CCME

Canadian Council of Ministers of the Environment
Le Conseil canadien des ministres de l'environnement

Guidance Document on the Management of Contaminated Sites in Canada

PN 1279

This document is designed as an overview report to provide general guidance on assessment and remediation of contaminated sites and to link existing Canadian Council of Ministers of the Environment/National Contaminated Sites Remediation Program technical references. As the report is intended for general guidance only, it does not establish or affect legal rights or obligations. It does not establish a binding norm or prohibit alternatives not included in the documents and is not finally determinative of the issues addressed. Decisions in any particular case will be made by applying the law and regulations on the basis of specific facts when regulations are promulgated or permits are issued.

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GUIDANCE DOCUMENT ON THE MANAGEMENT OF CONTAMINATED SITES IN CANADA

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The Canadian Council of Ministers of the Environment (CCME) is the major intergovernmental forum in Canada for discussion and joint action on environmental issues of national, international and global concern. The 14 member governments work as partners in developing nationally consistent environmental standards, practices and legislation.

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1. In 1996, the CCME replaced the term "criteria" with "guideline". However, as some older CCME/NCSRP documents refer to "criteria", both terms are used in this document, synonymously.

2. The terms "guidelines" and "criteria" are used synonymously in this document.

1.0 INTRODUCTION

Decades of human activity have left a legacy of contaminated land throughout Canada. Virtually every sector of the Canadian economy has contributed to the problem, ranging from resource industries (mining and forestry), heavy industries (steel-making) and petro-chemical production to small manufacturing plants and retail gasoline stations. Historical practices, most of them environmentally unacceptable today, have created current conditions that could potentially harm human health and the environment. These activities include improper use, handling, storage and disposal of materials containing chemicals with the potential to cause an adverse effect. In many cases, release of these chemicals into the environment has resulted in "unsafe" exposures to humans and the environment.

A contaminated site is broadly defined as a location at which soils, sediments, wastes, groundwater and surface water are contaminated by substances that are above the benchmark criteria[1] and/or that pose an existing or imminent threat to human health or the environment. The management of a contaminated site refers to the process used to identify, assess and remediate a contaminated site.

In the Government of Canada's publication, *The State of Canada's Environment (1991)*, the following excerpt addressed contaminated sites:

> *"Across Canada, an estimated 1,000 sites are contaminated with hazardous materials. These include coal tar pits, leaking landfills, old plant sites and storage facilities, many of which must be [remediated] at public expense because the owners have long since disappeared. Depending on the nature of the contamination the size of the site, the [remediation] method used and several other factors, the cost can vary from [several thousand dollars] to tens of millions of dollars.*
>
> *At present some of the more visible sites are being [remediated]. The Canadian Council of Ministers of the Environment has initiated a program to set guidelines for these activities and to fund the [remediation] of sites where the parties legally responsible for the problem cannot be identified."*

The establishment of the National Contaminated Sites Remediation Program (NCSRP) by the Canadian Council of Ministers of the Environment (CCME) represented a major commitment by the federal, provincial and territorial governments to address the issue of contaminated sites in Canada. This program's primary objectives are to identify, assess, then remediate sites that threaten human health, safety or environmental quality.

1.1 Background

The NCSRP was established by the CCME in October 1989. The program had three key objectives:

- to apply the "polluter pays" principle ensuring responsible parties are accountable for costs associated with the remediation of a contaminated site;
- to remediate high-risk orphan sites (i.e., those sites for which the owner or responsible party cannot be identified or is financially unable or unwilling to carry out the necessary work); and
- to work with industry to stimulate the development of innovative remediation technologies.

As of March 1995, work has proceeded at 48 high-risk orphan sites across Canada and 55 new technology demonstrations have been initiated.

In 1990, the CCME held two multi-stakeholder workshops to determine the key factors necessary to develop a national framework for dealing with the assessment and remediation of contaminated sites in Canada. Workshop participants indicated that there was an urgent need for the assessment and remediation of contaminated sites in Canada. Key recommendations from the workshops included a need for a simple classification system to identify priority sites, a "two-tiered" approach (i.e., generic and site-specific) to site assessment and remediation, and equal consideration of human health and the environment in the development of all common scientific tools for use in the NCSRP.

Accordingly, the CCME has developed a number of technical documents in support of this national framework. The present document provides a general overview of the process used in contaminated site management in Canada and links the various technical CCME/NCSRP documents within this process.

1.2 Purpose

CCME has published a number of technical guidance documents dealing with contaminated site assessment and management in Canada. Consequently, the CCME recognized the need for an overview document to provide general guidance on assessment and remediation of contaminated sites that will link existing CCME/NCSRP technical references. Accordingly, this document has the following objectives:

- **provide procedural guidance** to those managing contaminated sites;
- **link** existing CCME documents to aid their effective use;
- **educate and inform** government, industry and the public about the issues involved; and
- assist in **establishing a common approach** to manage contaminated sites.

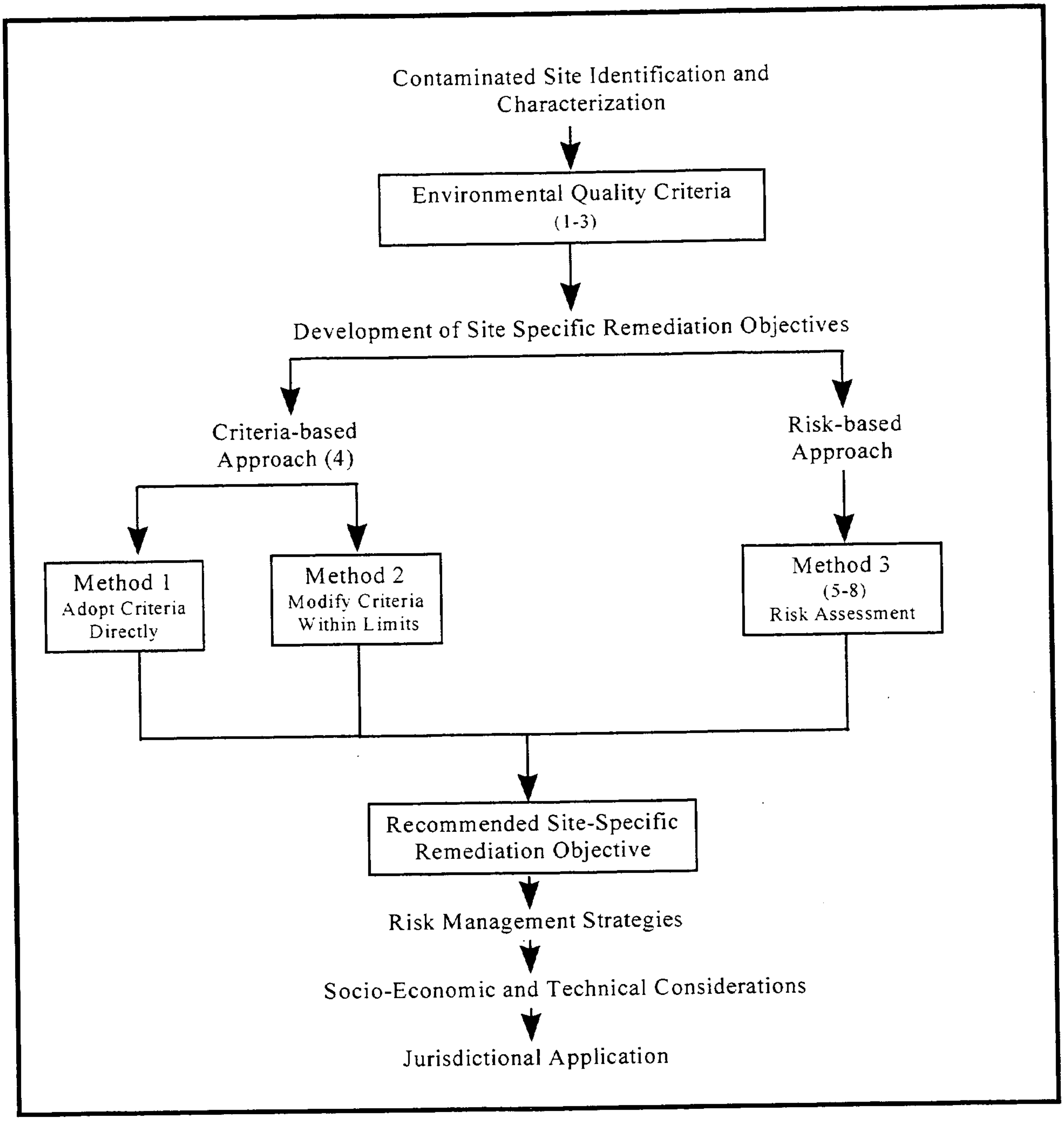
This document has been developed for use by those responsible for, or involved with, identifying, assessing and remediating contaminated sites. This includes owners/managers of contaminated sites, government regulators, environmental professionals, concerned citizens and any other person affected by contaminated sites.

Figure 1.0 describes the national framework developed by the CCME for the assessment and remediation of contaminated sites. The framework involves a staged approach which addresses:

- identification of contaminated sites through a classification process which designates sites relative to the risk they pose to human health and the environment;
- assessment of sites by various scientific methods to determine the nature and extent of contamination;
- comparison of site conditions to generic environmental quality guidelines to identify whether further action is required;
- determination of site-specific remediation objectives using either a guideline-based approach or a risk-based approach. The risk-based approach includes ecological risk assessment (ERA) and human health risk assessment (HHRA);
- development of a remedial action plan and associated activities to reach remediation goals;
- verification that remediation goals have been achieved; and
- identification of ongoing monitoring requirements.

To aid those responsible for contaminated sites, a number of technical guidance documents have been developed.

Figure 1: National Framework for Contaminated Site Assessment and Remediation



NOTE: NUMBERS IN BRACKETS REFER TO THE SCIENTIFIC TOOLS LISTED IN SECTION 6.0

2.0 JURISDICTIONAL FRAMEWORK FOR CONTAMINATED SITE MANAGEMENT IN CANADA

Canadian provinces have constitutional control over property and land management within their respective province. They have exclusive power to legislate regarding contaminated sites on non-federal land within their boundaries. The Constitution Act grants the federal government the power to legislate with respect to lands which it owns or has an interest in.

As with most environmental matters, the management of contaminated sites is subject to a complex framework of laws and regulations resulting from the division of powers between the federal and provincial governments as interpreted from the *Constitution Act, 1867*, between the provinces and their municipalities as interpreted by provincial legislation, and between different departments or ministries of the same government. All these regulatory bodies may have overlapping and/or conflicting mandates. The courts of justice determine whether a law is valid after they have identified whether that level of government had the power to pass such a law. When the *Constitution Act* was developed, environmental issues were not specifically addressed, therefore, jurisdiction of these issues has been interpreted by government bodies and clarified by the courts to identify which level of government has power in these areas.

Additionally, through the process of common law in all the provinces except Quebec, which has a legal system based on civil law, and federal jurisdictions, the courts have made decisions which, through precedent, have become part of Canada's regulatory and legal system. Some of these decisions, such as those pertaining to legal liability, are pertinent to the management of contaminated sites.

2.1 Division of Powers

An important issue which effects the management of contaminated sites is determining which level of government (federal, territorial, provincial or municipal) has authority to regulate a contaminated site or aspects of a contaminated site. Environmental matters are addressed both in federal and provincial/territorial statutes and regulations and in many municipal by-laws. Jurisdictional responsibility for the environment is divided between the federal government and the twelve provincial/territorial governments. The federal and provincial/territorial jurisdictional authority or powers are set out in sections 91, 92 and 92A of the *Constitution Act, 1867* (now the *Constitution Act 1867 - 1982,* being part of the *Canada Act, 1982* [U.K.] S.C. 1982, c.11). Key constitutional powers allocated to the federal and provincial governments which may have a bearing on contaminated sites, based on interpretations by governments and the courts, are briefly summarized as:

Federal Jurisdiction

- Peace, order and good government of Canada;
- Public property, federal lands and public works such as canals, harbours, railways, lands set aside for the public such as national parks;
- Regulation of trade and commerce;
- Taxation;
- Navigation and shipping;
- Sea coast and inland fisheries (although the provinces own the resource);
- Criminal law;
- Lands reserved for native peoples; and
- Bankruptcy and insolvency.

Provincial Jurisdiction

- Direct taxation raising revenue for provincial purposes;
- Municipal institutions;
- Local works and undertakings;

- Management and sale of public lands belonging to the province;

- Property and civil rights;

- Development, conservation and management of non-renewable resources in the province; and

- Generally all matters of merely local or private nature in the province.

Environmental issues *per se*, such as contaminated sites, are not addressed in the Canadian Constitution. Rather, governments have authority to legislate on environmental matters falling within their specific jurisdictions. The federal and provincial governments each have exclusive jurisdiction over certain areas (over which the other level of government has no authority). For example, only the federal government can legislate with respect to criminal law or fisheries. On the other hand, matters respecting property and civil rights are the domain of the provinces. However, the federal government also has a residual power to make laws for the peace, order and good government of Canada. This permits it to make laws in areas of national concern or in cases of national emergency. For example, some propose that the release of ozone-depleting, greenhouse-contributing substances constitute such a national emergency. A complex array of legal cases has evolved since the early days of Confederation dealing with over-lapping, concurrent or conflicting jurisdiction which provides certain principles of interpretation in the event of jurisdictional disputes.

Municipalities are created by the provinces and all municipal powers flow from the provinces. Municipalities can only do that which provinces authorize them to through statutes. Municipalities typically pass by-laws to legislate in the environmental area but may not forbid an activity which the provinces have authorized.

As provinces press municipalities to incorporate greater environmental concerns into their daily functions and as more legislative powers are delegated to them, municipalities are becoming more pro-active in environmental matters. These include, noise by-laws, sanitary and storm sewer by-laws, waste reduction, collection and disposal by-laws, and land use planning and development.

In this section, some of the legislation passed by the federal, provincial/territorial and municipal governments which may affect those responsible for contaminated sites will be discussed. Additionally, this section will address cross-jurisdictional efforts such as those of the CCME and the documents produced by this organization.

2.2 Legislation

2.2.1 Federal Government

Contaminants in air and water can be mobile in the environment and therefore easily cross provincial and international boundaries. In theory, therefore, the federal government would have wide control over environmental legislation. In practice, the role of the federal government has traditionally been leadership in information-gathering, research and setting national standards and objectives. These activities have generally been conducted with the participation of provincial/territorial governments.

The federal government has environmental jurisdiction over contaminated sites which are on federally-owned public land, sites where provincial and territorial governments have adopted federal legislation or where no such provincial/territorial legislation exists. Lands owned by Crown corporations are also subject to federal requirements.

Environment Canada has stated that in the absence of federal legislation, the technical requirements of provincial/territorial legislation will be met. On federal lands where both federal and provincial/territorial legislation exist, the more stringent of the two will be used.

Environment Canada has provided technical support and direction during the implementation of the NCSRP. By coordinating activities with other federal departments and provincial and territorial counterparts, Environment Canada staff have gained experience in contaminated site management which may be beneficial to those developing an assessment and remediation program.

Since human health is an important concern for those managing contaminated sites, Health Canada may play an important part in assessing possible health risks posed by sites and in providing health-related advice. In some cases, Health Canada also evaluates the toxicity of chemicals and wastes and monitors human exposure to contaminants, particularly where danger exists to the health of persons or communities under federal jurisdiction. The department also conducts research on factors which determine the degree of human exposure to contaminants and wastes.

Federal legislation that pertains to contaminated sites includes:

Canadian Environmental Protection Act (CEPA) (1987): designed to protect human health and the environment from risks associated with exposure to substances "suspected of being toxic". CEPA governs activities within federal jurisdiction such as cross-border air pollution, dumping of substances into oceans and navigable waterways and regulation of new and existing substances. One part of the Act deals with the release of toxic substances into the environment. If the substance is a listed toxic substance the government may pass a regulation concerning it.

Another part of the Act deals with federal departments, agencies, Crown corporations, works, undertakings and lands. Essentially, regulations with respect to these federal activities may be passed. This may be relevant in the event of releases of toxic substances onto federal lands.

There are a number of regulations under CEPA which may affect the management of contaminated sites. These include the Polychlorinated Biphenyls (PCB) Regulations, the PCB Treatment and Destruction Regulations, Storage of PCB Material Regulations and Contaminated Fuel Regulations.

Fisheries Act (1985): designed to conserve and protect fish and fish habitat and manage Canada's fisheries resource, the Act has relevance to contaminants which are deposited into waters frequented by fish. Essentially, it is an offence to carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat. Further, it is an offence to deposit or permit the deposit of deleterious substances in waters frequented by fish. Further, if anyone is to engage in any work which may result in the disruption or destruction of fish habitat, or to deposit a deleterious substance in water frequented by fish, then plans, studies and specifications of the procedure must be provided to the Minister. Although the Act is a federal responsibility, much of its administration and enforcement has been delegated, in varying degrees, to the provinces.

The Canadian Environmental Assessment Act (1992): a statute whose purpose is to set out a framework for planning projects in an environmentally-acceptable way so as to avoid potential adverse effects. Only projects that require federal action or approval in order to proceed are subject to the Act. The implementation of the Act is contingent upon certain regulations which have been drafted or are being drafted but which are not yet in force. These regulations may have a direct effect on which projects are subject to the Act.

Numerous other federal statutes and regulations may pertain to various aspects of the management of a contaminated site which are subject to federal jurisdiction or have impacts on areas of federal jurisdiction. Some of these include:

- *Arctic Waters Pollution Prevention Act;*
- *Canada Hazardous Products Act;*
- *Canada Shipping Act;*
- *Canada Water Act;*
- *Hazardous Products Act* (Workplace Hazardous Materials Information System: WHMIS);
- *Oil and Gas Production and Conservation Act;*
- *Pest Control Product Act;*
- *Transportation of Dangerous Goods Act;*
- *Bankruptcy and Insolvency Act;*
- Canada Labour Code;
- National Fire Code; and
- National Building Code.

Additionally, Environment Canada has developed guidelines for federal facilities, which are not legally enforceable unless referenced by regulatory instruments (i.e., control orders, etc.). These include:

- Air Pollution Guideline Applicable to Incinerators (August 1978);
- Air Pollution Guideline Applicable to Boilers (December 1978);
- Code of Good Practice for Handling Solid Waste (December 1979);
- Code of Good Practice for the Management of Hazardous and Toxic Wastes (January 1977);
- Guidelines for Effluent Quality and Wastewater Treatment (April 1976);
- Technical Criteria for Designating Hazardous Wastes in Canada (1984);
- Nox Voc Management Plan (1990);
- Environmental Code of Practice for Underground Storage Tank Systems Containing Petroleum and Allied Petroleum Products (1993);
- Environmental Code of Practice for Aboveground Storage Tank Systems Containing Petroleum Products (1994);
- Code of Practice for Used Oil Management in Canada (1989);
- Code of Practice for the Reduction of Chlorofluorocarbon Emissions from Refrigeration and Air Conditioning Systems (1991);
- User's Guide to Hazardous Waste Classification (1986); and
- Sanitary Landfilling Guidelines for Federal Facilities (1988).

2.2.2 Provincial/Territorial Governments

Provincial and territorial governments have taken the lead role in the development and enforcement of environmental legislation, including that related to contaminated sites. Some provinces, such as Alberta and British Columbia, have enacted legislation which directly addresses contaminated sites. Others, such as Ontario, have released guidelines which address contaminated sites but have not drafted regulations directly pertaining to contaminated sites. Examples of the regulations and guidelines which affect contaminated sites are briefly described below. A more comprehensive list of provincial/territorial regulations, as they existed in 1991, can be found in Appendix E of the *National Guidelines for Decommissioning Industrial Sites* (CCME, 1991a). Up-to-date information can be obtained by contacting the appropriate jurisdiction (addresses and phone numbers are provided in Appendix B).

Alberta

- *Alberta's Environmental Protection and Enhancement Act (AEPEA):* in force since September 1, 1993, is intended to provide a consolidated and comprehensive environmental protection framework. The basic principle of the AEPEA is to support and promote the protection, enhancement and wise use of the environment and to incorporate the principles of economic growth, through sustainable development, public participation, the polluter pays principle and a cooperative working relationship with the federal government. One of the major areas that is addressed in the AEPEA is contaminated sites.

The Act casts a broad net in terms of the persons who may be responsible for remediation of contaminated sites. Those persons responsible may make agreements with the Alberta environment department concerning necessary remedial action in exchange for protection from future environmental protection orders. There are also provisions limiting the potential contaminated site liability of receivers and trustees in bankruptcy. It should be noted, however, that bankruptcy laws are under federal jurisdiction. The CCME *Contaminates Sites Liability Report: Recommended Principles for a Consistent Approach Across Canada* (CCME 1993a) recommends that lenders be granted a pre-foreclosure exemption from personal liability, which is not the same as limiting liability of receivers of contaminated land. In addition, operators will be required to conserve and reclaim specified lands as described in the regulations and to secure a reclamation certificate in respect of the conservation and reclamation.

British Columbia

There are two main provisions enabling control of contaminated sites under the existing *British*

Columbia Waste Management Act. Part 3.1 of the Act provides a definition of "contaminated site" which refers to criteria established by the Director of Waste Management. In July 1995, British Columbia formally adopted the CCME interim environmental quality criteria in its policy document, *Criteria for Managing Contaminated Sites in British Columbia*.

The Contaminated Sites Fees Regulation is another new provision under Part 3.1 of the existing Act. This regulation implements the "polluter pays" principle by charging for various contaminated sites services offered by the B.C. environment department. The fees vary according to the size of a site and complexity of contamination.

The *Waste Management Amendment Act* was passed in June 1993, and will come into effect when consultations on regulations are complete. It establishes procedures for identification, assessment and remediating of sites in British Columbia. Site profiles for screening potentially-contaminated sites and a computer-based site registry accessible to the public are unique provisions. The Act also contains extensive provisions for allocating responsibility and liability for remediation. Government approval and public consultation may be required prior to site remediation.

Ontario

The Environmental Protection Act (R.S.O. 1990) gives the Ministry of the Environment and Energy a mandate to deal with situations where there is an adverse effect or the likelihood of an adverse effect associated with the presence or discharge of a contaminant. The 1996 "Guideline for Use at Contaminated Sites in Ontario" gives advice and information to property owners and consultants for determining whether or not restoration is required and for determining the kind of restoration needed. The policy provides for the use of three main approaches to site restoration: a background based approach, a generic criteria based approach, and a site specific risk assessment approach. The background approach provides acceptable background values for 89 substances for both agricultural use and an all other uses category, and allows for development of background values where they are not provided. The generic criteria approach is supported by numeric criteria for 118 substances for each of three different land use categories. Within these are numbers for two soil depths (surface and subsurface) for both potable and non-potable groundwater situations. Provision is also made for differences in soil texture. A rationale document supplies the background information on derivation of the criteria. Additional companion documents give details on human health and ecological risk assessment as well as on sampling and analytical methods.

Quebec

Environmental Quality Act/Loi sur la qualité de l'environnement (1972): known under the acronym LQE, it is the most important piece of provincial legislation pertaining to the environment in Quebec. Since 1990, a number of amendments pertaining to contaminated sites have been implemented or proposed, including Law 65, the Polluter Pays Law, which attempts to resolve the complex issue of liability of contaminated sites and empowers the Minister to issue orders to responsible parties requiring contaminated site restoration.

2.2.3 Municipal Governments

There are two common situations in which municipal governments actively participate in the management of contaminated sites -- when the municipality owns the land and when it is called upon to approve development or redevelopment. In the latter case, the municipality may call upon the provincial environment department to comment on development plans. In the former case, the circumstances of acquisition are important. In particular, management responsibilities of a municipality are likely to be influenced by whether or not the property was acquired as a result of a tax recovery action. Some provinces have implemented or are considering certain liability restrictions under their contaminated sites legislation in such cases. Accordingly, compliance with provincial cleanup or decommissioning guidelines may be required as a condition of approval. The role of the municipal government has not been as significant as the role of the federal, provincial and territorial governments in regulating contaminated sites.

2.2.4 Cross-Jurisdictional Organizations

The CCME is the major intergovernmental forum in Canada for the discussion and joint action on environmental issues of national, international and global concern. The 13 member governments work as partners in developing nationally-consistent environmental objectives, practices and frameworks for developing legislation. The CCME has produced a number of documents which directly address contaminated site issues. Additional Environment Canada documents may relate to situations occurring at some contaminated sites. One such document is the *Environmental Codes of Practice (ECP) for Aboveground and Underground Storage Tanks*. Whenever an aboveground or underground storage tank is suspected or known to be the cause of contamination, the Code of Practice should be consulted. The provincial statute and regulation regarding such tanks should also be consulted.

For contaminated sites where transformers and capacitors are present, compliance with the federal and provincial legislation concerning PCBs is necessary. The document *Guidelines for the Management of Waste Containing Polychlorinated Biphenyls* (CCME, 1989) should also be reviewed.

3.0 GOVERNMENT POLICY

Public and regulatory concern for pollution and contaminated sites has increased considerably in recent years. In Canada, governmental policy and legislation pertaining to contaminated sites has attempted to keep pace with the complex issues of pollution prevention and management. This section highlights the regulatory philosophy that has emerged in response to the contaminated sites issue.

3.1 Protection of Human Health and the Environment

In Canada, government policy and legislation relating to contaminated sites emphasizes the equal protection of human health and the environment. Inherent in this philosophy is the concept that the environment (upon which human life depends) shall not be viewed as secondary to human health and shall be protected for its own sake. All activities initiated by those responsible for the management of a contaminated site should recognize this intent.

When assessing a contaminated site prior to remediation, the protection of human health and the environment may be addressed through the application of environmental quality guidelines protective of human health and the environment or through risk assessment. Often, when both human health and environmental generic or site-specific remediation targets are required and are available or have been developed for a site, the lower of the two values is used as the overall remediation target. This ensures that a suitable level of protection is provided to both humans and ecological receptors.

As a consequence of this basic philosophy, the framework designed for the management of contaminated sites in Canada under the NCSRP has led to the development of scientific tools for the identification, assessment and remediation of contaminated sites from both a human and environmental perspective.

3.2 Responsibility and Liability

Contaminated sites must be properly managed to control or deal with existing contamination and to prevent or minimize additional impacts on human health and the environment. This normally involves assessing the nature and extent of contamination at a suspected site and implementing measures to remove or contain the problem. The cost of implementing these measures can be significant both for the public and private sectors. Identification of who should pay for cleanup is a complex and difficult issue. Identification of "potentially responsible parties" (PRP), those who may be liable for the costs associated with a contaminated site, is an important aspect. This is all the more difficult when the sites have been abandoned, ownership has changed or when sites are owned by persons innocent of contaminating the land or are controlled or owned by those who cannot afford the costs associated with remediation (i.e., "orphan site").

To address these concerns, the CCME formed a *Task Group on Contaminated Site Liability* composed of representatives of government, industry, financial and legal services fields. The Task Group developed the *Contaminated Site Liability Report: Recommended Principles for a Consistent Approach Across Canada* (CCME 1993a) to provide a model framework upon which individual member governments can develop legislation and regulations that will facilitate a consistent approach to the issue of environmental liability. For situations where liability for the assessment and remediation is not clear, these principles may impact those responsible for the management of the contaminated sites.

The first five principles identified by the Task Group are fundamental concepts defining the general policies that should form the basis of this type of legislation. These principles are:

- the "polluter pays" principle, where those suspected of causing the pollution are held accountable for the costs associated with the cleanup of a contaminated site;
- the principle of fairness which incorporates the concepts of certainty of process, effectiveness, efficiency, clarity, consistency and timeliness in achieving environmental objectives (fairness also relates to issues associated with the principles of polluter pays and "beneficiary pays");
- the concepts of openness, accessibility and participation, for the public to provide input into the development and operation of government policy and legislation;
- the principle of "beneficiary pays", meaning that those who will benefit from the cleanup of a contaminated site should contribute to the costs of the cleanup; and
- the principle of sustainable development which integrates environmental, human health and economic concerns into the decision making process.

Eight other recommended principles are categorized as specific principles and relate to substantive issues that must be dealt with in legislation and can be found in the Liability Report.

Any person who could be considered in control of a contaminated site (i.e., manager, trustee, etc.) should consult with the relevant provincial/territorial legislation prior to accepting control of such a site.

3.3 Priority Shift to Prevention

The problems associated with contaminated sites relate both to the management of existing contaminated sites and the prevention of future contamination. Those in control of activities that have the potential to pollute should prepare operational, emergency and contingency plans to prevent or control any conditions that could result in contamination. These plans should identify the nature of the activity, anticipated harm or risk to human health and the environment, procedures and equipment in place to mitigate the effects of an event. Increasingly, the government focus, especially at the provincial/territorial level, will be on the reduction of pollution and elimination or reduction of such pollutants and wastes at the source.

3.4 Remediation Based on Intended Land Use

In Canada, both at the federal and provincial level, the development of remedial targets is conducted within the context of specific land uses. It is important to note that it is the *intended* future land use that governs the decision on the level of remediation performed at a site. The generally-accepted categories of land uses, which may be combined if they have common receptors and/or objectives, include:

- agricultural;
- residential;
- parkland;
- commercial; and
- industrial.

To sustain the activities associated with these specific land uses, remedial targets must ensure that protection is afforded to the key receptors (both human and ecological) associated with these lands. For example, to sustain the activities associated with agricultural land use, remedial targets must ensure that crops can be grown, grazing livestock are not threatened and humans are not adversely affected by normal agricultural activities.

Human reliance on the land for sustaining land use activities decreases from agricultural use to industrial use. Therefore, remediation guidelines that are protective of the environment will generally be more stringent for agricultural and residential/parklands land uses than for commercial or industrial land uses. The sensitivity of the land (and its receptors/exposure pathways) to contamination is also regarded to decrease from agricultural to industrial lands.

Land use planning using the ecosystem approach involves planning on the basis of a balance of ecosystem health, human health and quality of life including social and economic vitality. Interactions in the ecosystem become a major focus of research, analysis and decision making. When assessing or remediating a contaminated site, the concept of the ecosystem approach should be applied to decision making.

3.5 Protection of Groundwater Resources

The federal government has adopted groundwater quality guidelines and guidelines for surface water quality in the *Canadian Water Quality Guidelines* (1987) for a number of uses including drinking water. In some cases, analytical detection limits were selected as water quality guidelines. The objective of the federal government in adopting these values was the protection of groundwater quality.

Some provincial governments, such as New Brunswick and Prince Edward Island, have passed legislation with the objective of protecting the groundwater resources upon which much of the population relies for drinking water. Quebec has developed an approach for the protection of groundwater. Ontario is in the process of developing a framework for groundwater protection and management.

The use of environmental fate modelling techniques and environmental partitioning of substances are expanding our understanding of the behaviour of contaminants in the environment and are expected to play an increasingly important role in the development of regulatory guidelines (e.g., the CCME's *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* established in 1996).

4.0 A STRATEGY FOR CONTAMINATED SITE MANAGEMENT

When confronted with a contaminated site, the owner or manager is well advised to consider the reasons and need for remediation. These will govern the extent of the assessment required and the criteria by which the results will be judged.

The successful management and remediation of a contaminated site is a function of obtaining sufficient information to evaluate the necessary measures to carry out the remedial action required. Obtaining sufficient data on a contaminated site's characteristics is often expensive. Too little data will produce limited results, possibly requiring additional future expenditure in excess of that originally required to obtain complete data. Too large a potential cost may lead to minimal or insufficient action, delays and, ultimately, more expensive remedial action to cover the uncertainties. A balance should be struck and maintained between the expense of information gathering and the return on this investment. However, project cost should not be the sole variable used when determining the focus of the study. Often, environmental, socio-political or technological elements will determine the appropriate course of action to be taken at a site.

The strategy has four parts which tend to be iterative since the evolving strategy frequently leads to a reassessment of its rationale and objectives. The four parts are briefly introduced below and amplified in other sections noted in parentheses.

1. The need and reasons (rationale) for potential remediation. (Sections 2 and 3)

2. The environmental site assessment. (Section 5)

3. The evaluation of results with respect to applicable/agreed remedial goals. (Section 6)

4. The development and implementation of a remedial action plan to satisfy the targets. (Section 7)

4.1 The Rationale for Remediation

Before entering the process, the manager should ask why the remediation is required -- is it necessary or simply desirable? The answer will likely govern the level of future work.

Some remedial work is driven by regulatory requirements or, in severe cases, ministerial orders, as noted in Sections 2 and 3. Other work may be instigated in the interests of environmental responsibility or good housekeeping. In the former case, remediation goals will be defined by the regulators; in the latter, more likely by the manager. Another situation may involve the sale of land and mutual agreements between the parties involved. In any event, knowing the reasons for the remediation will lead to a more focussed and optimal approach that will have a good chance of being implemented in a timely manner.

4.2 Assessment of Contaminated Sites

Contaminated site assessments identify the nature and extent of contamination. The impact of contamination on human health and the environment may then be determined by using risk assessment. If these effects are identified, the assessment should yield enough information to select effective remedial measures to mitigate or prevent such effects and, in so doing, restore the site.

Contaminated sites vary in size and impact on the environment. Consequently the level of effort in assessment is gauged accordingly. For example, a retail gasoline station with a leaky tank would not undergo the same extensive assessment procedure as the decommissioning of a petroleum refinery.

In determining a site's characteristics and the need for remediation, a selection of common points and questions might arise:

- Field Testing Methods - Which are applicable and of most use at the site, e.g., remote methods, field screening methods, monitoring wells, test pits, boreholes, etc.?

- Environmental Quality Guidelines - are guidelines available and appropriate for target chemicals at the site?

- Development of Site-Specific Objectives (see Section 6.2.1) - Can environmental quality guidelines (EQGs) be adopted directly as the site-specific remediation objective (SSRO)? Can EQGs be modified to account for site conditions? Is a risk assessment approach required to develop the SSRO? The analytical process will be based on the outcome of these questions.

- Analytical Methods - Which are most suitable and which laboratory will be used? This extends to traditional chemical analytical techniques with or without bioassays, the chemicals to be analyzed, and the quality assurance and quality control applied to obtaining the results.

- Professional Help - Is an environmental consultant required? Does the situation require a specialized environmental law firm?

- Regulatory Agencies - What is their degree of involvement? Do such agencies require notification before work commences and copies of the results?

In this document, procedures to be followed when assessing a contaminated site are outlined. The descriptions include the reasons or triggers for different types of assessment methodologies. Each should be considered within a specific site context as generalities are not feasible.

4.3 Remediation of Contaminated Sites

When the assessment of a site is completed and the results do not meet the numerical site-specific objectives, remediation may be warranted. Remediation raises important issues and a typical selection follows:

- What type of remediation is necessary -- complete or partial?
- What factors will influence the ultimate choice of the preferred remediation method -- applicability, effectiveness, cost, etc.? How will these be rated?
- The development of a health and safety plan.
- The input of regulatory agencies.
- The involvement of local residents and the possibility of a Community Information Program.
- The credentials of contractors and their disposal practices.

The framework for sound decision making stems from data provided by the assessment, along with the experience and resources of those involved in the process. There are many remediation methods and techniques available at various stages of development. Though many techniques might be applicable to the contamination in question, only a few will be effective at a given site, and usually only one or two are fully evaluated based on an owner's preferences.

Likewise, an individual health and safety plan may not be needed to remove a leaking underground gasoline storage tank that has contaminated a small quantity of soil and not the groundwater. In this case, it would be satisfactory if the contractor follows a generic approach with written standard procedures for tank removals, and has trained personnel and experience with this type of operation. However, if the same tank contained an unknown solvent waste, then leaked and contaminated a large volume of soil and groundwater, and was also adjacent to a tank farm containing flammable liquids, a specific health and safety plan would be required.

5.0 CONTAMINATED SITE IDENTIFICATION AND ASSESSMENT

Identifying and then assessing, or characterizing, a potentially-contaminated site is a critical phase of site management. A well-planned, comprehensive assessment will allow site managers to make informed decisions about potential remediation.

Environmental Site Assessments (ESAs) should identify the nature and extent of contaminants that may be adversely affecting both human health and the environment. A phased approach has been developed and now is in general use. This approach involves up to three stages of phased investigation, depending on the size and complexity of the contaminated site, leading from the general to the specific. The fourth phase is remedial action planning dealt with in Section 7. The concept is to narrow the scope of the investigation to specific areas and potential targeted contaminants through a tiered approach. This approach avoids the duplication of effort and increased budgets resulting from a full frontal attack of the problem where, for example, areas may be penetrated by a grid of many boreholes leading to excessive sampling and analysis hoping to pin-point "hot spots" of contaminated soil and groundwater conditions. The phased approach narrows the problem using screening techniques before employing more extensive and expensive analysis.

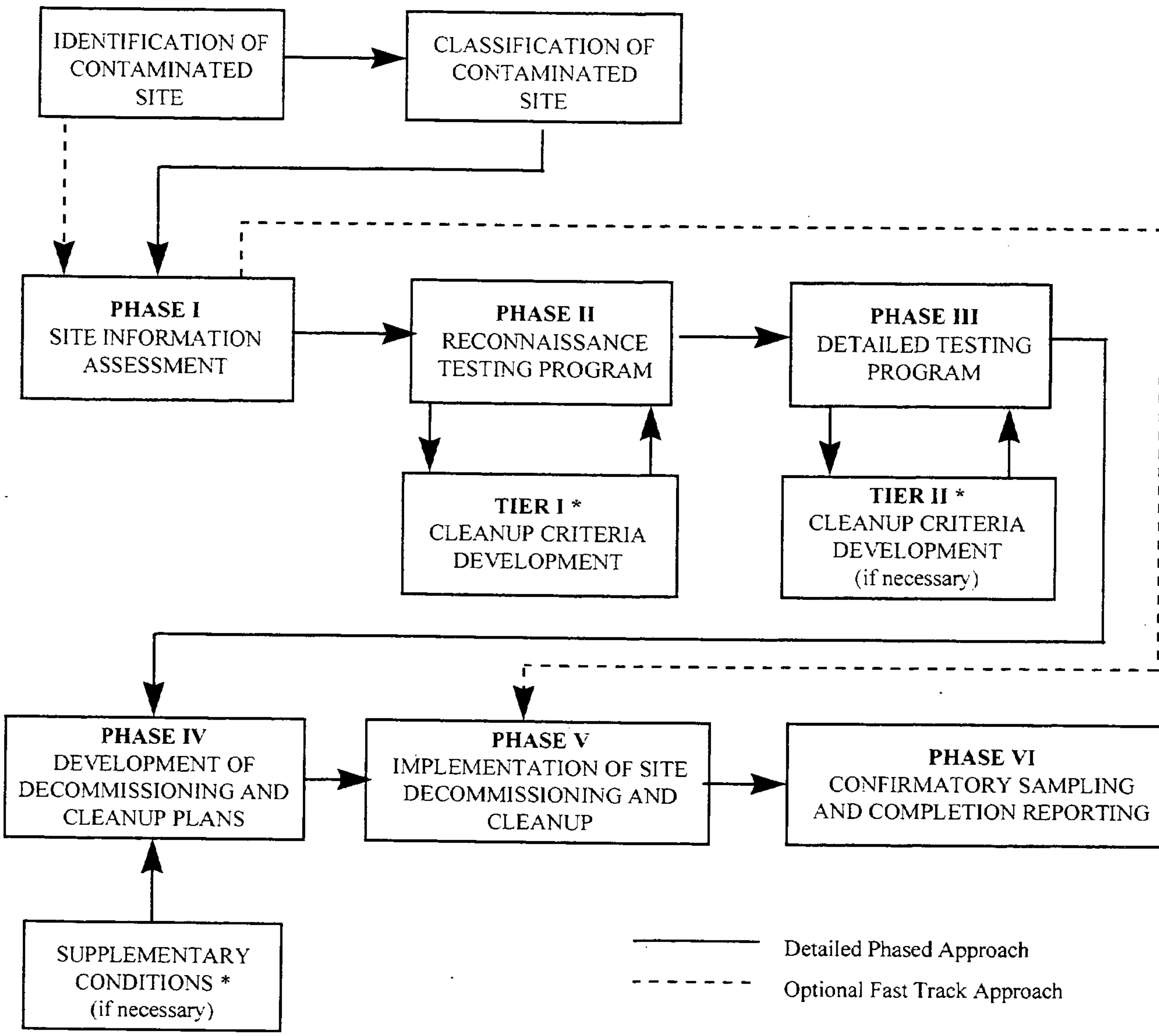
The *National Guidelines for Decommissioning Industrial Sites* (CCME, 1991a) provides a model for a phased site assessment protocol, not only for decommissioning industrial facilities but also for all types of contaminated sites. The process of site investigation described in the guidance document is shown in Figure 2. This document can be supplemented by information from the CCME document *Subsurface Assessment Handbook for Contaminated Sites* (CCME, 1994), which outlines the methodologies that may be applied during the various phases. With respect to the analytical work, the CCME has published the *Guidance Manual for Sampling, Analysis and Data Management, Volume 1: Main Report* (CCME, 1993b), and *Volume 2: Analytical Summaries* (CCME, 1993c). These documents provide useful information about sampling and analyzing complex environmental matrices.

5.1 Identification of Potentially - Contaminated Sites

Prior to embarking on the sometimes long and expensive process of a full site assessment, it is advisable to obtain a preliminary overview of the significance of the environmental issues. For instance, contaminated sites are typically associated with industrial and waste disposal activities and may have contaminated surrounding lands affecting their use. This is commonly the result of improper chemical storage, waste disposal, spills and leaks, (e.g., fuel service stations). Conversely, the problems may be confined to the site only.

Currently, there are several rather different routes to the identification of contaminated sites. Frequently, contaminated sites are identified following an environmental audit (sometimes referred to as a Phase I audit). Such audits address a multitude of issues, including soil and groundwater contamination, and are often commissioned pending a property sale or transfer (transactional audit). At other times, an internal environmental program may reveal concerns. Regulatory authorities may also identify contaminated sites when responding to citizens' complaints, or when investigating off-site impacts. Additionally, contaminated sites may be identified following spill incidents that are often publicized and involve regulatory authorities.

Figure 2: Phased Approach to Contaminated Site Management



* Tier 1 cleanup criteria are based on existing numerical guidelines, and are not site-specific. Tier 2 cleanup criteria are generally applicable where Tier 1 guidelines are not promulgated or where background levels exceeding guidelines occur, and are developed using detailed assessment of site-specific factors. At some sites, supplementary conditions may complement cleanup criteria when available technology (or other factors) restricts the level of cleanup carried out, contaminants must be isolated on-site, or long-term remedial action is necessary.

Figure based on Figure 3 of National Guidelines for Decommissioning Industrial Sites (CCME, 1991)

5.1.1 National Classification System for Contaminated Sites

In 1992, the CCME developed *The National Classification System for Contaminated Sites* (CCME 1992) to provide a well-documented and consistent approach with scientific and technical guidance to classify sites as high, medium or low risk. The classification system is a five-step process using a method of combined scores for various characteristics which address contaminant characteristics, exposure pathways and receptors. Once sites have been classified, priorities can be assigned to contaminated sites needing some form of action. This system is a screening method only. As such, it was designed to address the classification and general prioritization of sites in Canada and does not constitute a general or quantitative risk assessment. Technological, socio-economic, political and legal issues are beyond its scope.

The Classification System is generally intended for people with technical expertise capable of using professional judgement. This document contains a users' guide; a facility/site description and site classification worksheet; and short and detailed evaluation forms. The forms are also available in an electronic format. It is a recommended tool to provide a "first glimpse" of a contaminated site's characteristics. The Classification System should be consulted during design of this part of the program.

5.2 Phase I: Site Information Assessment

In the site assessment's first phase, the objective is to assemble all available historical and current information to help develop a field-testing program, should one be required. The work will begin by reviewing all data gathered for legal, transactional or environmental reasons (i.e., site classification if already conducted) and supplementing this information as required. The review will also include a site inspection and discussions with personnel and local residents informed about the site and its history and conditions.

The work frequently encompasses three broad aspects:

Facility Characteristics. A current and an historical description of the site and its facilities is developed, particularly as it relates to the areas of concern. Contaminant sources and discharge points, both past and present, are investigated. Visual inspections, facility records reviews and discussions with informed personnel are employed. In addition, above- and below-ground structures are reviewed, using blueprints if available, as possible sources of contaminant migration. Prior site uses and surrounding land uses are also considered.

Contaminant Characteristics. Contaminants that may be present at the site are identified. Their quantities and concentrations are estimated by visual inspections, reviews of documentation and discussions with informed staff.

Physical Site Characteristics. The geology, hydrology, hydrogeology and geomorphology are examined using a number of sources to conduct a literature review of any available data about the site. The overall aim is to provide a more comprehensive description and understanding of the local site characteristics and to develop a current and historical description of the area.

The sources will include aerial photographs, published reports such as those on the geology and groundwater from the Geological Survey of Canada and the Provincial Geological Surveys. Topographical, geological and other maps are also reviewed from these sources. Furthermore, if previous site investigation reports are available, these will be included.

The review will also include a site inspection and discussions with personnel and local residents informed about the site and its history and conditions. The site inspection will examine vegetation stress, key ecological receptors, leachate breakout and signs of contamination discharge. Surrounding land uses will also be considered. Drinking water sources and wells will be noted using published well records correlated to site observations. Proximity of the site to surface water bodies or sensitive habitats (e.g., wetlands) should also be identified if not already done during the site identification process using the Classification System.

The information gathered should be sufficient to identify and evaluate:

- the physical condition of the site and its geology, hydrogeology, facilities and surroundings, operational history, waste disposal practices, etc.;
- potential key ecological receptors and pathways of exposure;
- potential problem areas and contaminants of concern;
- health and safety considerations;
- areas requiring immediate and interim action;
- a preliminary concept of scope of required site investigations;
- proposed future land use and adjacent land uses;
- a public information program; and
- a preliminary remediation schedule.

5.3 Phase II: Reconnaissance Testing Program

The objective of the Phase II reconnaissance testing program is to characterize the contamination (degree, nature, estimated extent and media affected) and site conditions (geological, ecological, hydrogeological and hydrological) so an effective remedial plan can be developed (if necessary) or to identify the need for more specific Phase III investigations. It also may be decided that no further action is required or that immediate action is needed. Further study may be necessary to determine risks to public health, safety or the environment. This may take the form of human health and ecological risk assessments using Phase II investigation data. These assessments are described in Section 6.0.

The Phase II sampling program should include the adoption of sampling procedures, quality control/quality assurance procedures and laboratory analytical protocols. The CCME documents, *Subsurface Assessment Handbook for Contaminated Sites* and *Guidance Manual for Sampling, Analysis and Data Management, Volume 1: Main Report* (CCME, 1993b), should be consulted during design of this part of the program. In addition, preliminary environmental quality remediation criteria must be selected. The selection process is described in Section 6.0.

Proposed programs might be presented to regulatory agencies for review. In addition, if public participation is deemed necessary, a public review (i.e., by a liaison committee) of the program should be conducted.

The Phase II work usually begins with one or two field-screening methods which permit a closer identification of suitable locations for test pits, boreholes and groundwater monitors.

5.3.1 Field-Screening Methods

Field-screening methods are techniques used to rapidly identify potential subsurface contamination that may be in solid, gas or liquid form and thus orient the investigation to be able to deal with the nature of the contamination. The most commonly employed field-screening methods are briefly described below.

Geophysical Assessments

Geophysics is the application of physical principles, such as magnetism and gravity, to the study of the earth. The characteristics assessed depend on the geophysical method used. For instance, terrain conductivity (electro-magnetic surveying) is the most common geophysical technique used for contaminated site investigations and can identify buried drums and tanks, along with conductivity anomalies caused by some contaminants. By providing a broad view of the subsurface, once anomalies have been identified, boreholes and test pits can be located in areas of concern. Better placed, and often fewer boreholes, help lower the cost of conducting an otherwise arbitrary sampling program and increase the useful data obtained. Furthermore, as subsurface geological conditions can be complicated, the information interpolated between boreholes by geophysical results may be critical for remedial action planning. Geophysical techniques generally depend on contrasts between the media for the physical properties they are measuring. If such contrasts are not strong, the results may be poor or the use of geophysics may be inappropriate.

In the CCME document *Subsurface Assessment Handbook for Contaminated Sites* (CCME, 1994), 13 individual geophysical evaluation techniques for site assessment are assessed (including remote techniques) in Chapter 3. Information from preliminary site investigations, such as the contaminant of concern, contaminant source and general site geology are important to determine which geophysical method (if any) should be used in a site assessment. The CCME Subsurface Assessment Handbook should be consulted when determining the appropriate geophysical evaluation technique for a site.

Soil Gas Surveys

These surveys are used to identify many volatile organic chemicals and provide semi-quantitative results. The gas present in the soil voids (soil gas) is extracted, usually by pumping with a portable instrument from shallow probe holes. The instrument used is commonly a photoionization detector (PID), organic vapour meter (OVM) or an explosive/ methane gas detector. A more sophisticated method is to collect the gas in a syringe and then analyze it in a portable gas chromatograph (GC). A more basic preliminary method extracts soil samples with a hand auger or portable drill, immediately followed by a headspace analysis on the sample in the jar with an organic vapour analyzer. Section 5.3.1 of the CCME's Subsurface Assessment Handbook (1994) describes this process in greater detail.

Screening Groundwater and Soil Samples

There is a selection of portable equipment for extracting both soil and groundwater samples quickly, such as hand augers, portable drills, hydro-punches, etc. In addition, there are a variety of field analytical equipment and kits which can be used to characterize various properties, the details of which are provided in Section 5.3.2 of *Subsurface Handbook for Contaminated Sites* (CCME, 1994). These methods, while commonly used on groundwater, can be applied to soil and sediment samples for semi-quantitative analysis by disaggregating them in distilled water and analyzing the distilled water for leached chemicals.

Additionally, the following more sophisticated techniques are available.

Portable Gas Chromatograph is an instrument used for measuring concentrations of organic compounds. It is also used in combination with Mass Spectroscopy (GC/MS).

Field Atomic Absorption is used for metal analysis in soil and water samples and employs a low mass tungsten furnace to provide results. An electrical supply is needed and samples must be prepared.

Field X-Ray Fluorescence (XRF) can detect concentrations of several common heavy metals in soil and sediments. Samples must be prepared before analysis. The method is non-destructive allowing for future reanalysis.

Radon Prospecting uses the naturally-occurring presence of radon, an inert gas, as a detector of the presence of volatile gases. There is a direct relationship between the presence of volatile hydrocarbons and solvents in soil and abnormally high concentrations of radon gas. By measuring the alpha particles emitted by radon, hydrocarbon contaminant plumes can be located.

Immunoassay Tests have been used for decades in the clinical diagnostics sector of the medical field, and recently field immunoassay kits have been developed for identification of pesticides, polycyclic aromatic hydrocarbons and light volatile organic compounds in soil and water samples. Large volumes of samples can be analyzed quickly and impressively giving results within 15 to 30 minutes per sample.

Thus, by approximating laboratory analyses with field-screening techniques, decisions can be made in the field. Field-screening equipment generally allows samples to be obtained more quickly than conventional methods but is limited as to depth of penetration. Field-screening techniques are not as accurate as traditional laboratory methods and cannot detect some contaminants.

5.3.2 Development of a Sampling Program

Once areas or "hot spots" have been identified by screening, a Phase II investigation and sampling program is designed for the site to obtain more definitive information about the nature and extent of the contamination. The program may include retrieval of samples from all affected media -- soil, groundwater, sediment and surface water for subsequent laboratory analyses.

Under the NCSRP, the CCME has published *Guidance Manual for Sampling, Analysis and Data Management, Volume 1: Main Report* (CCME 1993b) and, *Volume 2: Analytical Summaries* (CCME, 1993c). These documents provide guidance on sampling and analyzing complex environmental matrices and assist in selecting from the many available analytical test methods currently in use. Volume 1 discusses details of a sampling program (e.g., sampling equipment, documentation) and Volume 2 summarizes analytical methods used to identify chemical parameters in various media. The most effective analytical methods for a particular site can be selected by referring to these summaries. Once a sampling program has been designed and implemented according to the manuals, the resulting analytical data should be of measurable quality and defendable interpretation.

By following these guidance documents, one may:

- develop data quality objectives;
- prepare QA/QC programs;
- obtain representative samples of soil, sediment, surface water and groundwater media;
- select sampling programs and equipment;
- select appropriate analytical methods; and
- design a data management system, including documentation, chain of custody, data validation, etc.

The guidance manuals describe how data quality objectives (DQOs), an important aspect of quality assurance (QA), are derived. DQOs are statements providing critical definitions of the confidence required to draw solid conclusions from the entire project data. DQOs allow decisions to be made with acceptable confidence by setting limits for the overall uncertainty of results.

Quality Assurance is a series of practices, procedures and protocols to ensure reliability and quality of sampling program results. The Guidance Manuals describe quality assurance procedures that must be followed to ensure the validity of all investigation results. This includes sample collection, analysis, data interpretation and evaluation. Quality control samples are an integral part of quality assurance. They are vital to identifying sources of sampling, analytical and laboratory error. By following the Guidance Manual, a quality assurance program can be developed specifically for the assessment of individual contaminated sites.

In addition, Chapter 5 of the *Subsurface Assessment Handbook for Contaminated Sites* (CCME, 1994) provides insight to developing a sampling program for a subsurface investigation.

5.3.3 Hydrogeological Investigations

Hydrogeological investigations examine the physical characteristics of a subsurface system that control contaminant migration, usually through groundwater. These include geological, hydrogeological and hydrogeochemical characteristics. As with other Phase II investigations, a staged approach is used to obtain information to progressively define the distribution and migration of contaminants in the groundwater.

In the *Subsurface Assessment Handbook for Contaminated Sites* (CCME, 1994), Chapter 4 describes the requirements of a hydrogeological site investigation and methods of sampling different hydrogeological conditions.

A conceptual hydrogeological model is gradually developed, based on an initial assessment supported by information obtained from monitoring wells, often including hydraulic conductivity tests and elevation measurements. The findings will normally include such items as:

- the direction, gradient and flow rate of groundwater movement, i.e., the groundwater regime;
- the physical and chemical parameters controlling groundwater flow and contaminant transport in the subsurface, e.g., hydraulic conductivity;
- the principal pathways of groundwater flow and the factors controlling the migration of contaminants in the subsurface;
- a plan-view and cross-sectional view of the hydrogeology incorporating flow nets; and
- a plan for follow-up monitoring (if required).

This information is used to evaluate site conditions, input to models for contaminant migration, input to risk assessment calculations and examination of alternatives for site restoration.

5.3.4 Groundwater Flow and Contaminant Transport Models

Groundwater flow and contaminant transport computer models are tools to help understand the physical, chemical and biochemical processes taking place in groundwater systems by representing them in terms of mathematical equations. Hydrogeological systems are highly complex and, while mathematical models are useful to analyze a wide range of conditions rapidly and inexpensively, their results should be viewed as screening-level information to direct further site-level hydrogeologic investigations.

Sensitive parameters and their effects can be identified by using models to analyze plausible scenarios. Using models, these systems can be quantified to assist in the prediction of the future movement and behaviour of contaminants. These predictions can be used as a basis for decisions regarding the management or remediation of a contaminated site.

In the *Subsurface Assessment Handbook for Contaminated Sites* (CCME, 1994), Chapter 6 describes the purpose and process of modelling groundwater flow and contaminant transport, including the advantages and limitations of mathematical models. The application of models to commonly-encountered contaminated site situations is also described.

5.3.5 Bioassessment

Bioassessment or "biological assessment" refers specifically to the use of bioassays (toxicity tests) in the assessment phases of contaminated site management. Bioassessment provides biological "effects" data that complement chemical analysis data when evaluating the overall impact of a contaminated site.

As living organisms often reflect the general health of their surrounding environment, they can be used as indicators of environmental conditions at contaminated sites. Controlled studies, where an organism's response is observed after exposure to several different doses or concentrations of a chemical over a predetermined time is called a bioassay (or toxicity test). Bioassays can be conducted under laboratory conditions (where media samples are transported to a lab and organisms are exposed under standardized, controlled conditions) or conducted *in situ* (where exposures better reflect environmental conditions and sample disturbance is minimized). Because factors affecting exposure (e.g., bioavailability, chemical synergism) cannot be accounted for from chemical data alone, the results of bioassays provide an integrated measure of the effects of contaminants on biota.

Bioassays are often used within the context of a formalized risk assessment to provide the effects-based information in the assessment. The use of bioassays outside formal ecological risk assessment frameworks (such as discussed in Section 6.2.2.2) can provide a means of biological assessment (sometimes called "bioassessment" or "toxicity assessment") to complement routine chemical analysis performed on various contaminated media. Bioassays complement, but usually do not replace, chemical analyses.

When a formal ecological risk assessment is not called for but some measure of the potential for chemical effects to resident biota at a site is needed, bioassays are often used to provide a measure of the potential for effects. The resulting data are evaluated and considered during the creation of a site remedial action plan. Significant remedial measures may be taken based on the combined bioassay and chemical data.

Bioassays (usually screening-level tests) have also been used in Phase II assessments to help delineate contaminant "hot spots" within the site or establish the boundaries of the site. They have also proved useful during the actual remediation of a site to ensure that the remedial measures being implemented are not adversely affecting the site or surrounding biota (e.g., from cross-media transfer of contamination). As a monitoring tool, bioassays provide a means for ensuring that remedial targets have been met and are being maintained over time.

Under the NCSRP, Environment Canada has produced three documents dealing with the types and applications of bioassays at contaminated sites in Canada:

A Review of Whole Organism Bioassays for Assessing the Quality of Soil, Freshwater Sediment and Freshwater in Canada (Environment Canada, 1994a) was published as a guidance document to recommend bioassays for use in contaminated site assessment in Canada under the NCSRP.

Application of Recommended Whole Organism Bioassays for the Assessment of Contaminated Sites in Canada (Keddy, *et al*, 1995, draft) was developed to provide guidance on the application of the recommended whole organism bioassays within the assessment and remediation framework of the NCSRP.

Development of a Methodology for Post-Remedial Bioassessment of Contaminated Sites (BEC 1995, draft) was developed to provide guidance on the use of bioassessment procedures in the context of a post-remedial evaluation. This methodology has been incorporated with other evaluation components (i.e., technological, socio-economic, community relations/consultations and occupational health and safety) to form a guidance document on conducting post-remedial evaluation of NCSRP sites (see Section 10).

5.4 Phase III: Detailed Testing Program

The results of the Phase II reconnaissance investigation will determine the need for a Phase III detailed testing program. If sufficient data have been obtained to characterize the site and/or the risk to human health and the environment, then the process may move directly to a remedial action plan (if it is required).

Alternatively, if the results indicate that significant contamination exists that will require remediation, a Phase III detailed investigation is probably necessary. This investigation will specifically address outstanding issues with a view to obtaining enough information to formulate a remedial action plan. The objectives of Phase III investigation are:

- to target and delineate the boundaries of identified contamination;
- to define, in greater detail, site conditions to identify all contaminant pathways, particularly with respect to possible risk assessment;
- to provide contaminant and other information necessary to finalize environmental quality remediation guidelines or risk assessment; and

- to provide all other information required to develop a remediation plan and input to specifications and tender documents.

Generally, the Phase III Detailed Testing Program will concentrate on areas identified in the Phase II program and involve a similar systematic process of sampling and analysis, evaluation, conclusions and recommendations. However, a greater number of samples are usually collected and a smaller suite of chemical substances may be analyzed as the program converges on the environmental issues. Screening techniques are not usually employed in this phase. Further information is available in the *National Guidelines for Decommissioning Industrial Sites* (CCME, 1991a).

6.0 ENVIRONMENTAL QUALITY GUIDELINES AND REMEDIATION OBJECTIVES

When a contaminated site has been identified and an initial characterization of the nature, extent and magnitude of contamination at the site has been completed, numerical guidelines or objectives values are required for the purpose of evaluating whether further action is necessary and to guide remediation activities.

The development and application of numerical guidelines and objectives for the purposes of site assessment and remediation are intended to be carried out utilizing some of the common scientific tools developed by the CCME and under the NCSRP. These scientific tools include:

1. Interim Canadian Environmental Quality Criteria for Contaminated Sites (CCME, 1991)
2. A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines (CCME, 1996a)
3. Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada (CCME, 1996b)
4. A Framework for Ecological Risk Assessment: General Guidance (CCME 1996c).
5. Framework for Ecological Risk Assessment Technical Appendices (CCME, *in prep.*)
6. Procedures for Conducting Human Health Risk Assessments at Contaminated Sites in Canada (CCME, *in prep.*)

The recommended framework for the use and/or development of generic environmental quality guidelines and site-specific remediation objectives is reviewed in the following sections, and is illustrated in Figure 1.

6.1 Environmental Quality Guidelines[2]

Environmental Quality Guidelines are numerical limits or narrative statements which are to be used for comparison with measured contaminant levels at a site in order to determine whether further investigative or remedial actions are required. Guidelines (both federal and provincial) that are often used in contaminated site assessment in Canada are available for soil, sediment (freshwater and marine) and water media (freshwater and marine). The main purpose of guidelines is to aid in the establishment of site-specific remediation objectives.

6.1.1 Guidelines for Soil and Water

Under the NCSRP, environmental quality guidelines have been developed for soil and water (including groundwater) for initial assessment purposes (called assessment criteria) and for setting remedial targets for specific land uses (called remediation criteria). The criteria for soil are based on existing criteria/guidelines from selected jurisdictions in Canada following an extensive review (Environment Canada, 1991). The criteria for water are based on direct adoption of the Canadian Water Quality Guidelines (CCREM, 1987) and are subject to the categories of water use therein.

A brief description of the assessment and remediation criteria for soil and water is given in the following sections. However, the document *Interim Canadian*

Environmental Quality Criteria for Contaminated Sites (CCME, 1991b) contains a more detailed description of these criteria and how they are to be used for the assessment and remediation of contaminated sites in Canada and should be consulted during assessment phases of site remediation.

In addition, some provinces have soil and water quality guidelines designed with the same intent as the CCME guidelines which should be considered in addition to the CCME guidelines or for parameters not listed in the CCME soil and water quality guideline documents.

Interim Assessment Criteria

The interim assessment criteria are approximate background concentrations (generally for inorganic parameters) *or* approximate analytical detection limits (generally organic parameters) intended to serve as benchmark values against which an initial assessment of the degree of contamination at a site can be made.

Interim assessment criteria, based on representative background concentrations, are subject to updating and replacement by the CCME as additional Canadian soil and water data become available. Interim assessment criteria, based on analytical detection limits, are subject to updating and replacement by the CCME as improvements occur in analytical methods.

Interim Remediation Criteria for Soil

The interim remediation criteria for soil are presented in the context of three types of land use -- agricultural, residential/parkland and commercial/industrial. The criteria are considered generally protective of human and environmental health for specified uses of soil and water at contaminated sites. The interim soil remediation criteria were adopted from various Canadian jurisdictions and were not, in general, originally developed using a single consistent and scientifically defensible method. Therefore, the CCME decided to update the interim criteria with scientifically-validated numbers on a chemical-by-chemical basis using procedures described in *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME, 1996a).

The Protocol is primarily intended to be used by the CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites, to derive scientifically-defensible soil remediation criteria. In summary, the Protocol provides a consistent method for deriving soil quality guidelines, under defined exposure scenarios, that will be generally protective of key ecological and human receptors for specified land use categories (agricultural, residential, parkland, commercial and industrial). It is intended that soil remediated to guideline levels developed under the Protocol will represent a healthy, functioning ecosystem capable of sustaining the current and likely future uses of the site by ecological receptors and humans, including uses of groundwater.

Although the Protocol is primarily intended for use by the CCME Subcommittee, there are circumstances (discussed in later sections) under which managers of contaminated sites may be required to understand and use elements of the Protocol. For this reason, it is recommended that site managers understand the derivation basis of the guidelines developed using the Protocol before applying them at a contaminated site.

Interim Remediation Criteria for Water

For water, the interim remediation criteria are presented in the context of four water use scenarios – freshwater supporting aquatic life, water used for irrigation, water used for livestock watering and water used as drinking water by humans. The interim water remediation criteria were adopted from the *Canadian Water Quality Guidelines* (CCREM, 1987) which include the *Guidelines for Canadian Drinking Water Quality* (HWC, 1989). The adopted criteria for water were, in general, originally developed using consistent, scientifically-defensible methods [e.g., *A Protocol for the Derivation of Water Quality Guidelines for the Protection of Aquatic Life* (CCME, 1991c); *Protocol for Deriving Water Quality Guidelines for the Protection of Agricultural Water Uses* (CCME, 1993d)] and are not subject to replacement as with the interim soil criteria.

However, managers should be aware of updates to the CWQG which do not appear in the interim criteria document. For similar reasons to those stated for the soil Protocol document, it is recommended that site managers understand the derivation basis of water guidelines developed using the above Protocols before applying them at a contaminated site.

6.1.2 Guidelines for Sediment

At contaminated sites in Canada, the assessment of impacts to freshwater or marine sediment is often of primary concern. This is of particular importance in situations where target chemicals are known to partition to sediments from surface water or groundwater inputs. The CCME has established scientifically-defensible guidelines for assessing freshwater and marine sediment quality using a similar process to that described in the soil Protocol document. The guideline derivation process for sediments is described in the document *A Protocol for the Derivation of Canadian Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME, 1995). Currently, only a few sediment quality guidelines are available for heavy metals, but *Interim Sediment Quality Guidelines* are generally available for many of the parameters listed in the CCME interim criteria document. In addition, some provinces have sediment quality guidelines designed with the same intent as the CCME guidelines (e.g., Ontario) which should be considered in addition to the CCME guidelines or for parameters not listed in the CCME sediment quality guideline documents.

For similar reasons to those stated for the soil and water Protocol documents, it is recommended that site managers understand the derivation basis of CCME sediment guidelines developed using the above Protocol before applying them at a contaminated site.

6.2 Application of Environmental Quality Guidelines at Contaminated Sites

Because contaminated sites can present specific conditions that cannot always be accounted for in the development of "generic" guidelines, site-level information must be considered when applying guidelines at a site. *The process of applying environmental quality guidelines at the site level to establish remediation targets for the site is known as establishing site-specific remediation objectives.* Specific CCME guidance (including examples) on the application of environmental quality guidelines at contaminated sites is described in *Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada* (CCME, 1996b). The following section gives an brief overview of this document.

6.2.1 Development of Site-Specific Remediation Objectives

As previously mentioned, the CCME has developed the document *Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada* to both guide and establish consistency in the development of remediation objectives (CCME, 1996b).

Under the CCME approach, there are three basic methods which may be utilized for the development of Site-Specific Remediation Objectives:

Method 1 - Direct adoption of Environmental Quality Guidelines for use as Site-Specific Remediation Objectives;

Method 2 - Adoption of Environmental Quality Guidelines, with limited modifications, for use as Site-Specific Remediation Objectives; and

Method 3 - The use of risk assessment methods to develop Site-Specific Remediation Objectives.

Methods 1 and 2 comprise a *guideline-based approach* to setting remediation objectives, while Method 3 comprises a *risk-based approach*. The guideline-based approach is designed to require fewer resources while providing a scientifically-defensible basis for protection that is sufficiently flexible to account for certain site-specific factors. This approach is believed to provide an effective alternative to detailed risk assessment methods. The risk-based approach can be more complex and more costly, and is generally utilized when a guideline-based approach is not suitable for a site.

The guidance manual for developing site-specific objectives identifies conditions under which the various methods may be utilized and provides guidance on the implementation of the methods. Utilization of any of the three methods is subject to the approval of jurisdictional regulatory authorities. The following sections provide an outline of the utilization of the methods.

6.2.1.1 Guideline-based Approach

Direct Adoption of Environmental Quality Guidelines

Under this method, the environmental quality guidelines selected for use at a site are adopted *de facto* as the remediation objectives. In general, this method is most applicable where site conditions, receptors, and exposure pathways are congruent with those assumed in the development of the guidelines. Other factors that may bear weight on the decision to directly adopt guidelines include cost, time, simplicity and technical considerations. Specific guidance on situations where the method may be utilized is provided in the guidance document on setting site-specific objectives (CCME, 1996b).

Adoption of Modified Environmental Quality Guidelines

In certain circumstances, environmental quality guidelines may be modified, within specified limits, and adopted for use as the remediation objective for the site. In general, this method is only applicable for soil guidelines derived using the soil Protocol document (i.e., guidelines that have replaced the Interim Remediation Criteria).

In general, the method may be utilized in situations where site conditions, land use, receptors or exposure pathways differ only slightly from those assumed in the soil Protocol document for the various land use scenarios. Specific guidance on situations in which modifications are allowed to the guideline, as well as details concerning the implementation of the method, are provided in the guidance manual (CCME, 1996b).

6.2.1.2 Risk-Based Approach

In certain circumstances, the guideline-based approach may not be suitable for a site (e.g., pathways of exposure, target chemicals, receptors or other site characteristics do not approach those used under the guideline-based approach) and risk assessment procedures may be required in the development of Site-Specific Remediation Objectives. By doing so, site-specific objectives are developed from the results of the risk assessment to establish a concentration corresponding to an acceptable risk to human or ecological receptors.

Site-Specific Remediation Objectives for soil should be developed using risk assessment when there are:

- significant ecological concerns (e.g., critical or sensitive habitats for wildlife; rare, threatened or endangered species; parkland or ecological reserves; hunting or trapping resources);

- unacceptable data gaps. Examples include:

    - exposure conditions are particularly unpredictable or uncertain;

    - there is a lack of information about receptors;

    - there is a high degree of uncertainty about hazard levels;

- special site characteristics. For example:

    - the site is so large, or the estimated cost of remediation is so high, that a risk assessment is needed to provide a framework for site investigation and to set remediation priorities;

    - site conditions, receptors and/ or exposure pathways differ significantly from those assumed in the derivation of guidelines.

There are two basic types of risk assessment -- Human Health Risk Assessment and Ecological Risk Assessment. One or both of these may be required to be utilized for the development of Site-Specific Remediation Objectives. In situations where both types of risk assessment are used, the lowest Site-Specific Remediation Objectives resulting from the assessment process should be selected for the purposes of site remediation. Details concerning the use of risk assessment to set Site-Specific Remediation Objectives are provided in the guidance manual (CCME, 1996b).

Guidance on the application of risk assessment at contaminated sites can be found in the following documents:

- A Framework for Ecological Risk Assessment: General Guidance (CCME, 1996c)
- A Framework for Ecological Risk Assessment Technical Appendices (CCME, in prep.)
- Procedures for Conducting Human Health Risk Assessments at Contaminated Sites in Canada (Health Canada, in prep.)
- A Framework for Ecological Risk Assessment at Contaminated Sites in Canada: Review and Recommendations (Environment Canada, 1994b)
- Review of Predictive Modelling and Uncertainty Analysis for Application in Ecological Risk Assessments (Environment Canada, in prep.)
- Speciation of Toxic Elements in Soils: Review and Recommendations for Application in Ecological Risk Assessment (Environment Canada, in prep.).

It should be noted that, in addition to contaminated soil and water, many contaminated sites contain discrete waste material and products. Site-Specific Remedial Objectives are intended to apply primarily to contaminated environmental media which remain on-site after the removal and management of discrete waste materials.

7.0 DEVELOPMENT AND IMPLEMENTATION OF A REMEDIAL ACTION PLAN

The objective of a contaminated site remediation is to mitigate environmental and health concerns associated with the site and to provide for future beneficial land use. Remediation can range from being a straightforward and simple cleanup to a complex, expensive project over an extended period. The groundwork of conducting a comprehensive site assessment, evaluating alternatives and carefully planning remedial action, will result in a contaminated site being restored more effectively, efficiently and economically. The development of a remedial action plan is referred to as Phase IV in the *National Guidelines for Decommissioning of Industrial Sites*.

7.1 Identification and Evaluation of Remedial Options

A feasibility study is the first step in developing and implementing a remedial action plan. This study evaluates remedial action plan options and the final choice will be guided initially by the cleanup objectives and philosophy of the proposed remediation, i.e., considering risk assessment and the ensuing overall remedial concepts and strategy.

The results of the Phase III study and risk assessment may lead to four broad options:

1. Complete cleanup;
2. Partial cleanup of priority items;
3. Establish a monitoring program; or
4. Do nothing.

Depending on appropriate action, one of these options will be selected for a site. Assuming that either partial or complete remediation is desirable as opposed to a "do nothing" or "monitoring" approach, then a defined remedial concept will be required to achieve the objectives of the work. Several approaches or concepts are frequently used in combination to form a remedial strategy.

Three general concepts are available:

- Removal and disposal
- Containment or encapsulation
- Treatment

These may be achieved either:

- *In situ*
- *Ex situ*
- Off site

A combination of these concepts forms a strategy. The strategy employed in the remedial program is represented in the fundamental approach to the mitigation of the problem, e.g., off-site (ex-situ) disposal, in-situ treatment. A strategy will normally have an underlying theme of either waste treatment and/or destruction, as opposed to disposal or containment technologies which merely manage contamination, or waste processing, such as volume reduction, or improved materials handling or increased disposal opportunities.

Once the strategy has been adopted, all potential remedial technologies, either proven or innovative, will be subjected to a selection process. This process will take the technologies and reduce them through a screening evaluation for potential feasibility concerning the particular waste types involved, through site-specific feasibility and, lastly, to a preferred option or options for implementation.

The selection should take into consideration general factors such as technical effectiveness in achieving remediation goals, practicality, safety and cost when narrowing the list of possible options. Site-specific conditions must then be evaluated in relation to the applicability of the plan to the site in hand to arrive at a short list of acceptable alternatives. In many cases, consultation with regulatory agencies will be necessary to determine if the plan meets regulatory requirements. Then the preferences of the manager for one course of action or another are determined. A good summary of an approach to the process of selection is contained in *Remediation Technologies Screening Matrix* by the U.S. EPA and U.S. Air Force (1993).

Site conditions include:

- media affected (soil, groundwater, surface water, sediments, debris, structures);
- contaminant type (inorganic, volatile organics, semi-volatile organics, radioactive materials);
- geological, hydrogeological, hydrological and ecological characteristics;
- climatic conditions; and
- site restrictions (buildings, proximity of sensitive receptors, residential neighbourhoods, schools, wildlife habitats).

The method of evaluation should be selected on the basis of the needs of site managers. It may be as simple as a pass/fail and/or rating process or involve conducting a risk assessment. The philosophy of the evaluation should favour permanent solutions involving contaminant destruction, preferably on site and better still, *in situ*, thus limiting the handling and potential movement of contaminants in the environment and also associated potential future liabilities.

To illustrate the point, the remediation of contaminated sites often involves mobilization of contaminants in order to treat, destroy or concentrate them. Some methods, such as excavation, can be disruptive and cause fugitive dust emissions to the surroundings. The risk to human health and the environment should be quantified in areas of likely high exposure (residential community, wildlife habitat) and potential disruption (ex-situ treatment processes). In such cases, not only can risk assessment be used to determine whether a contaminated site poses an unacceptable risk, but also to assess whether the proposed remediation process poses an even greater risk and to choose between different remedial scenarios.

Finally a draft cleanup plan will be developed for the site which reflects the preferred remedial technology. This will be submitted for approval by all parties and subsequently finalized.

7.2 Overview of Existing Technologies

Selecting a technology to remediate a contaminated site should be given careful consideration. The site characteristics, contaminants, affected media and the objectives of the site owner must be reviewed to ensure that the technology will meet all specified goals. The application requirements and associated costs vary significantly with different technologies.

A number of treatment technologies have been developed that have successfully eliminated or removed hazardous materials from contaminated sites. Many other innovative or emerging technologies are currently being developed to provide cost-effective treatment options. Such technologies may be at bench-scale level or in pilot programs.
Under the NCSRP, Environment Canada initiated the *Development and Demonstration of Site Remediation Technologies (DESRT)* program to encourage the development and testing of new methods for assessing and remediating contaminated sites in Canada with the goal of promoting Canadian technologies as world-leading in the area of contaminated site assessment and remediation.

Currently, Environment Canada has made available technical summary reports of 55 technologies developed or demonstrated under the DESRT program that can be consulted when selecting a technology suitable to address site contamination. In addition, a *Site Remediation Treatment Technology Database* has been developed by the Site Remediation Division of the Wastewater Technology Centre (WTC). The database contains a comprehensive collection of technologies for the treatment of soil, sediment, groundwater and off-gas and is available through the WTC.

Most treatment technologies used on contaminated sites were developed from well-known civil, industrial, chemical and mining engineering applications. These include water and wastewater treatment, metal extraction, petroleum extraction and refining, and chemical treatment processes. The principles of these physical and chemical processes have been applied to many contaminants in various media on contaminated sites to destroy, detoxify, isolate or otherwise remove the hazardous constituents of materials.

Selecting a treatment technology for a contaminated site is a demanding process. There are hundreds of technologies available, many specializing in the treatment of certain contaminants and specific media. However, those technologies that permit the re-use of treated material should receive priority consideration when selecting a technology to address site contamination. The re-use of treated site material may potentially lower overall project costs and minimize the environmental impact of using new materials at a site. Grouping these technologies into convenient categories for ease of evaluation is not straightforward. Many technologies are in several categories as they use several treatment methods. However, some general categories are established from which options can be considered, based on the particular needs of each individual site. Often, the complex nature of a site demands a number of technologies to extract contaminants, treat complex chemical mixtures, multi-media contamination and contaminants created by a treatment technology itself. The grouping of a number of technologies is a treatment train.

Classification by General Method

In-situ treatment. Contaminated material, such as soil and groundwater is treated in place on the site without removal. Examples of these technologies are air stripping, soil flushing, bioventing and some vitrification technologies.

Ex-situ, on-site treatment. Contaminated material is removed by excavation or pumping, treated on site and then replaced. For instance, excavated soil may be processed through a mobile treatment technology (incineration, low-temperature thermal desorption, bioreactor, chemical precipitation, neutralization, etc.). Pump-and-treat methods of groundwater remediation also fall in this category.

Ex-situ, off-site treatment/disposal. Contaminated material is removed by excavation or pumping, transported off site to a licensed facility, either for treatment (possibly by similar methods to those described above) or disposal in a regulated landfill or secure containment cell.

Classification by Objectives

Decontamination. Breaking down toxic chemical compounds into less toxic or innocuous compounds or their constituent elements, is usually seen as remediation's most desirable result. For inorganic contaminants, this may also involve lowering the valence state of metals, making them less toxic.

Isolation. The segregation of contaminated material from the surrounding environment is, in some circumstances, an acceptable method of environmental protection by reducing the risk of exposure. Isolation techniques use impermeable covers, low-permeability slurry walls, sheet piling or reversing groundwater flow by pumping from extraction wells to prevent contaminant migration.

Solidification/Stabilization. Such methods immobilize contaminants in solid chemical matrixes using cement, lime, thermoplastic materials or organic polymers. Leaching and consequent migration of chemicals off site, where they might affect sensitive receptors, is greatly reduced, if not eliminated. Depending on circumstances, solidified/stabilized contaminated material may remain *in situ* or removed for disposal off-site.

Classification by Applied Agent

Chemical Treatment. This involves either detoxifying or immobilizing contaminants to eliminate associated hazards. Detoxification changes the chemical compound, for example, by dehalogenating PCBs or other complex organics, or by the addition of hydrogen peroxide, alkalis, acids or other chemicals. Immobilization may be achieved with alkalis, sulphides or organometallic complexes. Some metals can be reduced to their lowest and least toxic valence state by adding chemicals. As part of the process, contaminants may first be mobilized by introducing solvents. These include acids, alkalis, complexing and chelating agents. The solution is then extracted for chemical treatment.

Physical Treatment. These methods are usually directed at reducing the volume of contaminated material and concentrating it for subsequent (often chemical) treatment. Sorting, by sieving or segregation, will eliminate gross contamination such as debris. Soil washing concentrates contaminants by removing the organic carbon and separating the contaminated fine grain soil particles from the uncontaminated coarser material. Other approaches include solidification and stabilization methods involving high temperature such as vitrification.

Thermal Treatment. This approach raises the temperature of a material until contaminants volatilize and are extracted for further treatment (thermal desorption), or are destroyed into their constituent elements to reform as less harmful compounds (incineration). Vitrification is a high-temperature thermal treatment method that can be conducted *in situ*, resulting in a glass-like material which cannot readily be leached and release contaminants.

Biological Treatment. In this case, the breakdown of chemicals is carried out by particular microorganisms which attack specific organic compounds. *In situ* biological treatment identifies the relevant indigenous microorganism and promotes its activity by providing nutrients and oxygen. In other cases, the same process may be carried out by excavating and placing the contaminated material in a bioreactor which could be on or off the site. After treatment, the material is returned to the site. Another approach uses non-indigenous organisms cultivated for the purpose and introduced to the site. It should be noted that bioremediation acts in the natural attenuation (passive remediation) of organic contamination, such as hydrocarbons, where there is no intervention by man.

7.3 Use of Treatability Studies

Treatability studies evaluate the performance and cost-effectiveness of a remedial technology on a given contaminated matrix. They are carried out if available information is insufficient to detail a technology's performance in a similar site situation. In a laboratory, a sample of contaminated material from the site is treated in a small scale version of the technology, known as a bench-scale test. A larger version, the pilot-scale process, can also be used to evaluate the technology. Pilot-scale equipment may be located in a laboratory or can be transported to a contaminated site.

Additionally, treatability studies are important for evaluating the performance of technologies on new contaminated matrices, complex contaminants or geology. Such studies are usually conducted by companies supplying the remedial technology or by research organizations developing the technology.

7.4 Cost-Benefit Analysis

Cost-benefit analysis helps to prioritize remedial actions for a number of sites, or determine the optimum technology for remediation. It is also an effective evaluation tool when combined with risk assessment. In cases where human health or a sensitive environment is affected, this analysis would be used to compare options, not to justify inaction.

The following questions establish the framework for any cost-benefit analysis:

- What events, actions or aspects will change as the result of the action?
- What is the estimated value of the environmental and human health benefits that will come about as a result of the action?
- What are the estimated costs associated with and created by the action?
- Given the estimated benefits and costs, is remedial action justified?

Also, the Green Plan Environmental Corporation (1995) provides guidance on conducting an evaluation of treatment technologies at contaminated sites in Canada which would be useful to site managers before implementing a remedial action plan to ensure that the technology selected provides the required benefit within the remediation budget.

7.5 Preparation of Remedial Action Plan

At this stage in the contaminated site management process, all findings should be summarized in a Remedial Action Plan (RAP). The *National Guidelines for Decommissioning Industrial Sites* (CCME, 1991a) is the primary CCME reference source for developing Remedial Action Plans.

The RAP should:

- summarize all data on contaminants identified during the site investigation(s);
- identify contaminants of concern and the media affected;
- identify the proposed cleanup criteria and the method(s) from which they have been derived;
- identify, quantify and characterize materials to be treated/removed; and
- summarize remedial options evaluated and the method used to select the preferred remedial strategy.

The RAP should address the following aspects of the proposed work by:

- describing the selected cleanup method and its technical feasibility;
- detailing an implementation plan, including a schedule and approximate costs;
- discussing control measures to minimize fugitive air emissions, surface water control, worker health and safety;
- identifying the fate of residual contaminants; and
- identifying remedial verification and long-term monitoring plans.

In most circumstances, the Remedial Action Plan should be submitted to the appropriate regulatory agency for review. After addressing all concerns raised by the regulatory agency, the Remedial Action Plan may be released to the public for comment. This release may be coordinated with the regulatory agency. The consultation process is aimed at achieving a consensus which will facilitate completion of the proposed work.

7.6 Preparation of a Worker Health and Safety Plan

A Worker Health and Safety Plan should be developed concurrently with the Remedial Action Plan. The content of the Health and Safety Plan is described in more detail in Section 8.0.

7.7 Preparation of Specification and Tender Documents; Contractor Selection

In 1994, Environment Canada developed *Model Terms of Reference for an Assessment Study of a Contaminated Site* to assist site mangers in retaining consultants to conduct assessment for contaminated or potentially-contaminated sites. The report provides examples of each of the components in a generic Terms of Reference and emphasizes their importance in ensuring that the resultant assessment study is of high quality. As in any project, preparing detailed specifications and selecting a knowledgeable, experienced contractor is critical to successfully implementing remedial activities.

Tender documents should be carefully prepared and contain clear, concise descriptions and specifications that outline each component of the implementation plan. The remedial action's objectives should be clearly stated. All available pertinent information regarding the site, including geology, hydrogeology, hydrology, surrounding land uses and contaminant distribution, should be included in the tender document. Remedial activities are often unpredictable and complicated, particularly with respect to anticipated quantities of contaminated material. In this context, the tender documents should request unit rates for critical items so that the manager of the contaminated site can prepare contingency budgets, e.g., more extensive contamination.

A bidders' meeting should be held and contractors should be allowed to conduct a site walk-through. They should be given sufficient time to complete the bid in a thoughtful manner and should be encouraged to present other remedial options based on their experience.

Both the primary contractor and subcontractors selected should be able to demonstrate previous successful experience with similar work and contaminants. Work experience required would depend on the site's characteristics, but where applicable, should include a background in demolition, hazardous/toxic remediation, treatment and implementation of remedial measures on contaminated sites. The contractor should also have adequate environmental insurance.

7.8 Documentation and Record-Keeping

During the course of a contaminated site remediation, it is critical to establish and maintain an organized, comprehensive record-keeping and documentation system. Information to be documented should be of sufficient quantity and detail to fulfill the following objectives:

- provide an accurate and complete record of the activities carried out and any alterations to the original plan;
- support decisions affecting the implementation and changes to Remedial Action Plans;
- present a legally-defensible position regarding actions taken to remediate the site;
- defend those implementing remedial activities from regulatory, employee or public action concerning potential exposure to contaminants; and
- support possible legal action against potentially responsible parties (PRP) who may have contributed to the contamination of the site.

Methods for documenting information include daily, weekly and monthly reports, training forms, sample logs, air monitoring logs, copies of permits, manifests and analytical reports, etc. Reporting and documentation requirements should be clearly defined in the tender and contract documents and include the job descriptions of all site workers and supervisors. A clear chain of responsibilities will facilitate the proper collection of required information.

7.9 Site Control/Access

Access to a contaminated site should be controlled during the investigation and remediation. This will help to minimize the exposure of workers and adjacent unaffected areas to contamination, as well as protect the public from site hazards and prevent vandalism. Site-control planning must take into consideration the following points in the context of site characteristics:

- site activities;
- site emergencies and evacuation routes;
- contamination control;
- topography and effect of precipitation; and
- access control (prevent trespassing).

For small, short-term projects, control may involve only temporary fencing (e.g., snow fence) and hazard tape. On large, long-term projects, access may be controlled by permanent fencing (e.g., chain link). In some cases, site security may be desirable on a full-time basis or only during off hours to prevent unauthorized access, trespassing, theft, vandalism and obstruction of work activities.

7.10 Changed Site Conditions

During remediation, unanticipated developments can frequently occur. Everyone involved must be prepared to respond promptly to changed site conditions and the Remedial Action Plan should be flexible enough to allow for changes.

For example, if unknown, highly-contaminated areas or "hot spots" are discovered, contaminant concentrations may exceed a treatment system's design specifications or the criteria for an off-site disposal facility. Amendments to the Remedial Action Plan to deal with these new site conditions should be documented. Other responses might include increasing requirements for personal protective equipment due to encounters with this additional contamination. In other cases, if personal air-monitoring results indicate that workers may wear air-purifying respirators instead of supplied-air respirators, their level of protection may be lowered to reflect this unexpected site condition.

When making such amendments, the rationale for the change must be documented and attached to all copies of the plan. Any persons affected, whether they be site workers or the general public, should be notified of the change, including regulatory bodies if necessary.

7.11 Remediation Validation and Long-Term Monitoring

The remedial activity's objectives, which could be to reduce or remove all contaminants, contain them or remove their source from a site, requires verification on completion of these activities. The *National Guidelines for Decommissioning Industrial Sites*, provides guidance for remediation validation and long-term monitoring in Section 4.6.

The completion of remedial activities is validated by using a process of confirmatory sampling. Confirmatory sampling demonstrates that contamination has (or has not) been removed or stabilized effectively, and that cleanup objectives have (or have not) been attained. Materials remaining on site and in place, such as soil, groundwater, surface water, air and structures are sampled. Sample results are compared to selected cleanup criteria, or to local background samples taken off site and unaffected by the site contamination or to general background levels. If confirmatory sample results indicate that the cleanup criteria were not attained, further remediation may be necessary. It is, therefore, desirable not to demobilize from a site until satisfactory results are obtained.

In some cases, long-term monitoring may be required to ensure that contaminant problems do not recur and that all contaminants have been removed from the site. Long-term monitoring is always required for activities using containment, isolation and *in situ* stabilization techniques. Monitoring usually involves periodically sampling groundwater, monitoring wells and analyzing the samples for targeted indicator contaminants.

7.12 Completion Report

When confirmatory sampling has been conducted and remedial activities have been finalized, a completion report, sometimes referred to as a closure report, should be prepared. It is advisable to submit the report to the regulatory agency for review and acceptance. Completion report requirements are detailed in the *National Guidelines for Decommissioning of Industrial Sites*. The report generally encompasses all site activities conducted, contaminated material quantities treated/removed, treatment/disposal technologies used and analytical data generated. Additionally, the report should be retained by the manager of the contaminated site as a permanent record of remedial activities conducted. In some jurisdictions, these documents may be required as a reference on the property's land registry record.

8.0 OCCUPATIONAL HEALTH AND SAFETY

Occupational health and safety concerns fall into three categories for contaminated sites -- site management, human controls and environmental controls. To ensure the safety and health of site workers, site visitors and the surrounding communities, concerns relating to these categories must be addressed in all elements of contaminated site management. The most effective method of control is to develop a site-specific health and safety plan or to enforce existing operational procedures.

8.1 Occupational Health and Safety Regulations

Federal and provincial labour ministries require workers to be protected through occupational health and safety (OH&S) measures during remedial activities. Although there are no statutes specifically regulating occupational health and safety requirements for contaminated sites, these sites are subject to general work place regulations. Construction site regulations also apply in jurisdictions which have such legislation. Issues of concern regarding health and safety of workers carrying out the assessment and remediation of contaminated sites include:

- hazard and exposure identification;
- exposure to and protection from hazardous chemicals;
- engineering controls for hazard mitigation;
- respiratory protection;
- medical surveillance; and
- confined-space entries.

Additional safety issues may be included in various federal, provincial and territorial regulations. Requirements may also be found in guidelines and policies published by the jurisdiction's labour or environment agencies.

8.2 Worker Training/Qualifications

At this time in Canada, no training requirements exist for those specifically involved with the assessment, management or remediation of contaminated sites. However, many jurisdictions' general OH&S regulations do have training requirements for workers exposed to some hazards (ie. chemicals, asbestos, etc.). It is also recommended that employers ensure that workers have received sufficient training to conduct the work in a safe and responsible manner.

The depth and duration of training required for workers in Canada is to be determined by those responsible for the site. Training should be comprehensive, pertinent and updated regularly. On-the-job training and daily safety meetings are a recommended part of any remedial action. It is critical to document all training provided for each employee.

In the United States, legislation has been implemented which stipulates training requirements. A certain hourly allotment of training based on job classification is required, before access to a contaminated site is permitted. This includes requirements for on-the-job training and annual refresher training. In addition, a number of organizations have published a document entitled *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, October 1985.* This document outlines health and safety issues associated with site remediation. Environment Canada has developed and offered a Contaminated Site Health and Safety Training Course which has been endorsed by the National Contaminated Sites Training Program. Also, Anacapa, et al. (1995) provide guidance on conducting an evaluation of an occupational health and safety plan at contaminated sites in Canada which would be useful to site managers before implementing a site plan to ensure completeness of the proposed plan.

8.3 Occupational Health and Safety Considerations for Contaminated Site Assessments

Occupational health and safety considerations protecting those involved with assessing contaminated sites should be given due consideration during site assessment planning. Site investigations, although not as disruptive as remedial activities, can expose site workers to hazardous conditions. As the site is undergoing assessment, hazards have not been identified. Therefore, site workers must be prepared for a wide variety of contingencies. Procedures to protect the health and safety of site workers should be included in the site assessment plan. Some safety issues which should be addressed include:

- protective clothing;
- respiratory protection;
- heat stress/cold exposure; and
- emergency procedures.

Results of preliminary research may warrant additional contingencies.

8.4 Occupational Health and Safety Plans for Contaminated Site Remediation

A Health and Safety Plan (HASP) should be developed for a contaminated site concurrently with a Remedial Action Plan. Its objective should be to protect the health and safety of site workers and the public.

By combining the elements described below into a clear, concise document, those responsible for managing contaminated site assessment and remediation can minimize hazards during these activities to workers, the public and the environment.

Site Management

Hazard Identification and Evaluation: Contaminated sites pose a multitude of health and safety concerns, many of which could result in injury or death. Hazards include chemical exposure, fire and explosion, oxygen deficiency, ionizing radiation, biologic, physical and electrical hazards, heat stress, exposure and exposure to noise, cold or vibration. The HASP should identify and evaluate all anticipated hazards on the site, and provide approaches for mitigation (i.e., procedures, protective equipment and clothing, etc.). A list of hazardous substances on site, their concentrations and the potential for exposure to site workers and members of the surrounding community should be addressed in the HASP or other documents.

Record Keeping Procedures: Having proper records enables site managers to maintain a history of activities and helps her/him comply with local, provincial and federal regulations and guidelines. Records maintained should include Material Safety Data Sheets (MSDS), daily work logs, incident reports, training records, instrument calibration logs and any others that may be pertinent to the site.

Site Emergencies and Emergency Response: Contaminated site assessment and remediation is inherently dangerous. Potential emergencies include fire, explosion, release of toxic chemicals to the air or water and exposure of workers to heat stress, chemicals or physical injury. Anticipating and planning for different emergency scenarios can help protect the health and safety of workers and the public. Elements of emergency planning include lines of authority, training, communication systems, evacuation routes and reporting to outside agencies.

Human Controls

Responsible Personnel Identification: There should be a clear line of authority for both those on site, those responsible for a contaminated site and those active in the decision-making process. The responsibilities of the site management team must be specified and the central point of reference to site workers, the general public, emergency workers and regulatory agencies should be clearly indicated. A Site Safety Officer should be identified as responsible for all health and safety matters. Alternates for all site management should be indicated.

Training: The HASP should identify site-specific training requirements relating to site hazards and specialized work. This training should ensure that all site workers and visitors have been provided with information needed to protect them while on site. Records of training sessions should be maintained.

Personal Protective Equipment (PPE): PPE, including both disposable clothing and equipment, is used to protect site workers against potential hazards by shielding or isolating individuals from such exposure pathways as respiration, ingestion and dermal contact. PPE may also protect workers from physical agents by using specialized eyewear, footwear and hearing protection. Appropriate PPE should be clearly outlined in the HASP. Selection should be based on site conditions and potential exposure.

Medical Surveillance Program: The program's objective is to identify any change in the health of a worker involved in a remedial activity that may be attributed to a site hazard. These programs should be developed for contaminated sites based on site characteristics and potential exposures. A medical examination should be conducted before remedial activities (or employment) begins and on completion of the activities (or employment) for each person involved. Such a program may involve routine testing of workers for exposure (i.e., blood tests for the presence of lead or hearing tests when exposed to excessive noise). Local medical officials should be informed of possible hazards associated with the work so they are better prepared to respond to an emergency. Finally, a medical surveillance program's effectiveness is dependent on worker involvement. Workers must be trained to identify unusual physical or psychological conditions and communicate them to safety or medical officials.

Decontamination: This is the process of removing or neutralizing contaminants that have accumulated on personnel and equipment. The procedures associated with decontamination should be included in the HASP and carefully followed throughout the remedial action. When rigorously adhered to, decontamination procedures protect workers, the public and the environment. Decontamination elements for worker protection include using disposable clothing, cleaning of equipment and specific procedures to be followed when leaving the site. These elements ensure uncontaminated areas remain that way. By ensuring all equipment, such as trucks, heavy equipment and air-monitoring equipment, is decontaminated before leaving the site, the public and environment are protected from uncontrolled contaminant transport.

Site-specific contaminant control procedures are critical to minimizing potential contaminant exposure of workers and the public. Elements of contamination control should be addressed in the HASP. These elements include establishment of work zones, decontamination procedures for personnel and equipment, site security and communication networks.

Communication: The HASP should identify procedures for communicating with off-site personnel, such as emergency personnel, and amongst site personnel. Communication ensures that work proceeds in a logical and orderly fashion, thus reducing unnecessary risks. The use of on-site telephones, emergency telephone numbers, the availability of bull-horn/loud hailers and standard hand signals in the event of an emergency are also elements of communication.

Environmental Controls

Environmental Surveillance: A comprehensive environmental surveillance plan should identify procedures for monitoring potential impacts on surrounding properties. This may include an air-monitoring plan which would evaluate conditions on-site, along the site perimeter and at off-site locations. Direct-reading instruments and laboratory testing of samples from air-sampling devices should be used at contaminated sites to identify and quantify airborne contamination. The information obtained can be used to determine whether protective measures for workers are adequate and impacts to the surroundings acceptable. Records should be maintained for instrument calibrations and maintenance.

Site Security: Site security controls are measures taken to restrict access to authorized personnel and thereby protect the general public. This may include fencing, visitor logs and security personnel.

8.5 Protection of Public Health and Safety

Protecting the health and safety of the general public is an important concern during the assessment, management and remediation of a contaminated site. Concerns of private citizens in the surrounding area can be addressed by providing adequate site security, monitoring the off-site effect of activities and informing the general public of these activities and their effects.

Providing security in the form of fencing and a full-time presence at the site (employees or a security firm) minimizes the chance of unauthorized access. Security fences should be provided with signs indicating that hazardous conditions exist inside the enclosure. Those who have not been provided with training to improve on-site hazard awareness may be in danger of injury or harm.

During a contaminated site assessment, conditions of the surrounding area should be quantified before remedial activities commence. This may include surface testing of soils and air monitoring. During remediation, these conditions should be periodically monitored to ensure that the activities do not create off-site effects.

The general public, especially private citizens and businesses in the surrounding area, should be informed of activities planned. For some sites, this may involve public consultation and involvement in the planning process. By providing citizens with information regarding precautions being taken to protect their health and safety, confrontation, fear and misconception may be avoided.

9.0 PUBLIC INVOLVEMENT AND COMMUNITY RELATIONS

General public awareness about environmental issues has increased dramatically in the last decade. Residents located near a contaminated site realize that these contaminants may affect their quality of life and property. The presence of a contaminated site may be identified by the owner, member of the general public, public officials or rumour and speculation. Those responsible for contaminated site management should develop a Community Information Program to guide their relationship with the public.

The degree of public involvement must be decided before a Community Information Program can be developed. A site located close to residences, schools, farms, public water supplies or public parks, or one that is highly visible, will require a Community Information Program. Conversely, a program may be unnecessary for an isolated site without any of the above characteristics. Generally, where a contaminated site exhibits a potential to affect people or areas off site, a Community Information Program is needed.

The Community Information Program's goals must be developed before designing a program. They may include:

- taking measures to identify public concerns;
- giving the public the opportunity to comment on and provide input to technical decisions, including such matters of public interest as noise, pollution, traffic and public safety;
- informing the public of planned or ongoing actions;
- focusing and resolving conflict; and
- implementing measures to validate public participation and to bring it to closure.

Direct public involvement in a Community Information Program may be started at any time of the site assessment/remediation process. However, highly-visible subsurface site assessments (i.e., drilling equipment) and remedial activity stages are most likely to be noted by surrounding residents and implementing the program early in the process should be considered. The guidelines put forth in the *Environmental Assessment and Review Process* (EARP, 1973) and the *Canadian Environmental Assessment Act* may be used in determining the extent of public consultation.

Some of the more common public relations methods are described below.

Contact Person: One member of the staff should be designated as the sole contact person for citizens and will be responsible for responding to all citizen concerns. This person should have the skills and experience necessary to implement a successful Community Information Program. One source of contact with citizens will establish consistency and familiarization.

Facts Sheets/Newsletters: Current or proposed site assessment, or remedial activities can be distributed to local residents, concerned citizens and the media via fact sheets and newsletters. These publications should present technical information in a clear, understandable format.

Press Releases: Press releases are news items similar to fact sheets and newsletters and will provide the media with current and proposed activities on a contaminated site. By providing the information to the media, a large audience is reached inexpensively.

Public Meetings: Information sessions announced in local newspapers/radio, can provide a forum for informing citizens of ongoing activities and receiving citizen feedback on these activities.

Public Liaison Committee: A public liaison committee comprises citizens who will represent the concerns of their neighbours. They are an integral part of the decision-making process and should be involved in the contaminated site management process at an early stage.

Site Tours: Tours can be conducted during remedial activities to familiarize local residents, concerned citizens and the media with the technologies and precautions involved.

9.1 Identification of Key Community Members

Community members who are knowledgeable about the community and represent a constituency in the community are those appropriate to be involved in a representative body such as a Public Liaison Committee. These individuals may be local government officials, surrounding property owners or community organization leaders.

Also, Anacapa, et al. (1995) provide guidance on conducting an evaluation of community relations/consultations procedures at contaminated sites in Canada which would be useful to site managers during the planning stages of a site project when it is important to consider public involvement.

10.0 POST-REMEDIAL EVALUATION OF CONTAMINATED SITES

As a number of contaminated sites have undergone remediation under the NCSRP, Environment Canada initiated a project in 1995 to develop a method for post-remedial evaluation (audit) of these sites to determine the effectiveness of the assessment and remediation process used on *federal* sites remediated under the NCSRP. The methodology is contained in the document *Contaminated Sites and Remedial Actions: Audit and Evaluation Framework* (Anacapa, et al., 1995-draft). Within this overall methodology, four individual components that address post-remedial evaluation of remedial technology used (GPEC, 1995), socio-economic impacts, community relations/consultation procedures, occupational health and safety plans (Anacapa, 1995) and bioassessment considerations (BEC, 1995) were brought under one framework. The methodology uses a series of key questions to provide feedback to managers on the above components of a site assessment and remediation so that lessons learned from the evaluation process can be applied to future remediation projects.

While this methodology was designed for use under the NCSRP, it is applicable to the evaluation of remediated sites in Canada, in general. Site managers or managers of remedial programs in Canada may find this methodology useful when evaluating the efficiency and effectiveness of remedial projects with regard to the component aspects noted above. Information from this process can be used to refine future assessment and remediation activities proposed for contaminated sites in Canada.

11.0 PUBLICATIONS

Environment Canada serves as the technical secretariat for the development of CCME and NCSRP technical documents. For further information on any of the CCME- or NCSRP-related documents cited in this report, please contact:

Guidelines Division
Evaluation and Interpretation Branch
Ecosystem Conservation Directorate
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Copies of CCME publications can be ordered from:

CCME Documents
c/o Manitoba Statutory Publications
200 Vaughan Street
Winnipeg, Manitoba
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APPENDIX A: GLOSSARY

A

Acceptable Risk - a risk which is so small, whose consequences are so slight, or whose associated benefits (perceived or real) are so great, that persons or groups in society are willing to take or be subjected to that risk.[3]

Acute Toxicity - the adverse effect occurring within a short time of administration of a single does of a chemical or multiple doses given within 24 hours.[8]

Acute Exposure - short-term exposure usually involving a single dose or exposures less than two weeks in duration.[8]

Additive Effect - an effect that is the result of two chemicals acting together and this is equivalent of the simple sum of the effects of the chemicals acting independently.[8]

Adverse Effect - an undesirable or harmful effect to an organism, indicated by some result such as mortality, altered food consumption, altered body and organ weights, altered enzyme concentrations or visible pathological changes.[8]

Aesthetic - is the perception of a site as determined using the natural senses with respect to sight, sound, taste and odour.[5]

Ambient - the conditions surrounding a person, sampling location, etc.[8]

Antagonistic Effect - the effect of a chemical in counteracting the effect of another; for example, in a situation where exposure to two chemicals together has less effect than the simple sum of their independent effects; such chemicals are said to show antagonism.[8]

Approach - the philosophy and procedures used by a regulatory agency to establish environmental quality criteria. The components of the approach can include the types of information considered, the management goal underlying the criteria (e.g., protection of aquatic life), relative priorities assigned to various types of information and the ways that information is combined to set the criteria.[7]

Aquatic - growing or living in water.[4]

Aquifer - rocks or unconsolidated sediments that are capable of yielding a significant amount of water to a well or a spring.[2]

Assess or Assessment - means such investigations, monitoring, surveys, testing and other information-gathering activities to identify: (1) the existence, source, nature and extent of contamination resulting from a release into the environment of a hazardous material or chemical substance; and (2) the extent of danger to the public health, safety, welfare, and the environment. The term also includes studies, services, and investigations to plan, manage and direct assessment, and decommissioning and cleanup actions.[5]

Atomic Absorption Spectrophotometry - an analysis technique that uses the absorption spectra of isolated atoms to determine elemental concentrations.[1]

B

Background - an area not influenced by chemicals released from the site under evaluation.[8]

Background Concentration - is the concentration of a chemical substance occurring in media removed from the influence of industrial activity at a specific site and in an area considered to be relatively unaffected by industrial activity. Background air and soil concentrations should be measured in an area of residential land use at least 1000 m upgradient with respect to prevailing wind direction from the industrial site. Background concentrations in water should be measured upgradient with respect to the direction of water flow to the industrial site and before the water flows onto the industrial site. A sufficient number of samples should be collected to represent the statistical confidence limits required.[5]

Background Samples - matrices minus the analytes of interest that are carried through all steps of the analytical procedure. They are used to provide a reference for determining whether environmental test sample results are significantly higher than "unpolluted" samples, which contain "zero", low or acceptable levels of the analytes of interest. They are needed to attribute the presence of analytes of interest to pollution rather than to a natural occurrence or to a previous occurrence of the analytes of interest in the environmental matrix. All matrices, reagents, glassware, preparations and instrumental analyses are included in the analysis of background samples.[1]

Benthic - refers to organisms, samples or bottom strata related to, living in or associated with the benthos.[4]

Bioaccumulation - the net accumulation of a chemical by an organism as a result of uptake from all routes of exposure. Efficient transfer of chemical from food to consumer, through two or more trophic concentrations, results in a systemic increase in tissue residue concentrations from one trophic concentration to another.[8]

Bioassay - a controlled, experimental study in which organisms (typically rodents) are exposed to several different doses/concentrations of a chemical over predetermined times and the resulting effects are identified and measured.[3]

Bioassessment - the laboratory toxicity testing of biological organisms and the evaluation of field populations and communities.

Biodegradation - the process of destruction or mineralization of either natural or synthetic materials by the microorganisms of soils, waters or wastewater treatment systems.[1]

Bioavailability - an analysis of the amounts of potentially-toxic chemicals or their metabolites present in body tissues and fluids, as a means of assessing exposure to these chemicals and facilitating timely action to prevent adverse effects. The term is also used to mean assessment of the biological status of populations and communities of organisms at risk in order to protect them and to have an early warning of possible hazards to human health.[8]

Bioconcentration - a widespread term that describes the process by which contaminants are directly taken up by terrestrial and aquatic organisms from the medium.[3]

Biomagnification - results from the process of bioaccumulation by which tissue concentrations of accumulated chemical compounds are passed up through two or more trophic levels so that tissue-residue concentrations increase systemically as trophic levels increase.[3] The bioaccumulation of xenobiotics up a food chain (e.g., from plant to herbivorous animal to predator).[8]

Biomonitoring - the use of biological attributes of a system to evaluated exposure to chemical contaminants, or other stresses, and subsequent biological impairments.

Biomonitor - a single species used to identify responses to contaminants by evaluating the presence of these contaminants in the tissue of the species.

Biota - biological organisms (including plants, microbes, invertebrates, animals).[3]

Blank - the measured value obtained when a specified component of a sample is not present.[1]

Borehole - a hole drilled or bored into the earth, and into which casing or screen can be installed to construct a well.[2]

C

Calibration (in the context of measuring instruments) - comparison of a measurement standard or instrument with another standard or instrument in order to report or eliminate by adjustment any variation (deviation) in the accuracy of the item being compared.[1]

Calibration (in the context of modelling) - the process of matching a model simulation with observed data. Typically, one or more model parameters are varied within reasonable limits until a suitable match is obtained.[2]

Chemical - any element, compound, formulation or mixture of a substance that might enter the aquatic environment through spillage, application or discharge. Examples of chemicals that are applied to the environment are insecticides, herbicides, fungicides, sea lamprey larvicides, and agents for treating oil spills.[4]

Chronic Toxicity - the development of adverse effects after an extended exposure (conventionally at least one-tenth of the expected life span of an organism), to relatively small quantities of a chemical.[8]

Chronic Toxicity Test - the determination of the dose of a chemical that results in adverse effects (e.g., carcinogenic, teratogenic, reproductive) in an organism following long term exposure, usually via administration in the food, drinking water or via inhalation. Chronic tests are designed to define safety margins to be used for the regulation of chemical exposure.[8]

Clean Soil/Sediment/Water - medium that contains no toxic substances at concentrations which cause discernible distress to the test organisms or reduce their survival, growth or reproduction.[4]

Cleanup - is the removal of a chemical substance or hazardous material from the environment to prevent, minimize or mitigate damage to the public health, safety or welfare, or the environment that may result from the presence of the chemical substance or hazardous material. The cleanup is carried out to attain specified cleanup criteria.[5]

Composite Sample - a sample obtained by mixing several discrete samples or representative portions thereof into one bottle.[1]

Compositing - the combining and homogenizing of samples (e.g., soils) before performing an analysis of the composite sample.[2]

Concentration - the amount of chemical or substance in a given environmental medium. Concentration is typically expressed in units such mg/L (in water), mg/kg (in soil or food) and mg/m^3 (in air).[8]

Conceptual Model - our idealization of a hydrogeological system on which we can base a mathematical model. The conceptual model includes assumptions on the hydrostratigraphy, material properties, dimensionality and governing processes.[2]

Contain or Containment - means actions taken in response to the release of a chemical substance or hazardous material into the environment to prevent or minimize such release so that it does not migrate or otherwise cause or threaten substantial danger to present or future public health, safety or welfare, or the environment.[5]

Contaminant - is any chemical substance whose concentration exceeds background concentrations or which is not naturally occurring in the environment.[5] Any physical, chemical, biological or radiological substance in air, soil or water that has an adverse effect.[2]

Contamination - the introduction into soil, air or water of a chemical, organic or radioactive material, or live organism that will adversely affect the quality of the medium.[2]

Criteria - are numerical standards that are established for concentrations of chemical parameters in various media to determine the acceptability of a site for a specific land use.[5] Generic numerical limits or narrative statements intended as general guidance for the protection, maintenance and improvement of specific uses of soil and water.[6] The numerical limits or narrative statements that are recommended to protect and maintain the specified uses of water, sediment or soil. The criteria used in the NCSRP are functionally equivalent to the guidelines that are promulgated in other CCME programs.[7]

Guideline-based Approach - an approach which incorporates such site-specific considerations as background levels of contaminants, technological capabilities, economic limitations and site/situation-specific negotiations in the development of objectives.[9]

D

Data Quality Objectives (DQO) - those desired outcomes in which the collected data are accompanied with the best-achievable and optimum data quality parameters, such as precision, accuracy, data completeness and confidence limit values, that can be extracted from the monitoring system.[1]

Data Quality Objectives (DQO) - statements developed by data users to define the quality of data needed to meet the objectives of a site assessment activity.[2]

Decommissioning - is the closure of an industrial facility followed by the removal of process equipment, buildings and structures (on a site-specific basis). Decommissioning may include all or part of a facility, and "mothballing". Cleanup may be required to remove chemical substances or hazardous materials from the environment, or to render the industrial site safe and aesthetically acceptable. Decommissioning may result in a change in land use.[5]

Dense-Non-Aqueous-Phase Liquids (DNAPL) - organic liquids that are more dense than water. They often coalesce in an immiscible layer at the bottom of a saturated geologic unit.[2]

Detection Limit - the smallest concentration of a substance that can be reported as present with a specified degree of precision and accuracy by a specific analytical method.[1]

Disposal Site - is any structure, well, pit, pond, lagoon, impoundment, ditch, landfill or other place or area, excluding ambient air or surface water, where a chemical substance or a hazardous material has come to be located as a result of any spilling, leaking, pouring, abandoning, emitting, emptying, discharging, injecting, escaping, leaching, dumping, discarding or disposing of by any other means.[5]

Dose (human health) - the amount or concentration of a substance absorbed into the body. It requires exposure to the substance of interest (see exposure).[3]

Dose (general) - the amount of chemical administered or taken by an organism. Considered a measure of chemical exposure. Generally expressed as mg per kg body weight per day (mg/kg/day)[8]

Duplicate Sample - a second sample randomly selected from a population of interest to assist in the evaluation of sample variance.[1]

E

Ecological Receptor - a non-human organism identified as potentially experiencing adverse effects from exposure to contaminated soil either directly through contact or indirectly through food-chain transfer.[3]

Ecological Risk Assessment - the process of defining and quantifying risks to non-human biota and determining the acceptability of those risks.[8]

Ecosystem - a community of organisms, interacting with one another, plus the environment in which they live and with which they also interact.[3]

Effects-Based - the use of data indicating adverse effects from toxicological studies to form the basis for criteria derivation. In this document, this pertains to the use of data from toxicological tests to organisms to support criteria derivation.[3]

Effluent - any liquid waste (e.g., industrial, municipal) discharged to the aquatic environment.[4]

Element - a chemical substance that cannot be separated into substances of other kinds. All atoms of a chemical element have the same atomic number.[1]

Environment - means water, land, surface or subsurface strata, or ambient air of Canada.[5]

Environmental Analytical Laboratory - a laboratory engaged in the physical, chemical or biological measurements of either the receiving environment or discharges to the receiving environment.[1]

Environmental Fate - the destiny of a chemical or biological substance after release into the environment.[8]

Environmental Fate Model - in the context of exposure assessment, any mathematical abstraction of a physical system used to predict the concentration of specific chemicals as a function of space and time subject to transport, intermedia transfer, storage and degradation in the environment.[8]

Environmental Media - one of the major categories of material found in the physical environment that surrounds or contacts organisms (e.g., surfacewater, groundwater, soil or air), and through which chemicals or pollutants can move and reach the organisms.[8]

Environmental Samples - a representative sample of any environmental material (aqueous, nonaqueous or multimedia) collected from any source for determination of composition or contamination.[1]

Exposure (general) - contact between a substance and an individual or population. It may occur via different pathways including ingestion, dermal absorption and inhalation.[3] Is the co-occurrence or a stressor with an ecological receptor. It is usually determined by understanding the fate of the stressor and then measuring or estimating the amount of the stressor in environmental compartments (e.g., soil, air and water).[3]

Exposure (human health) - is any contact with or ingestion, inhalation or assimilation of a chemical substance or hazardous material.[5]

Exposure Pathway - the route by which an organism comes into contact with a contaminant. In the ecological effects-based procedure, exposure pathways are restricted to organisms that come in contact with contaminated soil. In the human health-based procedure, exposure pathways cover contaminant contact through consumption of contaminated food, direct soil ingestion, dust inhalation and dermal absorption.[3] The route by which a receptor comes into contact with a chemical. Examples of exposure pathways include the ingestion of water, food and soil, the inhalation of air and dust, and dermal absorption.[8]

Exposure Route - the mode of entry of a chemical into the body. The three basic routes are ingestion, inhalation and dermal absorption.[8]

F

Fate - the immediate or ultimate change in a chemical typically brought about by chemical or biological reaction.[2]

Flame Ionization Detector - a sensitive, general purpose detector for most organic compounds. It has as excellent linear range and low maintenance, but poor sensitivity for halogenated compounds and those that lack hydrocarbon characteristics (e.g., carbon monoxide, carbon dioxide and phosgene).[1]

G

Gas Chromatography (GC) - an analytical technique that employs separation of components of a gas phase mixture by passing the mixture through a column.[1] A method for separating, identifying and measuring concentrations of organic compounds. Compounds pass through a chromatographic column and the differences in their rates of travel form the basis for their separation and identification. Detection limits are usually 1 to 10 micrograms per litre.[2]

Gas Chromatography/Mass Spectroscopy (GC/MS) - a method for separating, identifying and quantifying organic compounds. The compounds are separated in the gas chromatography, but their identification is based on both their retention time in the gas chromatography column and their mass spectral pattern. Quantification is achieved by measuring peak heights in the mass spectra. Detection limits are usually 5 to 10 micrograms per litre.[2]

Ground Penetrating Radar - a geophysical method in which bursts of electromagnetic energy are transmitted downward from the surface, to be reflected and refracted by velocity contrasts within the subsurface. Also known as "ground probing radar".[2]

Groundwater - all subsurface water that occurs beneath the water table in rocks and geologic formations that are fully saturated.[1] Water under hydrostatic pressure in interconnected pores of the saturated zone. This water emerges from springs and enters wells.[2]

Groundwater Flow - movement of water through openings in sediment and rock of the saturated zone.[2]

Guidelines - are statements outlining a method, procedure, process or numerical value which, while not mandatory, should be followed unless there is a good reason not to do so. The publication of this guideline does not preclude development of province, industry of site-specific guidelines within a similar procedural context.[5] The numerical limits or narrative statements that are recommended to protect and maintain the specified uses of water, sediment or soil. The guidelines that are promulgated in other CCME programs are functionally equivalent to the criteria used in the NCSRP.[7]

H

Habitat - place with a particular type of environment inhabited by an organism.[3]

Harm - 1) a loss to a species or individual consequent of damage; 2) a function of the concentration to which the organism is exposed and of the duration of exposure.[8]

Hazard - the adverse impact on health that can result from exposure to a substance. The significance of the adverse effect depends on the nature and severity of the hazard and the degree to which the effect is reversible. In some instances, the substance itself is also referred to as the hazard, rather than the adverse effect which the substance can cause.[3] A state that may result in an undesired effect, the cause of risk.[8] Refers to the type and magnitude of effect caused by a stressor, and is usually evaluated by identifying biological effects associated with exposure to concentrations of the stressor in laboratory field studies.[9]

Hazardous Material - is material including but not limited to, because of its quality, concentration, chemical composition, corrosive, flammable, reactive, toxic, infectious or radioactive characteristics, either separately or in combination with any substance or substances, that constitutes a present or potential threat to human health, safety or welfare, or to the environment, when improperly stored, treated, transported, disposed of, used or otherwise managed.[5]

Headspace - the empty volume in a container between the cap and the solid/liquid level of the sample.[2]

Heavy Metals - metallic elements, some of which are required in trace concentrations for plant and/or animal nutrition, but which become toxic at higher concentrations (e.g., lead and mercury).[2]

Heterogeneity - the condition in which a property of a material is different at different locations within a specified volume of space.[1]

Homogeneity - the degree to which a property or substance is randomly and uniformly distributed throughout a material.[1]

Human Health Assessment - the process of defining and quantifying risks and determining the acceptability of those risks to human life.[8]

Hydraulic Conductivity - a coefficient of proportionality that describes the ease with which a fluid can move through a porous medium. It is a function of both the medium and of fluid flowing through the medium.[2]

Hydrogeological Model - a representation, often simplified and perhaps conceptual, of the hydrogeological flow system. The aspects important for the site are emphasized.[2]

I

Industrial Site - means any land and associated buildings, structures, pipelines, disposal sites and storage, production, resource extraction and shipping areas, without limitation, where an industrial activity is carried out, or was carried out and the land site not decommissioned and cleaned up prior to a new land use being allowed.[5]

Instrument Detection Limit - the smallest analyte signal above background noises that an instrument can detect. It does not take into consideration matrix or laboratory blank interferences.[1]

Interim Criteria - the criteria that have either been adopted directly from the existing criteria that are currently being used in Canadian jurisdictions or derived using incomplete toxicological and/or environmental fate data sets. Interim criteria are reviewed and modified as new information becomes available.[7]

L

Landfarming - the practice of spreading organic wastes over an area of land, then relying on natural microbial degradation (and volatilization) to degrade the wastes. Can also be used to treat shallow soils contaminated by some organic chemicals.[2]

Landfill - a disposal facility where waste is placed in or on land, but which is not a land treatment facility, a surface impoundment or an injection well.[2]

LC_{50} (Median Lethal Concentration) - the concentration of a chemical in medium that results in mortality to 50% of the organisms exposed during the toxicity test.[8]

Leach - to wash or drain solids (e.g., wastes) by percolation. Usually, the washing fluid removes or leaches chemicals from the solid.[2]

Leachate - a solution produced by the percolation of liquid through soil or solid waste, and the dissolution of certain constituents in the water.[2] Water or wastewater that has percolated through a column of soil or solid waste within the environment.[4]

Leaching - the process by which contaminants in soil dissolve into water percolating through the soil (such as rainfall) and are gradually removed from the soil.[3]

Light Non-Aqueous Phase Liquids (LNAPL) - fluids that are lighter than water. They are capable of forming an immiscible layer that floats on the water table (e.g., petroleum hydrocarbons or other organic liquids). Also referred to as Floaters.[2]

M

Media - the fundamental components of the environment, including water, sediment, soil and biota.[7]

Method Detection Level (MDL) (proposed) - the lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.[1]

Migration - the movement of chemicals, bacteria and gases in flowing water or vapour in the subsurface. Also, a seismic/radar term that generally means the correction of the recorded image for the effects of reflector dip. A very typical result of migration is the removal of hyperbolic events on the record resulting from diffractions from faults and other discontinuities.[2]

Model - a conceptual, mathematical, or physical system intended to represent a real system. The behaviour of a model is used to understand processes in the physical system to which it is analogous.[2]

Monitoring - the routine (e.g., daily, weekly, monthly, quarterly) checking of quality, or collection and reporting of information. In the context of this report, it means either the periodic (routine) checking and measurement of certain biological or water-quality variables, or the collection and testing of samples of effluent, leachate, elutriate or marine estuarine receiving water for toxicity.[4]

Monitoring Well - a well that is used to extract groundwater for physical, chemical or biological testing, or to measure water levels.[2]

N

Non-Detectable - a concentration value that is below the detection limit. It is generally recommended that these values be included in the analysis as values at the detection limit.[8]

O

Objective - a numerical limit or narrative statement that has been established to protect and maintain a specified use of soil or water at a particular site by taking into account site-specific conditions.[6] The numerical limits or narrative statements that are established to protect and maintain the specified uses of water, sediment or soil at a particular site. Objectives may be adopted directly from generic criteria or formulated to account for site-specific conditions.[7]

Organic Contaminant or Compound - substances containing carbon, with the exception of carbon dioxide (CO_2) and carbonates (e.g., calcium carbonate, $CaCO_3$).[2]

Orphan Site - a contaminated site for which the responsible party cannot be identified or appears to be incapable or unwilling to initiate remedial measures.[7]

P

Parameter - a statistical property or characteristic of a population of values. Statistical quantities, such as means, standard deviations, percentiles, etc., are parameters if they refer to a population of values rather than to a sample of values.[8]

Pathway - means the route along which a chemical substance or hazardous material moves in the environment.[5]

Pathway (exposure) - a description of the movement of a chemical through various environmental media.[8]

Polluter Pays - the principle that the polluter is responsible for correcting or remediating whatever environmental degradation their actions have caused.[7]

Population - a group of individuals within a specified location in space and time.[8]

Pore Space - an opening, void or interstice in a soil or rock mass.[2]

Procedures - the methods used by a regulatory agency to establish environmental quality criteria. In contrast to an approach, a procedure does not include the philosophical basis of the process (e.g., guiding principles).[7]

Protocol - a toxicity test describing strict adherence to required procedures for performance of the scientific experiment.[4]

Potentiation - the effect of a chemical that may not itself have an adverse effect but that enhances the toxicity or effect of another chemical.[8]

Q

Qualitative Risk Assessment - an analysis that is a qualitative statement of risks, based on historical information, circumstantial evidence of contamination or limited sampling information. Only a qualitative statement of uncertainty is possible and uncertainty is generally high.[8]

Quality Assurance (QA) - relates to a system of activities whose purpose is to provide the producer or user of a product (e.g., data) or a service the assurance that the product or service meets defined standard of quality. It consists of two separate but related activities: quality control and quality assessment. The quality assurance process includes documentation of procedures, identification of critical points within the data collection activities that require monitoring by quality control procedures, the level of quality achieved, problems encountered and corrective actions undertaken.[1] Management of the data to ensure they meet the data quality objectives. This includes steps to control data quality and to assess data quality. It commonly includes designing appropriate protocols, ensuring they are carried out, and independently testing data quality.[2]

Quality Assurance/Quality Control (QA/QC) - those procedures and controls designed to monitor the conduct of a study in order to ensure the quality of the data and the integrity of the study.[8]

Quality Control (QC) - the overall system of activities whose purpose is to control the quality of a product (e.g., data) or service so that it meets the needs of users. The aim is to provide quality that is satisfactory, adequate, dependable and economical.[1] Management of the collection and analysis of data to ensure they meet the data quality objectives. Activities include following sampling protocols, and routinely checking calibration of laboratory equipment.[2]

Quantitative Risk Assessment - an analysis in which uncertainty is minimized, quantified and explicitly stated. The resulting or final uncertainty may be highly variable (either high or low). Confidence limits or probability distributions may be developed for all key input parameters. A quantitative risk assessment with low uncertainty will generally be conducted using well-designed, robust data sets and models directly applicable to site conditions. The sampling program will be based on geostatistical or random design and will support statistical analysis of results to characterize the monitoring data.[8]

R

Receiving Water - natural surface water (e.g., in a river) that has received a discharged waste, or else is about to receive such a waste (e.g., it is just "upstream" or up-current from the discharge point). Further descriptive information must be provided to indicate which meaning is intended.[4]

Receptor - the person or organism subjected to chemical exposure.[8] An ecosystem component that is, or may be, adversely affected by a pollutant or other stress emanating from a contaminated site. Receptors may include biological or abiotic (e.g., air or water quality) components.[9]

Receptor/Critical Receptor - a receptor is the person or organism subject to chemical exposure. For the purposes of human health risk assessment, it is a common practice to define a critical receptor as the person expected to experience the most severe exposure (due to age, sex, diet, lifestyle, etc.) or most severe effects (due to state of health, genetic disposition, sex, age, etc.) as a result of that exposure.[3]

Reference Soil - a natural soil used to assess localized soil conditions exclusive of the specific contamination of concern or an artificial soil prepared in the laboratory using standard procedures which serve as control or solid phase dilutant in soil toxicity tests.[4]

Remediation - the improvement of a contaminated site to prevent, minimize or mitigate damage to human health or the environment. Remediation involves the development and application of a planned approach that removes, destroys, contains or otherwise reduces availability of contaminants to receptors of concern.

Remedial Alternative - means measures or a combination of measures proposed to clean up an industrial site.[5]

Remediation Criteria - the numerical limits or narrative statements pertaining to individual variables or substances in water, sediment or soil which are recommended to protect and maintain the specified uses of contaminated sites. When measurements taken at a contaminated site indicate that the remediation criteria are being exceeded, the need for remediation is indicated.[7]

Risk - in this protocol, risk is a measure of both the severity of health effects arising from exposure to a substance and the probability of its occurrence. It may involve quantitative extrapolation from animals to humans or from high dose/short exposure time to low dose/long exposure time. It may consider potency (physical/chemical properties, biological reactivity), susceptibility (metabolic activation, repair mechanisms, age, sex, hormonal factors, immunological status), level of exposure (sources, concentration, initiating events, routes, pathways), and adverse health effects (nature, severity, onset, reversibility).[5] The evaluation of whether an adverse effect will occur; an adverse effect is likely to occur in the natural environment only if exposure approaches or exceeds the levels associated with the adverse effects identified in the hazard assessment.[9]

Risk (human health) - the likelihood, or probability, that the toxic effects associated with a chemical will be produced in populations of individuals under their actual conditions of exposure. Risk is usually expressed as the probability of occurrence of an adverse effect, i.e., the expected ratio between the number of individuals that would experience an adverse effect in a given time, and the total number of individuals exposed to the factor. Risk is expressed as a fraction, without units, and takes values from 0 (absolute certainty that there is no risk, which can never be shown) to 1.0, where there is absolute certainty that a risk will occur.[8]

Risk Analysis - the process of risk assessment, risk management and risk communication. In addition to the scientific considerations involved in risk assessment, risk analysis includes consideration of such factors as risk acceptability, public perception of risk, socio-economic impacts, benefits and technical feasibility.[3] The process and techniques that are used to identify and evaluate the nature and magnitude of a risk, as well as methods to best use the resulting information. Risk analysis includes risk assessment, communication and management.[8]

Risk Assessment - a procedure designed to determine the qualitative aspects of hazard identification and usually a quantitative determination of the level of risk based on deterministic or probabilistic techniques.[3]

Risk Assessment (human health) - the process whereby all available scientific information is brought together to produce a description of the nature and magnitude of the risk associated with exposure of human receptors to an environmental chemical. The information includes: 1) risk characterization: an estimation of the risk and uncertainty in that risk; 2) toxicity assessment: an evaluation of the types of toxicity that the chemical can produce and an evaluation of the conditions of exposure - dose and duration - under which the chemical's toxicity can be produced; 3) identification of chemicals present in the environment; and 4) exposure assessment: an identification of the conditions - dose, timing and duration - under which the population whose risk is being evaluated is or could be exposed to the chemical.[8]

Risk-Based Approach - an approach based on a detailed evaluation of hazard and exposure potential at a particular site. Risk assessment is an important tool to use where, for example, national criteria do not exist for a contaminant, where cleanup to guideline-based levels are not feasible for the targeted land use, where guideline-based objectives do not seem appropriate give the site-specific exposure conditions, where significant or sensitive receptors of concern have been identified or where there is significant public concern, as determined by the lead agency.[9]

Risk Communication - the process of explaining the results of the risk assessment and the risk management decisions to concerned parties.[8]

Risk Estimation - estimation of the level of risk. It involves statistical analysis of toxicological and epidemiological data and of the level of human exposure. It examines the severity, extent and distribution of the effects of an event or activity and leads to a specific numerical point estimate or a range of values.[3]

Risk Management - the selection and implementation of a strategy of control of a risk, followed by monitoring and evaluation of the effectiveness of that strategy. Risk management may include direct remedial actions (e.g., removal, destruction, or containment of contaminants) or other strategies that reduce the probability, intensity, frequency or duration of exposure to contamination. The latter may include institutional controls such as zoning designations, land use restrictions or orders. The decision to select a particular strategy may involve considering the information obtained from a risk assessment. Implementation typically involves a commitment of resources and communication with affected parties. Monitoring and evaluation may include environmental sampling, post-remedial surveillance, protective epidemiology, and analysis of new health risk information, as well as ensuring compliance.

Risk Perception - an impression or intuitive judgement about the nature and magnitude of a risk. Perceptions of risk involve the judgements people make when they are asked to characterize and evaluate hazardous substances, activities and situations.[3] An integral part of risk evaluation. The subjective perception of the gravity or importance of the risk based on the subject's knowledge of different risks and the moral and political judgement of the risk's importance.[8]

S

Saturated Zone - the zone where voids in the soil or rock are filled with water at greater than atmospheric pressure. In an unconfined aquifer, the water table forms the upper boundary of the saturated zone.[2]

Screening - a rapid analysis to determine if further action (e.g., detailed analysis or cleanup) is warranted.[2]

Screening (Risk Assessment) - the process of filtering and removal of implausible or unlikely exposure pathways, chemicals or substances, or populations from the risk assessment process in order to focus the analysis on the chemicals, pathways and populations of greatest or probable concern.[8]

Sediment - fragmental soil material that originates from weathering of rocks and is transported or deposited by air, water or ice, or that accumulates by other processes, such as chemical precipitation from solution or secretion by organisms. The term is usually applied to material held in suspension in water or recently deposited from suspension and to all kinds of deposits, essentially of unconsolidated materials.[1]

Semi-Quantitative Risk Assessment - an analysis in which the results of risk assessment may be quantified but uncertainty surrounding these measures cannot be quantified. Because the magnitude of uncertainty is unknown, no explicit quantitative estimates are provided. A qualitative tabular summary of factors influencing risk estimates may be provided for determining possible bias in error and qualitative statements regarding the uncertainty are provided. The risk assessment is generally conducted using a data set of limited quality and size and no meaningful statistical analysis can be conducted. The majority of baseline risk assessments typically fall into this category. See Quantitative Risk Assessment and Qualitative Risk Assessment.[8]

Sludge - the solid residue resulting from a process that also produces liquid effluent.[2]

Soil Gas - the vapour or gas that is found in the unsaturated zone.[2]

Solvent - any substance that can dissolve another substance (e.g., petroleum hydrocarbons). Although water is a solvent, the term is often reserved for organic liquids.[2]

Standard - a legally-enforceable numerical limit or narrative statement, such as in a regulation, statute, contract or other legally-binding document, which has been adopted from a criterion or an objective.[6] The numerical limits or narrative statements, which are usually adopted from criteria or objectives, that are recognized in the enforceable environmental control laws of one or more levels of government. Standards may be specified in a regulation, statute, contract or any other legally-binding document.[7]

Surface Water - natural water bodies, such as rivers, streams, brooks and lakes, as well as artificial water courses, such as irrigation, industrial and navigational canals, in direct contact with the atmosphere.[1]

Synergistic Effect - an effect of two chemicals acting together that is greater than the simple sum of their effects when acting alone. See Addition Effect, Antagonistic Effect, Potentiation.[8]

T

Test Pit - a shallow pit, made using a backhoe, to characterize the subsurface.[2]

Tolerance - the ability of an organism to experience exposure to potentially-harmful amounts of a chemical without showing any adverse effect.[8]

Topography - the relief and form of the land.[2]

Toxic - adverse effect (such as reduced survival of a population, growth inhibition or reduced reproduction rates) which occurs in an organism, or population of organisms, due to exposure to a contaminant.[3]

Toxicity - the production of any type of damage, permanent or temporary, to the structure or functioning of any part of the body. The conditions of exposure under which toxic effects are produced - the size of the dose and the duration of the dosing needed, vary greatly among chemicals. See also Acute, Chronic and Subchronic Toxicity.[8]

Toxicology - the study of the adverse effects of chemicals on living organisms.[8]

Toxin - a potentially-toxic organic substance or chemical produced by a living organism.[8]

Trace (element) - any chemical (element) present in minute quantities in soil or water.[2]

U

Unconfined Aquifer - an aquifer that has a water table and is not bounded by an overlying layer of distinctly lower permeability.[2]

Unconsolidated Material - naturally-occurring geologic material that has not been lithified into cohesive rock.[2]

Unsaturated Zone - the area between the ground surface and the water table, including the root zone, intermediate zone and capillary fringe. Pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Also known as vadose zone or zone of aeration.[2]

Uptake - the process by which a chemical crosses an absorption barrier and is absorbed into the body.[8]

V

Volatile Organics/Volatile Organic Compounds (VOC) - liquid or solid organic compounds that tend to pass into the vapour state.[2]

Volatilization - the chemical process by which chemicals spontaneously convert from a liquid or solid state into a gas and then disperse into the air overlying contaminated soil.[3]

W

Water Table - the upper limit of the saturated zone. It is measured by installing wells that extend a few feet into the saturated zone and then recording the water level in those wells.[2]

Worst Case - a semi-quantitative term referring to the maximum possible exposure, dose or risk that can conceivably occur, whether or not this exposure, dose or risk actually occurs or is observed in a specific population. Historically, this term has been loosely defined in an *ad hoc* way in the literature, so assessors are cautioned to look for contextual definitions when encountering this term. It should refer to a hypothetical situation in which everything that can plausibly happen to maximize exposure, dose or risk does happen. This worst case may occur (or even be observed) in a given population, but since it is usually a very unlikely set of circumstances in most cases, a worst-case estimate will be somewhat higher than what occurs in a specific population. As in other fields, the worst-case scenario is a useful device when low probability events may result in a catastrophe that must be avoided even at great cost, but in most health risk assessments, a worst-case scenario is essentially a type of bounding estimate.[8]

The following is a list of reference sources from which glossary definitions were selected:

1 National Contaminated Sites Remediation Program Guidance Manual for Sampling, Analysis and Data Management, Volume 1: Sampling, Analysis and Data Management, p. 95.

2 Subsurface Assessment Handbook for Contaminated Sites, Waterloo Centre for Groundwater Research, Dec. 1992, p. 506.

3 A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines, CCME, 1996a.

4 Application of Recommended Whole Organism Bioassays in the Assessment of Contaminated Sites the Quality in Canada, Keddy et at., March 1995.

5 National Guidelines for Decommissioning Industrial Sites, CCME TS/WM-TRE013E, March 1991, p. 113.

6 Interim Canadian Environmental Quality Criteria for Contaminated Sites, CCME EPC-CS34, Sept. 1991, p. 25.

7 Recommended Procedures for Developing Site-Specific Environmental Quality Remediation Objectives for Contaminated Sites in Canada, Second Draft, CCME, May 1993, p. 188.

8 Human Health Risk Assessment of Chemicals from Contaminated Sites, Volume 1: Risk Assessment Guidance Manual, Contox Inc. & Golder Associates.

9 An Introduction to Ecological Risk Assessment Framework for Contaminated Sites in Canada, CCME, 1994.

APPENDIX B: PROVINCIAL/TERRITORIAL DEPARTMENTS OF THE ENVIRONMENT

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