

Australian Standard™

**Guide to the investigation and sampling
of sites with potentially contaminated
soil**

**Part 1: Non-volatile and semi-volatile
compounds**



This Australian Standard was prepared by Committee EV-009, Sampling and Analysis of Soils and Biota. It was approved on behalf of the Council of Standards Australia on 14 October 2005.
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Australian Collaborative Land Evaluation Program (ACLEP)
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Australian Society of Soil Science Incorporated
CSIRO Minerals
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Australian Standard™

Guide to the investigation and sampling of sites with potentially contaminated soil

Part 1: Non-volatile and semi-volatile compounds

Originated as AS 4482.1—1997.
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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee EV-009, Sampling and Analysis of Soil and Biota as part of a series on the identification, analytical methods and investigation procedures for the assessment of soil. After consultation with stakeholders in both countries, Standards Australia and Standards New Zealand decided to develop this Standard as an Australian, rather than an Australian/New Zealand Standard.

This Standard supersedes AS 4482.1—1997, *Guide to the sampling and investigation of potentially contaminated soil*, Part 1: *Non-volatile and semi-volatile compounds*.

The objective of this Standard is to derive the information which may be required to satisfy regulatory authorities, although additional detail may be required in some localities. The Standard does not prescribe levels of contaminants which are considered to pose a risk to human health or the environment. Such levels are prescribed in documents such as the criteria produced by EHC/NEPM on contaminated sites and various regulatory agencies.

The objective of this revision is to reconfirm the Standard with minor changes to clarify certain aspects, update referenced documents and bring the Standard in line with current editorial practices. For the purposes of this Standard, the term ‘soil’ is taken to also include other solid materials, such as fill, rubble and waste.

There is a widespread community perception of potential health risks associated with contaminated land. These perceived risks may or may not be appropriate, depending on the quality of the information upon which they are based. Unfounded fears may be difficult to dispel whereas ‘real’ risks associated with the exposure to hazardous materials may not be fully appreciated. Quantitative risk assessments are required in order to clarify these perceptions. Such risk assessments require a sampling strategy representative of the site.

The contamination of land and groundwater by chemicals has been well recognized and acted upon in Europe and North America. Because of the relatively short history and low intensity of industrialization in Australia, the number of contaminated sites is far fewer than for Europe or North America.

This Standard provides guidance for the sampling and investigation process to professionals engaged in these activities. The professionals should consider the relevance of the various components of this Standard to the particular site under investigation and apply them accordingly. Where site specific issues are raised which are beyond the scope of this Standard, for example where radioactive, unexploded ordnance or pathogenic contamination is suspected, then the relevant expertise should be sought and sampling and investigations targeted accordingly.

It is assumed that execution of the provisions of this Standard would be entrusted to appropriately qualified and experienced people. This Standard calls for the use of procedures that may be hazardous or injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Contaminated soils may also have an effect on the surrounding environment. Therefore, investigation of air, biota, surface water and groundwater should be performed where appropriate.

Procedures for sampling of soils for volatile analytes and potential acid sulfate soils are not included in this Standard.

CONTENTS

	<i>Page</i>
SECTION 1 SCOPE AND GENERAL	
1.1 SCOPE	5
1.2 REFERENCED DOCUMENTS	5
1.3 DEFINITIONS	5
1.4 THE PRACTICE OF COMPOSITE SAMPLING.....	8
SECTION 2 SITE INVESTIGATION PROCESS.....	
SECTION 3 PRELIMINARY SITE INVESTIGATION	
3.1 GENERAL	10
3.2 PRELIMINARY STUDY	10
3.3 SITE INSPECTION.....	12
3.4 PRELIMINARY SITE INVESTIGATION REPORT	13
SECTION 4 DETAILED SITE INVESTIGATION	
4.1 GENERAL	15
4.2 PROCEDURE	15
4.3 DETAILED SITE INVESTIGATION REPORT	16
SECTION 5 DATA QUALITY OBJECTIVES	
5.1 GENERAL	19
5.2 DQO PROCESS	19
SECTION 6 DESIGN OF THE SOIL SAMPLING STRATEGY	
6.1 GENERAL	20
6.2 SAMPLING OBJECTIVES.....	20
6.3 CONTAMINANT DISTRIBUTION.....	20
6.4 SAMPLING PATTERN SELECTION	21
6.5 UNCERTAINTY OF SAMPLING	22
6.6 SAMPLING PLAN FOR SITE CHARACTERIZATION AND VALIDATION	22
SECTION 7 SAMPLE COLLECTION	
7.1 SCOPE	23
7.2 SAMPLING PROGRAM.....	23
7.3 SAMPLING.....	24
7.4 HANDLING, CONTAINMENT AND TRANSPORT OF SAMPLES	27
7.5 DECONTAMINATION OF SAMPLING EQUIPMENT	29
7.6 FIELD SAMPLING FORMS.....	30
SECTION 8 QUALITY ASSURANCE	
8.1 GENERAL	31
8.2 QUALITY CONTROL SAMPLES	31
8.3 CHAIN-OF-CUSTODY	33
8.4 CALIBRATION OF FIELD INSTRUMENTS	33
APPENDICES	
A HEALTH AND SAFETY OF INVESTIGATORY PERSONNEL.....	34
B GUIDELINES FOR THE COMPOSITE SAMPLING OF SOILS	37
C EXAMPLE OF THE USE OF THE DQO PROCESS.....	40

D	NUMBER OF SAMPLE LOCATIONS REQUIRED FOR HOT SPOT DETECTION	42
E	SAMPLING PLAN FOR SITE CHARACTERIZATION AND VALIDATION	43
F	NUMBER OF SAMPLE LOCATIONS REQUIRED FOR DETERMINING THE DEGREE OF CONTAMINATION	46
G	SITE CHARACTERIZATION	48
H	EXAMPLE OF A STRATA LOG	53
I	EXAMPLE OF CHAIN-OF-CUSTODY FORM	54
J	CHEMICAL CONTAMINANTS LISTED BY INDUSTRY TYPE	55
K	EXAMPLES OF SAMPLING IMPLEMENTS.....	59

STANDARDS AUSTRALIA

Australian Standard

Guide to the investigation and sampling of sites with potentially contaminated soil

Part 1: Non-volatile and semi-volatile compounds

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard provides guidance for collecting sufficient and reliable information for the assessment of a site potentially contaminated by non-volatile and semi-volatile compounds. It includes the formulation of data quality objectives and design of a sampling plan to meet the objectives of the investigation.

This Standard is suitable for use in determining compliance with criteria such as those produced by Assessment of Contaminated Sites-National Environment Protection Measure (EHC-NEPM) and various regulatory agencies.

NOTES:

- 1 This Standard does not establish any regulatory limits, remediation requirements or make any recommendations about the proposed land use.
- 2 Appendix A gives information on health and safety aspects when collecting soil samples. This appendix is intended only as a general guide to the issues that should be considered in the development of a site specific occupational health and safety plan.
- 3 Statistical methods and tools other than those described in this Standard may be used if they can be proven at least equivalent. Guidance on other statistical approaches can be obtained from the references cited in Appendix D.
- 4 For the purposes of this Standard, the term 'soil' is taken to also include other solid materials, such as fill, rubble and waste material.

1.2 REFERENCED DOCUMENTS

The following documents are referred to in this Standard:

AS

1726 Geotechnical site investigations

AS/NZS

5667 Water quality—Sampling

5667.1 Part 1: Guidance on the design of sampling program techniques and the preservation and handling of samples

ISO

3696 Water for analytical laboratory use—Specification and test methods

1.3 DEFINITIONS

For the purposes of this Standard, the definitions below apply.

1.3.1 Background concentrations

The naturally occurring, ambient concentration of substances in the local area of a site.

1.3.2 Composite sample

A sample resulting from the bulking and thorough mixing of individual soil samples collected from the same site.

NOTES:

- 1 The individual samples are collected from within the same depth and soil materials of similar characteristics at more than one sampling location to form a single soil sample for chemical analyses.
- 2 Guidance for the composite sampling of soil is given in Appendix B.

1.3.3 Confidence level

The probability, expressed as a percentage, that a statistical statement is correct.

1.3.4 Contaminant

A chemical substance of concern.

NOTE: This Standard does not pertain to radioactive substances or unexploded ordnances.

1.3.5 Contamination

The condition of land or water where any chemical substance or waste has been added at above background level and represents, or potentially represents, an adverse health or environmental impact.

1.3.6 Contaminated site

A site where assessment indicates hazardous substances occur at concentrations which pose, or are likely to pose, an immediate or long-term hazard to human health or the environment.

1.3.7 Data quality objective (DQO)

A qualitative and quantitative statement derived from the output of each of the following steps of the DQO process:

- (a) Clarification of the study objective.
- (b) Definition of the most appropriate type of data to collect.
- (c) Determination of the most appropriate conditions from which to collect the data.
- (d) Specification of acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.
- (e) Evaluation of the data collected and confirmation that the objective has been met.

1.3.8 Field quality assurance procedures

A series of procedures integral to the sampling plan to assure that the data collected in the field are representative and valid.

1.3.9 Field quality control samples

Samples additional to those from the original marked sampling points on the site, taken for quality assurance purposes.

1.3.10 Hot spot

Localized contaminated area where the contaminant concentration is significantly higher than in surrounding areas.

NOTE: Investigators should refer to the appropriate regulatory agency for threshold contaminant concentration level.

1.3.11 Investigation level

The concentration of a contaminant above which further appropriate investigation and evaluation is required.

1.3.12 Preliminary site investigation

An investigation consisting of a desktop study, and a site inspection with or without limited sampling.

1.3.13 Remaining soil

The soil remaining after the removal of contaminated soil.

1.3.14 Replicate samples

Samples taken from the same location which provide data on variation in analyte concentration.

NOTE: These samples are different from the blind replicate samples (Clause 8.2.2).

1.3.15 Risk

The probability in a certain timeframe that an adverse outcome occurs in a person, a group of people, plants, animals and/or the ecology of a specified area that is exposed to a particular concentration of a hazardous agent, i.e. it depends on both the level of toxicity of the hazardous agent and the level of exposure.

1.3.16 α risk

The probability, expressed in decimals, of making a 'Type I error' when a hypothesis is tested statistically. A Type I error is the error of wrongly rejecting a null hypothesis when in fact the null hypothesis is true. For the purpose of this document, where the null hypothesis always assumes the site to be 'contaminated', α risk refers to the probability that a contaminated site is statistically concluded to be clean by sampling when in fact the site is contaminated, i.e. a false negative result.

1.3.17 β risk

The probability, expressed in decimals, of making a 'Type II error' when a hypothesis is tested statistically. A Type II error is the error of wrongly accepting a null hypothesis when in fact the null hypothesis is false. For the purpose of this document, where the null hypothesis always assumes the site to be contaminated, β risk refers to the probability that a site is statistically concluded to be contaminated when in fact the site is clean, i.e. a false positive result.

1.3.18 Sampling pattern

The design that governs from where the soil samples should be collected within a sampling area.

1.3.19 Site characterization

The earlier stages of a contaminated site investigation at which the objective of the investigation is to identify the contamination status of the soil and to characterize the nature, degree and spatial extent of the contamination. A typical site characterization involves a preliminary investigation followed by a detailed investigation if necessary.

1.3.20 Site investigation

The combined planned and managed sequence of activities carried out to determine the nature and distribution of contaminants on and below the surface of a site that has been identified as 'potentially contaminated'. These activities comprise identification of the principal hazards, establishment of DQO, design of the sampling and analytical programs, collection of samples for analysis, reporting on and interpreting the results.

1.3.21 Site validation

The process of demonstrating that a contaminated site has been successfully remediated.

1.4 THE PRACTICE OF COMPOSITE SAMPLING

1.4.1 Composite sampling

Composite sampling is only suitable as a preliminary assessment tool. Composite sampling of semi-volatile compounds should not be undertaken. Composite sampling should not be undertaken for validation programs.

If sampling or compositing is undertaken inappropriately the analytical results may be meaningless.

NOTES:

- 1 The pitfalls of composite sampling are detailed in Appendix B.
- 2 Compositing or splitting of samples may be subjected to regulatory requirements.

1.4.2 Requirements for the use of composite samples

Prior to deciding on the type and number of samples to be collected, the project manager should consult the laboratory, so that composite sampling may be designed to meet site and analytical requirements.

NOTE: Appendix B provides guidelines for the composite sampling of soils.

SECTION 2 SITE INVESTIGATION PROCESS

It is important that a prescriptive approach not be adopted to assess contaminated sites as it may result in over-assessment or under-assessment of uniquely contaminated sites. A minimum assessment protocol is necessary for any potentially contaminated site as a reduced investigation at an early stage can result in failure to identify potential contaminants.

The strategy is to carry out a formal assessment through a preliminary site investigation. If the results of the preliminary site investigation indicate that contamination is present or likely to be present, the preliminary site investigation should be followed by a detailed site investigation. During a subsequent assessment of risks and hazards, potential migration routes relevant to the contamination should be determined and a three dimensional picture of the contamination established. To be able to present a logical conclusion, it is essential to acquire a detailed knowledge of the geology, soil physical and chemical properties, the topography and the local hydrology.

The process of site investigation and assessment is as follows:

- (a) Preliminary site investigation.
This should consist of:
 - (i) Preliminary study.
 - (ii) Site inspection with or without sampling.
 - (iii) Preliminary site investigation report.
- (b) Detailed site investigation.
This should consist of:
 - (i) Site investigation.
 - (ii) Site investigation report.
- (c) Validation.
- (d) Final report.

SECTION 3 PRELIMINARY SITE INVESTIGATION

3.1 GENERAL

A preliminary site investigation is the collection and assessment of information derived from records of its previous use (preliminary study) and site inspection, usually with limited sampling. Limited sampling should be carried out to—

- (a) produce evidence through an investigation to indicate whether a site is potentially contaminated; and
- (b) determine whether a detailed site investigation should be conducted.

3.2 PRELIMINARY STUDY

3.2.1 General

The objectives of the preliminary study should be to determine—

- (a) whether there has been potentially contaminating land use;
- (b) the nature of probable contaminants; and
- (c) the possible locations of contamination.

3.2.2 Information requirements

As much relevant information as can be obtained should be listed in chronological order up to and including the current use, under headings such as the following:

- (a) Site history.

This should include the following:

- (i) Site definition, using title details and the location relative to roads and topographic features.

NOTES:

- 1 Demographic features, such as street names, allotment numbers and alignment of roads may have changed with time.
- 2 A map of the site, to scale, noting current buildings, services, relevant sites features and indicating the site orientation and general contours should be drawn.

- (ii) Previous and present owners, occupiers, managers and those responsible for current use of the site.
- (iii) Previous and present industries and uses, with an overview of the operations.
- (iv) Charts and diagrams of previous and current buildings.
- (v) Raw materials used, by common, systematic and trade names.
- (vi) Products, discharged during batch or continuous production processes. These products should be listed by common, systematic and trade names where possible.
- (vii) Chemical storage and transfer locations.
- (viii) Wastes (including failed batches) produced as for Item (vi), listed by common, systematic and trade names where possible.
- (ix) Disposal locations of the waste from Item (iii), identifying solid waste and liquid waste lagoons, settling tanks and sumps.

- (x) Discharge to land, water and air.
- (xi) Product spills, losses, incidents and accidents, including fires, with an indication of the chemicals spilled, frequency, estimates of quantity, extent of fire damage and structures affected.
- (xii) Plans of sewer and other underground service.
- (xiii) Location size of previous or existing storage tanks, (both above ground and underground) infrastructure and type of potential contamination.
- (xiv) Location of on-site and nearby wells and groundwater monitoring bores.
- (xv) Location of transfer lines and notation of whether they are above or below ground.
- (xvi) Locations of dispensing or fill points.
- (xvii) Spill control systems, e.g. bund (materials of construction should be noted).
- (xviii) Current and previous uses of adjacent land taking into account relevant features listed above as appropriate.
- (xix) Complaint history—regulatory actions, legal actions.

(b) Geology/hydrogeology.

This should include the following:

- (i) Distribution of geology, field characteristics of soil, type and distribution of fill.
- (ii) Preferential surface and sub-surface migration pathways for the contaminants of concern in addition to groundwater flow direction.
- (iii) Depth to the groundwater in unconfined and confined aquifers.
- (iv) The location of preferential water flows, surface water courses, springs and wells.
- (v) Groundwater quality, present and future uses of groundwater (e.g. registered bores, diversion points) within relevant proximity of the site.

(c) Metrological data.

3.2.3 Sources of information

The preliminary study should require the collation of data from a wide variety of sources (see Table 1). Data sources may include soil, regolithic, geological and hydrogeological maps and reports, soil data bases with information about the occurrence of similar soils in other locations and previous site investigations. The reliability of existing soil and geological information depends on the data quality, size and history of use of the site under investigation.

The data should identify the following:

- (a) Possible distribution and type of contamination by relating site history to existing conditions.
- (b) Probable types of soil and fill and their physical and chemical characteristics.
- (c) Surface and subsurface hydrogeological processes affecting the redistribution of contaminants across the site.
- (d) Potential off-site sources.

TABLE 1
POTENTIAL DATA SOURCES

Data information	Source
Environmental	Government departments (Federal, State and local government) Including the following: Geological survey organizations Conservation Environment/EPA. Planning Primary industries Bureau of Meteorology Water Resources Land
Historical and current land use	Government departments (Federal, State and Local government), e.g. lands, environment/EPA, Planning Aerial survey offices Libraries Companies and employees Local residents Historical societies
Complaint history	Government departments (Federal, State and local government) e.g. Department of Environment/EPA

3.3 SITE INSPECTION

3.3.1 General procedure

The whole area should be traversed, preferably on foot. Relevant information from the following should be identified and mapped:

WARNING: IN UNDERGROUND CHAMBERS, TUNNELS OR MINE WORKINGS, HAZARDOUS SUBSTANCES INCLUDING GASES MAY BE PRESENT. PRECAUTIONS IN ACCORDANCE WITH APPENDIX A SHOULD BE TAKEN.

- (a) Areas of discoloured soil, polluted water, affected plant growth and animal populations and significant odours.
- (b) The presence of any stockpiled material, imported soil or fill material such as slag, ashes, potential asbestos containing materials, scrap and industrial or chemical waste, as well as any signs of settlement, subsidence and disturbed ground.
- (c) Assessment of soil loss or deposition that has occurred in the past and evaluation of the future erosion potential.
- (d) The direction of the flow of water run-off from the site and adjacent properties.
- (e) The depth of any standing water, the direction and rate of flow of rivers, streams or canals, together with their flood levels and any tidal fluctuations.
- (f) Any differences between the present conditions and the information obtained from the site history.

- (g) Location and condition of all visible features, including foundations, positions of former buildings, tanks, pits, wells, drains and bores.
- (h) Condition and type of ground cover, e.g. bare ground, asphalt, concrete, gravel, etc.
- (i) Chemical storage and transfer areas, including the presence of waste or chemical containers.
- (j) The apparent condition and use of adjacent properties.
- (k) Location of settlement ponds.

In addition, record all other pertinent information (e.g. author of report, date of site inspection and sampling, climatic conditions, etc.)

Consideration should be given to the likelihood of the uses of the surrounding environment being affected by further stages of investigation or subsequent development of the site.

3.3.2 Preliminary sampling

The samples collected during the site inspection should be collected in accordance with Section 7 of this Standard. They should be tested to identify any hazards that may affect later stages of the investigation.

NOTE: No sampling plan, however exhaustive, can completely eliminate the possibility that contaminants are present on a site. A satisfactory sampling plan is one which has an acceptable probability of detecting the presence of contaminants.

The possible effects of recent weather on current field conditions should be taken into consideration.

3.4 PRELIMINARY SITE INVESTIGATION REPORT

The report of the investigation should contain all available information and the following as a minimum:

- (a) The objective of the preliminary site investigation report and its limitations.
- (b) Location and titles information of the site with a copy of the certificate of title.
- (c) Current owner/occupier.
- (d) A scaled site plan and diagrams to show—
 - (i) location of former activities on the site and adjacent properties;
 - (ii) location of known and potential contamination;
 - (iii) distribution of soil and fill materials including zones of accumulation and depletion;
 - (iv) description of the ground cover across the site;
 - (v) surface run off and drainage;
 - (vi) presence of above and below ground services, storage tanks, etc; and
 - (vii) sample locations.
- (e) The present condition of the site.
- (f) The findings of the site history review.
- (g) Potential sources of contamination and associated contaminants.
- (h) The sources of information used, including consultations made and pertinent maps, diagrams and photographs used.
- (i) Rationale for the selection of any sampling points.

- (j) Rationale for selection of any analytes and their detection limits.
- (k) Results and evaluation of any samples analysed.
- (l) Relevant information of soil types and underlying geology (see Clause 3.2.2(b)(i)).
- (m) Preliminary information of the hydrogeology of the area.
- (n) Plan(s) showing analyte concentrations above investigation thresholds.
- (o) Copies of the laboratory result sheets if samples were collected and analysed.
- (p) Chain-of-custody documents, if samples were collected and analysed.
- (q) Conclusions of the preliminary site investigation, identifying probable and existing contaminants and any other features requiring further investigation. One of the conclusions may be a recommendation that a detailed site investigation be conducted. This is usually the case if the preliminary site investigation indicates that contaminating activities took place on the site at some time, or that contaminants are present.
- (r) All pertinent additional information (e.g. author of report, date of site inspection and sampling, climatic conditions, etc).

NOTE: Without sampling and subsequent analysis of soils from a given site, there is no sure way of determining whether a site is contaminated. Even if the preliminary site investigation indicates no likelihood of contamination, an initial sampling and analysis program for a limited range of analytes may be conducted to confirm the findings of this study. This also applies if the preliminary site investigation indicates the other extreme, a high likelihood of contamination.

SECTION 4 DETAILED SITE INVESTIGATION

4.1 GENERAL

The objectives of the detailed site investigation are to—

- (a) assess contamination status;
- (b) establish the lateral and vertical distribution of contamination; and
- (c) identify, if possible, the source(s) of on and off site contamination.

In a detailed site investigation, decisions need to be made as to what data are to be collected. Section 5 provides guidance on a methodology which may be used for this purpose.

A detailed site investigation may take several episodes of site assessment as further evidence of impacts is obtained.

NOTES:

- 1 If the preliminary site investigation indicates potential impacts from contamination, assessment of soil should be followed by assessment of groundwater or other media.
- 2 The results of the detailed site investigation may be used to carry out a risk assessment or remediation, according to the proposed use of the site. On the basis of the risk assessment, a site management plan may be developed which may include some or all of the following:
 - (i) Land use control.
 - (ii) Remedial action as regards on-site and off-site contamination.
 - (iii) Future monitoring.

4.2 PROCEDURE

4.2.1 General

All activities relating to the investigation should be focused towards the objectives and deliverables while maintaining quality assurance procedures.

4.2.2 Detailed site investigation

The detailed site investigation should contain the following:

- (a) A sampling strategy to test the conclusions of the preliminary site investigation (see Section 6).

NOTE: No sampling plan, however exhaustive, can completely eliminate the possibility that contaminants are present on a site. A satisfactory sampling plan is one which has an acceptable probability of detecting the presence of contaminants.

- (b) Reporting on the methodology, basis of the works conducted, site observations, sampling and analytical procedures, data collected and interpretation of the data.
- (c) Conclusions of the investigation.

The overall detailed site investigation process is described in Figure 1.

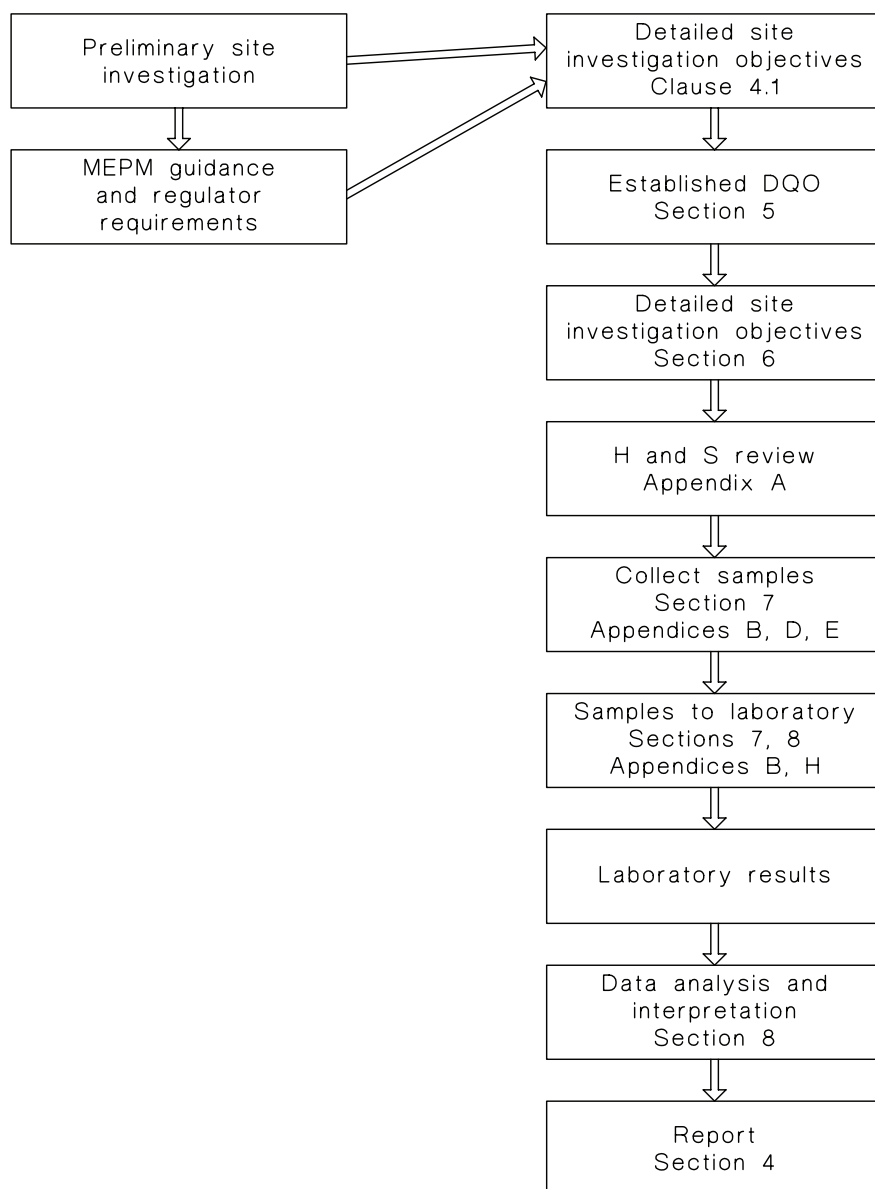


FIGURE 1 DETAILED SITE INVESTIGATION PROCESS

4.3 DETAILED SITE INVESTIGATION REPORT

A detailed site investigation report should reference the preliminary site investigation report where applicable and contain all or part of the following information as relevant to the objective of the report:

- (a) Limitations of the report.
- (b) Site identification including—
 - (i) map showing north, GPS references, scale, grid lines and the relationship to surrounding streets and properties;
 - (ii) certificate of title and plan/parcel information; and
 - (iii) photographs showing topography, nature of surface and existing structures.

- (c) Current and previous ownership, as listed on title documents and previous and current occupants if known.
- (d) Party responsible for site management, if not the owner.
- (e) Name of project manager and company which conducted the investigation.
- (f) Any available details of the proposed use.
- (g) History of site and adjoining properties including—
 - (i) prior or present usage;
 - (ii) sources of information;
 - (iii) validation of information; and
 - (iv) map detailing historical uses.
- (h) site condition, including—
 - (i) topography;
 - (ii) relevant local geological and hydrogeological factors;
 - (iii) local soil types; and
 - (iv) evidence of possible naturally occurring contaminants.
- (i) Soil testing, including the following:
 - (i) Rationale for choice of analytes (i.e. factors relating to the objective of the investigation, e.g. historical factors).
 - (ii) Sampling location map and methods (e.g. number of boreholes, depths, pattern) with objective for sampling and rationale for selection of sampling points (e.g. knowledge of previous land use, soil characteristics, contaminant, mobility and binding capacity of contaminant).
 - (iii) Laboratories used.
 - (iv) Analytes and details of analytical methods.
NOTE: A precis of the sample preparation, extraction and digestion methods and analytical instrumentation should be included.
 - (v) Field and laboratory quality control methods for specific analytes.
 - (vi) The following data:
 - (A) Field and laboratory measurements, in tabular, graphical or plan format.
 - (B) Identification of local soil types and their relevant physical and chemical properties, such as conductivity, moisture content and pH.
 - (C) Borehole logs and soil profiles (including description of fill).
 - (D) Concentration ranges of analytes, most significant results, results by stratum including relevant summary statistical appraisal.
 - (E) Quality control results, including full data validation (Clause 8.2.6).
- (j) Conclusions of the detailed site investigation including the following:
 - (i) A table of relevant soil reference criteria (i.e. threshold levels) and indication of their source (e.g. NEPM, State Government Guidelines), and relevance to the study objective.
 - (ii) Site plan(s) showing analyte concentrations exceeding soil reference criteria.

- (iii) Discussion of exceedance of threshold levels and significance of the results in respect of the contamination status of the site relative to the potential land use.
- (iv) Any recommendation for further action.

SECTION 5 DATA QUALITY OBJECTIVES

5.1 GENERAL

Data Quality Objectives (DQO) are qualitative and quantitative criteria that:

- (a) Clarify study objectives.
- (b) Define appropriate types of data to collect.
- (c) Specify the tolerable levels of potential decision making errors.

The purpose of the DQO process is to ensure that the data collection activities are focused on—

- (a) collecting the information needed to make decisions; and
- (b) answering the relevant questions leading up to such decisions.

NOTES:

- 1 A unique set of DQO should be developed for each site.
- 2 The DQO vary according to the end use of the data.

5.2 DQO PROCESS

The DQO process, as defined by the US Environment Protection Agency, consists of seven distinct steps, as shown in Figure 2. Further details of the use of DQO process are given in Appendix C.

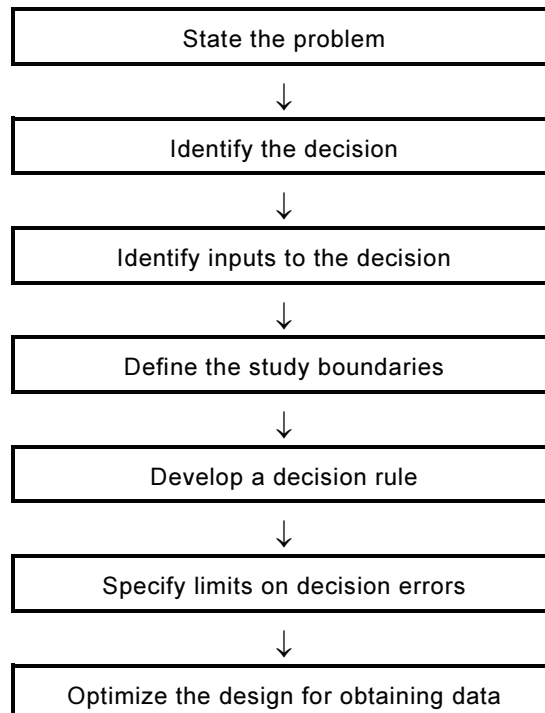


FIGURE 2 DATA QUALITY OBJECTIVE PROCESS