

Environmental Site Assessment Procedures for Upstream Petroleum Sites

**Saskatchewan Petroleum Industry /
Government Environmental Committee
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1.0 Defining Objectives

The objectives of the site assessment are to:

- Define the distribution of contamination in the environment, including air, water and soil;
- Determine the risk from the exposure to these contaminants; and
- Evaluate the possibility of mitigating these risks, and then mitigating the risk.

CCME Surface Assessment Handbook for Contaminated Sites, CCME EPC-NCSRP-48E pg. 3.

The site assessment process is designed to assist in the verification of the existence or non-existence of contamination, determination and conceptualization of the extent of contamination and selection of the most appropriate mitigative/treatment options.

The site assessment process used in these guidelines is divided into three phases. Phase I consists of gathering preliminary information to determine if further investigation is required for the site. Phase II involves detailed site investigation by implementing air/soil/water sampling and analysis. Interpretation of the sampling and analytical data is used to determine the extent of the contamination and build a conceptual model(s) of the contamination at the site. In the final remediation phase, one can explore remedial options, develop hazard assessment, exposure modelling and risk assessment, develop clean up criteria (risk based or criteria based), carry out remediation and verify the success of the remediation.

Environmental Site Assessment Principles

General Principles:

- use competent, objective assessors;
- determine an appropriate level of assessment; and
- use systematic and scientific procedures.

Quality of the ESA Assessor:

- The assessor should be objective and free from influence throughout the ESA process. Ideally, the assessor should be independent of the client.
- Where ESA is performed by in-house personnel of an organization, there should be a functional separation (i.e., arms-length) between the Assessor and the organization. This relationship shall be clearly described in the ESA.
- The assessor shall disclose to the client any conflict of interest.
- The assessor should possess an appropriate combination of formal education, knowledge, skills and experience to provide a technically sound and rational ESA.
- The assessor should be familiar with applicable federal, provincial and municipal legislation and published guidelines used to evaluate the presence of contamination on a property.

2.0 Phase I Environmental Site Assessment: Preliminary Desk-top Information Review and Site Inspection

The goal of Phase I ESA is to gather a sufficient amount of information to estimate the likelihood, types and location of subsurface contamination that may be present at the property. The information generated in Phase I ESA can be used by the property owners, purchasers, lenders and lessees to make informed decisions about property management, facility operations, future land use, investment and remedial actions.

In the context of these guidelines, the Phase I ESA will be used as a screening tool to:

- determine if Phase II ESA is required or not required; and
- if Phase II ESA is not required then the information gathered from Phase I ESA must provide convincing evidence to satisfy the regulators, surface land owner(s) and stakeholders that contamination is not present on the property.

2.1 Desk-Top Review

The desktop review requires gathering and examining the existing information available on the site without actually collecting physical data in the field. A comprehensive desktop review of existing and historical information about the site can facilitate appropriate planning and ensure implementation of an efficient, safe and thorough field investigation program. The purposes of desktop reviews are to:

- identify potential subsurface contaminants and environmental concerns at the site;
- identify subsurface conditions (by reviewing existing and historical data) and develop a conceptual model of the site, e.g. ground water flow direction, subsurface geology and hydrogeology; and
- establish the framework for the subsequent site investigation and work plan.
- Information about current and historical land use and activities can indicate the existence or likelihood of subsurface contamination at the site.

2.2 Recommended Record Review

Table 1. Recommended Record Review

RECORD TO BE REVIEWED	INFORMATION SOUGHT	SOURCE OF INFORMATION
aerial photograph	general site plan, and site usage	archives and company records
title search	chronology of ownership, previous land use	land titles
previous ESA reports	ESA review or other environmental reports to avoid duplication	company record files
company records	site plans, spill reports, audits, permits, monitoring data	company record files
geologic report	ground water flow and depth, subsoil type, conduits (fractures), topography	company record files
regulatory information	permits, license, control orders, fines or prosecution records	regulators

2.3 Potential Extent of Contamination

The extent of the known or suspected contamination will depend on the environmental properties (geophysical, hydrological, meteorological or biological factors), volume of chemicals released and nature of the contaminants. It may be possible to predict the extent of contamination based on information obtained during the desktop review.

2.4 Site Inspection

The purpose of the site inspection is to:

- identify visual signs of on-site and off-site soil contamination (e.g., surface staining, reduced vegetative growth and visible salt crystals);
- identify equipment and infrastructure to be decommissioned and potential sources of contamination;
- identify surrounding land use, topography and vegetation; and
- identify nearby surface water and water wells.
- identify and mark underground utilities that may be affected prior to subsurface investigations.

This information can be used to confirm site remediation requirements, to assess the environmental sensitivity of the site with respect to the potential receptors or future land use and to identify sources and potential locations of the contamination.

2.5 Surface Soil Sampling

Where there is evidence of contamination, during the desktop review or site inspection, it is recommended that soil samples be taken in order to:

- conduct preliminary screening for typical contaminants found in the upstream petroleum site, including salts and hydrocarbon contamination; and
- obtain background soil samples for comparison with the potentially contaminated soil.

2.6 On-Site Interviews

Meetings with adjacent landowners/occupants and facility operator and staff should be made to determine potential sources of contamination. Items to be discussed include:

- location of backfilled and/or previously remediated drilling sumps and pits;
- location of unproductive land (e.g., salt, sterilant or hydrocarbon damaged soil);
- details of past spills and the clean up procedures implemented; and
- details of waste management and waste disposal practises.

2.7 Contaminated Site Assessment Criteria

Assessment criteria are approximate background concentrations or approximate analytical detection limits for contaminants in soil and water. They serve as benchmarks against which to assess the degree of contamination at a site and to determine the need for further action. If the concentrations of a substance in the soil or water at a site do not exceed the assessment criteria, further action is not required. When concentrations exceed assessment value investigative action (ESA Phase II) should be

considered to assess the extent of contamination and the nature of any hazards at a site and to determine the scale and urgency of remedial action(s).

The assessment criteria used in this document is partly adopted from the *CCME Interim Canadian Environmental Quality Criteria for Contaminated Sites* (Report CCME EPC-CS34, September 1991) and modified in some cases to ensure that the criteria are relevant to the upstream oil industry. Levels of substances at specific sites that are higher than these criteria do not necessarily indicate contamination of soil or water.

Table 2. Sites Assessment Criteria Potential Triggers For ESA II

Parameters		topsoil	subsoil	water ¹
General Parameter	pH	6-8	6-8	6-8
	electrical conductivity	2 dS/m	8 dS/m	NR
	SAR	5	8	NR
	chloride (total)	NR	NR	250 mg/L
	sodium	NR	NR	200 mg/L
Organic	TEH	C ₁₁ -C ₂₂	1000 µg/g	visible sheen
		C ₂₃ -C ₆₀	4000 µg/g	
	PCB	NR	5 µg/g ¹	0.1 µg/L ¹
Inorganic	barium	NR	750 µg/g	NR
	cadmium	NR	1.4 µg/g	NR
	copper	NR	63 µg/g	NR
	chromium (total)	NR	64 µg/g	NR
	lead	NR	70 µg/g	NR
	mercury	NR	6.6 µg/g	NR
	nickel	NR	150 µg/g	NR
	vanadium	NR	130 µg/g	NR
zinc	NR	200 µg/g	NR	

Legend:

NR: analysis is not usually required unless *evidence(s)* that the contaminant is present.

1: analysis should be conducted when *evidence(s)* of the contaminant is present.

TEH: total extractable hydrocarbon C₁₁ to C₆₀: appropriate extraction followed by GC/FID.

mercury: cold vapour method/electrothermal furnace AAS or ICP/MS

2.8 Phase I ESA Evaluation - The Next Step

Upon completion of the Phase I ESA, an evaluation of the information should be carried out to answer the following questions:

- Is sufficient information available to conclude the likelihood that the contamination is a result of the operation?
- If contamination is present, is there sufficient information available to comment on the extent of contamination?
- If further investigation is not intended, is there sufficient information to satisfy the land owners, stakeholders and government?

3.0 Phase II Environmental Site Assessment: Detailed Review and Site Investigation

The purpose of a Phase II ESA is to confirm and delineate or to demonstrate the absence of contamination on a property identified through the Phase I ESA procedure. In some cases, a Phase II ESA may be undertaken to establish a quantitative baseline for environmental conditions at a site. Phase II investigations are undertaken prior to remedial investigation. It is not essential that a Phase I ESA is completed prior to conducting a Phase II ESA. In some instances, sufficient information exists regarding potential contamination to proceed directly to a Phase II ESA.

The key differences between Phase I and Phase II ESA investigations are:

1. The use of quantitative sampling and analytical techniques in Phase II ESA.
2. Phase II ESA is usually much more expensive and time consuming.
3. Phase II ESA requires contribution from specialized environmental professionals.

CSA Z768, Phase I Environmental Site Assessment

3.1 Phase II ESA Literature Review Requirements

The Phase II ESA requires a more detailed record review to confirm the existence of the contamination and to accurately delineate the extent of the contaminant plume. Once this information is collected, an overall sampling/monitoring plan can be devised. The plan will assist to save money and time. The following information may be included in the literature review:

- **Aerial photograph:** aerial photographs may provide a convenient means for confirming on-site and nearby land-use practices. If historical sequences of aerial photographs are available, it may be possible to identify how land practises have changed through the years. Historical changes in land-use practices may result in changes in the types of materials used and handled on the site and in the nature and the location of contamination of the subsurface.
- **Contaminant Profile:** as part of the desktop review, consideration must be given in researching the typical chemical contamination associated with the type of property being assessed. The key research areas in the desktop review include:
 - **Nature of contamination:** physical and chemical properties of the contaminant along with the soil and groundwater regimes determine the contaminant interaction with the subsurface environment and potential risk posed to human. However in most situations, accurately predicting the contaminant interaction with the environment can be difficult.
 - **Sources of contamination:** some potential sources of contamination are obvious and their locations may be defined in the desktop review. For example, crude oil and oily byproducts (produced sand) storage areas, tank farms, wellhead areas and disposal pits are typical sources. Identify and document all potential sources of contamination during the desktop review process. This information can assist the assessor to develop a better site inspection plan.
- **Geologic and hydrologic information:** the focus of this review is to determine the make-up and condition of the subsurface properties, which affects ground water flow and the movement of the contamination. This information includes: regional soil survey; subsurface geology and topography; meteorological data; regional drainage; local drainage; depth of the water table; water resources; local pumping or dewatering activities.

- Water well driller's records: well logs, records produced by water well drillers during well installations may provide information on the depth of useful aquifers, geologic conditions encountered during drilling and quality of the water.
- Baseline environmental studies.
- Ground water monitoring program results.
- Regional soil survey and subsurface geology reports.

3.2 Sampling Plan Development

The sampling plan and requirements are dependent on the amount, quality and nature of information obtained during the Phase I ESA. The components of the sampling program can involve one or more of the following:

- Soil sampling;
- Ground water sampling;
- Surface water sampling;
- Sludge sampling; and
- Geophysical survey.

It should be emphasized that the success of any field investigation is based on obtaining representative samples. The following general guidelines can apply to all types of sampling:

- Sample location should be selected in order to delineate the extent of contamination both horizontally and vertically, within the matrix of interest. Consideration should be given to the direction of ground water and surface water flow when selecting locations. Samples should be collected down-gradient of any source of contamination (e.g. pits, ponds and spill locations).
- Adequate numbers of background samples should be obtained in all cases. This will assist in determining whether or not elevated levels of certain substances exist within the site.
- Discussions should be held with the analytical laboratory prior to undertaking the sampling program. Based on the analytical parameters considered, the laboratory will specify:
 - volume of sample required;
 - type of sample container (e.g., glass or plastic);
 - sample preservation requirements; and
 - sample storage and transportation requirements (e.g., ice packs in coolers).
- Sampling equipment should either be used only once, or thoroughly cleaned after obtaining each sample. This will help to eliminate the potential for cross contamination of the sampling equipment. The method of cleaning will be dependent on the chemical parameters being analyzed. In some cases, distilled water or organic solvents (hexane) may be required. Cleaning methods should be reviewed with the analytical laboratory prior to undertaking the sampling program.
- Sample Labeling and Shipment. If a commercial carrier such as a trucking company, courier, bus, etc., is used to transport samples to the laboratory, ensure that the transporters are complying with *The Dangerous Goods Transportation Act and Regulations*. Please refer to *The Dangerous Goods Transportation Act and Regulations*.

3.2.1 Soil Sampling

In undertaking a soil sampling program, the site should be divided into sub units having distinct physical and operational characteristics (e.g., on a battery site crude oil storage and administration areas would likely be separated into different sub units.) Soil samples can then be obtained from several sample points within the individual sub unit. The spacing between sample points depends on several factors such as: type of contaminants, environmental conditions at the site (e.g., the presence of an obvious source of contamination); and the level of detail required. Generally, the horizontal spacing is limited by site access, but vertical spacing usually is at surface, 15 cm, 30 cm, 60 cm and 90 cm depth and deeper as required. Soil samples obtained in this manner can be composited from several sampling locations within the sub unit in order to reduce analytical costs, if it appears that they are relatively homogenous. Samples not appearing homogenous should not be composited.

Soil samples can be obtained with a shovel/spade, auger (hand or vehicle mounted), backhoe or rotary drilling rig depending upon the depth of the samples to be obtained, the soil conditions and the accessibility of the site. Sample locations should be referenced by location either through a grid system or survey coordinates. In general, the following guidelines apply to the selection of soil sampling equipment:

- shovel/spade, used for topsoil & shallow subsoil sampling.
- hand auger, used for shallow sampling (<1.5m) in cohesive soils.
- drilling rigs with solid stem augers and either shelby tubes or split spoon samplers, used for deep sampling (>1.5m) in cohesive soils.
- drilling rigs with hollow stem augers and either shelby tubes or split spoon samplers, used for deep sampling (>1.5m) when hole sloughing is likely.
- backhoe, used in rocky conditions to depth <3.0m.
- rotary drilling rigs, used in rocky conditions for depth >3.0m.
- air hammer, used in rocky conditions for depth >3.0m.

3.2.2 Ground Water Sampling

In sampling and analyzing ground water, you are trying to ensure:

- samples are representative;
- changes in the water chemistry prior to analyses are minimal; and
- analyses are reliable (accurate and reproducible).

To ensure representative samples, proper placement of ground water monitoring wells is vital. This may involve employment of a regular grid pattern or specific target site locations, which intersect, suspected pathways of the contaminated ground water. This type of work usually requires the involvement of hydrogeologists or environmental professionals with appropriate experience and knowledge.

In preparation to sample wells, we recommend that a site-specific sampling plan be devised prior to taking any samples. The sampling plan should be site and contaminant specific. Generally, the sequence of sampling involves:

- measure the water level and thickness of non-aqueous phase liquid (NAPL);

- sample the NAPL (if present);
- remove (flush or purge) the standing water in the well; and
- collect samples of the ground water and perform field measurements.

When collecting ground water samples, it is highly recommended that all sampling procedures and deviation from procedure be documented on site. Field books are essential for documenting field activities and observations. It is important to know when and how protocols change because these changes may affect the water chemistry.

A number of devices are available for bringing ground water to the surface for sample collection. If you use the same sampler in multiple wells, clean it and ensure that contaminants were not carried from one well to another. Typically, you can drain the sampler and thoroughly rinse it with distilled water. Ideally, sampling devices should be dedicated to each well to avoid cross contamination problems.

3.3 Sample Collection - Volume, Containers, Preservatives and Holding Time

Samples are taken to provide sufficient volume of water for desired chemical analyses. Table 3. presents the typical required volumes.

Table 3. Typically recommended containers, preservatives and maximum holding times.

Compounds	Containers : Volume (ml)	Preservatives	Maximum Holding Time
Major cations	P,G:100-1000 ml	HNO ₃ to pH<2	6 months
Major anions	P,G:100-1000 ml	cool, 4°C	14 to 28 days
N species, P	P,G:100-500 ml	H ₂ SO ₄ to pH<2	14 to 28 days
Metals	P,G:50 to 100 ml	HNO ₃ to pH<2	6 month
Cyanides	P,G:500 ml	NaOH to pH>12	14 days
VOC	G:10 to 250 ml	cool, 4°C, no head space	5 to 14 days
Semi-volatiles	G:100 to 1000 ml	cool, 4°C	7 days

Legend:

P = plastic container with sealable lids

G = glass container with sealable lids

VOC = volatile organic compounds

where biological activity is concerned (e.g., sulphate or nitrate) prepare it like major cations

The operator is recommended to consult with the laboratory for the specific requirements.

3.3.1 Analytical Parameters

Parameters to be analyzed should be based on a site-specific evaluation of the potential contaminants, which may have been introduced to the site from the operation of the facility. In general, the following constituents should be considered when deciding what to analyze for at upstream petroleum sites.

- pH: when produced water, acid or caustic spills are suspected;
- electrical conductivity (EC): when produced water spills are suspected;
- routine ions (Ca, Mg, Na, K, Cl, NO₃ and SO₄): for determining chemical amendment requirements for soil enhancement; and used to calculate sodium adsorption ratio (SAR);
- total extractable hydrocarbon (TEH);
- PCB and/or glycol, only when there is evidence that these contaminants are present;
- trace metals (Ba, Cd, Cu, Cr, Hg, Ni, Pb, V and Zn).

It should be noted that in most cases, it is not necessary to analyze samples for all of the above parameters.

3.3.2 Sample Field Preservation

Preservation of some water (see Table 3) and sludge samples prior to shipment to the analytical laboratory may be required depending upon the analysis to be performed. This is necessary to ensure that chemical reactions, which may change the actual concentration of the specific parameter, do not occur during transit. Preservation requirements should be discussed with the laboratory prior to sampling.

In addition, samples should be kept cool during transport (<4°C). Long periods of time between sampling should be avoided. If possible, samples should be analyzed within 24 hours of sampling. However, periods of time between one day and six months may be permissible depending upon the parameter being analyzed. This issue should be discussed with the analytical laboratory prior to conducting the sampling program.

3.3.3 Quality Assurance and Quality Control for Sampling Program

In addition to ensuring that the laboratory selected has a QA/QC program, other measures can be implemented to augment the QA/QC program. The various blanks and checks that could form a part of the quality assurance plan are included in Table 5.

Table 5. Quality Assurance Sampling Plan - Blank Samples

QA Sample	Purpose	Description	Recommended Frequency
Trip Blank	To identify contamination of sample container and samples during the travel and storage.	Laboratory fills container with contaminant free matrix (water, soil) and sampler ship and stores it with samples.	One per shipment, usually for volatile contaminants
Field Blank	To identify contamination of samples during collection.	Prepared as trip blank, but expose the contaminant free matrix water to site air and conditions (high temp, humidity, rain, etc...).	One per site or sampling day.
Equipment Blanks	To identify contamination from well & sampling equipment.	Flush casing material and sampling devices with distilled water or laboratory grade solvents.	Only if problem suspected, e.g., using a bailer for multiple wells for sampling.
Blind Replicates	To identify laboratory variability.	Split a sample into three containers; label as different samples.	One per day or per 10 to 25 samples.
Spiked Samples	To identify error due to sample storage & analysis.	Add known concentration(s) to sample bottle.	One per site or per 25 samples.

3.3.4 Selecting a Laboratory

The laboratory selected should have demonstrable expertise in commercial environmental analytical work. Some of the questions that should be asked when selecting an analytical laboratory are:

- Does the laboratory routinely participate in inter-laboratory testing programs?
- Does the laboratory possess state-of-the-art analytical equipment and is it staffed by qualified personnel to operate the equipment?
- Does the laboratory maintain an internal quality assurance/quality control program?
- Does the laboratory have a dedicated quality assurance/quality control person?
- Are the laboratories analytical and sample preparation procedures based on standard methods?
- How does the laboratory rate amongst participant of inter-laboratory testing programs?
- Can the laboratory achieve the same detection limits as other laboratories?

REFERENCES

- CCME (Canadian Council of Ministers of the Environment) National Guidelines on Physical-Chemical-Biological Treatment of Hazardous Waste, CCME-TRE-27F, August 1989.
- CCME Interim Canadian Environmental Quality Criteria for Contaminated Sites, CCME EPC-CS34, September 1991.
- CCME Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites Volume I: Main Report, CCME EPC-NCS62E, December 1993.
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- CCME Recommended Canadian Soil Quality Criteria, March 1997.
- CCME Surface Assessment Handbook for Contaminated Sites, CCME EPC-NCSR-48E
- CSA (Canadian Standards Association) CSA Z768, Phase I Environmental Site Assessment, Fifth Draft, July 1993.

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