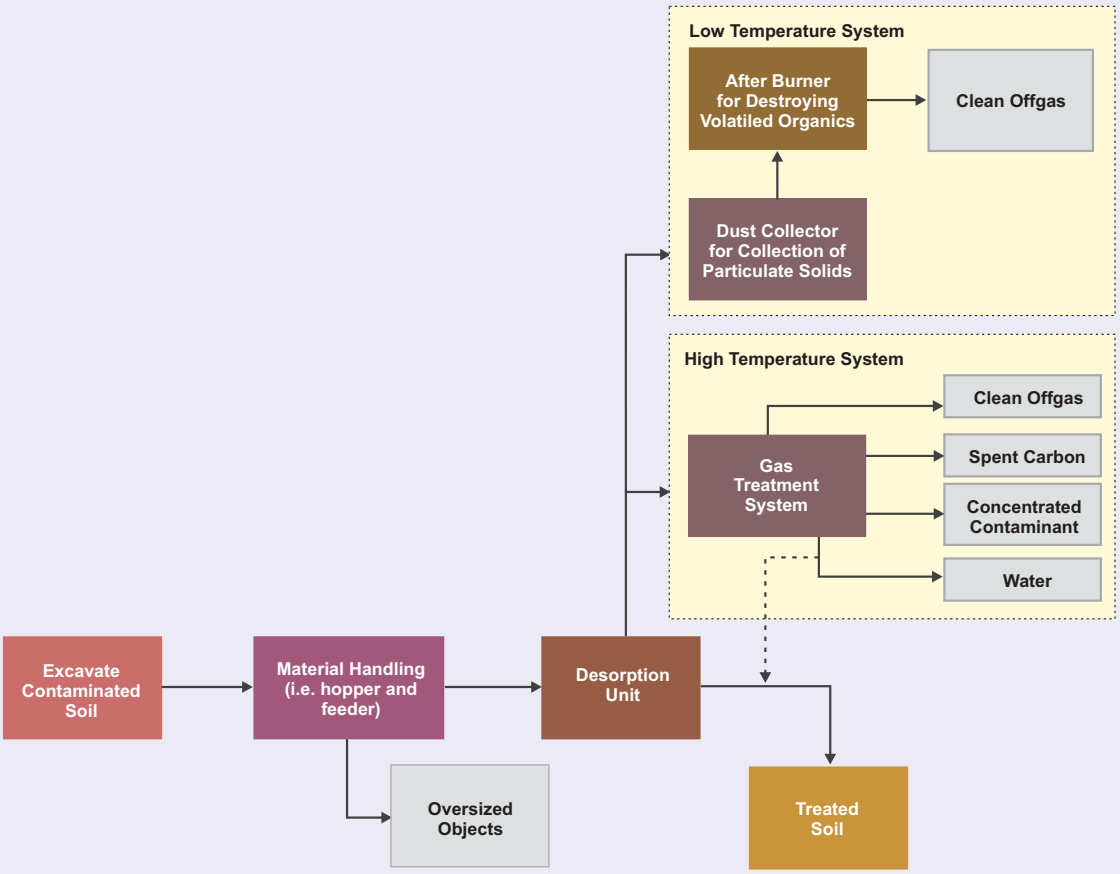
Remediation Methods - Applied in Hong Kong since the commencement of the Environmental Impact Assessment Ordinance

Figure G6

Typical Setup of a Thermal Desorption System

Thermal Desorption

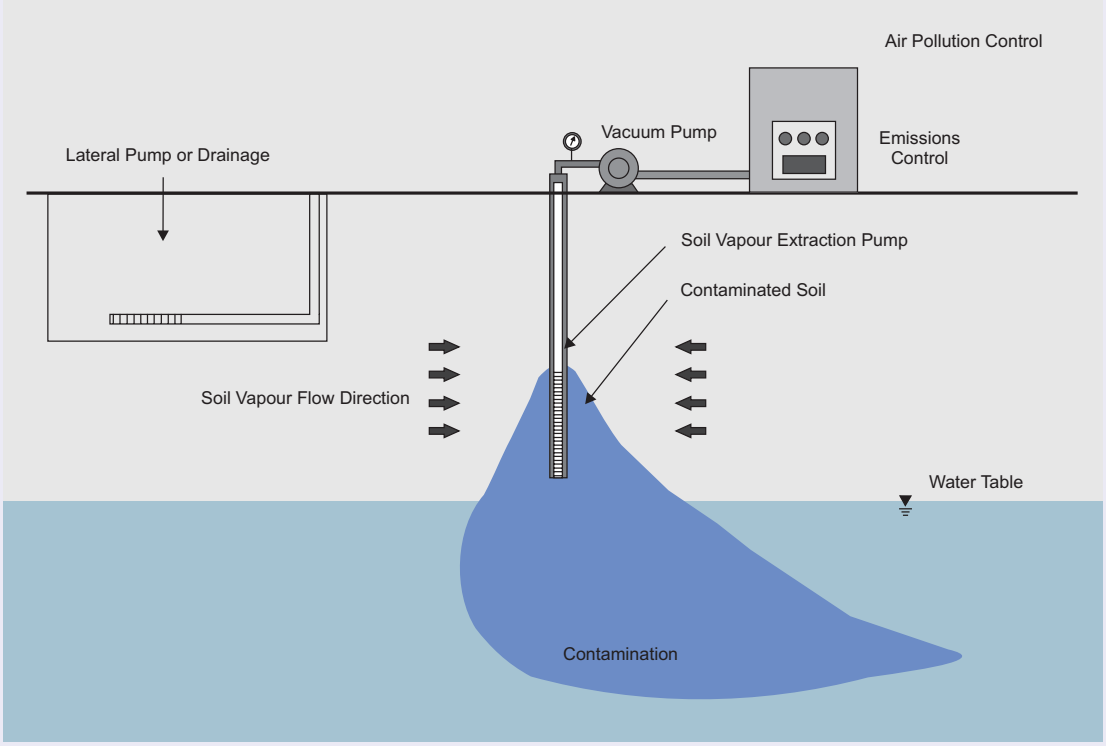
A technology that utilizes heat to increase the volatility of contaminants so that they can be removed/ separated from the soil matrix.



Annex G2
Remediation Methods - Applied in Overseas Cases

Figure G7
Typical Setup of a Bioventing System

Bioventing
Bioventing stimulates the natural in situ biodegradation of degradable contaminants in the unsaturated zone (above the water table). Air is supplied in situ at low flow rates to oxygen deprived soil microorganisms therefore stimulating biodegradation and minimizing the volatilisation of volatile organics into the atmosphere.



Annex G2
Remediation Methods - Applied in Overseas Cases

Figure G8
Typical Setup of Chemical Methods: Oxidation, Dehalogenation, Soil Flushing and Solvent Extraction

Chemical methods including: chemical oxidation, dehalogenation, soil flushing, solvent extraction and surface amendments
Oxidation: In situ or ex situ addition of reactive chemicals (oxidants) to soil or groundwater in order to transform harmful chemicals into harmless forms.

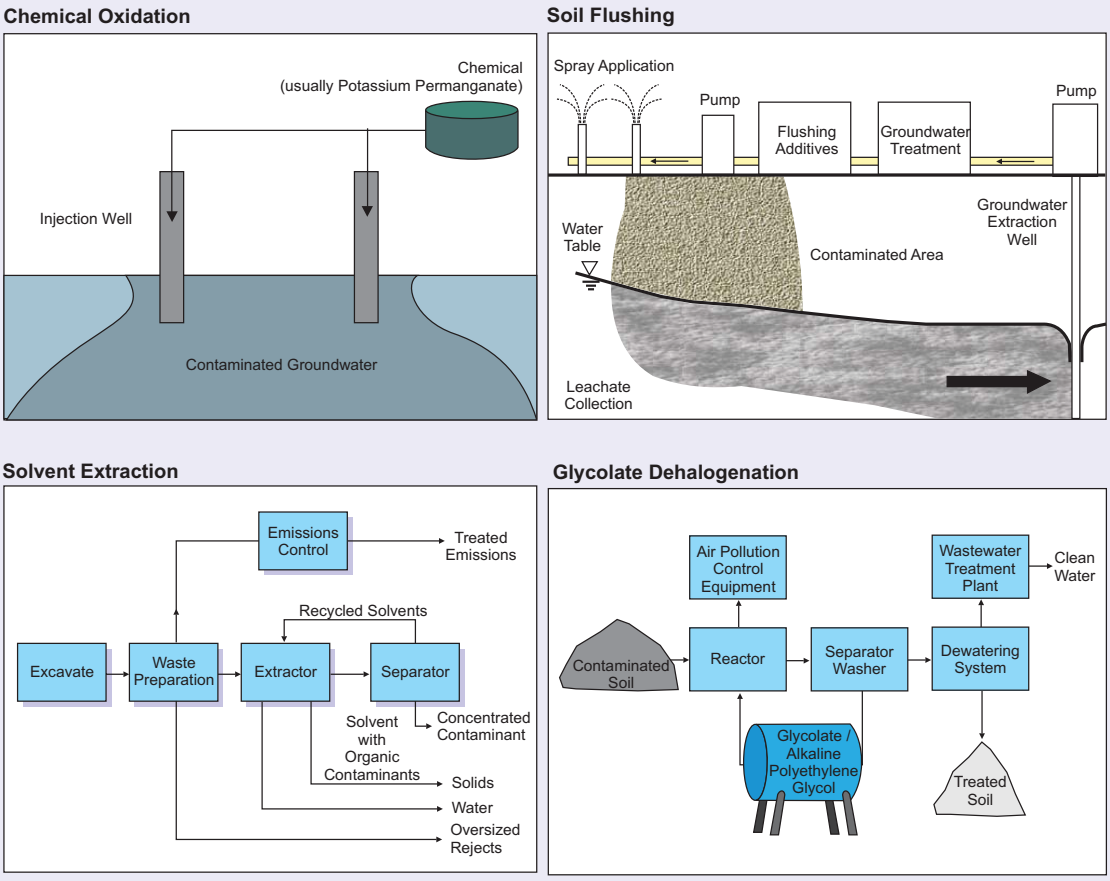
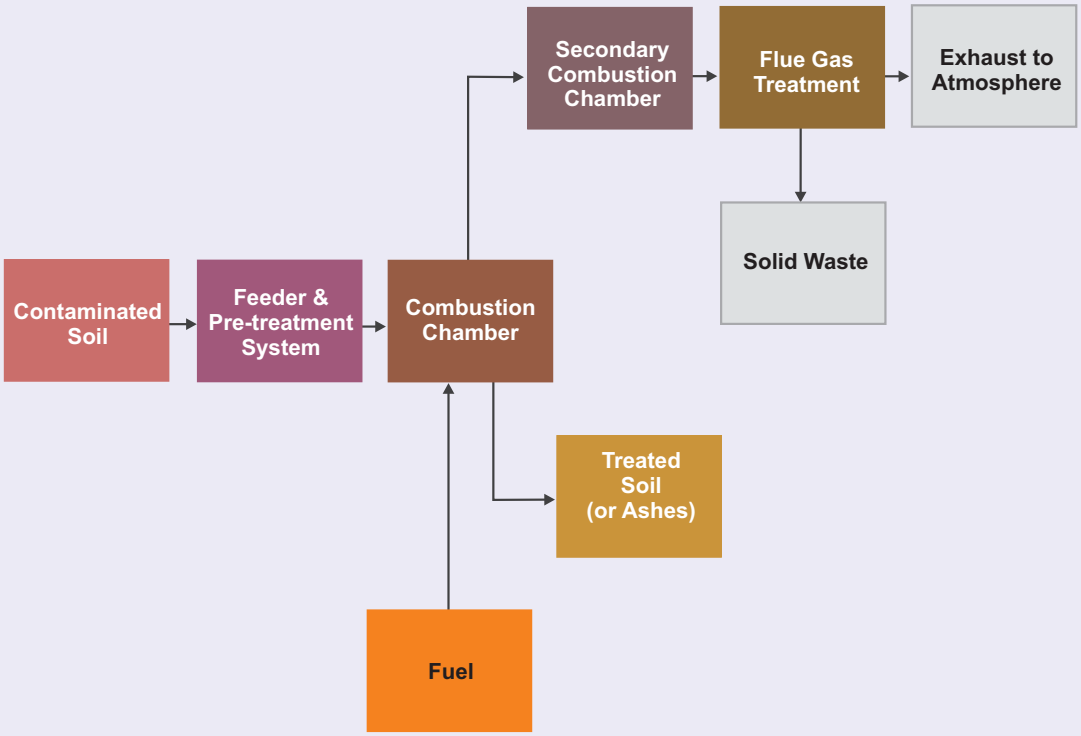


Figure G9
Typical Setup of Incineration Remediation Technology

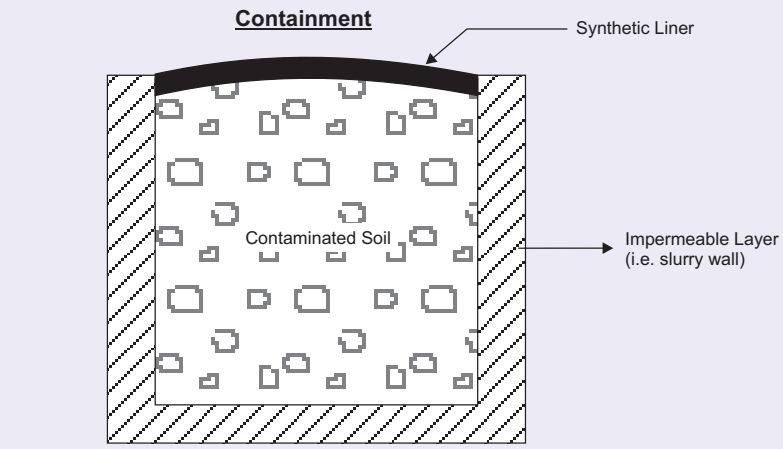
Incineration
Treatment of contaminated soils and hazardous materials by burning in order to destroy harmful chemicals. On-site incineration can reduce the amount of material that must be disposed of by other means.



Annex G2
Remediation Methods - Applied in Overseas Cases

Figure G10
Typical Setup of Capping & Containment System

In Ground Containment / Capping
Engineered impermeable barriers ("caps") designed to protect identified receptor. Capping involves placing a cover over contaminated material. Caps themselves keep contaminated material in place so it will not come into contact with people or the environment.



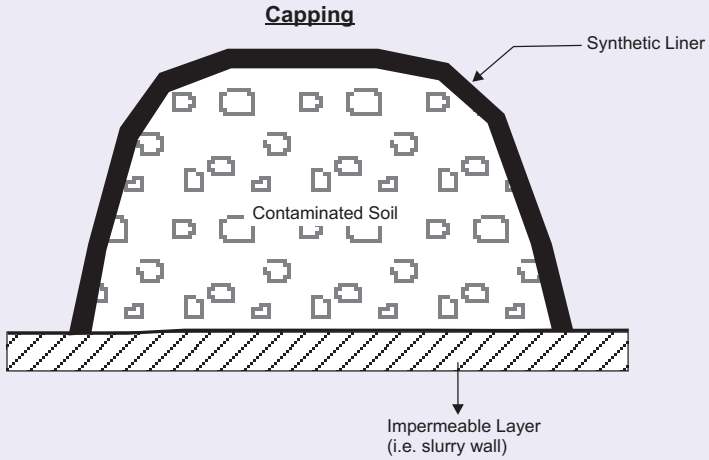
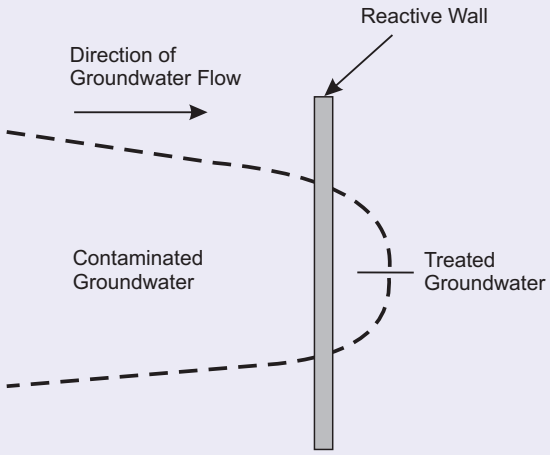
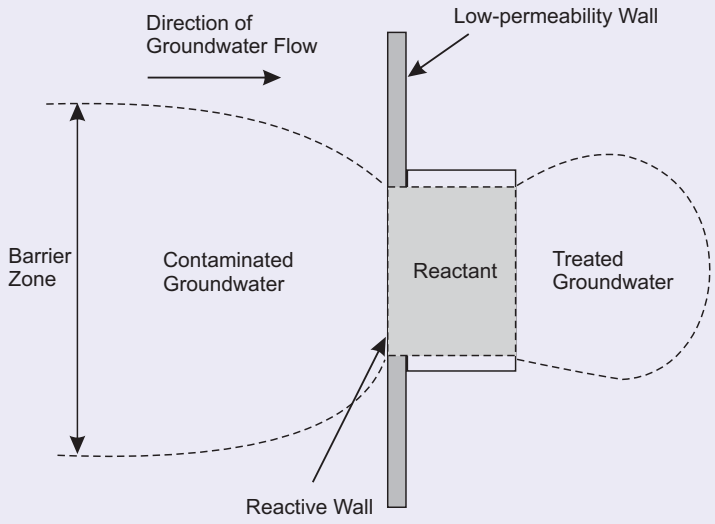


Figure G11
Typical Setup of Permeable Reactive Barriers (PRB)

Permeable Reactive Barriers
In situ treatment of contaminated water by means of engineering and use of reactive materials.



Continuous - Type PRB



Funnel & Gate - Type PRB

Annex G2
Remediation Methods - Applied in Overseas Cases

Figure G12
Typical Setup of a Soil Washing System

Soil Washing
Contaminants absorbed onto fine soil particles are separated from bulk soil in a water-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, or chelating agent or by adjustment of pH to help remove organics and heavy metals. Soils and wash water are mixed ex situ in a tank or other treatment unit. The wash water and various soil fractions are usually separated using gravity settling.

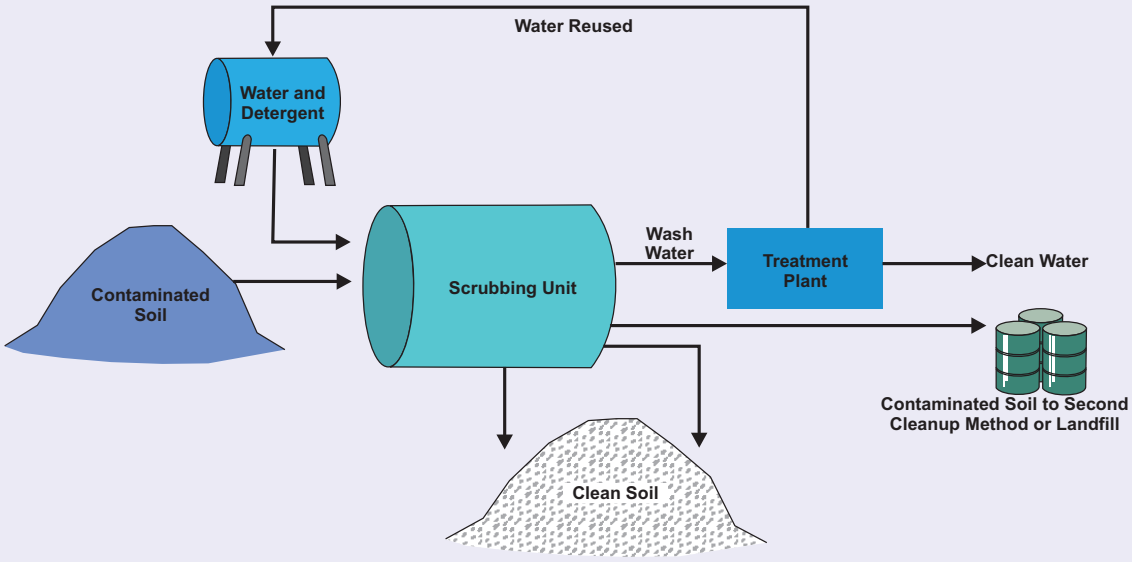
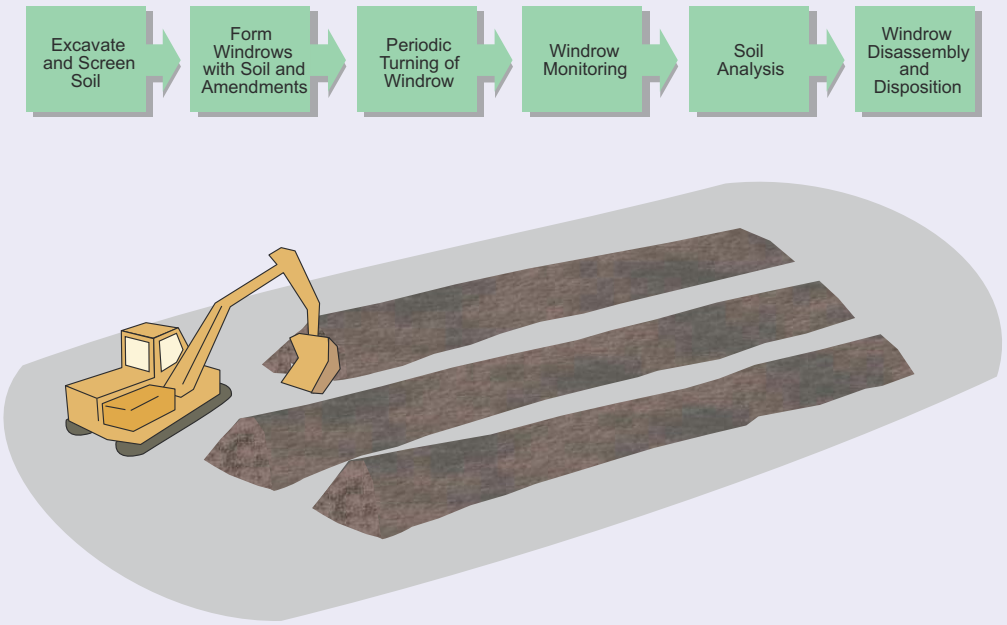


Figure G13
Typical Setup of a Windrows System

Windrows
Soil piles in which aeration and mixing of contaminated soil by mechanical processing, addition of nutrients (and in some cases microorganisms), and control of moisture content by periodic addition of water/covering with special fleeces for treatment of contaminants. Windrows differ from biopile since there are limited engineering measures to control the environmental conditions of the soil piles (e.g. no aeration pipes underneath the piles).



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