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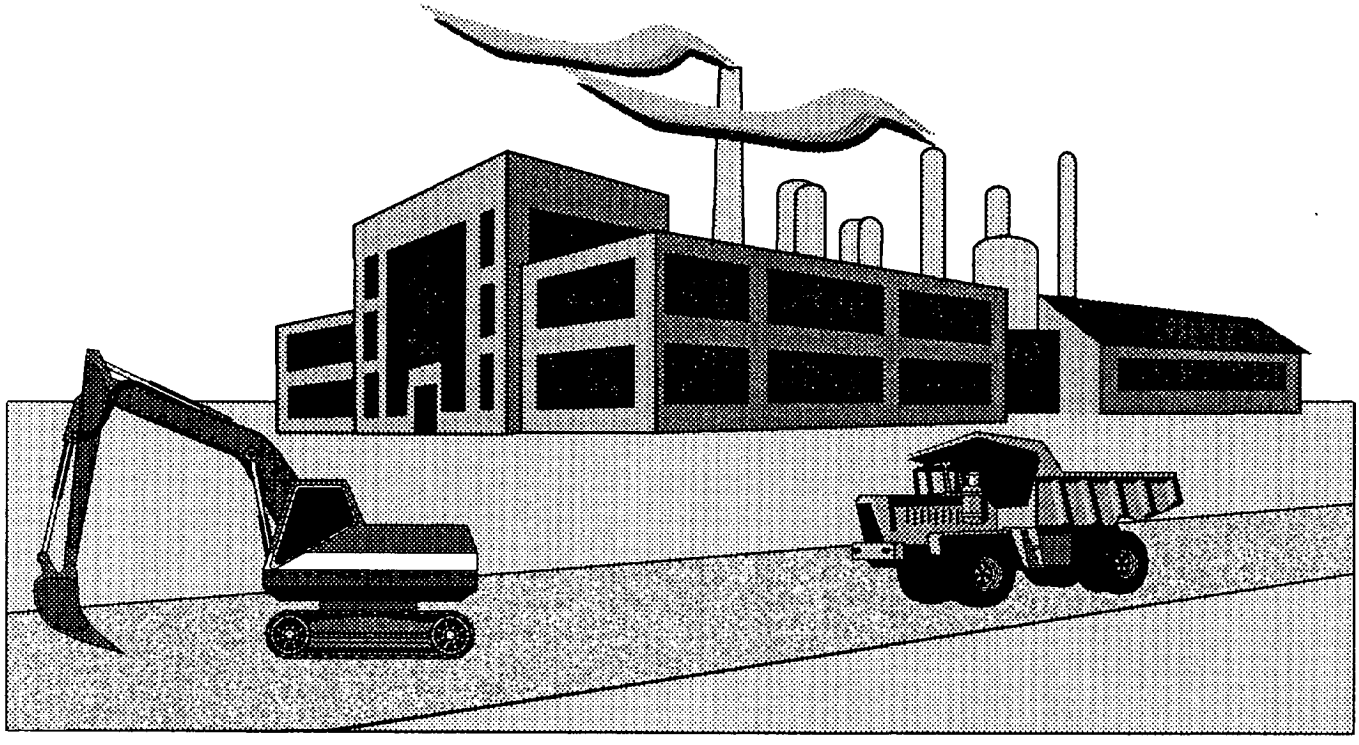
National Guidelines for Decommissioning Industrial Sites

CCME-TS/WM-TRE013E
March 1991



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National Guidelines for Decommissioning Industrial Sites

by

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for the

Decommissioning Steering Committee
Canadian Council of Ministers of the Environment

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Ottawa, Ontario
K1A 0H3

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CCME Secretariat
326 Broadway, Suite 400
Winnipeg, Manitoba
R3C 0S5

Abstract

Closure of industrial facilities because of economic considerations may result in reclamation of industrial lands to allow other uses. This report is about the decommissioning of industrial sites and the logical process of evaluation and guidelines that should be followed to eliminate environmental concerns and long-term liabilities.

Résumé

La fermeture d'installations industrielles pour des raisons économiques peut donner lieu à la remise en état de terrains industriels pour d'autres fins. Le présent rapport traite de la désaffectation des sites industriels et expose le processus logique d'évaluation et les lignes directrices qu'on devrait suivre pour éliminer les préoccupations et les obligations à long terme en matière d'environnement.

Table of Contents

Abstract v
Résumé vi
List of Figures ix
List of Tables x
Glossary xi

Section 1
Introduction 1
1.1 Background 1
1.2 Purpose of the Guidelines 1
1.3 Overview of Guidelines 2

Section 2
Legislation 4
2.1 Environmental Agencies 5

Section 3
Decommissioning Planning 7
3.1 Decommissioning Options 8
3.1.1 Facility Mothballing 8
3.1.2 Partial Decommissioning 9
3.1.3 Complete Facility Decommissioning 9
3.2 Minimum Acceptable Decommissioning Requirements 9
3.3 Project Management 9
3.4 Future Land Use 10
3.5 Government and Public Involvement 10

Section 4
The Phased Approach to Site Decommissioning 12
4.1 Phase I: Site Information Assessment 13
4.2 Phase II: Reconnaissance Testing Program 19
4.2.1 Program Staffing 20
4.2.2 Program Design and Review 20
4.2.3 Program Implementation 21
4.2.4 Data Interpretation 23
4.3 Phase III: Detailed Testing Program 24
4.3.1 Types of Samples 25
4.3.2 Sampling Procedures 26
4.3.3 Sampling Density and Location 27
4.3.4 Analytical Procedures 28
4.3.5 Data Interpretation 28

4.3.6 Finalization and Approval of Cleanup Criteria by Regulatory Agencies **29**
4.4 Phase IV: Preparation of Decommissioning and Cleanup Plans **29**
4.4.1 Cleanup Technologies and Disposal Options for Facilities and Sites **30**
4.4.2 Cleanup and Reclamation Research **30**
4.4.3 Development of Worker Occupational Health and Safety Plan **33**
4.4.4 Draft Cleanup Plan **34**
4.4.5 Review of the Plan by Regulatory Agencies and the Public **34**
4.4.6 Finalization and Approval of the Final Cleanup Plan **34**
4.5 Phase V: Implementation of Decommissioning and Cleanup Plans **35**
4.5.1 Preparation of Specifications and Tender Documents, Contractor Selection **35**
4.5.2 Worker Safety and Health Monitoring **36**
4.5.3 Construction of On-site Containment Facilities **36**
4.5.4 Handling of Wastewater and Surface Drainage **37**
4.5.5 Control of Fugitive Atmospheric Emissions **37**
4.5.6 Removal and Disposal of Materials and Residues **37**
4.5.7 Removal and Disposition of Process Equipment **37**
4.5.8 Cleaning and Dismantling of Buildings **37**
4.5.9 Removal of Buried Equipment and Services **38**
4.5.10 Excavation of Contaminated Soil and Sediments **38**
4.5.11 Reclamation Measures **38**
4.5.12 In-program Contaminant Monitoring **38**
4.6 Phase VI: Confirmatory Sampling and Completion Reporting **38**
4.6.1 Confirmatory Sampling of Soil, Groundwater, Surface Water, Air, and Remaining Structures **39**
4.6.2 Interpretation of Confirmatory Sampling Data **39**
4.6.3 Preparation of Completion Report **39**

Section 5
Development of Cleanup Criteria **41**
5.1 Introduction **41**
5.2 Preferred Approach **42**
5.2.1 Tier 1 Criteria Development **42**
5.2.2 Tier 2 Criteria Development **42**
5.3 Supplementary Conditions **48**
5.4 Roles of Other Factors and Interested Parties **48**

Section 6
Miscellaneous Considerations Relevant to Site Decommissioning Management 50
6.1 Introduction 50
6.2 Regulatory Agencies Approval of Decommissioning Completion 50
6.3 Long-term Monitoring 50
6.4 Liability 51
6.5 Future Controls of Land Use 51
6.5.1 Unrestricted Future Land Use 51
6.5.2 Defined Future Land Uses 51
6.5.3 Land Use Controls 51
6.5.4 Financial Provisions 52
6.6 Preventive Measures 52
6.6.1 Site Selection 52
6.6.2 Facility Design 52
6.6.3 Operating Procedures 53
6.6.4 Audits and Monitoring 53
6.6.5 Cleanup Response to Contamination 54

References 55

Appendix A
Sites Decommissioning Field Programs: General Considerations 57

Appendix B
Sample Occupational Health and Safety Plan 65

Appendix C
Summary of Guidelines for the Decommissioning and Cleanup of Sites in Ontario, February 1989 73

Appendix D
Summary of Contaminated Sites Rehabilitation Policy, Environment Quebec, February, 1988 77

Appendix E
Summary of Environmental Regulations in Canada 81

Appendix F
Review of Approaches Used to Establish Cleanup Guidelines in Various Jurisdictions 93

List of Figures

1 Overview of the Site Decommissioning and Cleanup Planning and Implementation Process 3

2 Decommissioning Planning 8

3 Phased Approach to Industrial Site Decommissioning and Cleanup 13

4 Phase I Site Information Assessment 15

5 Original Plant Setting 15

6 Current Plant Setting 16

7 Process Information 16

8 Site Inspections 17

9 Operations History 17

10 Regulatory Agency Concerns 18

11 Literature Review 18

12 Phase II: Reconnaissance Testing Program 21

13 Reconnaissance Testing Program Implementation 22

14 Phase II: Reconnaissance Testing Program Data Intepretation 24

15 Phase III: Detailed Testing Program 25

16 Phase IV: Preparation of Decommissioning and Cleanup Plan 31

17 Phase V: Implementation of Decommissioning and Cleanup Plan 35

18 Cleanup Guideline Development 43

List of Tables

1 Environmental Departments and Ministries Concerned with Decommissioning 6

2 Some Proven Cleanup Technologies and Disposal Options 32

3 Minimum, Maximum, and Mean Values for Soil Samples from Physiographic Regions of Canada 45

Glossary

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

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.

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.

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, 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.

Cleanup Guideline means specified concentrations for chemical substances or hazardous materials in various environmental media (soil, groundwater, surface water and air) for a specific land use that should not normally be exceeded by residual concentrations remaining after completion of cleanup. Residual concentrations exceeding the cleanup criteria will require further remedial action or on-going site monitoring.

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, welfare or the environment.

Contaminant is any chemical substance whose concentration exceeds background concentrations or which is not naturally occurring in the environment.

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.

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.

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.

Environment means waters, land, surface or subsurface strata, or ambient air of Canada.

Exposure is any contact with or ingestion, inhalation, or assimilation of a chemical substance or hazardous material.

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 or site-specific guidelines within a similar procedural context.

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

Industrial Site means any land and associated buildings, structures, pipelines, disposal sites, storage areas, production areas, resource extraction areas, 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.

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

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

Section 1

Introduction

1.1 Background

Economic considerations, and in many cases the increasing pressures of urban encroachment on industrial lands, may result in the closure of industrial facilities and the selling of lands for reuse. The process of closing, dismantling, remediation of contamination, and reclamation of the industrial lands to render the property suitable for another beneficial purpose is referred to as decommissioning.

The age of the facility, the nature of the industrial process(es), operational practices, and the waste management practices employed during the facility's operation may have resulted in the introduction of contaminants to site soils, sediments, air, surface water and groundwater. The concentration of contaminants deposited on or about an industrial site may pose a risk to human health and safety; if a different type of land use is permitted on the site prior to decontamination there may be a risk to the environment. It is also possible that the level of contaminant cleanup required for a particular land use may be economically unfeasible in the short term, but nevertheless necessary to eliminate environmental concerns and long-term liabilities.

When an industrial site or portion thereof, is to be closed down and decommissioned, the owners should commence a logical process of evaluation and decision making to provide a decommissioned site that is:

(1) not a risk to human health and safety;

(2) not the cause of unacceptable effects on the environment;

(3) in compliance with all applicable laws and regulations;

(4) suitable for the proposed new land use;

(5) not a liability to current and future owners; and

(6) aesthetically acceptable.

The decommissioning and cleanup of industrial sites is of increasing importance in Canada. The Waste Management Committee (WMC) of the Canadian Council of Ministers of the Environment (CCME) has determined that a national guideline, which incorporates the various steps in decommissioning and site cleanup, is required for the decommissioning of industrial sites in Canada. An important aspect of the guideline is the development of a method to determine site-specific cleanup criteria. CCME considers that the "polluter pays" principle is paramount in all site decommissioning and cleanup.

A Decommissioning Steering Committee (DSC) has been assigned the task of developing the guidelines. The DSC membership consists of representatives from the provinces of Alberta, Ontario, and Quebec; the Canadian Petroleum Association (CPA), the Canadian Chemical Producers Association (CCPA); and the Petroleum Association for Conservation of the Canadian Environment (PACE). The Committee is chaired by Environment Canada.

1.2 Purpose of the Guidelines

The objectives of the national decommissioning guidelines are to:

(1) provide an approach to decommissioning industrial facilities requiring that the public and environment be adequately protected;

(2) assist industry with planning and implementing the measures necessary to decommission a site; and

(3) provide regulatory agencies with a standard framework for assessing the completeness and applicability of decommissioning and reclamation plans proposed by industry.

The "National Guidelines for Decommissioning Industrial Sites" provide a logical step-by-step approach:

(1) to determine if environmental contaminants are present on an industrial property;

(2) to develop decommissioning and cleanup guidelines that are compatible with the intended future land use by eliminating human health concerns and mitigating environmental effects; and

(3) to also address safety and aesthetic factors which should be considered as part of decommissioning planning.

It is recommended in the guidelines that a site be cleaned up to a level which will provide long-term environmental protection and that will be safe for its intended future use.

1.3 Overview of Guidelines

The recommended decommissioning process is a phased approach that collects and assesses site-specific data. The site data are utilized in conjunction with site cleanup guidelines to ascertain the appropriate level of cleanup or remedial action. An overview of the decommissioning and cleanup process is shown schematically in Figure 1.

The phases for development and implementation of a decommissioning plan are:

Phase I: Site Information Assessment

Phase II: Reconnaissance Testing Program

Phase III: Detailed Testing Program

Phase IV: Preparation of Decommissioning and Cleanup Plans

Phase V: Implementation of Decommissioning and Cleanup

Phase VI: Confirmatory Sampling/Completion Reporting

The decommissioning and cleanup of contaminated industrial lands can be an extremely expensive process costing millions of dollars. Industry is encouraged to follow environmentally sound siting procedures for facilities and exemplary product and waste management practices during operation to prevent adverse effects on the environment, and to avoid excessive costs and liabilities at future decommissioning projects.

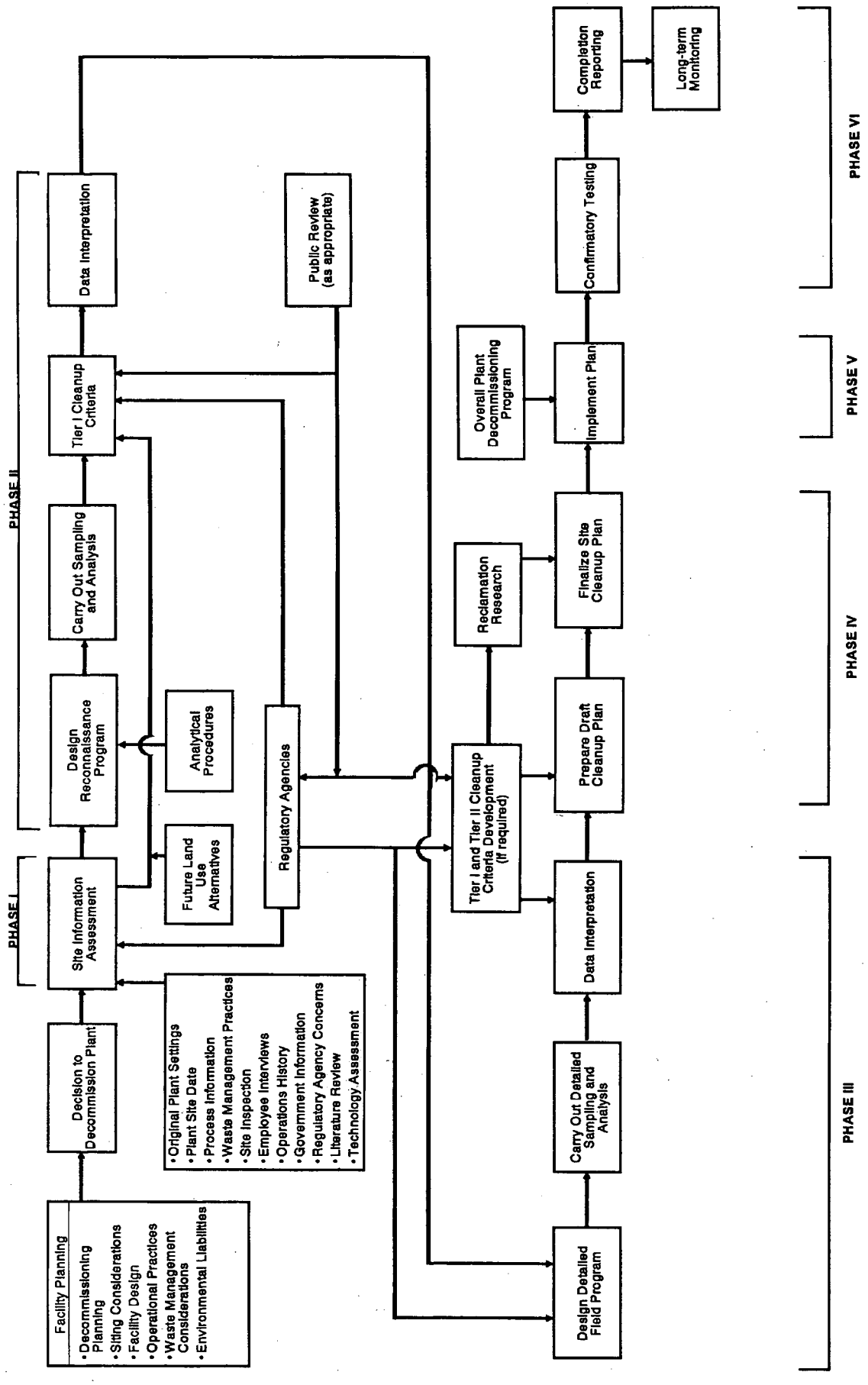

Figure 1 Overview of the Site Decommissioning and Cleanup Planning and Implementation Process

Section 2

Legislation

Apart from the increased awareness that contamination from industrial activities can have an adverse effect on human health and the environment, the impetus for industry to conduct adequate decommissioning and cleanup of a site can occur through environmental protection legislation.

The provinces are responsible for regulating the decommissioning and cleanup of industrial lands within their jurisdictions. The provincial Ministry of the Environment is usually responsible for implementing environmental legislation that may be used to regulate industrial decommissioning and cleanup.

Existing environmental legislation, if employed, can be used to impose severe limitations on the redevelopment or use of contaminated or unsafe industrial sites. This may result in onerous liabilities for the owner if the property is left in an uncontrolled and contaminated state. As of April 1989, however, only Ontario and Quebec have guidelines or policy specifically addressing the decommissioning and cleanup of generic industrial sites. In 1989, British Columbia promulgated cleanup guidelines specific to the Pacific Place site in Vancouver and recently, criteria for managing contaminated sites was proposed.

CCME has proposed interim guidelines for the cleanup of polyaromatic hydrocarbon (PAH) contamination at abandoned coal tar sites in Canada.

Municipalities may also restrict the redevelopment of industrial lands that are contaminated through control exercised over land use zoning and issuance of construction permits.

Most environmental legislation requires the owner of a contaminant that is discharged into the environment in an amount that is in excess of an operating permit or Certificate of Approval to notify the applicable regulatory agency, to stop the excessive contaminant discharge, and to clean up the environmental contamination. Generally, the regulatory agency has no way of knowing when contaminants are discharged illegally or accidentally into the environment if the owner does not report the contamination. Even legally-permitted contaminant discharges can result in substantial contaminant accumulation over the operating lifetime of an industrial facility depending on environmental sensitivity and contaminant depositional mode. Regardless of applicable environmental regulation, the onus is on industry to protect the environment through use of good raw materials, products, and waste management practices therefore minimizing liability for expensive contaminant cleanups at the decommissioning stage.

It is expected that "good corporate citizens" will take the necessary steps to adequately decommission and clean up old facilities while implementing the measures required to manage wastes and protect the environment at new and operating facilities. Nevertheless, it is realistic to recognize that some industries may not have financial resources (bankruptcy) to decommission a site, others may mothball a facility indefinitely to avoid decommissioning and cleanup costs, and some may simply abandon a site. Mechanisms must be examined and implemented by governments to insure the costs of environmental protection, decommissioning, and cleanup are applied equitably to all industry, not just those with

financial resources available at the time of decommissioning. Some steps could be taken to strengthen the "polluter pays" policy of the government. Potential financial mechanisms which could be examined include:

(a) a decommissioning and cleanup bond deposit with the government at the time of facility approval;

(b) an annual decommissioning and cleanup surcharge assessed against each industrial facility based on operating and waste management practices and gross revenues; and,

(c) an industrial sector specific decommissioning and cleanup contingency fund to which all industries in that sector contribute on an annual basis to address cleanups at bankrupt or abandoned sites.

There is an apparent need for all provinces, except Ontario and Quebec, to draft policy statements under existing environmental legislation to specifically address the requirements for industrial site decommissioning and cleanup. It is recommended that these policies as a minimum embody the philosophy and decommissioning goals outlined in the National Guidelines for Decommissioning Industrial Sites.

A summary of current environmental regulations in Canada and their relevance to industrial site decommissioning is provided in Appendix E.

2.1 Environmental Agencies

The decommissioning proponent is advised to contact the applicable regulatory agencies to obtain copies of pertinent regulations and guidelines and an interpretation with respect to specific decommissioning projects.

A list of addresses and telephone numbers of environmental departments and ministries concerned with decommissioning in Canada is found in Table 1.

The decommissioning proponent is encouraged to contact the local or regional office of the applicable regulatory agency(ies) and municipal planning authorities once a decision to decommission or clean up an industrial site has been made.

Table 1 Environmental Departments and Ministries Concerned with Decommissioning

Canada
Industrial Programs Branch
Environmental Protection Programs Directorate
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A 0H3
Phone: (819) 994-2493

Alberta
Wastes and Chemicals Division
Alberta Environment
5th Floor, Oxbridge Place
9820-106 Street
Edmonton, Alberta
T5K 2J6
Phone: (403) 427-5837

British Columbia
Ministry of the Environment
Waste Management Branch
810 Blanchard Street
Victoria, B.C.
V8V 1X5
Phone: (604) 387-4321

Manitoba
Department of Environment
Environmental Control Services
Building 2
139 Tuxedo Avenue
Winnipeg, Manitoba
R3N 0H6
Phone: (204) 945-7008

New Brunswick
Department of the Environment
Pollution Control Branch
Industrial Wastes Section
P.O. Box 6000
Fredericton, New Brunswick
E3B 5H1
Phone: (506)453-2861

Newfoundland
Department of the Environment and Lands
Pollution Control
Industrial Environmental Engineer Division
4th Floor, West Block
Confederation Building
St. John's Newfoundland
A1B 4J6
Phone: (709) 576-2555

Nova Scotia
Department of the Environment
Field Services Division
5151 Terminal Road
P.O. Box 2107
Halifax, Nova Scotia
B3J 3B7
Phone: (902) 424-5300

Ontario
Ministry of the Environment
Waste Management Branch
Industrial Waste Management Unit
40 St. Clair Avenue West
Toronto, Ontario
M4V 1P5
Phone: (416) 323-5211

Prince Edward Island
Department of the Environment
Environmental Protection Branch
Jones Building
11 Kent Street
P.O. Box 2000
Charlottetown, Prince Edward Island
C1A 7N8
Phone: (902) 368-5035

Québec
Ministère de l'Environnement
Direction des Communications
Siège Social
6ième étage
3900, rue Marly
Sainte-Foy (Québec)
G1X 4E4
Phone: (418) 643-8852

Saskatchewan
Department of the Environment
Land Protection Branch
Waste Management Section
3085 Albert Street
Regina, Saskatchewan
S4S 0B1
Phone: (306) 787-6533

Section 3

Decommissioning Planning

Decommissioning follows the decision to close an industrial facility, and is defined as the close down of operations; the removal of process equipment, buildings, and structures; and site cleanup and remediation. Decommissioning may apply to all or part of the facility. Decontamination may be required depending on target residual concentrations for chemicals of concern.

Most decommissioned industrial facilities require some level of cleanup which involves the removal, treatment (in-situ, on-site, or off-site) and disposal of materials having levels of contaminants that exceed the defined criteria (allowable residual contaminant concentrations) for chemicals of concern. The level of cleanup is frequently site-specific and dependent on the requirements of regulatory agencies and proposed future land use. The primary objective is to protect human health and safety and avoid adverse short- and long-term environmental effects.

It is important to begin decommissioning planning as early as possible in the operational stage of an industrial facility. Planning for decommissioning at the facility development stage will highlight the components of the facility that should be addressed, and help to identify operational procedures and waste management practices that can be introduced to prevent or reduce site contamination. An estimate of the financial resources needed to decommission the facility can be made, and financial planning initiated to set aside the necessary funds during the operational life of the facility.

In some provinces legislation requires certain industries (mines, quarries, waste management facilities) to submit decommissioning plans when application for an operating permit is made. It is suggested that this practice be extended to include as many industrial sectors as considered practical.

The objective of the planning exercise is to assess the options available for decommissioning and to provide a preliminary estimate of the work necessary and time frame required to provide a site that is suitable for the future intended land use. Following the decision to decommission a facility, the proponent must make a corporate commitment to provide the necessary organization and resources to manage the project. The major factors influencing a decision to decommission an industrial facility, and those that play a role in establishing the infrastructure required to implement a cleanup program, are shown in Figure 2.

The decision to decommission an industrial plant is often based on economic factors, and may be the result of an economic recession, market changes, depletion of plant feedstock, outdated process technology, or environmental concerns. In determining the future of an industrial facility, the owner should assess the economics of alternatives such as process or technology updating, improved environmental control facilities, new product development, and replacement of raw material source against the cost and implications of facility decommissioning. Increasingly today, because of urban expansion, older, heavy, or dirty industries are often considered to be incompatible with adjacent urban land use, and the industry is encouraged to relocate in order that the land may be redeveloped for commercial and residential purposes.

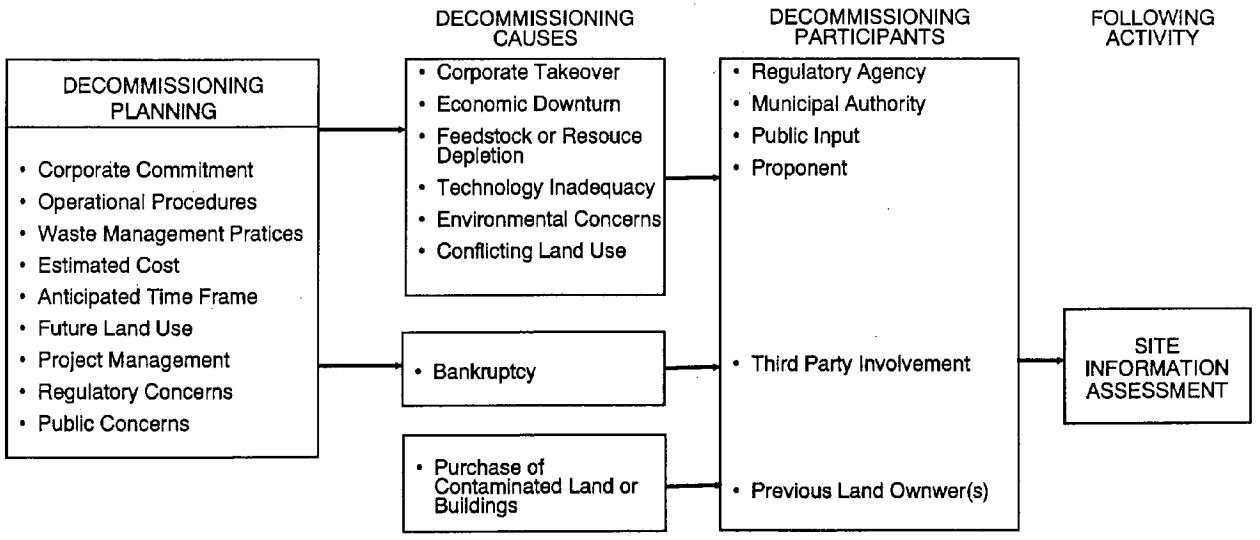

Figure 2 Decommissioning Planning

A decision to permanently shut down an industrial facility is normally made well in advance of actual closure. It is at this point that the decommissioning should commence in accordance with the corporate plan.

Bankruptcy because of severe economic conditions or other circumstances may result in the closure of an industrial facility. In this situation a third party, possibly the receiver or the government, may assume responsibility for decommissioning the site.

In some cases, improvements in soil remediation technology or proposed changes in current land use, may result in additional decommissioning and cleanup action. Decommissioning and cleanup may also be needed in cases where a new owner has purchased contaminated property. The decommissioning planning and implementation approach outlined in this guideline may also be applied to such sites.

3.1 Decommissioning Options

The decommissioning options that may be considered are: facility mothballing, partial site decommissioning and complete decommissioning of the site. Site abandonment is not acceptable as a decommissioning option.

3.1.1 Facility Mothballing

Mothballing is the closure of a facility with the implementation of measures to:

- maintain buildings, structures, and equipment in a state where deterioration is minimized and reuse is possible upon reactivation;
- access to the site is controlled;
- contamination on the site is stabilized, treated, and removed, or controlled as necessary to ensure compliance with applicable regulations; and
- site conditions are regularly monitored.

Mothballing of an industrial facility may be feasible if it can be determined that reactivation would be implemented in the foreseeable future. Mothballing should not be used to postpone the task of decommissioning.

3.1.2 Partial Decommissioning

Partial decommissioning may be applicable if only a portion of a site or facility is being shut

down. Depending on the proposed end land use for the closed portion of the facility, and possible effects from on-going operations on other operating portions of the site, it may be possible for a company to completely decommission, clean up and sell or redevelop the closed part. Alternatively, partial decommissioning may only involve a portion of the complete decommissioning process, until the entire facility can be closed and decommissioned. Partial decommissioning should involve many of the same principles and phases as applicable to a complete decommissioning.

3.1.3 Complete Facility Decommissioning

Complete decommissioning of an industrial facility involves application of the principles and phases described herein to the extent necessary to protect human health and safety, and minimize environmental effects appropriate for the proposed future beneficial land use. Decommissioning is a site-specific exercise.

3.2 Minimum Acceptable Decommissioning Requirements

The desirable approach to decommissioning is to provide for future beneficial land use by eliminating environmental and health concerns. The suggested minimum requirements for the decommissioning of an industrial site are:

(1) development of a decommissioning plan in conjunction with the applicable regulatory authorities and other interested parties;

(2) removal of all above ground and below ground structures that will not be used during future land use;

(3) removal, treatment, and disposal or secure isolation and/or treatment of contaminated materials, whether present on-site or off-site, to the extent necessary to ensure attainment and maintenance of the cleanup criteria;

(4) access controls for physical structures remaining on-site that are unsafe or hazardous to humans or animals;

(5) monitoring of contaminant containment, control or treatment systems remaining on-site;

(6) remediation of aesthetically unacceptable portions of the site (filling of pits, removal of stained soil and odorous materials, levelling of mounds, disposal of waste rock);

(7) cleanup of the site to a level which will provide long-term environmental protection and will be safe for the intended future use;

(8) registration on title to the property of any contaminants, wastes, or structures left on site that restrict future land use and/or that require periodic monitoring to ensure continued integrity; and

(9) submission to the applicable regulatory agency, and other required jurisdictions, of a report confirming that decommissioning and cleanup has been completed.

3.3 Project Management

To successfully decommission a facility, it is essential to plan and implement the program in a logical manner within the framework of an overall decommissioning master plan. The proponent should assign a capable project manager who has access to corporate policy and financial matters to ensure that appropriate resources are available in a timely manner.

Not all decommissioning and cleanup projects involve large facilities, but the rationale for managing the project is similar to that utilized in the design, construction, and commissioning of a new facility. The project must be organized to track time and material expenditures - a process best handled by a project management system.

Just as the design of the industrial facility was based on site- specific geological and geotechnical information, process design criteria, end product specifications and waste treatment/disposal standards, the design of the decommissioning and cleanup plan is based on operational and waste management practices, levels of contaminants in soils, sediments, groundwaters, etc., end land use and established cleanup criteria specific to the site.

3.4 Future Land Use

The proposed future land use for a decommissioned site, the sensitivity of the surrounding environment, and the complexity of contaminants identified will determine the level of effort and cost of cleanup required. In fact, on-site conditions may very well preclude certain future land uses due to economic feasibility or technology limitations. It is considered advisable for the proponent to discuss future land use alternatives and requirements with concerned parties (regulatory agency, municipality, and public) and assess site conditions and necessary remedial actions prior to committing to a specific future land use. In cases where on-site conditions after decommissioning and cleanup may represent short- or long-term liabilities for the owner, an assessment of the ability of the regulatory "system" to control future land use may be prudent.

Future land uses which may be considered for an industrial site and which could represent different site-specific levels of decommissioning and cleanup effort and resource commitment, include but are not limited to:

- operation of a new industrial facility within and utilizing existing buildings, structures, and lands;
- operation of industrial facilities in new buildings and structures;
- mixed industrial/commercial land use in existing or new buildings or structures;
- mixed commercial/residential land use in new buildings, or a combination of old and new buildings;
- reforestation or resource extraction;
- recreational land use;
- residential development of the lands; and
- agricultural land use.

3.5 Government and Public Involvement

The decommissioning of industrial sites and reuse of contaminated lands has become a major environmental issue in some parts of Canada. The public has become more aware through news reports and general environmental concerns of the effects of contamination on the environment and the quality of life. Government at all levels (federal, provincial, and municipal), therefore, have produced, or are planning, more stringent monitoring of activities related to the closure of industrial facilities and the redevelopment of the sites for other beneficial uses.

Involvement of the regulatory agency and municipality is essential from the time the decision to decommission is made since environmental regulation compliance and land use are controlled by these bodies. At the commencement of decommissioning planning, the decommissioning proponent and governmental authorities should discuss the level of public involvement required, and the phases at which public input would be most valuable to the decommissioning process. The establishment of a public information/participation program can be beneficial, particularly in urban or densely populated areas, and in some cases may be required (for example, where the site is to be rezoned). Transmission of the complexity of a site-specific decommissioning problem to

concerned parties in conjunction with remedial action alternatives, economic constraints, and technological limitations relative to various land use alternatives can facilitate approval of decommissioning plans and cleanup. Many delays in obtaining approvals result from both a failure of the proponent to communicate openly and a lack of public comprehension of the complexity, level of effort, options, and costs associated with a decommissioning project.

Section 4

The Phased Approach to Site Decommissioning

Decommissionings carried out over the past decade have shown that a phased approach applied to site assessment, cleanup, and reclamation is the most practical and cost-effective. Six phases of decommissioning plan development and implementation are possible to ensure that all factors relating to industrial site decommissioning are adequately considered. The level of effort to be expended in decommissioning is entirely site-specific depending on site size, industry operating and waste disposal practices, site contamination, and future land use. The decommissioning proponent should assess the components contained within each phase of the decommissioning program, and determine through information gathering and analysis, which tasks are required to decommission the facility; protect human health and safety and the environment; and obtain regulatory approval for the proposed beneficial future land use. If decommissioning involves cleanup of a contaminated site, the proponent should consider using individuals who are experienced in conducting this type of work.

The types of work and information gathered in each decommissioning phase are described briefly in the following sections; the results of each phase being built upon in subsequent phases. The phased approach is outlined in Figure 3.

The amount of work required to complete a particular decommissioning phase will depend on the past operational practices of the specific industry, whether a site is contaminated, the sensitivity of the local environment, and the complexity of the chemical contamination. Industrial facilities that commenced operation during an era when concerns about environmental effects and mitigative technologies were less developed than today may find contamination more prevalent on their sites. Most of these industries may have to conduct all decommissioning phases in detail at the time of facility closure.

Today, industry is expected to operate in an environmentally "clean" manner. Newer facilities that considered decommissioning requirements during the operational planning phase should have all the information regarding process operations, spill control and waste management practices readily available to implement decommissioning at plant closure. It is expected that facilities managed properly from an environmental viewpoint should be able to redevelop or return their sites to an unrestricted land use with minimum environmental cleanup. These industries may be able to progress directly from the site assessment phase to the implementation of decommissioning and site cleanup with minimal effort.

The detailed approach requiring all decommissioning phases is shown by the solid lines in Figure 3. The fast-track approach to decommissioning, which is more applicable to new or "clean" industrial facilities, is represented by the dashed lines in Figure 3. The preferred approach to the development of site cleanup is shown in Section 5.

Refer to Monenco, 1985; MENVIQ, 1988; and *Guidelines for the Decommissioning and Cleanup of Sites in Ontario*, Ontario Ministry of the Environment, 1989, for further information. In addition, decommissioning planning and implementation guidance can usually be obtained from provincial environment agencies and Environment Canada.

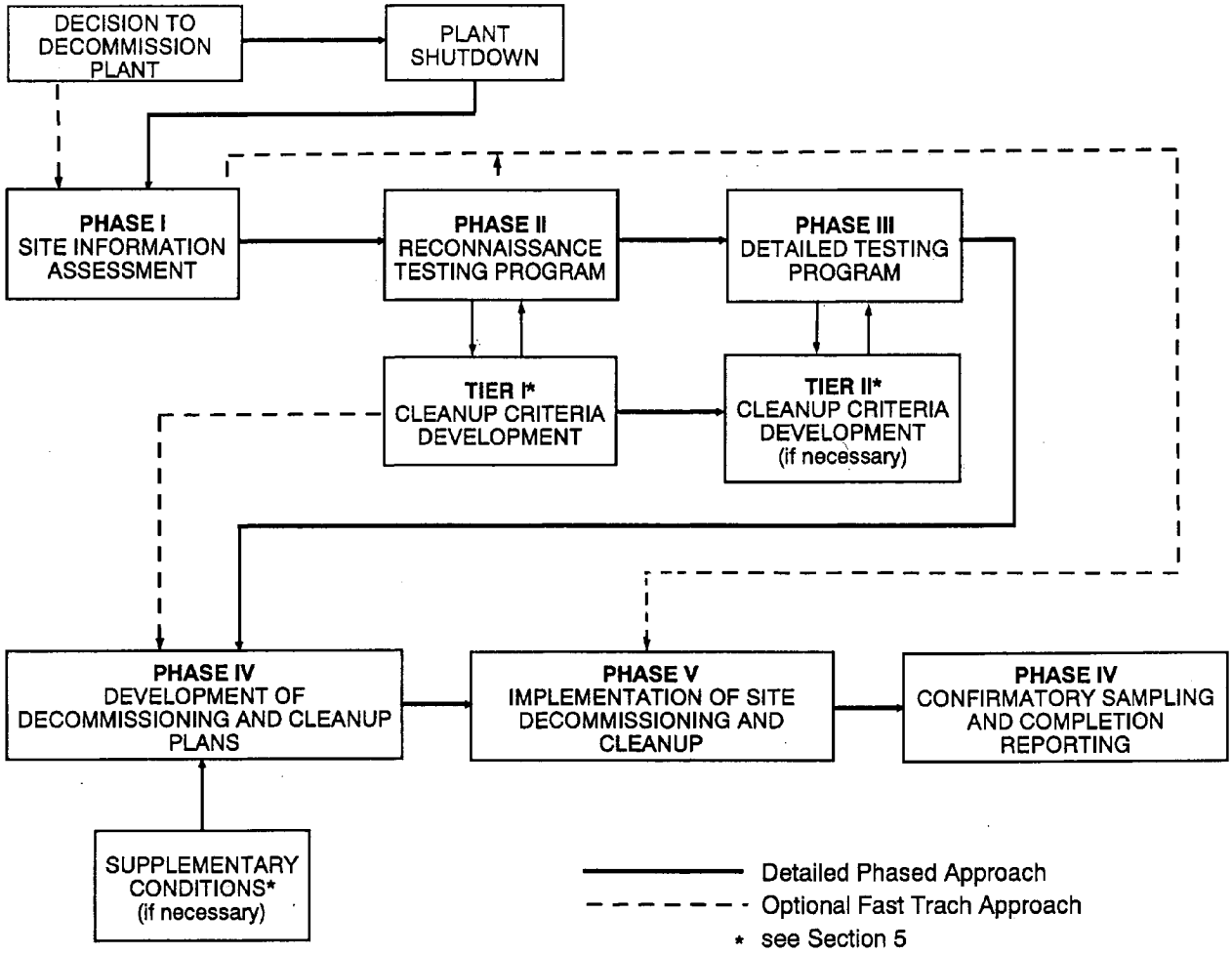

Figure 3 Phased Approach to Industrial Site Decommissioning and Cleanup

A number of industrial associations, such as:

- Petroleum Association for Conservation of the Canadian Environment (PACE);
- American Petroleum Institute;
- Canadian Petroleum Association;
- Canadian Chemical Producers Association;
- Chemical Manufacturers Association;
- Canadian Land Reclamation Association; and
- Mining Association of Canada.

may be able to provide decommissioning guidance to industries within those sectors of the economy.

4.1 PHASE I: Site Information Assessment

Phase I consists of a review of all available information relating to the industrial site. This work should commence as soon as possible after the decision to decommission has been made. The primary objective of Phase I is to assess if industrial practices on the site may have resulted in environmental contamination or unsafe conditions. If the site was used by others prior to the present industrial facility being decommissioned, it is also important to review the practices of these former site occupants.

During Phase I, consideration should also be given to components of the facility's operations that may be required during the implementation of decommissioning (e.g., site security, offices, waste treatment facility,

monitoring) to ensure necessary operations are not prematurely terminated. Phase I should also assess whether any portions of the site require immediate interim actions to ensure human health and safety are protected, and to prevent the spread of contamination in the environment. Any interim remedial actions taken should be consistent with the long-term decommissioning plans for the site.

The Phase I site information assessment should include the gathering and review of information relating to the following:

- original plant setting,
- current plant setting,
- process information,
- site inspection,
- operations and waste disposal history,
- regulatory agency concerns, and
- literature review.

The schematics in Figures 4, 5, 6, 7, 8, 9, 10 and 11 indicate some factors which should be addressed during each component of the site information assessment. Sources of information which should be examined during Phase I include:

- previous assessments completed for the property such as: environmental impact statements, baseline surveys, and well drilling and geotechnical reports for the property, including borehole logs;
- geological, hydrogeological, soils and biological reports or surveys;
- aerial photographs;
- topographic maps and site drainage plans; including areas of fill or water course realignment;
- water quality records for surface water and groundwater;
- site climatological data (e.g., prevailing winds);
- interviews with current and former employees, as well as individuals who live in the plant area;
- plant construction plans, specifications and drawings;
- piping schematics and plans;
- drawings and inventories of raw materials, product and fuel storage areas, and areas of off loading and loading;
- specifications for waste storage, treatment, and disposal areas, as well as operational and monitoring data, including those areas used "one time" or in emergency situations;
- history of any environmental accidents or spills on-site;
- process flow diagrams, operation practices, raw material feedstock requirements, and waste handling and disposal practices;
- diagrams of any underground utilities, structures, piping, workings, injection wells or storage tanks, and their operational history;
- laboratory operational practices, chemicals used and waste handling and disposal methods;
- operation and maintenance procedures for all components of the facility, and materials utilized;
- information relating to electrical transformers and capacitors, electromagnets and other equipment that may have dielectric fluids containing PCBs;
- pest and weed control practices used on site, including types of chemicals used, application area, and disposal practices;

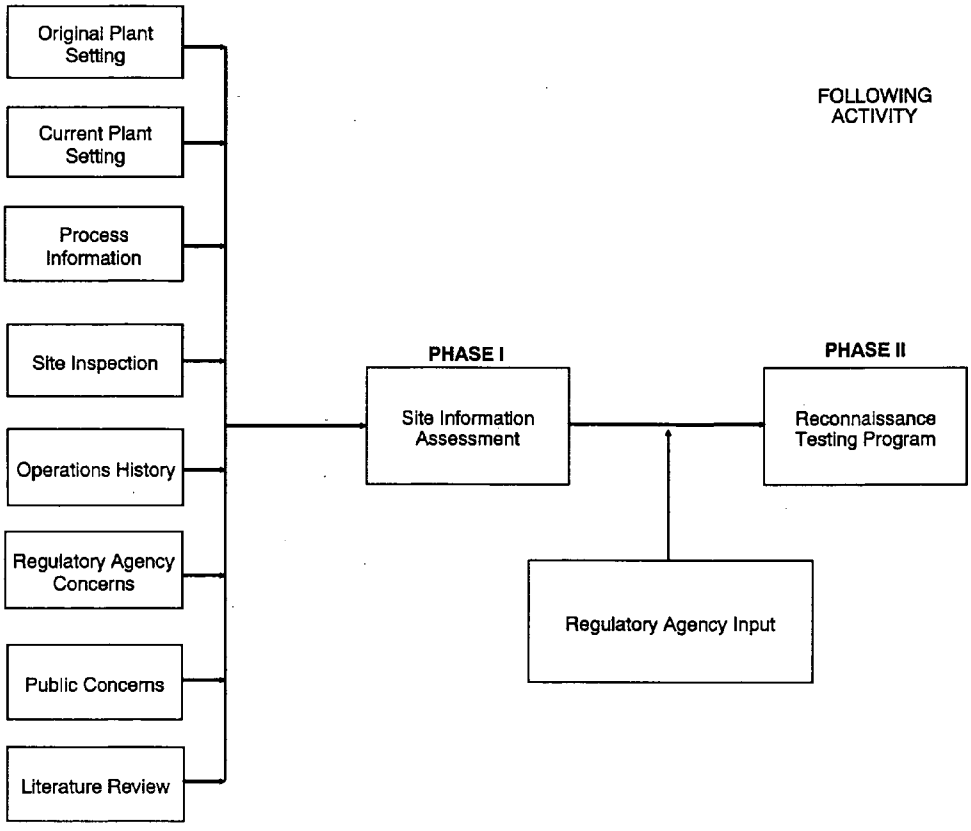

Figure 4 PHASE I Site Information Assessment

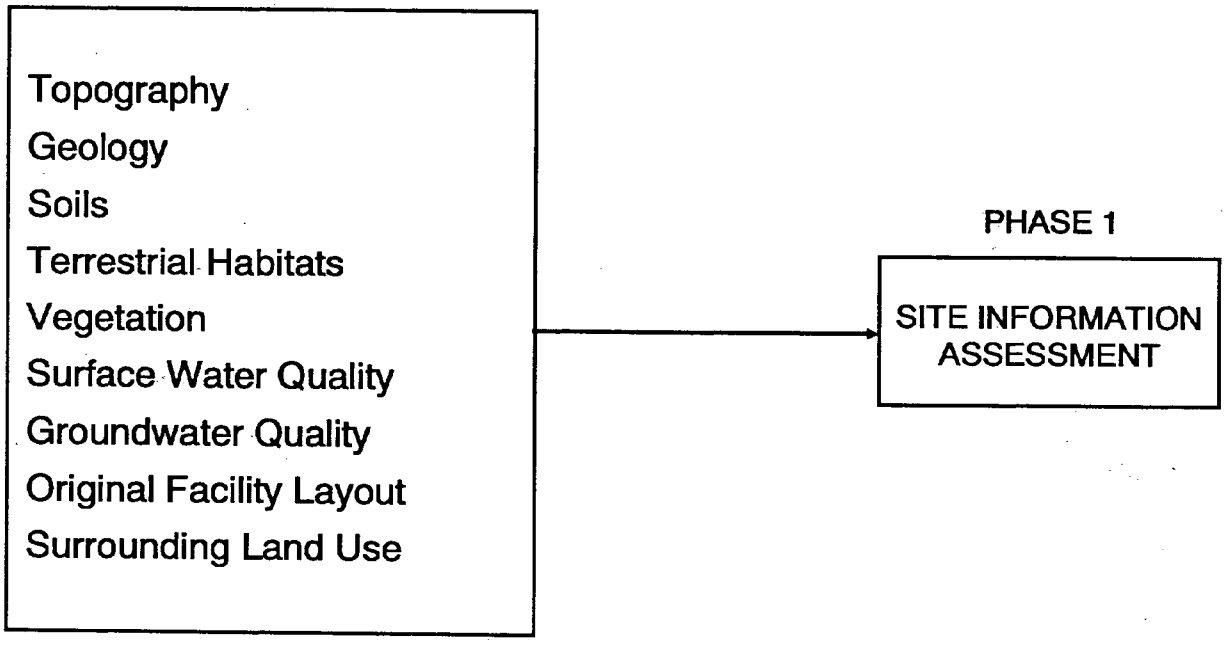

Figure 5 Original Plant Setting

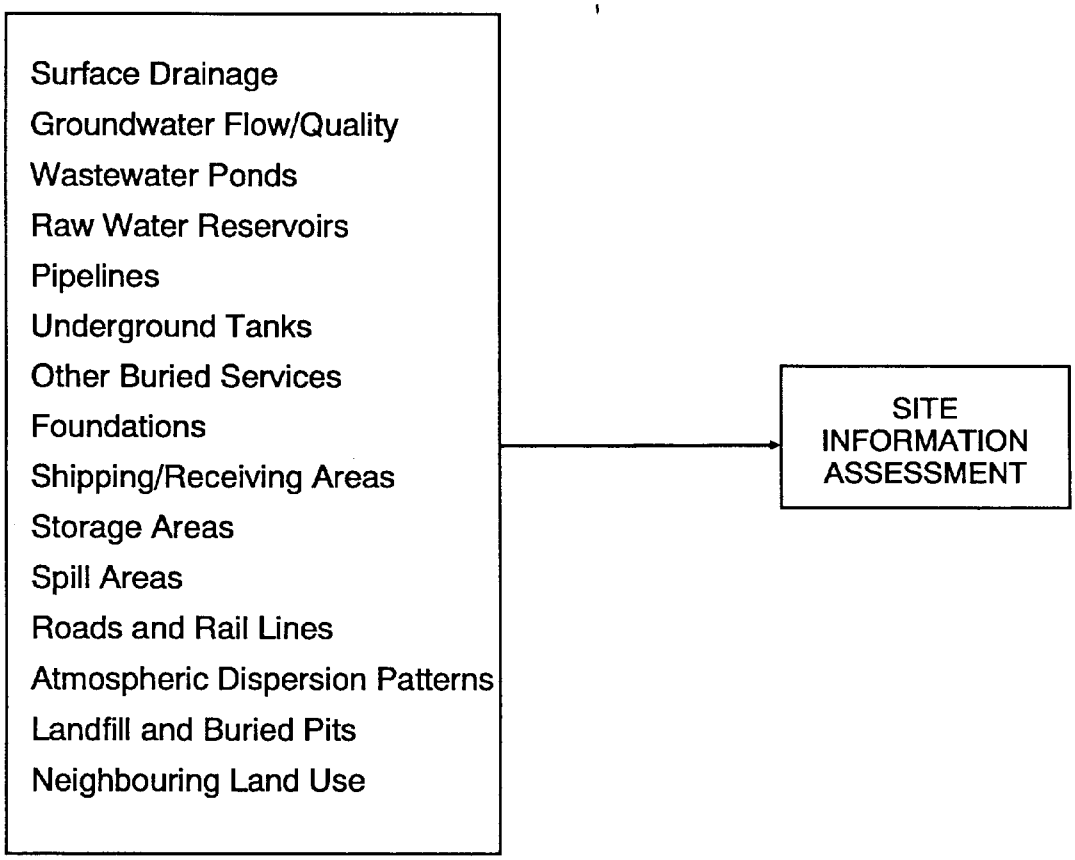

Figure 6 Current Plant Setting

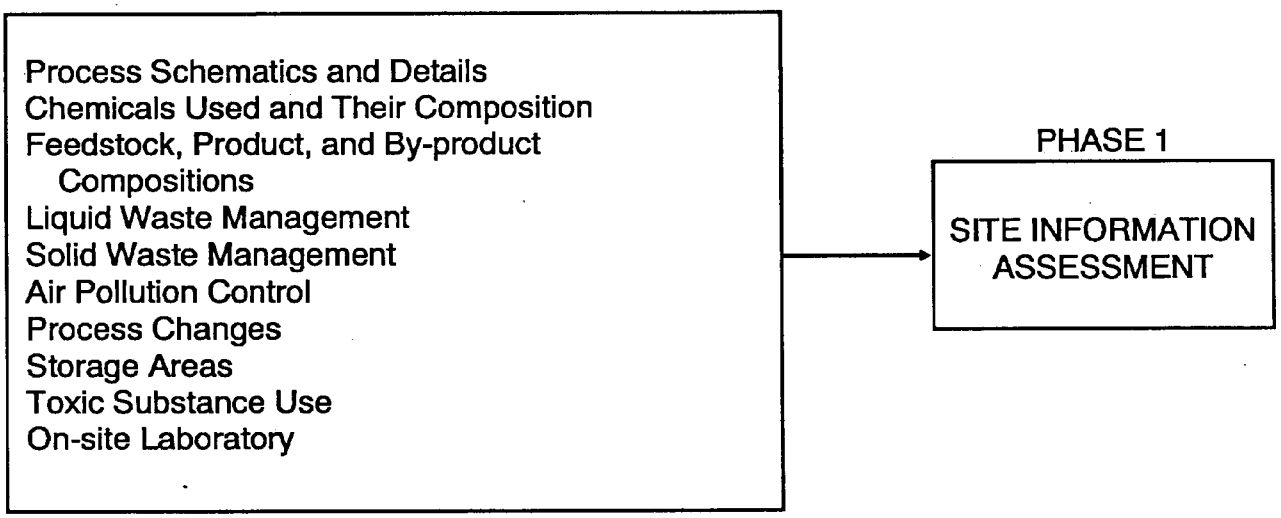

Figure 7 Process Information

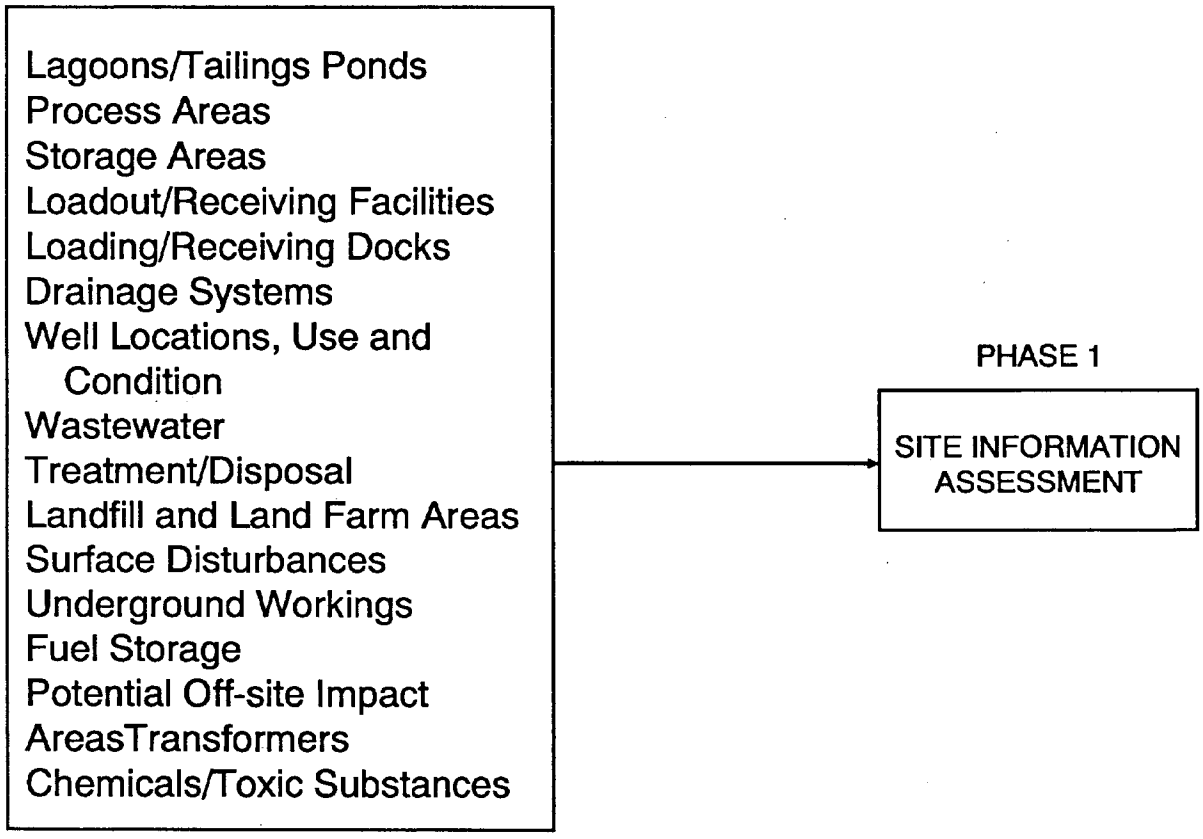

Figure 8 **Site Inspections**

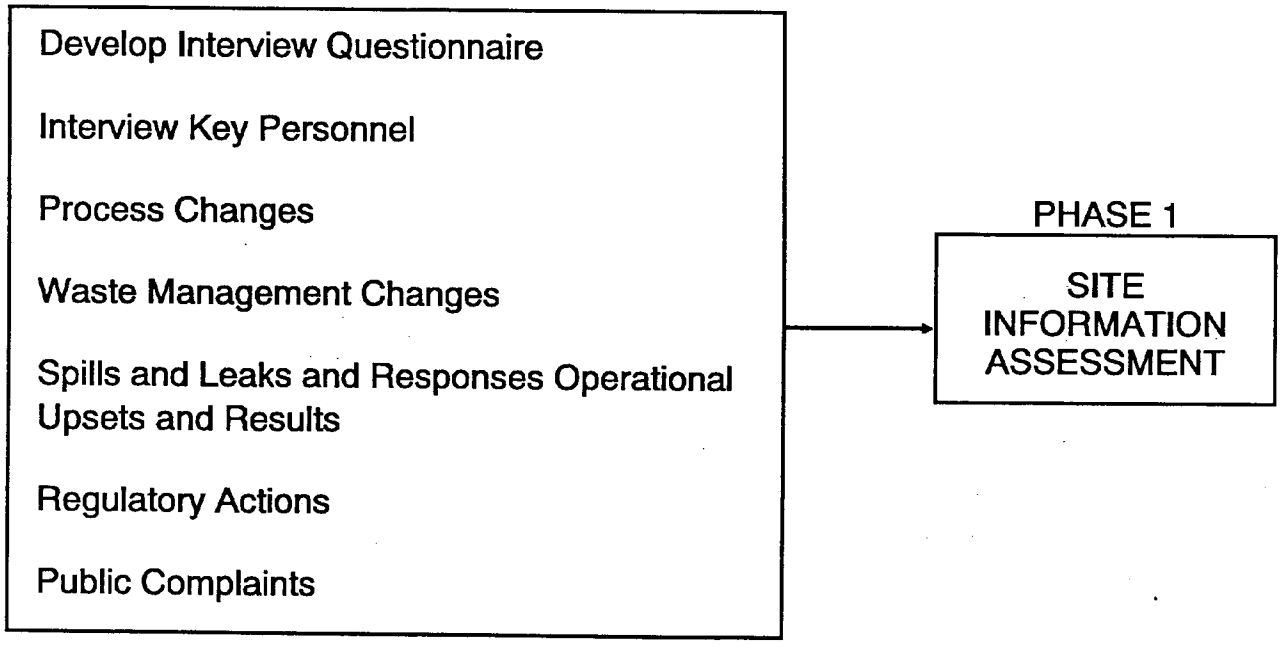

Figure 9 **Operations History**

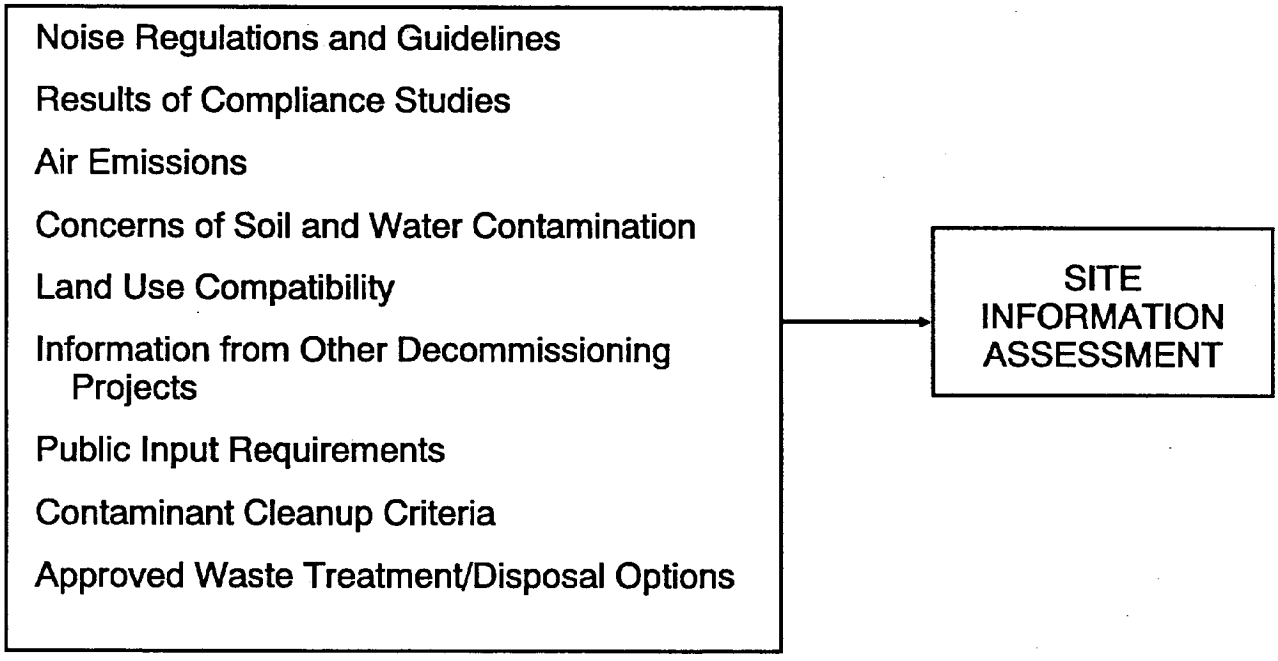

Figure 10 Regulatory Agency Concerns

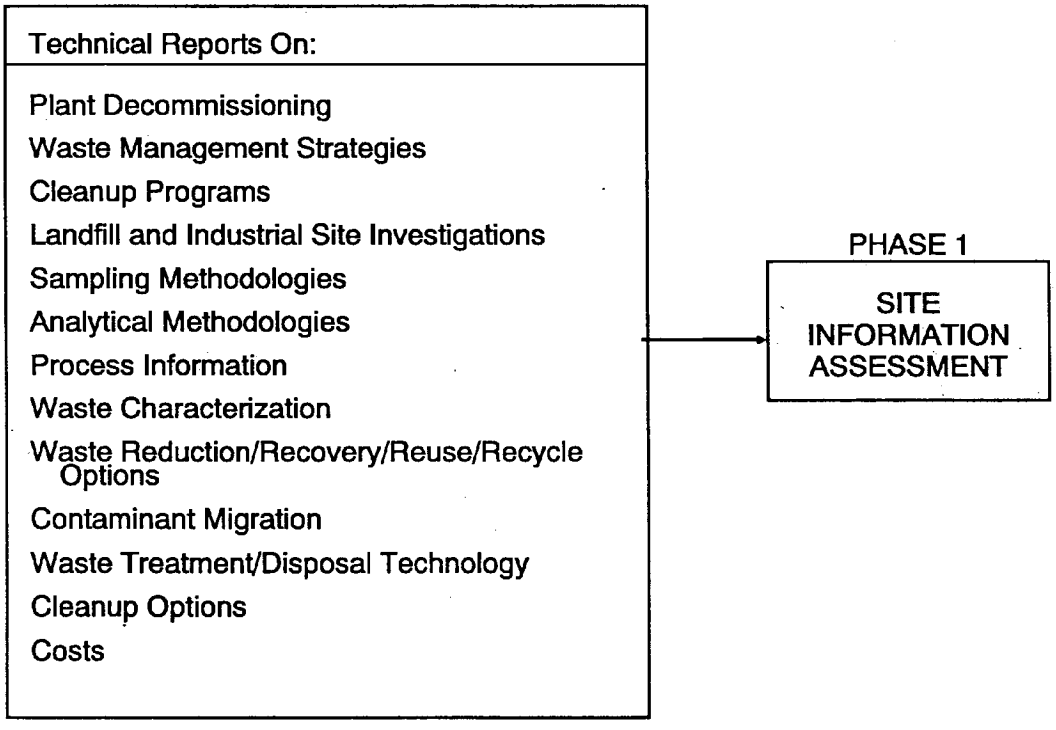

Figure 11 Literature Review

- a physical inspection of the site by trained specialists;
- public concerns the proponent is aware of relating to any site cleanup and future land use;
- literature review of previous decommissioning projects in similar industrial settings; and
- pertinent regulations promulgated by regulatory agencies responsible for environment, health, labour and natural resources, as well as municipal bylaws that may be applicable to site decommissioning.

A site information assessment report prepared from the information review may be submitted to the applicable regulatory agency, and contain the following:

- a description of the site and surroundings, its facilities, operational history and waste disposal facilities;
- potential problem areas, and contaminants of concern;
- health and safety considerations;
- areas requiring immediate remediation and proposed interim actions;
- proposed site assessment investigations;
- adjacent land use, and proposed future beneficial land use options for the site;
- plans for a public information program; and
- a preliminary decommissioning schedule.

The information assessment report should contain appropriate maps, figures, and schematics to adequately describe the location of the site and its current known status. At this point it would be beneficial to have initial discussions with the applicable regulatory agency(ies) to insure regulatory agreement with proposed subsequent actions, and to assess the need for public participation.

4.2 PHASE II: Reconnaissance Testing Program

The Phase II or Reconnaissance Testing Program will characterize the types and concentrations of contaminants present in various media on the site. This information will indicate whether more detailed testing is required in specific areas, and provide the initial inputs required to develop appropriate site cleanup criteria. The reconnaissance testing should target known and suspected areas of site contamination identified in Phase II, as well as areas believed to be relatively unaffected by site operations. In cases where contamination is suspected near site boundaries, or is known to have moved off-site (such as aeolian, groundwater, or surface water transport) samples should also be collected in these areas to assess off-site effects, potential liabilities, and remediation requirements.

Structures (such as buildings, towers, tanks, pits, mine workings, landfills, lagoons, ponds, etc.) and wastes for which treatment or removal may not seem feasible should also be investigated in the reconnaissance testing program. These must be further assessed to ensure isolation from environmental interaction, and protection of human health and safety with respect to the proposed future beneficial land use.

Investigations on an industrial site can be dangerous to project personnel; therefore, it is recommended that all site work be co-ordinated with an industrial representative who is familiar with site operations, and the types of materials handled, produced and disposed of on-site.

The main objectives of the reconnaissance testing program are:

- to identify types of contaminants, range of contaminant concentrations and general locations of contaminant problems;

- to clarify soil, geological, hydrogeologic, and hydrological conditions of the site and surrounding area;
- to determine background concentrations of chemical contaminants in all media (soil, subsurface materials, surface water, groundwater, and air);
- to investigate structures on site which due to their physical dimensions cannot be removed, but require specific remedial measures to make the site safe for future beneficial land use;
- to identify structures, process or manufacturing equipment which requires decontamination prior to reuse, removal and disposal; and,
- to identify the preliminary Tier 1 cleanup criteria that may be applied to the site decommissioning.

4.2.1 Program Staffing

Individuals who are experienced in assessing and analyzing contaminant problems, as well as specialists familiar with the operations of the industrial sector, are required to design and implement the field program. Amongst others, fields of expertise may include:

- contaminant hydrogeology and geology;
- air pollution control;
- environmental engineering and waste management;
- geotechnical and civil engineering;
- soil science;
- process engineering and organic chemistry;
- analytical chemistry;
- instrumentation and control technology;
- occupational health and safety, and industrial hygiene;
- medicine and toxicology; and
- aquatic and terrestrial biology.

The organization and components of the reconnaissance testing program are shown schematically in Figure 12. General considerations regarding the various components of the program including types of samples, methodology, quality assurance/quality control, and data analysis are provided in Appendix A.

4.2.2 Program Design and Review

The proposed reconnaissance testing program should be presented to key plant personnel to ensure completeness and feasibility. Proposed sampling sites should be staked and locations should be reviewed by plant personnel who are knowledgeable of historical site operations and the location of underground services. If the plant is still operating and underground services are 'live', each sampling site where excavation or drilling will take place should be inspected and approved by plant personnel. It may be necessary to undertake an investigation to precisely locate 'live' underground services. At this point, the proposed health and safety program should be reviewed with plant personnel, and all sampling protocols firmly established.

The proposed program should also be presented to the regulatory agency for review. If a public information program is deemed necessary, it may be advisable to seek public input through a public liaison committee. Suggested modifications should be incorporated to ensure that all relevant regulatory, and/or public concerns are adequately addressed.

The need for regulatory and/or public review will depend on the type of industry, size of site, site location, type of contamination expected, and proposed future land use. For example, a large remote site would require regulatory review but may not be of public interest. A major industrial site being

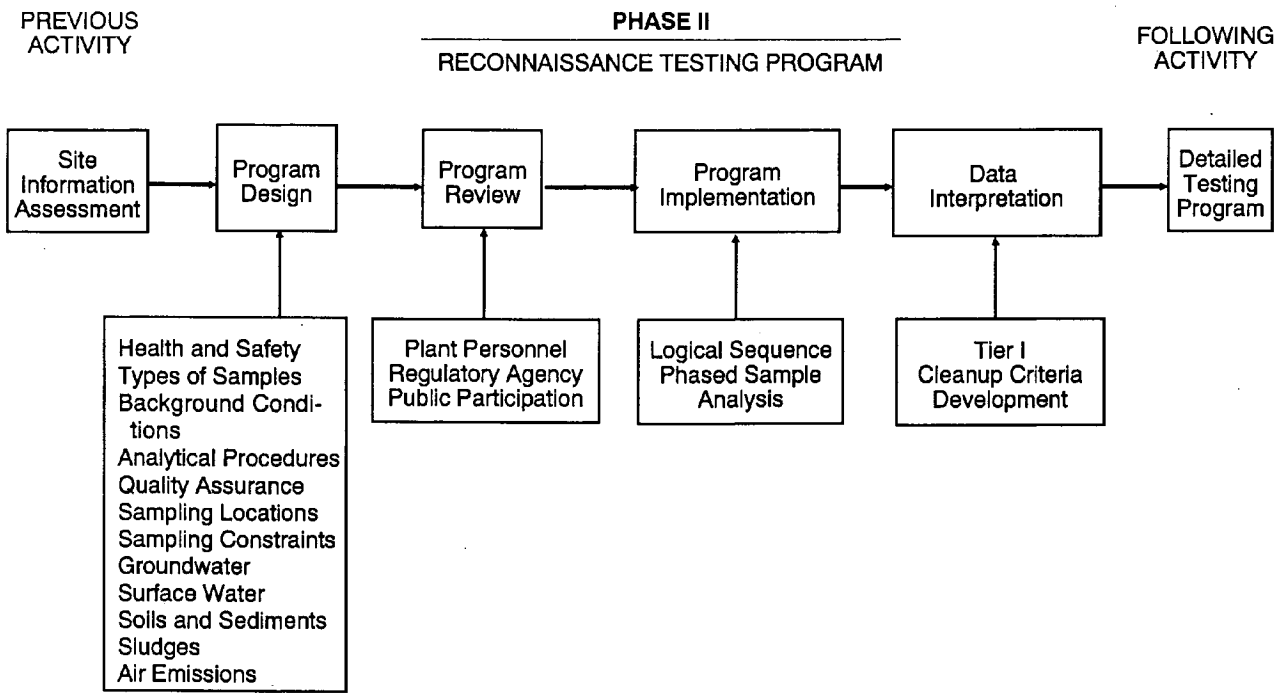

Figure 12 PHASE II: Reconnaissance Testing Program

decommissioned in an urban area will probably require regulatory, municipal, and public input, particularly if the proposed future use is for residential development. In contrast, a small local relatively clean industry or corner service station, may only require notification to the regulatory agency and municipality to decommission the site and reuse the land for another purpose. When in doubt as to the required notification process, it is advisable to contact the local environmental agency and/or municipality.

4.2.3 Program Implementation

Just as the site information assessment and reconnaissance testing program design were carried out by experienced personnel, the field component of the reconnaissance testing program should also be carried out by an experienced team. The judgment of the field team is an essential part of the assessment of site conditions (logging of boreholes, visual observations, etc.), of the siting and installation of piezometers and of the selection of samples to be analyzed. Also, as new information will be obtained from virtually each borehole drilled or test pit excavated, it will be necessary to fine tune and make modifications to the reconnaissance program as it is being carried out. It is suggested that personnel involved in the site information assessment and reconnaissance testing program design 'overlap' into the field program to ensure continuity.

Key items for successfully carrying out a complete reconnaissance testing program are shown in Figure 13. There are a variety of ways to execute the reconnaissance sampling program; however, a suggested sequence is as follows:

- establish on-site field office if site program warrants;
- provide for storage of samples;
- review program health and safety concerns with plant personnel;

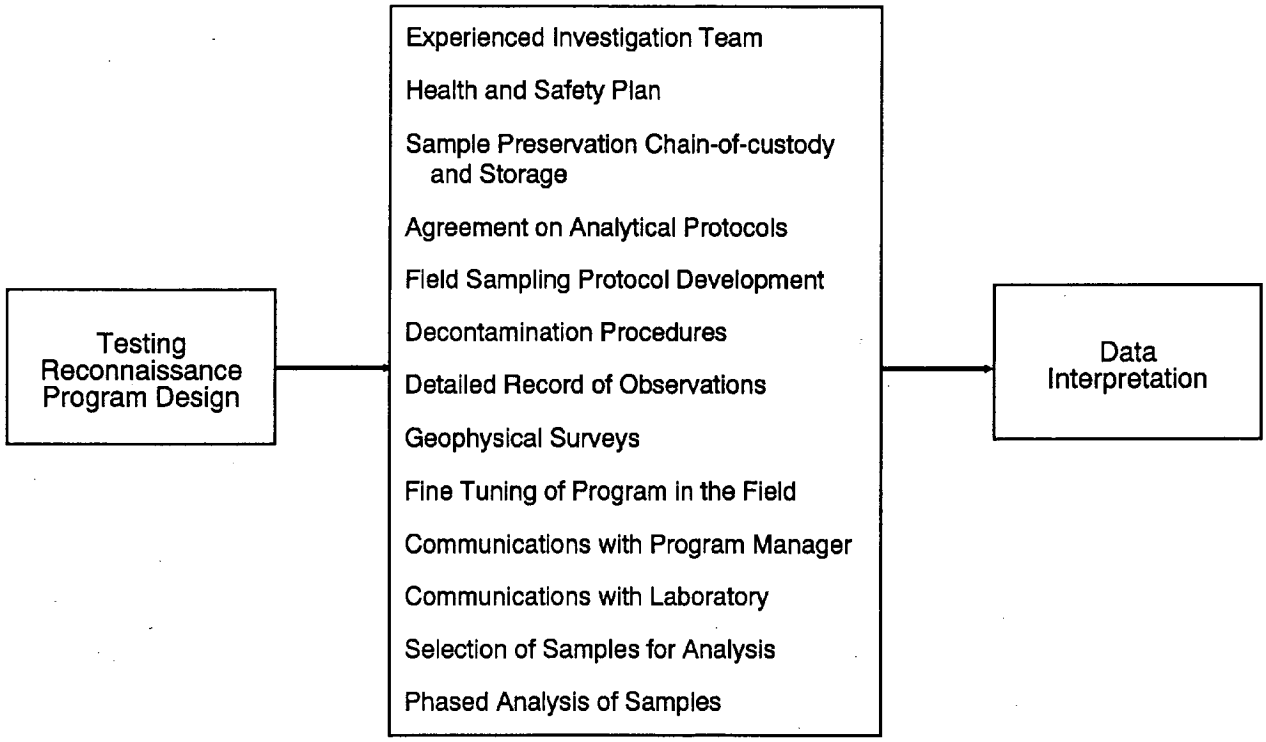

Figure 13 Reconnaissance Testing Program Implementation

- sample feedstocks, products, by-products, and chemicals and immediately transport to the laboratory for analysis; the results of these analyses may affect future analytical programs;
- sample background soils, overburden, and sediments and install background piezometers; transport contaminated or hazardous materials in accordance with applicable regulations;
- conduct on-site geophysical surveys as appropriate (earth conductivity), ground penetrating radar (GPR), magnetometer, etc.);
- initiate drilling of boreholes for hydrogeology study and commence installation of piezometers; deeper boreholes should be drilled first to increase knowledge of the site; caution must be exercised to prevent migration of contaminants to other zones through boreholes;
- commence soil sampling (boreholes, test pits, and hand augers);
- collect sediment samples and miscellaneous samples from drains, gutters, sumps, vessels, treatment facilities, and transformers;
- develop (pump or evacuate) piezometers and commence testing (field permeability, water level measurements, etc.);
- sample piezometers for chemical analysis;
- survey all sampling locations; and
- inspect all structures that may require stabilization, removal, decontamination, or other remediation to ensure the site is safe for the future proposed land use.

The reconnaissance team should maintain constant communication with the decommissioning program manager to report on progress and identify program changes as a result of information gained while sampling.

Management of significant numbers of samples can become a problem. To overcome this problem, constant communication with the laboratory is necessary, as well as a well-organized sample storage and transportation system, and a detailed sample chain of the custody system. If possible, a computer terminal in the field (linked to the laboratory) will expedite sample descriptions and analytical requests to the laboratory, particularly for larger or remote sites.

To meet the objectives of the reconnaissance testing program it is prudent to undertake the analysis of samples in phases. The locations and number of samples required must be determined from the site information assessment and are site-specific. For a marginal increase in sampling costs, additional samples can be collected and stored. If further information is required to characterize the types of contaminants, range in concentrations, or general boundaries of contaminated areas, these samples would be taken out of storage for analysis (these samples may also be used in subsequent analytical programs). It is particularly important when using phased sample analysis programs to ensure that samples can be properly preserved and stored to maintain contaminant concentration accuracy.

4.2.4 Data Interpretation

The results of the Phase II or reconnaissance testing program should be analyzed, (Figure 14), and the data presented in a report which:

- provides a review of quality control procedures for accuracy and precision;
- identifies the physiological, climatological, geologic, and hydrogeological setting of the plant site and surrounding area;
- identifies possible pathways of contaminant movement and potential receptors and exposure points;
- identifies types and concentrations of contaminants in soils, overburden, sediments, atmosphere, surface water and groundwaters on and adjacent to the site;
- compares chemical data with Tier 1 cleanup criteria consisting of background concentrations and other established guidelines and criteria;
- identifies structures and areas of filling, mining, and excavating that require remediation to ensure the site is safe for the intended new land use; and
- recommends additional work, if necessary, for further sampling and analyses (detailed field program), research requirements for site cleanup and reclamation, and/or long-term monitoring requirements.

The completion of the reconnaissance testing program is a decision-making point determining the subsequent appropriate level of action:

- contamination is not present on the site at a level above Tier I cleanup criteria, probably represents no risk to public health and safety, and the environment, and sufficient information is available to proceed with the development of a decommissioning plan;
- chemical contamination is present on the site in concentrations exceeding Tier 1 criteria, but not at levels considered to pose an immediate threat to human health and safety and the environment; further assessment may be required to determine health risks and environmental effects;
- chemical contamination is detected on site for which no Tier 1 cleanup criteria are available; further work is required to develop appropriate cleanup criteria using a Tier 2 approach (see Section 5); and
- chemical contamination and/or facilities and/or structures are present on site which

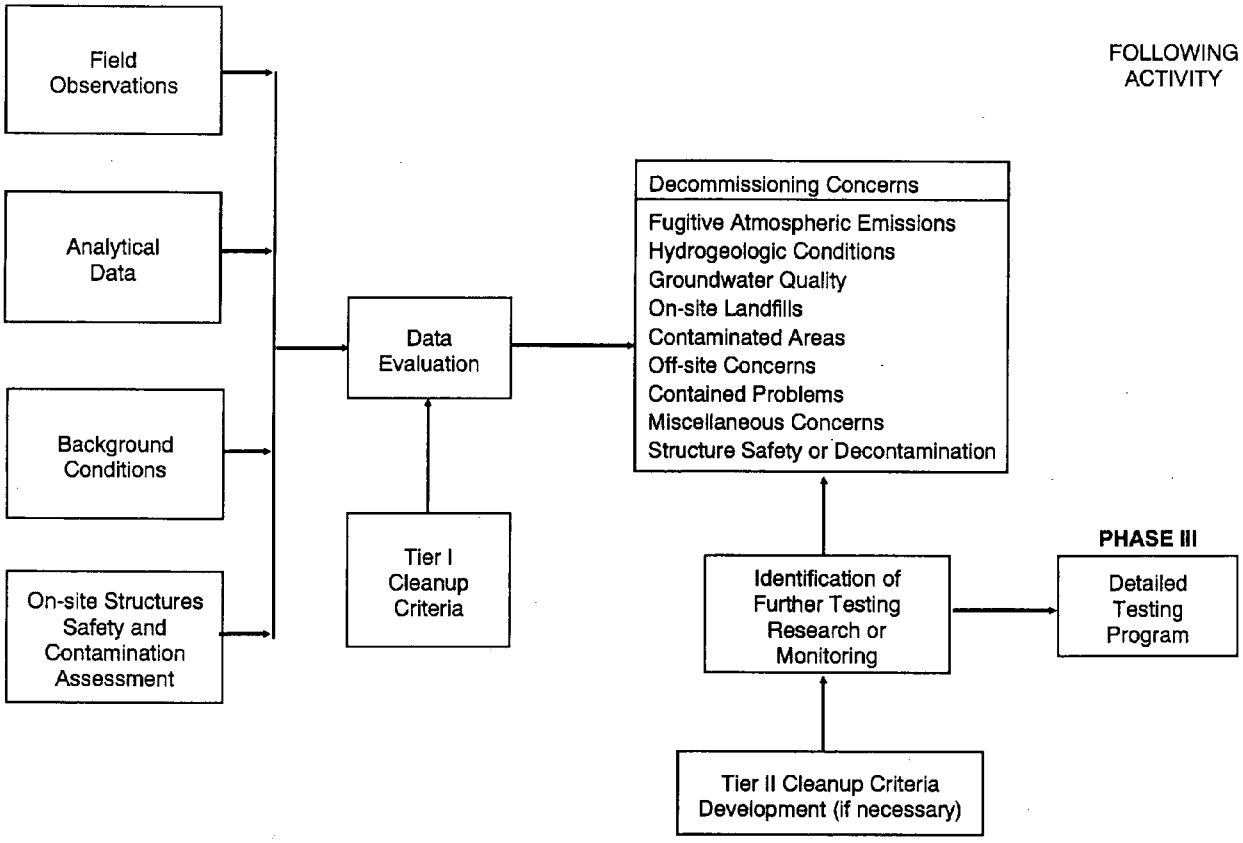

Figure 14 PHASE II: Reconnaissance Testing Program Data Interpretation

pose an imminent danger to human health and safety and the environment; short-term interim actions are required to stop, prevent, control, and remove contaminants and/or to stabilize or make on-site structures safe; immediate action and additional assessment are required.

The proponent should, as appropriate, discuss the Phase II findings with the regulatory agency prior to proceeding with further work.

4.3 PHASE III: Detailed Testing Program

The data collected during the reconnaissance testing program will have indicated whether chemical contaminants exist within the areas analyzed, on-site or adjacent property as a result of site operations, which exceed the defined Tier 1 cleanup criteria. Physical features and structures associated with the site have also been examined to determine if special handling, cleanup, and stabilization are required to assure the site is safe for future use.

The Phase III Detailed Testing Program, if required, will:

- target areas of indicated contamination to delineate boundaries;
- further define site physical, subsurface, and atmospheric conditions to assess chemical movement along various pathways and resulting human and environmental exposures;
- examine and define areas of unknown subsurface anomalies identified by remote sensing or geophysical techniques;
- collect structural and soil data required to demolish, clean, stabilize, and isolate man-made structures on the site (such as pits, lagoons, tailings ponds, buildings, tanks, and mine workings);

- provide information on areas which were not accessible during Phase II sampling because of existing structures, vessels, or piping which has since been removed during plant dismantling;
- provide a sufficient data base to further assess cleanup criteria, if required, through a Tier 2 risk assessment approach; and
- provide the information to assess the feasibility of various decommissioning and cleanup options necessary to attain the preferred end land use.

The systematic approach to the detailed testing program is similar to the Phase II reconnaissance testing program (Section 4.2) in that the same investigative procedures and protocols are employed; however, a greater number of samples are usually collected, and a smaller suite of chemical substances may be analyzed depending on target areas and use of indicator parameters. It is important, prior to commencing a detailed program, to ensure that the regulatory agency having jurisdiction is in agreement with the program design and that sufficient data are collected to address any public issues. The data collected should be sufficiently representative of site conditions to provide input to the development of the various components of a decommissioning plan as well as the preparation of specifications for the remediation plan and tender documents.

An overview of the detailed testing program is provided in Figure 15.

4.3.1 Types of Samples

All media (soil, sediments, surface water, groundwater, concrete, air, etc.) identified as having chemical contamination above Tier 1 cleanup criteria should be resampled as necessary to accurately define the extent and level of contamination.

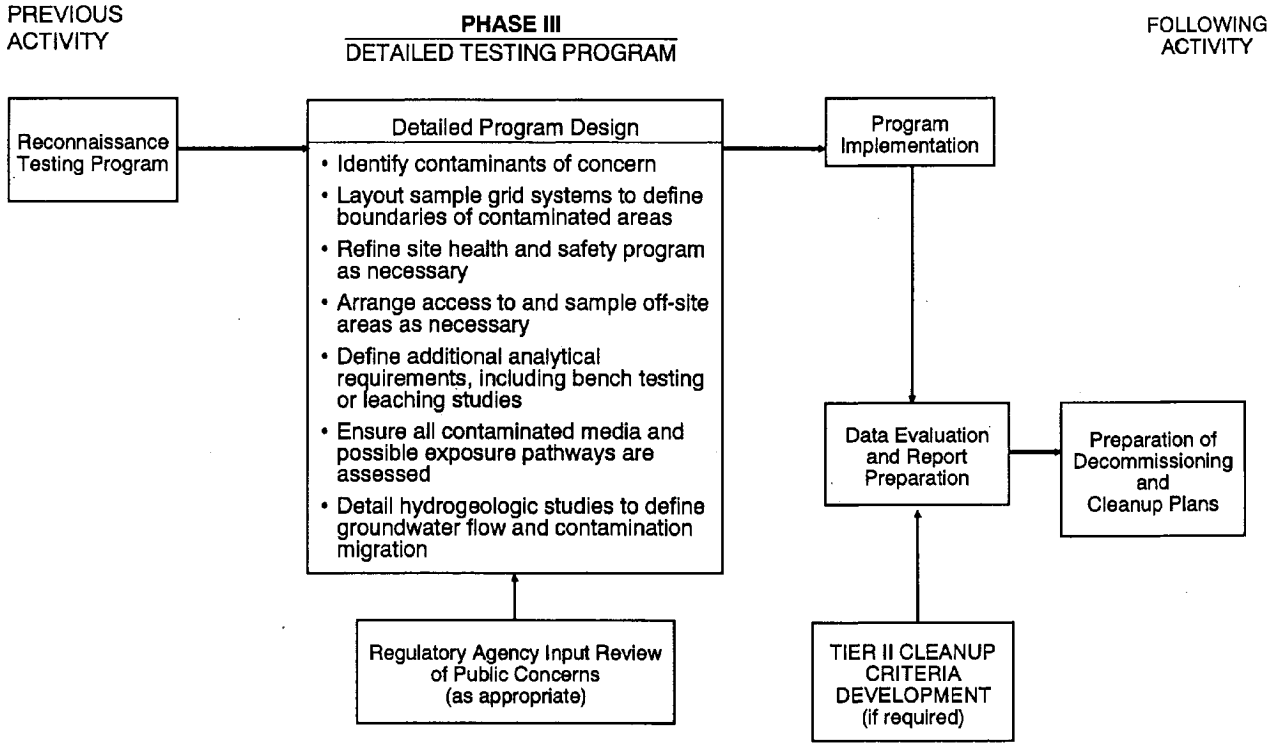

Figure 15 PHASE III: Detailed Testing Program

4.3.2 Sampling Procedures

The same sampling procedures and protocols should be used (where applicable) during the detailed sampling program as employed in the reconnaissance testing program to ensure representative samples are collected in a controlled manner and that scientifically defendable comparisons can be made amongst data sets (Appendix A). Employment of specific investigative methods, sampling protocols, and quality assurance/quality control (QA/QC) procedures throughout the decommissioning investigations and activities will enable comparison of data collected during each phase while minimizing the uncertainty associated with the results.

A summary of tasks which may be carried out during the detailed testing program follows.

(1) Boundaries of Contaminated Areas

- define boundaries (area extent and depth) to permit volume calculations;
- analyze samples preserved and archived from the reconnaissance testing program;
- computer spatial analysis programs may be used to interpolate chemical concentrations between sample points; however, ensure that a statistically significant amount of data is available; and
- analyze samples in stages to define a "clean-line"; the additional samples collected, preserved and archived during the reconnaisance program may reduce field work for this task.

(2) Extent of Contamination Beneath Ditches, Ponds, and Lagoons

- sediments in these areas may be contaminated with inorganic and organic compounds;
- identify the depth of contaminant movement beneath the ponds or ditches and the adjacent area affected by contaminant migration; and
- sample and analyze in sufficient detail to determine the extent and volume of contaminated sediments.

(3) Groundwater

- determine bedrock fracture orientation, aperture, and density where structurally-controlled groundwater systems occur;
- conduct additional drilling and install piezometers to clarify anomalies in subsurface formations and to further identify (if required) the hydrogeological conditions of the area;
- sample and analyze groundwater to assess temporal variation in groundwater physical and chemical characteristics;
- assess natural attenuation and breakthrough of contaminants in groundwater flow systems by determining the exchange capacity or sorption characteristics of aquifer materials;
- conduct hydraulic testing of piezometers and test pumping of aquifers, as necessary, to obtain aquifer characteristics required to predict and control contaminant migration, and to remediate groundwater contamination; and
- assess shallow and deep groundwater flow systems and their interaction in the vicinity of deep mines or open pits.

(4) Sludges and Residues

- conduct characterization, if required, to determine materials that are

hazardous and to define disposal requirements (such as: leaching tests, dewatering, ignition point, corrosiveness).

(5) Evaluation of Contaminants

- determine the form (species) and phase (non-aqueous phase liquids (NAPL), solid, emulsion, dissolved, etc.) of contaminants, particularly related to the mobility of contaminants and their environmental fate (stability, volatility, solubility, bioavailability, and persistence);
- carry out further analytical determinations for organics;
- determine analytical screening tools (present/absent tests) available to more cost-effectively define contaminants zones;
- determine reclamation parameters such as buffering capacity, exchange capacity, sodium adsorption ratio, and other parameters; and
- assess mobilization of contaminants fraction;
  - soluble,
  - extractable fractions, and
  - leaching test.

(6) Other Work

Other activities of a miscellaneous nature are site-specific and may include:

- analysis of soils and sediments near transformers or other electrical equipment (as well as the equipment) found to contain polychlorinated biphenyls (PCBs);
- analysis of building materials which may be contaminated to define health-related controls to be applied for dismantling reuse, or ultimate disposal; these may include concrete cores from walls, floors, sumps and gutters, wood from cooling towers, contaminated equipment, piping, etc.;
- analysis of samples from beneath areas now accessible because of plant dismantling;
- off-site investigations if contaminants are identified whose origin can be related to historical site operations;
- a further evaluation of waste materials in the on-site landfill to determine future remedial measures, given the more extensive knowledge of subsurface conditions;
- the tracking of specific contaminants of concern identified in unusual locations on-site, where the source has not been determined; and
- structurally-related and subsurface engineering investigations required to determine demolition, stabilization, sealing, filling or controlling measures required to remove or leave structures and materials on-site in a secure and safe manner.

4.3.3 Sampling Density and Location

The actual density of a sampling grid will be site-specific and dependent on the type of contaminant, its mobility in the environment, and the physical features of the site. It is more cost effective (than several sampling programs) to sample on a dense grid, preserve and archive samples, and analyze selected samples as necessary, based on previous results and the distribution and control required.

In general, the sampling density will be increased in areas of anomalies identified during reconnaissance testing. Samples are often analyzed in a concentric pattern extending outward from the probable

contaminant source in order to identify a "clean line" beyond which contamination does not extend.

4.3.4 Analytical Procedures

Generally the same procedures and laboratory as used in the reconnaissance program should be used for the detailed testing program. During this phase the range of chemical parameters examined may be narrowed to specific indicator chemicals defined at the reconnaissance level. It is advisable to discuss the use of a selected suite of indicator parameters with the regulatory agency prior to implementation.

Screening tests should be considered as a field control mechanism and for selection of samples for detailed analysis. These tests can be conducted with either portable gas chromatographic equipment, volatile organic chemical analysis or colourimetric kits, for example.

Special tests which may be necessary include:

- studies on mobility of contaminants;
    - soluble fraction,
    - extractable fraction,
- waste characterization;
    - leaching tests,
    - priority pollutants,
    - chemical/physical properties,
- treatability studies.

4.3.5 Data Interpretation

At the completion of the detailed testing program the data should be analyzed and a report prepared. This report is used to plan subsequent activities and may be submitted to the regulatory agency and other concerned parties. The report should:

- delineate those areas of the plant site with contaminant levels greater than the Tier 1 cleanup criteria and calculate the volume of contaminated material;
- determine volume of contaminated sediments in drainage ditches, lagoons and ponds;
- determine if contamination is present beneath buildings or structures that will remain on site;
- identify extent of groundwater contamination and projected future migration;
- identify off-site contamination concerns;
- characterize chemical and physical properties of all liquid and solid wastes that will have to be stabilized, treated, handled, removed, or disposed of;
- assess the effect on air quality of leaving or remediating contaminants on-site;
- determine, if possible, or estimate current and predicted exposure point concentrations for contaminants of concern at each exposure point, for each migration pathway; and
- identify miscellaneous concerns associated with decommissioning of the plant, such as:
    - stabilization, sealing or isolation of structures that will remain on-site;
    - removal of asbestos insulation;
    - disposal of transformers, capacitors, and fluorescent light ballasts containing PCBs;
    - removal and disposal of chemicals, catalysts, residues and sludges;
    - removal of contaminated structures; and,
    - identification of the technological options and the feasibility of cleaning up the site to meet Tier 1 criteria.

4.3.6 *Finalization and Approval of Cleanup Criteria by Regulatory Agencies*

The development and application of cleanup criteria on a site-specific basis through the use of past experience establishing analogous precedents and application of a risk assessment technique is a complex process. The presence of contamination has been identified in accordance with Tier 1 cleanup criteria developed on the basis of guidelines accepted or promulgated by the applicable regulatory jurisdiction and background chemical data.

If detailed testing and analysis has identified that: chemicals are present for which Tier 1 cleanup criteria do not exist; and/or the Tier 1 criteria are particularly onerous, not applicable to a site-specific situation or impossible to attain due to technology limitations or economically unfeasible with respect to the intended end land use; then the proponent should, through discussion with the regulatory agency, develop appropriate site-specific cleanup criteria using a Tier 2 process (see Section 5). It is possible for the Tier 2 cleanup criteria to result in concentrations above the Tier 1 criteria; however, the acceptable concentrations will be below the maximum acceptable exposure level, for the chemicals of concern, with respect to human health and environmental and aesthetic concerns. The Tier 2 levels will be chemical concentrations that are not phytotoxic, not biotoxic, and which are aesthetically acceptable.

Since risk assessment is a relatively new issue, and because regulatory agencies are responsible for defining allowable concentrations of contaminants in the environment, the development of cleanup criteria must be co-ordinated with and approved by the regulatory agency(ies) having jurisdiction.

Obviously the cleanup criteria specified will have a significant effect on the costs of remediating the decommissioned site. The inter-relationships between criteria and specific remedial options will have to be assessed to ascertain technical and economic constraints and socio-environmental effects. It may result that some additional modification in cleanup criteria relating to economic feasibility of control technologies, or protection offered, and/or modification in proposed end land use is required. It is important to have both regulatory agency(ies) and public involvement in this process in order that the expectations of concerned parties are commensurate with the complexity of the problem, and the remediation actions that are feasible to attain the level of human and environmental protection required for the proposed land use.

4.4 *PHASE IV: Preparation of Decommissioning and Cleanup Plans*

The desirable approach to decommissioning is to provide for future beneficial land uses by eliminating environmental and health concerns, but as a minimum the site must be cleaned up to a level which provides long-term environmental protection and is safe for its intended use.

Depending on the operational history of a specific site, and the complexity of contamination problems, preparation of a decommissioning and cleanup plan may commence as early as Phase I: Site Information Assessment. New sites, where "clean" industry has operated or where decommissioning and cleanup planning was carried out as part of operations planning, may have conducted ongoing waste management/site cleanup activities throughout the facility's life. Only minimal decontamination and cleanup may be required during decommissioning.

The development of a decommissioning and site cleanup plan involves a feasibility study to identify and evaluate remedial action alternatives if site cleanup is necessary. After decommissioning implementation and

remedial action options are identified, each one or a combination of alternatives is evaluated by considering effectiveness, practicality, and cost. This assessment, particularly research into new technologies, may also take place during the operational phase of the facility if sufficient information is available. At this point further Tier 2 cleanup criteria development may be undertaken in which remedial action alternatives, risk assessment, and associated costs for a specified level of health and environmental protection and aesthetic benefits are assessed. Both short-term and long-term costs are assessed.

The available alternatives and preferred approach to decommissioning and cleanup are documented in a draft decommissioning and cleanup or site remedial action plan. At most industrial sites the preferred approach will involve a combination of activities. It is recommended, where appropriate, that the draft plan be circulated to the regulatory agency for approval, and to other concerned parties for comment. After receipt and consideration of comments, the final decommissioning and cleanup plan should be prepared. The final plan includes the actual design and procedures to be used to implement the preferred decommissioning and cleanup plan. For instance, if contaminated soil is to be removed, the final plan must specify which soil to remove, how deep to dig, how to move heavy equipment to and from the contaminated area, how to decontaminate equipment, how to treat or where to take the contaminated soil for disposal, and what to replace the soil with. The cleanup of contamination must be logically integrated with the demolition, removal, and stabilization of buildings and structures on the site.

The final decommissioning and cleanup plan must also address occupational health and safety issues to ensure that both on-site decommissioning/cleanup staff and the public are adequately protected from exposure to contaminants. The detail must be sufficient in order that the final plan documents can be used to prepare tender documents to implement site decommissioning and cleanup. The final plan should be submitted to the regulatory agency for approval prior to implementation.

The preparation of a cleanup plan is shown schematically in Figure 16. The following sections outline considerations in the various components of developing a decommissioning and cleanup plan. It may not be necessary to conduct all of these components at a specific site.

4.4.1 Cleanup Technologies and Disposal Options for Facilities and Sites

Cleanup technologies generally are divided into three categories:

- on-site means that the contaminated material is treated, the contaminants destroyed and/or disposed of on the site;
- *in-situ* means that the contaminated material is treated, the contaminants destroyed and/or disposed of (through biological or chemical reactions, fixation, encapsulation or isolation, for example) on-site and in their place of occurrence; and
- off-site means the the contaminated material and/or the contaminants are treated, destroyed, or disposed of at a location other than the site.

The cleanup technology selected for a site and specific suite of contaminants may include combinations of remedial options employing one or more of on-site, *in-situ*, or off-site options. The primary consideration in technology assessment should be effective application to the contaminants of concern and cost-effectiveness of technology in mitigating health and environmental effects. The assessment of appropriate cleanup technology should commence as soon as an operating facility is aware that site contamination will have to be remediated.

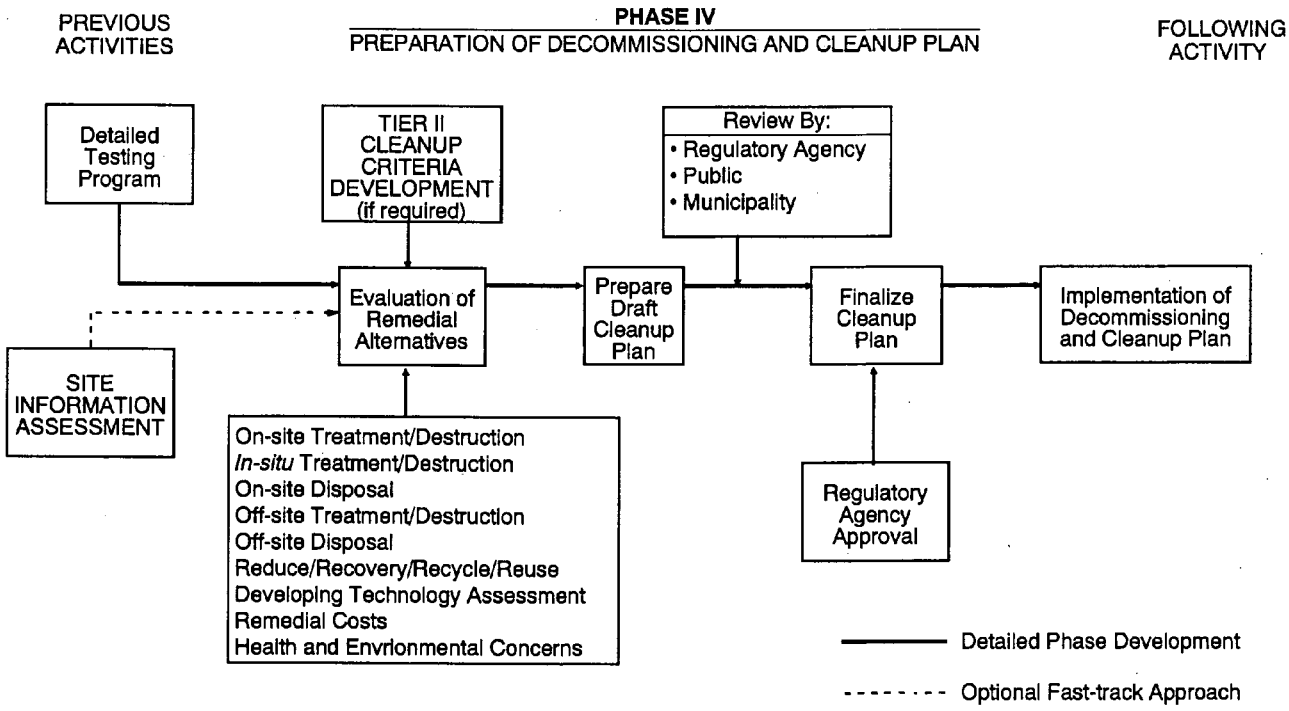

Figure 16 PHASE IV: Preparation of Decommissioning and Cleanup Plan

Technology development and field testing to manage or cleanup wastes, therefore, could be ongoing throughout the life cycle of an industrial facility.

Table 2 provides a generic overview of various cleanup technologies. Some factors that should be considered during technology assessment include:

- selecting a cleanup technology and disposal option for a particular area based on the type and amount of contamination and the proposed future land use;
- reviewing practicality, and cost, and obtaining favourable approval from appropriate regulatory agencies and acceptance by other concerned parties;
- site-specific testing may be prudent prior to large-scale field application;
- initial consideration should be given to options which reduce the volume of contaminated materials, or recover contaminants for reuse or recycling; such options may reduce treatment and disposal costs; and
- the preferred option, if feasible, will destroy the contaminated material.

On-site options, if acceptable to the regulatory authorities, are preferable since these will reduce the risk of off-site exposures associated with transportation, treatment, and disposal. Handling, transport, treatment, containment, and disposal of contaminated materials, whether on-site or off-site, must be carried out in accordance with all applicable laws and regulations.

4.4.2 Cleanup and Reclamation Research

If proven technologies (such as in Table 2) are not applicable, then it may be necessary to undertake research. The research should

Table 2 Some Proven Cleanup Technologies and Disposal Options

On-site Options	*In-situ* Options	Off-site Options
• bioremediation of organics in on-site reactors or lagoons	• solidification using fly ash, flue dust, cement, sodium bentonite clay or proprietary solidification methods, normally applicable to lagoons	• disposal of low-level contaminated materials in a local sanitary landfill
• landfarming, e.g., application of oily sludges to reduce levels of hydrocarbons through biological breakdown	• capping of contaminated soils, pond sediments and sludges with synthetic or natural clay materials	• treatment/disposal of hazardous materials in an approved secure waste disposal facility
• treatment of contaminated surface waters, groundwaters and washings to meet regulatory effluent standards and discharge off site (e.g., filtration, phys/chem, activated carbon, reverse osmosis, stripping)	• addition of soil amendments such as limestone to neutralize acid soils and/or organic matter	• destruction by incineration at an approved waste management facility
• incineration in an approved transportable incineration unit (rotary kiln, fluidized bed, infrared)	• installation of recovery/injection wells for recovery and treatment of groundwater and lighter than water non-aqueous phase liquids	• treatment/disposal of contaminated surface waters, groundwaters, and treated liquids into deep injection wells
• solvent extraction/washing of contaminated soils	• installation of passive physical barriers to isolate contaminated areas and assist control of contaminated groundwater	• reduction/recover/reuse/recycle options
• critical fluid extraction of organic chemical contaminated soils or waters	• *in-situ* removal of organic in soil using solution processes, surfactants or vapour extraction	
• treatment of low-level PCB-contaminated dielectric fluids by proprietary process such as PPM chemical destruction process or Sun Ohio PCBX Process	• treatment of contaminated groundwater using enhanced bioremediation, vapour extraction of volatile organics, surfactant flushing, oxidation, and solvent extraction and recovery	
• disposal in a secure containment unit comprising passive and active engineered barrier systems	• enhanced bioremediation using nutrient solutions	
• reduction/recover/recycle/reuse options	• thermal treatment of soils (infrared)	

determine and assess the effectiveness of the methods proposed for contaminant removal, isolation and immobilization and their technical feasibility and costs in relationship to site-specific conditions. It is advisable to carry out a literature search to assess available options and technology. Research should first be conducted at bench-scale level and progress toward full-scale application. These studies should be commenced, if possible, as part of the operational waste management and contaminant cleanup practices of an industrial facility.

Research could include the following fields:

- phase separation;
- chemical treatment;
- extraction techniques;
- biological processes, including bioreactors;
- thermal destruction processes;
- fixation/stabilization processes; and
- on-site land farming.

Prior to implementing a remedial option at full scale, it could be beneficial to conduct field trials. This approach is particularly appropriate for emerging technologies to ensure they operate effectively at full scale and provide required levels of health, safety and environmental protection. The application of new or innovative technology is often a contentious issue; therefore, it is important to obtain public understanding and regulatory agency support to facilitate approvals.

The proponent may want to contact research groups to ascertain work being conducted on new waste treatment technologies that may be applicable to a specific contaminant or medium.

4.4.3 Development of Worker Occupational Health and Safety Plan

Federal and provincial regulatory labour enforcement agencies may require that a worker occupational health and safety plan be developed and followed during decommissionings and cleanups.

Health and safety requirements that should be addressed in this plan include:

- definition of the scope of work;
- explanation of the specific hazards, both physical and environmental;
- requirement that all cleanup workers participate in a medical surveillance program as appropriate;
- establishment of "clean" and "dirty" work zones to prevent potential migration of contaminants;
- selection of appropriate level of personal protective equipment for each type of cleanup operation;
- adherence by workers to strict decontamination procedures and hygiene practices;
- selection of appropriate respiratory protective equipment such as air-purifying respirators and supplied air respirators (SCBA);
- implementation of adequate air monitoring both on-site and off-site to determine level of response on the types of respirators required; potentially explosive conditions; off-site transport of airborne particulate, etc.;

- implementation of training sessions for cleanup personnel;
- development of emergency response and contingency procedures for workers;
- establishment of safe operating procedures for equipment to be used, such as high-pressure washers, HEPA vacuums, sandblasters, scarifiers, etc.;
- development of specific guidelines and procedures to be followed by workers in each work zone and contingency plans to control and remediate sudden releases of contamination.

The development of a worker occupational health and safety plan is site specific and should involve, as appropriate, an industrial hygienist, a medical doctor, senior representatives from the proponent, and the decommissioning project manager. Prior to implementation the plan should be reviewed and approved by applicable environment and labour regulatory agencies, as well as other concerned parties.

An example of a worker occupational health and safety plan used during a major PCB cleanup is provided in Appendix B.

4.4.4 Draft Cleanup Plan

The draft cleanup plan should:

- summarize data on contaminants which are present at levels exceeding the proposed cleanup criteria;
- identify, delineate, characterize and quantify materials to be treated or removed;
- summarize and describe alternatives for site cleanup;
- assess disposal alternatives of contaminated materials;
- describe methods proposed for site cleanup including technical feasibility and approximate costs. This could include a Tier 3 cleanup criteria analysis;
- proposed schedule of work;
- discuss how the cleanup plan is integrated with other decommissioning measures;
- discuss fate of residual contaminants (i.e., contaminants in soils which are at levels above background but less than criteria) and how these conditions will affect future development of the site;
- summarize measures to control and monitor fugitive emissions and a worker occupational health and safety plan; and
- identify any long-term monitoring provisions and land use restrictions that may apply to future use of the site.

4.4.5 Review of the Plan by Regulatory Agencies and the Public

For review of the plan:

- submit decommissioning and cleanup plans to regulatory agencies and public interest groups for their perusal; and
- plans will either be accepted as proposed or accepted with some conditions that more sampling and analysis be done or that certain public concerns be addressed.

4.4.6 Finalization and Approval of the Final Cleanup Plan

For finalization and approval:

- submit a cleanup plan to the government for final review that includes detailed design of all cleanup, reclamation, containment, and monitoring plans;
- integrate cleanup plan with all other decommissioning activities; and
- include in the plan the following: safety of cleanup workers and staff; measures to treat washwaters generated during the decontamination activities; and other

measures to minimize potential spread of subsurface contaminants.

4.5 *PHASE V: Implementation of Decommissioning and Cleanup Plans*

Depending on site conditions, the implementation of an industrial site decommissioning and cleanup plan may be relatively simple or it can be a complex and challenging exercise. It is recommended that the work be carried out by experienced individuals to ensure successful completion and to minimize the potential for accidents or inadvertent release of contaminants into the environment.

The following sections outline basic considerations in implementing the decommissioning and cleanup plan. This is shown schematically in Figure 17. It is emphasized that site decommissioning and cleanup is site-specific, and the manner of plan implementation must be tailored to the specific problems and contaminants identified on a particular site.

4.5.1 *Preparation of Specifications and Tender Documents, Contractor Selection*

Contractors experienced in demolition, hazardous toxic waste cleanup, waste treatment, and the implementation of remedial measures should be used to implement the decommissioning and cleanup plan. It is generally advisable to prepare a short list of experienced contractors to whom tender documents are submitted rather than conducting an open or public tendering process. The tender documents should contain clear and concise descriptions and specifications outlining each component of the implementation plan. Three weeks should be allowed for contractor bid preparation, including a site visit, but this time frame may be reduced commensurate with the complexity and size of the project.

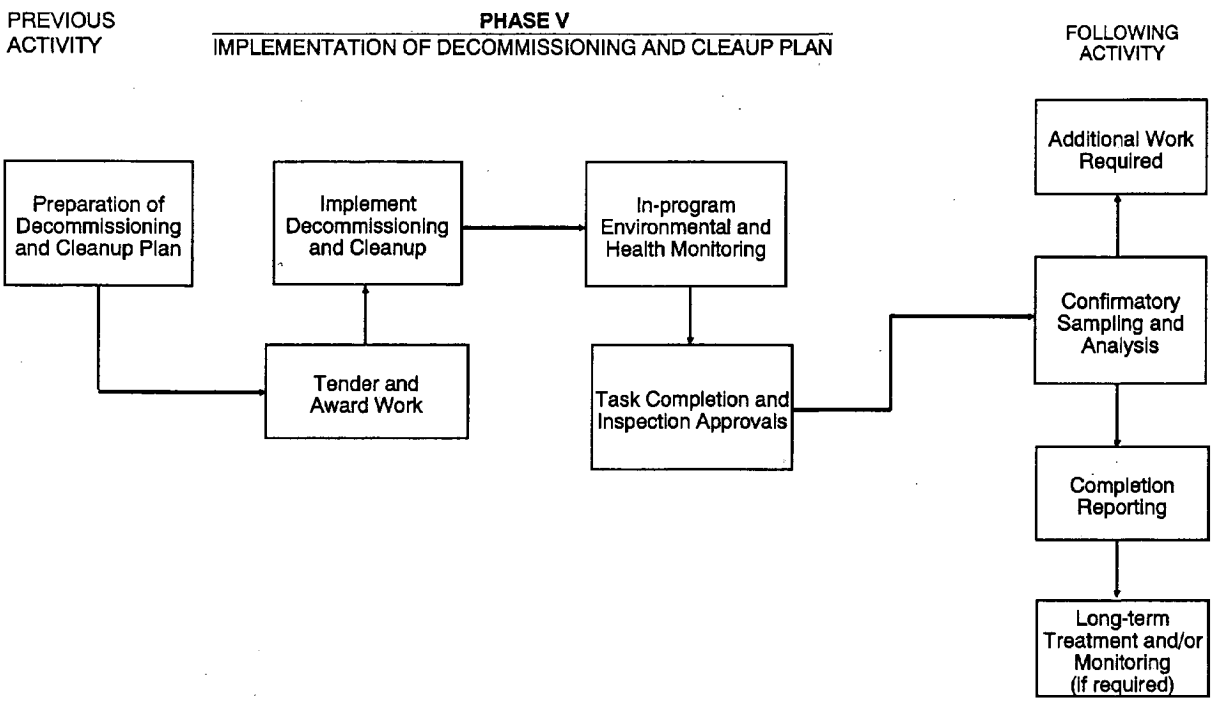

Figure 17 PHASE V: Implementation of a Decommissioning and Cleanup Plan

Depending on site conditions, decommissioning and cleanup can be a very expensive undertaking, amounting to tens of millions of dollars on large, highly-contaminated sites. Liabilities associated with having work conducted improperly or incorrectly, therefore, can also be very substantial in terms of human, environmental, and dollar costs. The proponent should ensure, when reviewing bid documents, that they are fully responsive to the tender document specifications. Normally, the lowest cost bidder who is fully responsibe to tender documents, including qualifications and experience, is awarded the contract.

In order to avoid problems, it is imperative that the contractor have a clear understanding of what is expected and when; this could be different from the work outlined in the tender documents. In addition, a procedure for handling changes in the scope of work (change orders) must be adopted. No additional work should be completed without prior written approval of the proponent.

The contractor will require on-site supervision during the implementation of the remedial action plan. This supervision can either be provided directly by the proponent or a consultant can be retained to undertake this task. The role of the on-site supervisor (or consultant) is:

- to ensure that the contractor adheres to the previously approved plans and specifications;
- if the contractor's payment is based on time and materials, to record manpower and materials on-site;
- if the contractor's payment is lump sum, (for a defined scope of work), to record any extras which will increase the cost of the project; extras should only be undertaken after approval by the on-site supervisor and/or the proponent;
- to monitor the contractor's on-site health and safety program;
- to identify any new issues that arise during site cleanup;
- to inspect and approve the work as completed; and
- to generally act as the proponent's representative on-site.

4.5.2 Worker Safety and Health Monitoring

For worker safety and health monitoring it is necessary to:

- ensure all workers have appropriate medical monitoring during the program;
- ensure workers follow safety and health protocols, including: breathing and skin protection; and provision of "clean" and "dirty" areas, shower facilities; etc.;
- carry out indoor air monitoring of constituents of concern during building decontamination and demolition phases; and
- conduct outdoor ambient air monitoring of fugitive emissions as required during the implementation phase.

4.5.3 Construction of On-site Containment Facilities

Prior to removal of any wastes:

- construct and inspect approved containment facility on-site; and
- install leachate control and collection systems and long-term monitoring devices at time of containment construction.

4.5.4 Handling of Wastewater and Surface Drainage

To handle wastewater and surface drainage:

- divert clean surface water from the area and maintain treatment system throughout cleanup in order to treat wastewater generated from cleanup and decommissioning operations and sewage generated from workers;
- monitor influent and effluent throughout the process, and when it can be demonstrated that treatment facilities are no longer required, then proceed with shutdown and cleanup; and
- monitor any wastewater treatment systems remaining over the period necessary to ensure remedial action and cleanup is complete.

4.5.5 Control of Fugitive Atmospheric Emissions

To control fugitive atmospheric emissions:

- ensure workers are using appropriate respiratory protection devices as and where needed;
- suppress fugitive emissions, if possible, by spraying with water or appropriate chemical (e.g., calcium chloride (CaCl));
- consider the use of temporary, negative pressure enclosures in highly contaminated zones; and
- monitor air quality in work areas and at the site boundary.

4.5.6 Removal and Disposal of Materials and Residues

For removal and disposal of materials and residues:

- dewater sludge materials and residues to reduce bulk and disposal costs;
- treat all wastewaters generated from sludge dewatering and cleaning of sumps and gutters in the plant's wastewater system, a temporary system, or alternatively, transport wastewaters off-site for treatment and disposal; and
- transport dewatered sludges, in vehicles equipped to control dusting or dripping, to the disposal or treatment facility, either on-site or off-site.

4.5.7 Removal and Disposition of Process Equipment

For removal and disposition of process equipment:

- decontaminate equipment, if necessary, and remove equipment for use elsewhere or sell as scrap;
- use cutting torches with caution for dismantling equipment (caution should be observed regarding explosive vapours in vessels or the existence of lead-based paints);
- ensure all tanks and piping are drained and vented/purged prior to removal;
- remove all asbestos insulation using special protective measures consistent with government regulations; and
- store or properly dispose of any equipment containing, or that previously contained, PCB fluids.

4.5.8 Cleaning and Dismantling of Buildings

Cleaning the interior of the building(s) is necessary, 1). if buildings are to be converted for another use (i.e., industrial or commercial), or 2). if building demolition costs are to be minimized by not sending building rubble to a landfill as waste material but instead as "clean" material, for example, to a crushing operation that produces road aggregate.

For cleaning and dismantling buildings:

- clean building walls, floors, ceilings, rafters, ducts, roof, sumps and drains by techniques including but not limited to vacuuming, power washing (with surfactant or solvent), sandblasting and/or scarifying;
- remove and dispose of all concrete sumps, gutters and drains to a disposal facility; and
- dismantle all structures such as cooling towers, boilers, bag houses, ventilation systems, etc.

4.5.9 Removal of Buried Equipment and Services

To remove buried equipment and services:

- drain, purge, excavate, puncture and dispose of all underground storage tanks;
- excavate and remove buried drums for treatment, destruction or disposal;
- drain and purge buried service pipes; and
- excavate and dispose of buried pipes which are not to be reused along with any associated contaminated soil to an approved facility.

4.5.10 Excavation of Contaminated Soil and Sediments

For excavation of contaminated soil and sediments:

- implement a site materials handling and traffic movement plan;
- excavate soil in contaminated areas in "lifts" with periodic sampling and chemical analysis to monitor progress of contaminant removal;
- undertake excavations in a logical sequence to avoid possible disturbances by vehicles in completed areas;
- do not backfill excavations until confirmatory sampling and analysis is completed; and
- do not import off-site soils for backfill in excavated areas unless the imported soil has been verified "clean" to the cleanup criteria required at the work site.

4.5.11 Reclamation Measures

For reclamation:

- establish access and surface drainage controls prior to implementing a program for those areas where soil amendments are to be applied, including landfarm areas; and
- stabilize all structures remaining on site to ensure they are safe for future site use and insure that access is controlled to potentially dangerous areas (such as pits, shafts, large bored wells, and underground workings).

4.5.12 In-program Contaminant Monitoring

For contaminants:

- monitor levels of ambient airborne dust and chemical constituents of concern using continuous high volume air samplers situated at off-site locations;
- if organic vapours are present, monitor using appropriate instruments such as organic vapour analyzers, total ionizing photometers, or hand-held, vacuum-operated pumps; and
- install piezometers near containment facilities or down gradient from the site if long-term monitoring is required.

4.6 PHASE VI: Confirmatory Sampling and Completion Reporting

The final phase in decommissioning and cleanup of an industrial site involves two principal activities:

1) confirmatory testing of all areas to demonstrate that contamination has been removed or stabilized effectively on site, and that the cleanup criteria have been attained; and

2) preparation of a completion report which documents all activities carried out during site decommissioning and cleanup, and includes as-built drawings for all completed works, relevant in-program monitoring data, and confirmatory monitoring data.

The "completion" report is submitted to the regulatory agency for review and acceptance that the industrial site is suitable for the proposed future land use. Some considerations during confirmatory sampling and completion report preparation are outlined in the following text.

4.6.1 Confirmatory Sampling of Soil, Groundwater, Surface Water, Air and Remaining Structures

As distinct phases of the decommissioning and site cleanup are completed, confirmatory testing of the "cleaned" or treated materials should be carried out to ensure that contaminants have been effectively removed. For confirmation:

- obtain cores and/or swab samples of concrete floors and walls of the plant, analyze the samples, and assess if decontamination was effective;
- sample and analyze soil from the contaminated zones and adjacent areas to determine if additional soil should be removed;
- install piezometers in areas where the depth of soil removed exceeded that of the water table or where the groundwater was found to be contaminated in the earlier investigations. Collect groundwater from these piezometers and analyze for contaminants of concern. Long-term monitoring of concentrations of contaminants in groundwater may be required;
- analyze adjacent bodies of surface water after the cleanup to verify that no transfer of contamination has resulted from cleanup operations;
- examine air and groundwater quality in the on-site vicinity, secure containment cells to ensure engineered barriers are functioning adequately; and
- monitor the air quality on site and off site after cleanup.

4.6.2 Interpretation of Confirmatory Sampling Data

For interpretation of confirmatory sampling data:

- remove/treat more soil if soil confirmatory tests show levels above cleanup criteria;
- continue with further decontamination activities if confirmatory analyses indicate that the floors and walls are not clean (non-registerable waste materials);
- treat groundwater and surface water if results show presence of unacceptable levels of contamination; and
- inspect for failure and remediate any deficiencies identified in waste disposal areas remaining on site.

4.6.3 Preparation of Completion Report

The completion report prepared for submission to the regulatory agency should include, but not be limited to, the following:

- physical description of the site and operational history;
- areas of contamination and contaminated materials identified on site;

- buildings and structures on site which required decontamination, demolition, stabilization or isolation;
- description of all demolition, remedial action and cleanup work carried out;
- as-built drawings showing the site conditions after completion of the decommissioning;
- description of the approved cleanup criteria for the site;
- identification of any disposal areas and controlled access areas remaining on site;
- description of any on-going treatment programs operating at the site;
- description of the proposed end land use for the decommissioned site;
- identification of conditions on site which restrict land use and should be registered on title to the property;
- copies of all pertinent chemical analyses, registrations and waybill summaries showing the volumes of contaminated materials removed, treated, stabilized, isolated, or disposed of;
- description of any on-going or long-term monitoring program applicable to the site; and
- certified copies of all confirmatory sample analyses conducted to demonstrate that the specified cleanup criteria have been attained.

Section 5

Development of Cleanup Criteria

5.1 Introduction

Decommissioning industrial sites in Canada is hampered by a general lack of policy, prescribed procedures, inconsistent definitions of key terms, and little precedent. While regulatory agencies need to enunciate decommissioning policy and the procedures to be used to promote effective decommissioning and to assess decommissioning issues, two of the more visible missing components of decommissioning are the establishment of guidelines that address "acceptable" concentrations of chemicals in soil and the establishment of methods or practices by which the guidelines can be developed.

Soil quality guidelines can be used in the same manner as similar guidelines or criteria for air and water quality. The guidelines could be used to compare with on-site measurements and serve as indicators of whether remediation is necessary, indicate when remediation is sufficient, and provide direction to soil monitoring programs. Some jurisdictions have explored the subject and issued documents (often in draft form) that indicate possible or preferred methods for establishing soil guidelines or criteria. In Canada, only the provinces of Ontario and Quebec have actually established "acceptable" concentrations that can be used as guidelines for the remediation of contaminated soil. Site-specific guidelines have also been developed in a number of provinces (e.g., British Columbia, Ontario).

In response to this need, and as part of its efforts concerning various aspects of decommissioning industrial sites, the Decommissioning Steering Committee set out to review and evaluate various approaches that have been used or suggested for establishing cleanup criteria. The approaches of several provincial, state, and federal agencies are described in Appendices C, D, and F. Workshops held in 1985 and 1986 under the direction of the Decommissioning Steering Committee and a subsequent review of possible approaches (Monenco, 1990) identified various features that should be included in a "preferred" approach. Those attributes have been considered in the two-tiered approach proposed in Section 5.2.

The development of cleanup criteria must consider a number of factors, some of which are site-specific. In principle, regulatory agencies generally prefer that the cleanup guidelines employed for site remediation permit the site to be returned to an unrestricted land use. While unrestricted future land use is recognized as an attainable goal if good waste management practices are employed during the operational phase of an industrial facility, experience has shown that unrestricted land use is not always feasible or practical. Nevertheless, the government will insist on full protection of human health and the environment during future land use. Site-specific considerations, therefore, must be examined when developing site cleanup criteria.

The major factors that should be considered when developing site cleanup criteria include:

- environmental and human health toxicology of the contaminant(s);
- background levels of the contaminant(s);
- the amount and type(s) of contaminated material(s);

- mobility of the contaminants of concern and the migration pathways to points of human or environmental impact;
- the combined or synergistic effects of contaminants at the site;
- the sensitivity of the environment surrounding the site;
- phytotoxicology of the contaminant(s);
- planned future land use and adjacent land uses;
- contaminant migration control mechanisms;
- aesthetics (appearance, odour);
- public perception;
- available treatment technologies; and
- cost.

It is the proponent's responsibility to assess the extent of contamination at a site, and to demonstrate and justify to the regulatory agency any decommissioning and cleanup program that will not result in application of cleanup guidelines to obtain an unrestricted land use. Industry operating today is expected to follow exemplary waste management practices that mitigate adverse effects on human health and the environment.

5.2 Preferred Approach

Decommissioning poses different levels of urgency to various jurisdictions and some jurisdictions have already invested considerable effort in evaluating various courses of action; therefore, use of a two-tiered approach is preferred. Such an approach offers regulatory agencies and proponents the option of using the level of detail best suited to the situation under consideration and the degree of site specificity needed. It may not be necessary or appropriate to apply the complete process of cleanup criteria development at each decommissioning site.

The two tiers through which the development of acceptable site cleanup criteria may progress are shown in Figure 18, and described in the following text.

Tier 1: cleanup criteria are based on existing standards or guidelines promulgated by the regulatory agency having jurisdiction, background concentrations of specific chemicals in similar media, analytical detection limits, and previous decommissioning and cleanup experience. Tier 1 criteria may include criteria used in other jurisdictions. These criteria are the primary objective of the regulators and are appropriate for either unrestricted or a specified land use.

Tier 2: cleanup criteria are developed using a detailed assessment of the site-specific factors noted in Section 5.1. The option of the Tier 2 criteria development is generally applicable where contaminants are identified for which Tier 1 guidelines are not promulgated or where background levels exceeding guidelines occur. Tier 2 cleanup criteria development may include an evaluation of exposures via natural pathways and through engineered systems.

At some sites, Supplementary Conditions (required by the regulatory agency) may complement cleanup criteria when available technology (or other factors) restricts the level of cleanup carried out, contaminants must be (temporarily) isolated on-site, or long-term remedial action is necessary (for instance, PCB oil in groundwater in fractured bedrock). Supplementary Conditions would require ongoing liability exposure by the site owner, monitoring, and continued institutional or regulatory control with land use restrictions.

The Tier 1 level of cleanup criteria is normally established during the Phase I and Phase II decommissioning activities. The types and amount of chemicals present on a

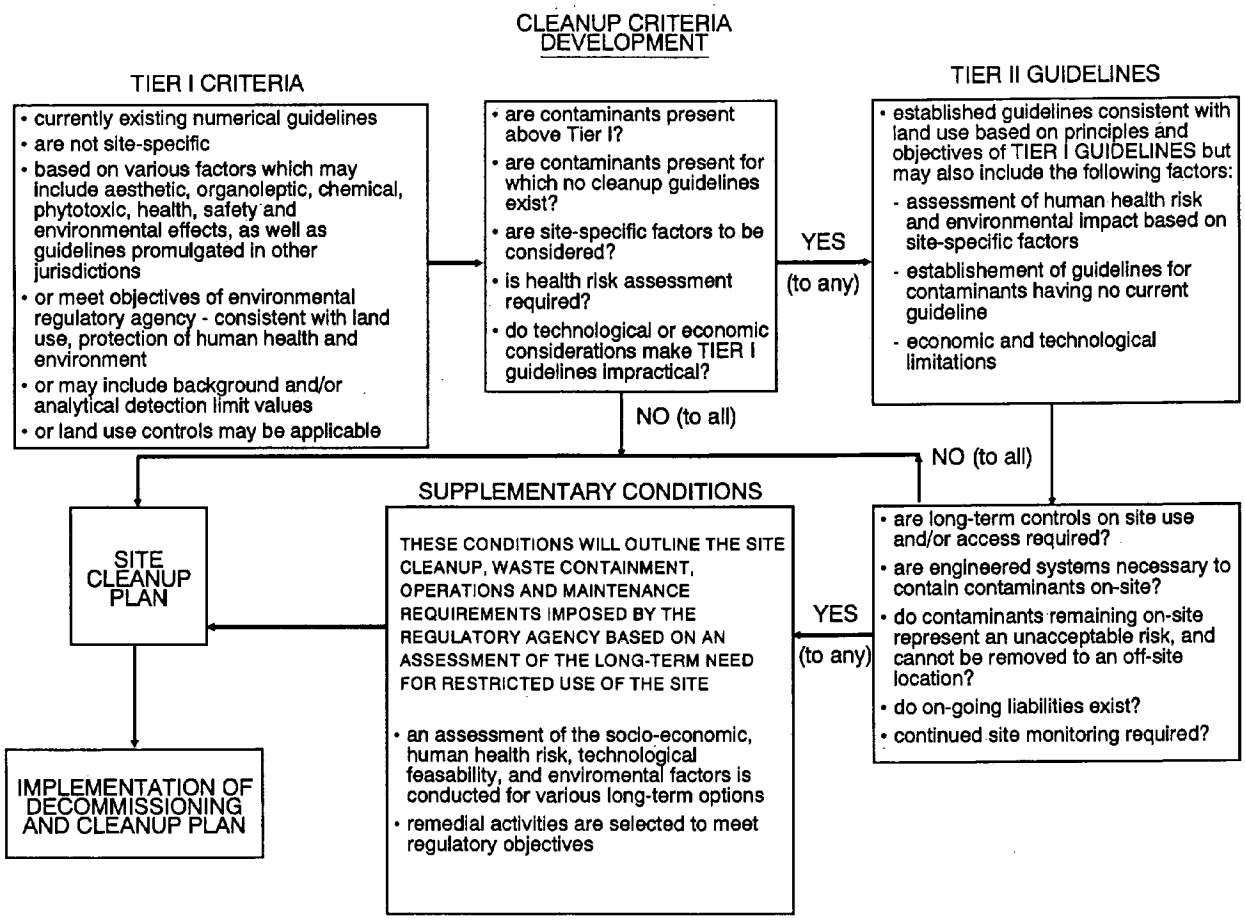

Figure 18 Cleanup Guideline Development

site and site-specific characteristics (soils, sediments, hydrogeology, disposal site conditions, technology availability, etc.) determine if development of a Tier 2 level of cleanup criteria is required during subsequent Phases or if Supplementary Conditions will be required at the site.

5.2.1 Tier 1 Criteria Development

Tier 1 guidelines are selected by the regulatory agency and are directly related to the environmental goals of the agency. Examples of Tier 1 guidelines are shown in Appendices C and D for the provinces of Ontario and Quebec. The Tier 1 approach requires a relatively small amount of information and is not suited to developing site-specific guidelines. It is relatively conservative (that is, there is a general philosophy that it is better to be overly protective of health and the environment when relatively little is known or certain). Tier 1 guidelines may also be based on existing environmental legislation or guidelines such as Canadian Water Quality Guidelines (CCREM, 1987); Guidelines for Canadian Drinking Water (Health & Welfare Canada, 1987) or air pollution control criteria (Air Pollution, Regulation 308, under Ontario Environmental Protection Act, as amended 1985).

Many types of information are considered in Tier 1. Factors such as: ambient (background) concentrations, analytical detection limits, and published accounts of chemical concentrations that cause adverse effects can readily be used by a regulatory agency. Information for a chemical would be used in the following manner:

(a) A representative ambient level or typical range of ambient concentrations is determined by analyzing a prescribed minimum number of samples. Natural variability should be taken into account. For example, the Ontario Ministry of the Environment defines an "upper limit of

normal" (ULN) concentration of a chemical as the mean value plus three standard deviations.

(b) Published accounts are reviewed to determine the minimum concentration in soil, water, or air recognized as causing adverse effects such as health problems, phytotoxicity, odours, etc.

(c) The analytical detection limit is defined by the agency's laboratory (and possibly other independent laboratories) as the lowest concentration that regularly can be measured with a suitable level of accuracy and reproducibility, sometimes referred to as a routine detection limit.

(d) The "acceptable" concentration of the chemical would be set at the lower value of (a) or (b) but would never be lower than (c) under any circumstance.

Chemicals detected in media at a site below the "acceptable" concentration would require no further investigation or remediation. Chemicals present at greater than the "acceptable" concentration may require further remediation or evaluation, such as that described in Tier 2. There may be certain chemicals that an agency prefers to see automatically progress to a Tier 2 approach, if present at a site.

Tier 1 requires that the proponent or agency gather background data and make decisions as to the definition of background (i.e., does background apply to a neighbourhood, a specific type of area such as urban or rural, a region, an entire province?). Table 3 is an example of the range of values normally detected for some inorganic parameters occurring in natural soils in the various physiographic regions of Canada. The Tier 1 criteria ascertain, when compared with site data, whether or not contamination is present in media on an industrial site.

The Tier 1 approach to determine if chemical contamination is present is based on the philosophy that prior to the occurrence of industrial activities at the site, the concentrations of naturally occurring inorganic chemical parameters in site media (soils, groundwater and surface water) should have been at background concentrations. Synthetic organic chemicals used in industrial activities at the site should not have been detected in in-site media prior to the commencement of industrial development. That is, the land and associated groundwater and surface water were restricted in use only by physical attributes, naturally occurring chemical concentrations, and the influence of man's activities from off-site locations. Other anthropogenic sources of chemicals unrelated to industrial activities at a particular site, therefore, can result in concentrations of both inorganic and organic chemicals exceeding natural concentrations occurring in undeveloped background areas distant from the site.

Background chemical parameter concentrations should be determined following a logical approach.

Off-site background data could be developed in the following manner:

(1) background concentrations of chemicals in soil are determined from appropriate agricultural and residential lands (examine land registry/land use records) located at least 1000 m upgradient from the industrial site with respect to the prevailing wind direction at the site;

(2) background concentrations of chemicals in groundwater are determined from sampling groundwater at locations hydraulically upgradient from the site with respect to the direction of groundwater flow; and

(3) background chemical concentrations in surface water are determined by obtaining surface water samples off-site and upgradient with respect to the direction of surface water flow.

Table 3 Minimum, Maximum, and Mean Values for Soil Samples from Physiographic Regions of Canada* (McKeague and Desjardins, 1979)

	All Regions				Appalachian Region				Canadian Shield			
Variable	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean
Org. C	293	0.03	36.8	1.5	54	0.03	36.8	1.8	13	0.1	12.0	2.3
Clay	243	1.0	82.0	21.8	47	1.0	38	15.7	8	2.9	11	5.0
pH	292	3.0	8.4	5.8	51	3.0	7.0	4.3	13	3.4	5.8	4.5
Al	285	0.1	11.5	6.2	53	0.1	8.4	5.5	13	5.7	8.4	6.7
Fe	285	0.1	12.2	2.6	53	0.1	12.2	2.4	12	0.7	6.1	2.5
Ti	191	0.04	1.8	0.44	53	0.1	0.75	0.48	13	0.12	1.8	0.57
Ca	184	0.03	13.1	1.5	52	0.03	2.5	0.19	11	0.92	2.5	1.8
Mg	185	0.03	4.5	0.82	53	0.03	1.2	0.48	13	0.25	0.80	0.53
Mn	285	69	4295	544	53	69	1010	415	13	127	810	417
Zn	282	5	300	77	51	5	300	85	13	8	146	57
Cu	288	1	78	22	53	3	48	17	13	6	20	12
Pb	285	5	71	20	51	5	51	21	13	12	28	20
Co	188	5	60	21	53	5	36	18	13	15	231	19
Ni	288	1	67	22	53	1	44	18	13	2	26	12
Cr	282	2	141	45	53	2	100	31	13	7	41	19
Sr	189	20	605	207	53	20	145	71	12	300	605	409
Se	188	0.02	3.7	0.30	45	0.02	2.2	0.23	12	0.06	0.71	0.18
As	90	1	20	5.2								
Hg**	253	1	770	54	38	2	660	82	13	7	396	107

	St. Lawrence Lowlands				Interior Plains				Cordillaran Region			
Variable	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean	No.	Min.	Max.	Mean
Org. C	153	0.1	8.6	1.2	53	0.1	18.0	1.5	20	0.1	11.0	2.9
Clay	151	1.5	82	24.6	31	10	57	22.7	6	6.0	3	117.5
pH	155	3.6	8.0	6.6	53	3.5	8.4	5.9	20	4.2	6.0	5.1
Al	152	2.9	11.5	6.4	48	0.9	8.2	5.3	19	4.5	9.0	7.8
Fe	152	0.8	6.3	1.6	49	0.5	4.2	2.0	19	2.8	4.9	3.9
Ti	55	0.19	0.7	0.44	51	0.04	0.48	0.32	19	0.34	0.73	0.56
Ca	55	0.33	13.1	2.8	47	0.33	4.7	1.4	19	1.3	2.5	1.9
Mg	55	0.25	4.5	1.2	45	0.08	2.0	0.69	19	0.83	1.7	1.2
Mn	152	102	4295	622	48	95	1120	378	19	410	1403	787
Zn	150	18	270	80	49	10	140	66	19	48	107	73
Cu	152	4	65	22	51	1	46	23	19	23	68	46
Pb	152	10	71	21	50	9	38	16	19	6	26	16
Co	52	10	60	25	51	6	28	16	19	21	52	34
Ni	152	6	67	23	51	2	42	21	19	27	65	40
Cr	146	10	141	30	51	5	76	40	19	41	106	78
Sr	54	130	472	296	51	55	330	178	19	164	505	280
Se	58	0.02	3.7	0.28	54	0.05	2.2	0.40	19	0.07	0.78	0.30
As	90	1	20	5.2								
Hg**	138	1	124	34	45	6	770	72	19	28	190	56

* Values for organic C, clay, Al, Fe, Ti, Ca, and Mg are percentages; those for Mn, Zn, Cu, Pb, Co, Ni, Cr, Sr, Se, and As are in parts per million and those for Hg are in parts per billion.

New industrial sites should develop a background data base for both on-site and off-site locations and media prior to site development and commencement of industrial operations. At decommissioning, the proponent must sample site media to determine if chemical parameters of concern are present in these materials. The decommissioning site data must be compared with baseline data (if available) and the off-site background data to assess if contamination has occurred. Concentrations of chemical parameters exceeding baseline data or off-site background data will be evidence of contamination.

A Tier 1 assessment indicates if contamination is present and whether remediation may be necessary. If there is a general desire or need to consider site-specific factors then a Tier 2 approach can be used. Tier 2 involves the use of risk assessment techniques and allows site-specific conditions to be considered.

5.2.2 Tier 2 Criteria Development

In Tier 2, various types of information are used to describe the chemical of interest, the environmental conditions at the site, the way the site would be used, and the types of people who would use the site. The Tier 2 process should not be seen above or beyond the Tier 1 process, but beside it. The results of the Tier 2 process will complement the Tier 1 criteria. Risk assessment is a main component of Tier 2 criteria development. The site information is used to estimate the extent to which a user of the site will be exposed to a chemical in the site soil. This process of quantifying health risks can be divided into five components:

(1) the environmental nature of the site must be characterized in terms of soil characteristics, groundwater regime, meteorology, etc.;

(2) the chemical of interest must be characterized in terms of information about the environmental behaviour and mobility (volatility, solubility, tendency to bioaccumulate, biodegradability, etc.) and the level of toxicological concern it poses (kinds of health effects it can cause, lowest doses at which effects occur, estimates of health risk associated with specific dose levels);

(3) while measured concentrations of the chemical in various environmental compartments (such as outdoor air, groundwater, soil, and plants) are preferred, it often will be necessary to estimate concentrations by using environmental fate models or calculations;

(4) the future use(s) of the site needs to be identified as do the associated features (such as the types of buildings that would be used) that could influence how a future site user is exposed to the chemical; and

(5) the type(s) of people who use the site (such as adults or children, full-time residents or occasional visitors) needs to be depicted in terms of physical characteristics (body weight, volume of air breathed, quantity of water ingested, etc.) and their on-site activities (such as working in a garden, playing outdoors, or working indoors).

Subsequently, all of this information is used to identify the routes by which the receptors will be exposed to the chemical; to estimate doses from each route; and to determine the cumulative dose from all routes. "Acceptable" concentrations based on pathway exposures and human health concerns can then be established by determining the concentration of a chemical in soil that will result in a total dose that does not exceed the "acceptable" dose (as defined by the toxicological information).

It is assumed that a decision to use Tier 2 reflects the availability of some site-specific information or the desire to minimize the

complexity of mathematical procedures. As such Tier 2 methods can use various assumptions, generalizations to simplify calculations, or substitute "typical" values in place of site-specific information.

Tier 2 criteria development can take the form of a series of manual worksheets, or a computer program can be used that effectively does the same sorts of calculations. An example of such a program is AERIS (Aid for Evaluating the Redevelopment of Industrial Sites) which was developed as part of a previous study by Monenco on behalf of the Decommissioning Steering Committee (Monenco, 1990). AERIS consists of four basic elements an "intelligent" preprocessor, component modules, a postprocessor, and supporting data bases. The preprocessor takes the form of a series of questions that AERIS asks the user about the redevelopment scenario to be evaluated. The preprocessor is referred to as "intelligent" because of the utilization of "expert system" technology.

The health-based concentrations produced by Tier 2 should be compared with the types of information gathered during Tier 1 and adjusted, as necessary, to ensure that the "acceptable" concentration does not exceed the lowest concentration associated with other types of adverse effects related to other factors (such as aesthetics, phytotoxicology, etc.), and is not lower than the analytical detection limit or the ambient concentration.

During the process of calculating an "acceptable" soil concentration calculated in Tier 2, associated concentrations are estimated for air and water. The concentrations for chemicals in the groundwater and air calculated from the model, along with the "acceptable" soil concentration, should be compared to guidelines the agency may have for air or water quality. Discrepancies may be caused by a number of factors and need not mean that either value is incorrect, only that they have been established within different contexts; however, reasons for differences should be understood.

It is recommended that the results be interpreted in the following manner. Chemicals detected at a site below the "acceptable" concentration would require no further investigation or remediation. Concentrations greater than the "acceptable" concentration would require remedial actions to be taken to reduce chemical concentrations to the "acceptable" level or further investigation and control measures.

The results of Tier 2 have the potential to affect the degree to which remediation is necessary; therefore, some form of risk-benefit analysis is conducted. Accordingly, various types of information or factors likely will need to be addressed in Tier 2 that are not part of Tier 1. Examples include:

- for unknown site parameters, or those where there is uncertainty about the most appropriate value to use, a set of calculations should be prepared using various values for the parameter to develop an appreciation of its role in the final outcome (a probabilistic approach to dose estimation may be necessary);
- attempts should be made to ensure that chemical-specific information is used for factors such as bioavailability, diffusivity, etc.;
- human health risk estimates should take into consideration factors such as age (child/adult) at the onset of exposure and the "duration of time spent on site";
- if the proposed plan for the site includes features such as cutoff walls or impervious caps on contaminated soil, the effects of those features on various pathways should be taken into account;
- reduction in health risks should be calculated for various remedial actions

and the results compared with the costs of the actions; and

- it may be necessary to estimate doses that receptors receive from off-site sources (including ambient concentrations) and take those doses into account when establishing "acceptable" soil concentrations.

5.3 *Supplementary Conditions*

Some industrial sites may contain contamination which due to its mode of occurrence (large volumes such as tailings or contaminated groundwater) cannot be practically or economically remediated within reasonable time frames. The contaminated material may have to remain on-site in a controlled state of engineered isolation or containment and treatment for some unknown time period. Restricted use of the site, or site resources, may result from contamination remaining on-site. The site will require on-going monitoring throughout the period of restricted use. The proponent will retain liability for contaminants remaining on site.

The regulatory agency will recognize the need for restricting future site use by arranging to have recorded against the property title, the supplementary conditions which will outline the waste containment, treatment and monitoring requirements and land use restrictions placed on the property. A complete assessment of all feasible remedial alternatives for the site, including socio-economic, human health risk, technological feasibility and environmental factors may be required to determine the level of supplementary controls required.

5.4 *Roles of Other Factors and Interested Parties*

Regardless of the level of detail examined when establishing cleanup criteria or evaluating the need for remediation at a site, there remain other factors and considerations that are not part of the approaches described in this review but which a regulatory agency should or must take into account in establishing cleanup guidelines. Many of these pertain to providing the opportunity for other interested parties to participate in the process, communicating the objectives and results of the process effectively, and striking an appropriate balance between risks and costs of risk reduction.

The following factors must also be considered:

- interested parties should be given adequate opportunity to comment at all stages of the process; such third party input should be carried out in a proactive manner without resulting in a significant delay of the project;

- the overall process must be fair and adequate, and be defensible by the regulatory agencies to those being regulated, and the public;

- the process must produce results which can be applied by the regulatory agency without undue difficulty and not conflict with existing regulations or guidelines;

- the results should be scientifically supportable and not unduly conservative;

- the process may be perceived as being misguided if "acceptable" concentrations are identified that far exceed background levels. Regulatory agencies may feel it necessary to adjust criteria downward for no other reason than it may be difficult to convince decision makers or members of the public that such high levels are indeed "acceptable". Cleanup to background levels will normally be preferred when available, proven technology and other factors make obtaining lower cleanup criteria feasible;

- A process that calls for actions such as sending marginally-contaminated soil to a registered hazardous waste disposal facility may be seen as being wasteful of a precious commodity; and

- Various sources of uncertainty in the overall process of cleanup criteria development cannot be avoided. Therefore agencies must be prepared for questions from the public about safety and questions from industry about the defensibility, practicality and effectiveness of the process.

Factors such as these, though not scientific or technical in nature, can play as large a role in the establishment of cleanup criteria as more scientific aspects. Regulatory agencies must remain responsive to the different sensitivities, priorities, and perspectives that interested parties bring to the process of developing environmental guidelines.

Section 6

Miscellaneous Considerations Relevant to Site Decommissioning Management

6.1 Introduction

There are a number of important considerations which are applicable to the various aspects of site decommissioning and cleanup that should be considered by the proponent. These considerations relate to:

- regulatory agency approvals;
- long-term monitoring;
- liability;
- site reuse; and
- preventative measures.

6.2 Regulatory Agencies Approval of Decommissioning Completion

It is important throughout all phases of a decommissioning and cleanup project to maintain communication with the lead regulatory agency, usually the environment department. This contact will ensure development of a good working relationship, and facilitate communications with other agencies, the local municipality, and the public. Regulatory involvement in the various phases of the program will ensure understanding of the nature of site-specific problems and the complexity of the cleanup tasks. This is important in developing public information programs, determining cleanup criteria and obtaining land use approvals when decommissioning has been completed.

The primary concerns of the regulatory agency(ies) are:

(1) ensuring that the site is cleaned up in a manner and to a level that is protective of human health and safety, and of the environment; and

(2) ensuring that future proposed beneficial uses of the site are compatible with the level of remedial action carried out and the level of cleanup attained.

6.3 Long-term Monitoring

It may not always be possible to clean up a site to a level that results in removal of all significant concentrations of contaminants. Limitations in technology, the accepted operating practices of the industry, and the nature of the contamination may limit the cleanup feasibility and result in short- or long-term restrictions on future site land use. For instance, resource extraction sites may contain large tailings ponds, groundwater contamination could require tens of years to remediate, and on-site disposal areas may remain for many years; all of which will require long-term monitoring to ensure their continued integrity.

The long-term monitoring may consist of:

- inspection of on-site containment and treatment facilities;
- groundwater, surface water, and atmospheric sampling and chemical analyses; and
- inspection of stabilized structures and restricted access areas on-site.

The monitoring programs must be developed on a site-specific basis, be periodic, and be conducted by qualified individuals. The results of the monitoring program will require

documentation and submission to applicable regulatory agencies to demonstrate continued compliance with site cleanup criteria, and to demonstrate the effectiveness of on-going remedial actions. In all cases, it will be required that human health and environmental impacts be mitigated to the fullest extent possible.

6.4 Liability

The Canadian Council of Ministers of the Environment has determined that the "polluter pays" principle is paramount when remediating pollution.

Liability issues will be a major concern to the proponent or owner of the facility being decommissioned. The owner can be defined as any person who owns, leases, invests in or rents the land in question. Liability can also extend to other third parties if they are determined to "have control" of contaminants at the time of environmental release. The potential legal consequences for the owner of contaminated land are minimized if the contamination is controlled on-site and does not threaten to contaminate off-site areas through various migration pathways.

Liability can become onerous, however, when the owner sells or redevelops the site for another purpose, and knowingly conceals the presence and extent of contamination. Subsequent owners may undertake legal action to recover the costs of the site cleanup from the vendor. Additionally, most environmental regulations impose liability when contaminants move off-site in concentrations exceeding permitted amounts. Penalties to individuals in Canada can exceed $25 000 plus incarceration, and corporations can be fined as high as half a million dollars, in addition to private court actions.

6.5 Future Controls of Land Use

6.5.1 Unrestricted Future Land Use

The preferred approach to decommissioning planning is to consider "unrestricted" future land use. Today, industry is expected, by the government and public, to employ exemplary environmental practices during siting, planning, operating, and decommissioning phases of an industrial plant. If this is done, site contamination is minimized and high cleanup costs at decommissioning are avoided.

To encourage high cleanup/reclamation standards, cleanup criteria consistent with unrestricted future land use could be developed. These criteria would establish quantitative objectives for:

- groundwater and soil quality;
- mobility of any contaminants from the site;
- the trafficability and structural capabilities of reclaimed surfaces; and
- the extent of site rehabilitation.

6.5.2 Defined Future Land Uses

An alternative to the "unrestricted" future use concept is to define land use and associated cleanup criteria for individual plants based on the remedial actions feasible at the time of decommissioning. The "defined" land use would be consistent with technical and economical constraints which affect the level of cleanup and removal of contaminants from the site during plant decommissioning. Proposed land uses could be reviewed periodically, as new technology becomes available or long-term remediation actions are completed which affect the land use.

Future land use strategy, defined at the facility construction stage, would compel industry to recognize high environmental standards for siting, design, and operation, by establishing quantitative site management objectives early in the project development process.

6.5.3 Land Use Controls

Where restrictions on future use of a decommissioned site are unavoidable, land use controls must be imposed to ensure future

owners are aware of restrictions. Possible control mechanisms include:

- registering on title the existence of and reasons for land use limitations and restrictions;
- requiring both regulatory and municipal approval for any changes to the land use; and
- conducting periodic inspections of the decommissioned site to ensure land title restrictions are being followed.

In some cases, where land use restrictions are implemented because of contamination, subsequent action may reduce or eliminate such contamination and associated effects. The site owner may submit documentation to show the site is acceptable for other uses to the regulatory agency and municipality, and make application to have the land use restrictions changed to the degree that is warranted on the basis of the supporting documentation.

6.5.4 Financial Provisions

An industry may be required to post a refundable bond or place money in trust for use in site remediation at decommissioning. In the event of business insolvency this would provide a measure of protection for an adequate decommissioning of the site.

6.6 Preventive Measures

It must be remembered that the desired approach to decommissioning is to provide for future land uses by eliminating environmental and human health concerns.

There are a number of preventive measures that can be applied during the siting, design, and operating phases of an industrial plant to minimize the severity and extent of environmental and health concerns at decommissioning. Some general measures that can be applied to mitigate the concerns previously described are described in this section.

6.6.1 Site Selection

It would be advantageous to prepare an environmental impact assessment for proposed new plants. Planning for site decommissioning at this stage will have a direct effect on the type and cost of cleanup programs to be implemented when the plant site is ultimately decommissioned. In selecting an appropriate site, the following factors should be addressed to limit the potential for adverse effects on the environment and minimize ultimate cleanup costs:

- select a site with little or no groundwater movement (i.e. underlain by an aquitard or aquiclude system);
- locate downstream of major groundwater users;
- avoid areas with highly fractured and permeable surficial strata;
- avoid sites with high surface drainage and significant watercourses; and
- select an area where groundwater is of poor background quality.

6.6.2 Facility Design

Various features can also be built into the design of an industrial facility to minimize effects on the environment from normal operations or accidental spills. Some factors to consider are:

- locate the plant and waste storage or disposal facilities over soils with low permeability, high buffering capacities, and high ion exchange capacities;
- install pipelines on above ground pipe racks or within secondary containment trenches;
- design sewer systems to avoid leaks;
- ensure inground or underground storage vessels or tanks are designed to protect

against leaks, and are instrumented to indicate leakage;

- construct proper containment pads under all vessels, pumps, loading areas, etc;
- divert surface runoff away from waste disposal sites;
- construct waste disposal sites and fuel/chemical storage facilities using appropriate natural or synthetic liners to ensure containment of spills or leachate;
- design waste disposal areas in a manner compatible with future reuse of the site;
- install appropriate monitoring systems around areas where hazardous or toxic materials are received, stored, shipped or disposed of; and
- include a leachate collection system in the liner design of land disposal sites to facilitate collection of leachate for treatment.

6.6.3 Operating Procedures

Operating procedures can have a direct effect on the nature and extent of contamination and, therefore, on the total cost of cleanup when the plant is closed. Changes in waste management practices at operating plants, and establishment of effective procedures for new or proposed plants, will affect the extent of plant cleanup. The general preventive measures or procedures that should be implemented to reduce the eventual cost of plant site cleanup are outlined in the following:

- appoint an environmental officer to oversee all environmental aspects of site operation and waste management and disposal;
- document the quality and type of chemicals used in all phases of site operations;
- characterize and quantify the waste output;
- maintain inventories of all waste in storage or disposed of on the site;
- reclaim abandoned disposal sites while the plant is still in operation;
- maximize waste utilization (reuse, recycle, recover, and reduce) and off-site disposal;
- monitor surficial soil and groundwater quality on the plant site regularly;
- implement a spill response and reporting procedure, including leak
- clean up all spills or leaks immediately;
- conduct in-house training programs for waste management, disposal and spill response and cleanup; and
- prepare an annual report summarizing all relevant environmental data.

6.6.4 Audits and Monitoring

Environmental audits of industrial plant sites are becoming important in the management and control of environmental risks. Audits, which may be conducted in-house or by independent consulting firms, provide information on wastes and regulatory compliance and identify environmental risks. Audits should be conducted with objective assessments of:

- adequacy of environmental/waste data;
- compliance with environmental regulations;
- compliance with established procedures with respect to environmental protection, health and safety and chemical handling and disposal;
- Material Safety Data Sheets (MSDS) for all toxic or hazardous materials used on site; and
- details of corrective response and subsequent follow up.

Periodic regulatory monitoring of atmospheric and aqueous emission, and soil, sediment, and groundwater quality will identify potential environmental problems, provide for expeditious application of suitable mitigative measures and assist in the development of appropriate remedial measures at decommissioning. The following monitoring should be implemented:

- collect and analyze groundwater samples from piezometers installed at appropriate locations upgradient from and downgradient of the plant site, waste impoundments, chemicals storage and underground storage tanks;
- collect air samples at emission points and ambient locations around the plant;
- collect surficial soil samples around the plant site to identify sources of contamination;
- sample surface waters at points of ingress to and egress from the site;
- periodically sample sludges and sediments to identify the extent of contamination, which will assist in the development of appropriate remedial measures at decommissioning; and
- regularly sample and analyze wastewaters discharged to sewers, drains, wells, sumps or watercourses.

6.6.5 Cleanup Response to Contamination

A spill response procedure should be developed with the objective of minimizing the spread of atmospheric, soil, groundwater and surface water contamination in the event of a release of chemicals or fuel. A spill response plan should address:

- clear identification of staff responsibilities;
- identification of outside assistance that is available;
- identification of potential spill/cleanup scenarios; and
- for each scenario:
  - document corrective actions to be followed to eliminate or minimize spill or leak;
  - identify techniques for product recovery;
  - list readily available equipment;
  - identify preferred options for the disposal of contaminated materials; and
  - identify the appropriate regulatory agencies and notification procedures.

References

British Columbia Ministry of the Environment, "British Columbia Standards for Managing Contamination at the Pacific Place Site", Waste Management Program Branch (April, 5 1989).

Canadian Council of Resource and Environment Ministers, Proposed Interim Guidelines for PAH Contamination at Abandoned Coal Tar Sites. Prepared by the Ad Hoc Federal-Provincial Working Group on Interim PAH Guidelines for Waste Management Committee (May 27, 1988).

Canadian Council of Resource and Environment Ministers, "Canadian Water Quality Guidelines" (1987).

Commonwealth of Massachusetts, Massachusetts Contingency Plan, 310 CMR 40.00 (1988).

Garie, H.,R. Hazen, K. Siet,and R. Tucker, "Standard Setting for Cleanup of Chemical Contaminated Soils", presented at the *Third Conference on Environmental and Public Health Effects of Soils Contaminated with Petroleum Products*, University of Massachusetts, Amherst, MA (Sept. 19, 20, 21, 1988).

Health and Welfare Canada, "Guidelines for Canadian Drinking Water" (1987).

Monenco Consultants Limited, "The Development of Soil Cleanup Criteria in Canada, Vol. 1, Methods and Strategies Currently Used to Develop Cleanup Criteria for Contaminated Sites, Vols. 2, 5, and 6, Development of the AERIS System", prepared for the Decommissioning Steering Committee, Canadian Council of Ministers of the Environment, (March, 1990).

Monenco Consultants Limited, "Guide to the Environmental Aspects of Decommissioning Industrial Sites", prepared for Supply and Services Canada, DSS 8040-4/2472 (1985).

Ontario Ministry of the Environment, "Guidelines for the Decommissioning and Cleanup of Sites in Ontario" (1989).

Petroleum Association for Conservation of the Canadian Environment, "Environmental Guidelines for Decommissioning of Service Stations, Pace Report 88-5 (1988).

Quebec Ministry of the Environment, Guide Standard de caractérisation de terrains contaminés (1988).

United States Environmental Protection Agency, Guidance on Remedial Investigation Under CERCLA, EPA/540/G-85/002 (June, 1985).

McKeague, J.A. and J.G. Desjardins, *Minor Elements in Canadian Soils*, ... (1979).

Appendix A

Site Decommissioning Field Programs: General Considerations

A.1 Types of Samples

- Soil and overburden
- Sediments including catch basins and dry wells
- Vegetation
- Soil gas
- Soil pore water (Unsaturated Zone)
- Groundwater (Saturated Zone)
- Surface water
- Ambient atmosphere
- Sludges, tailings, on-site landfills
- Sewers, drains, outfalls and seepage areas
- Residues, waste rock piles
- Tanks, lagoons, and ponds
- Construction materials (indoor and outside)
- Utility corridors and piping
- Buried Objects - underground storage tanks, drums, pipes, solids, waste
- Other Samples - transformer oil (PCBs?), insulation material (asbestos?), dust, etc.

A.2 Background Conditions

Definition

Conditions which represent levels of chemical constituents in the environment away from the influences of the industrial plant and away from other sources of contaminants in the area. Background locations should be at least 1000 m upgradient from the plant with respect to the prevailing wind direction, groundwater and surface water flow.

Procedure

- design sampling program to establish background conditions for all sample types of interest; sampling program will vary from site to site;
- select sufficient number of background sampling sites to provide statistical confidence limits as appropriate;
- locate background sites in area of the same geologic origin as the plant site; and
- obtain approval from landowner(s) to access the background sites.

A.3 Sampling Procedures

The goal of sampling procedures is to obtain representative samples for analysis. In general:

- establish the extent of investigation;
- select sampling equipment that would enable collection of a representative sample;
- select preferred sampling technique (i.e., grab, composite, or integrated sampling);
- determine sample preservation requirements;
- select desired sampling intervals and frequencies;
- make and record visual observations of the sample matrix;

- collect enough sample material for laboratory determinations and analytical quality control checks (e.g., replicates);
- properly label the sample to identify depth, location and date of sampling;
- record the sample's identity and time and date of sampling on a chain of Custody Record;
- store sample in suitable container inert to the chemical constituents which are to be analyzed;
- preserve sample, if necessary, with chemical additives (the short- and long-term requirements must be established and the validity of the program proven);
- clean and decontaminate sampling equipment after collection of each sample;
- transport samples to laboratory; and
- complete a "Chain of Custody Record" at the laboratory so as to provide the analyst with a record of the actual storage period prior to analysis and the parameters to be analyzed.

Sampling Techniques

- Soil and Overburden
  - sample soil horizons where well developed;
  - auger boreholes by hand and collect samples at approximate depths;
  - excavate test pits with a backhoe and collect samples off walls and bottom;
  - auger holes by a mobile drill rig and collect samples at appropriate depths; a continuous coring device or split spoon sampler should be employed to obtain depth specific samples through the auger annulus.
- Sediments
  - collect surface samples to a 15 to 25 cm depth using a sampling trowel or shovel, or with a dredge; and
  - use a coring device (ponds), or a drill rig or backhoe (ditches) should deeper sampling be needed.
- Soil and Volatile Vapours
  - install a perforated tube at a prescribed depth in the unsaturated zone soil and extract a vapour sample either into a collection vessel, absorption trap or directly into a gas chromatograph;
  - vapour measurements can also be made in wells, pump houses, sumps, piezometers, sewers, drains, utility corridors, tanks, along floor cracks and around foundation walls;
  - for combustible gases, use a manual sample pump and indicator tubes such as GastecTM or portable combustible gas meter to measure concentrations.
- Soil Pore Water (Unsaturated Zone)
  - collect soil pore water by either: vacuum pressure devices, vacuum plates and tubes, or pan lysimeters (glass bricks), core samples squeezing in laboratory.
- Groundwater
  - downhole geophysics should be carried out when drilling boreholes to outline vertical contamination and interpret stratigraphy and aquifer zonation;
  - piezometers or stand pipes can be installed in boreholes or test pits;
  - choice of piezometer materials and sampling mechanism must be

compatible with the constituents to be analyzed;

- withdraw groundwater from installed piezometers by one of the following mechanisms: positive displacement (bladder), grab samplers (bailer, syringe pump), positive displacement (mechanical), gas displacement (gas drive), or suction (peristaltic, vacuum).

- to minimize the possibility of cross-contamination it is preferable to install dedicated samplers in each piezometer; and

- all piezometers must be purged prior to sampling to ensure that a representative groundwater sample is collected.

- Surface Water

  - take a grab sample by lowering a teflon or stainless steel beaker directly into the water body; and

  - collect a time-weighted composite sample or time-specific samples using automated equipment.

- Ambient Atmosphere

  - use an organic vapour analyser (such as a TIP, OVA, or Gastec™) to detect certain volatile priority pollutants in air;

  - time-weighted samples can be obtained using hi-volume air samples and filters or special absorbent tubes for later laboratory analysis.

- Sludges and Residues

  - sample sludge and residues by either a trowel, vacuum tubes or a more sophisticated sampling device.

- Construction Materials

  - advance several holes in the concrete floors and walls with an electric concrete drill and bit and collect the concrete cores;

  - other materials should be sampled in a similar manner.

- Buried Objects

  - scan the area with geophysical devices (magnetometer, earth conductivity survey or ground penetrating radar) to locate buried drums, underground storage tanks, unknown buried materials, utility corridors and to outline groundwater contamination depending on contaminant characterization and material composition.

- Other Samples

  - sample contents of buried tanks, above ground tanks and other containers suspected to contain waste materials or unknown contents;

  - sample transformer oil;

  - collect insulation material around boiler and distribution pipes;

  - examine fluorescent light ballasts; and

  - scrape dust off inplant walls and floors.

A.4 Sampling Density and Location

- reconnaissance samples must be collected in areas where, because of process, loading, receiving and shipping, storage and waste treatment and disposal operations, contamination is likely to have occurred;

- sample materials where discoloration or odour suggest contamination; and
- density and location of discrete sampling points must be considered carefully to resolve spatial distribution of contaminants on a site-specific basis.

A.4.1 Soils and Overburden

- concentrate sampling density in areas suspected to be contaminated from a review of plant site assessment information;
- establish sampling sites also in areas which are not expected to be contaminated;
- establish a sampling grid (spacing is site-specific) over the suspected contaminated area and the adjacent areas;
- collect samples at each node, offsetting as necessary to sample suspected areas of contamination;
- at each sampling location collect a surficial sample (0 to 10 cm) as well as deeper samples (site-specific) sufficient to characterize the extent of contamination in the unsaturated and saturated zones;
- analyze a sufficient number of samples, selected on the basis of site characteristics and anticipated contaminant migration pathways, to indicate the presence of contaminated zones, contaminant type and concentration range; archive the remainder of the samples for later analysis if required;
- select number of sampling sites to be statistically sufficient; note that sample locations should be biased toward areas of suspected contamination, and randomly located in other areas of the property;
- during a reconnaissance program the baselines for sampling grids should be established and surveyed; samples may be collected from all grid nodes and archived for later analysis or samples may be collected from selected biased and random nodes for analysis; the grid baseline will be used for sample location control and co-ordinating further detailed work and cleanup if required.

A.4.2 Sediments

- sample sediments in all topographic depressions on the property that may have received site drainage;
- sample sediments in drainage ditches, drains, catchbasins, sumps and dry wells that may have been contaminated by carried process wastewaters; and
- sample sediments particularly in areas where water tends to pond, or where frequent spills or discharges have occurred; contaminants often concentrate in fine-grained sediments found in depositional portions of watercourses or drains.

A.4.3 Soil Gas

- particularly useful for delineating extent of contamination with volatile organic chemicals in the subsurface;
- measure soil vapour concentrations on-site at grid locations similar to the soil sampling grid pattern; and
- concentrate in areas where underground storage tanks are located, spills have occurred, or waste has been disposed of or migrated to in the subsurface.

A.4.4 Soil Pore Water

- concentrate pore water sampling devices in areas suspected of contamination; and
- soil pore water determinations are particularly useful in areas of lagoons, ponds, pits, drain and tank farm areas, land farming zones, known surface spill

zones, and other areas where suspected contaminants were handled, stored or disposed of.

A.4.5 Groundwater

- sample on-site wells for which construction information is available or can be obtained;
- install a series of piezometers (small diameter monitoring wells) on-site, one located upgradient from problem areas and the remainder situated downgradient from problem areas and at suitable depths for the expected contaminants; and
- the piezometer location and design must take into account the chemical phase(s) in which the contaminants are expected to occur (dense non-aqueous phase liquid) (DNAPL) or sinker; light non-aqueous phase liquid (LNAPL) or floater; dissolved; and emulsion).

A.4.6 Surface Water

- collect water samples from ditches, drains, ponds, seepage, springs, lagoons, creeks, rivers, sewers and outfalls, etc.

A.4.7 Ambient Atmosphere

- air quality measurements may examine ambient air quality or measure concentration of specific contaminants;
- measure levels of pollutants in air at locations similar to the soil sampling grid pattern; and
- take air quality measurements in and around process areas, enclosed areas (tanks, pits etc.), and pipe racks and utility corridors used to transport potentially hazardous liquid or gaseous materials.

A.4.8 Sludges and Residues

- collect sludges and residues from all drains, sumps, gutters, process vessels, treatment facilities, ponds and lagoons; and
- if present, equipment in the facility should be examined for residues and contamination prior to removal.

A.4.9 Construction Materials

- collect composite concrete core samples of floors and walls from every major process area or room; wood from cooling towers; dust from contaminated piping, etc.;
- sample support structures for equipment, vessels, pipe racks, utility corridors, tailings slurry, etc.; and
- instrumentation must be calibrated in a background area of the site or adjacent property having similar ground conditions and no known contamination.

A.4.10 Buried Objects

- geophysical equipment employed must be effective for the type of materials anticipated and the terrain constraints of the site;
- geophysical measurements should be made at a number of locations to form a grid pattern;
- the density of measurements should be increased in areas where buried objects are suspected to be present; and
- data should be normalized so that anomalies are readily apparent.

A.4.11 Other Samples

- collect inplant samples of transformer oil; insulation material; and dust;
- collect dust samples on roof and exterior walls;
- collect oil from transformers situated outside the plant; and

- collect samples of appropriate materials from all other parts of the site where contamination is possible.

A.5 Health and Safety Considerations

Conducting investigations on an industrial site can be very dangerous, particularly if facility operations are still being carried on in some areas, or if the facility is old or has been closed down for some period. Safety and health considerations will vary from site to site, but particular caution must be taken when sampling process lines, tanks, drums, pits, ponds and shafts as well as around known waste storage or disposal areas. The degree of safety and health considerations will reflect the nature of known and suspected chemical contaminants on the site. It is recommended that an industrial hygienist and medical doctor be consulted in developing an appropriate site-specific Occupational Health and Safety Plan (OH&SP) and monitoring program. All members of the project team, and any subcontractors working on the site must be briefed on the OH&SP. A Safety Officer should be appointed whose responsibility is to ensure that requirements of the plan are met by site personnel.

Some of the considerations to be included in an OH&SP are summarized in the following. An OH&SP developed and used by Monenco on a site where PCBs and other organic chemicals are present is found in Appendix B.

Safety Measures

- have project team staff obtain appropriate medical checks before, during and after field work;
- provide staff with protective clothing;
- provide staff with adequate breathing protection devices ranging from canister-type respirators to continuous air supply;
- monitor explosive vapour, dust, asbestos and/or airborne contaminants levels in air prior to and during sampling and cleanup; and
- enforce in-plant and on-site safety protocols on all staff.

A.6 Analytical Procedures

Analytical programs must be selected to ensure adequate characterization of the chemical contaminants and be of value in the delineation of the area(s) of contamination.

Design of Analytical Program

Select a reputable laboratory that:

(1) routinely participates in round-robin, inter-laboratory comparisons of analyses of environmental samples;

(2) has qualified personnel;

(3) has state-of-the-art analytical equipment and procedures;

(4) maintains internal quality control procedures; and

(5) is cognizant of analytical procedures used by regulatory agencies.

Include specific design considerations in the analytical program, such as:

- chemical determinations to be made;
- analytical methodologies;
- analytical detection limits;
- sample size, method of preservation, and transportation to laboratory;
- quality control; and
- in-lab sample storage and preservation.

Identify specific types of contaminants to analyze for in all samples.

Analyze all soil, vegetation, and water samples for general pollution indicators: pH,

electrical conductivity, oil and grease, total organic carbon (TOC) and total organic halogen (TOX). The determination of these parameters, indicative of gross disruption of subsurface conditions, is a low cost analytical alternative. The determination of the latter three parameters are for hydrocarbon processing industries, such as oil refineries, gas plants, organic chemical plants. Analyses for major cations and anions, metals, and specific organic chemical parameters depends on site-specific operations.

A.7 Quality Assurance/Quality Control

A.7.1 Quality Assurance (QA)

- system of documented checks which validates reliability of a data set; and
- a program must be developed, implemented and monitored outside the normal sampling and analytical operations procedures to ensure that quality control procedures are followed on a daily basis to reduce variability and errors, to identify and correct measurement problems, and to provide a statistical measure of data quality.

A.7.2 Quality Control (QC)

A.7.2.1 Sampling Quality Control

Decide on a minimal data set consisting of selected field measurements and the sample volume required to comprise a "representative sample".

Avoid potential sources of error by:

(1) calibration of all sampling and field measurement equipment;

(2) assurance of representative sampling through the use of written, proved protocols and trained staff; and

(3) follow proper sample handling, containerizing, identification, recording, preservation, storage and "chain of custody" procedures.

A.7.2.2 Analytical Quality Control

- ensure valid analytical results through the use of standards and accepted, documented analytical procedures;
- submit blind control samples and blanks as "normal samples" to laboratory;
- establish a measure of confidence in the analytical results of the QC program;
- include in QC program three main functions:

  (1) Control Procedures

  (2) Determination

  (3) Documentation of Data Quality

- ensure laboratory adheres to documented laboratory procedures, including :
  - proper calibration of instrumentation;
  - daily analysis of sample replicates (precision), standards (accuracy), spiked samples and blanks; and
  - use of QC charts to document validity of laboratory results.

A.7.3 Sources of Possible Error in a Sampling and Analysis Program

Sources of error can be derived from site selection, sampling, analytical measurements, reference samples and/or data handling. Some of these errors include:

- instrument malfunctions during field measurement;
- sampling mechanism bias;
- cross contamination during sampling;
- matrix interferences and operator error in preparation of field blanks and standards and in the preservation of samples;

- delay and sample loss during transportation of samples to lab;
- "aging" of samples prior to eventual analysis;
- cross-contamination and/or mishandling during subsampling in lab;
- use of "aged" standards in analytical determination;
- matrix interferences and possibly instrumental malfunction during analysis; and
- machine errors, and improper extrapolation/interpolation and/or over-reporting/ underreporting of errors during calculation of results.

Errors are basically either (1) systematic (biased accuracy); or (2) random (e.g., lack of precision due to improper handling or human failures).

Large systematic errors can result from poor sampling techniques, inappropriate sample handling materials and improper analytical procedures. Large systematic errors often result in reporting a false positive or no trend, when in fact an unbiased series of samples would show the opposite to be true.

Random errors induced by field conditions or system malfunctions can be controlled by repeated sampling and field measurements.

Appendix B

Sample Occupational Health and Safety Plan

Specification - TB 8287-9/000200
Containment of PCB Contaminated Soils

2.0 Environmental Protection and Worker Safety

2.1 General

Due to the nature of the materials being handled at the site, special environmental protection and worker hygiene protocols as specified herein and in the publications of Section 1.5 will be necessary in addition to the normal construction site health and safety requirements.

2.2 Environmental Protection

1. During the period of work the Contractor shall provide adequate means such as drains, collector wells, sumps or other methods approved by the Engineer, to prevent the movement of PCBs off the site via surface drainage, or sewers.

2. All oily liquids shall be collected and stored on-site in an approved manner as specified in Section 4.2.

3. Water entering excavations in areas A to I inclusive, as shown on the drawings, shall be collected and temporarily stored on-site for treatment and eventual discharge to the sanitary sewer system as specified in Section 4.2.

4. Equipment used for handling the contaminated material shall be thoroughly cleaned, to the satisfaction of the Engineer, before being used to place the uncontaminated backfill material.

5. All equipment used for removing the contaminated material shall be steam cleaned, washed with a high pressure water unit or an approved solvent prior to removal from the plant site.

6. The Contractor shall set up a secure decontamination pad on site to decontaminate all construction equipment. Wash and rinse solutions shall be collected, stored and/or treated as specified in section 4.2.

2.3 Worker Protection

1. The Contractor shall ensure he is familiar with the Occupational Health and Safety Plan (Section 2.4) for this contract, and ensure his employees and any subcontractors are also familiar with the plan. Prior to starting work signed Compliance Agreement forms must be submitted to Monenco for each person working on the site.

2. Contaminated areas shall be clearly marked and entrance restricted to those personnel wearing the appropriate level of protection.

3. The Contractor shall ensure that all personnel entering or leaving contaminated areas shall, at all times, log in and log out.

4. Personnel departing contaminated areas for a break, lunch, end of day, etc. must be thoroughly decontaminated.

5. Decontamination procedures for personnel wearing protective equipment shall be set up in accordance with the

Occupational Health and Safety Plan, to wash and rinse or dispose of all the personal protective equipment worn in contaminated areas. The Contractor shall provide a facility for such washing, rinsing and disposal during the period of work.

6. Boots and gloves shall be decontaminated by scrubbing with an approved detergent-water solution, followed by rinsing with copious amounts of water.

7. Discarded contaminated clothing and wash/rinse solutions shall be placed in closed containers and disposed of with other substances on site or decontaminated.

8. Contractor shall ensure that non-impervious clothing which becomes contaminated shall be removed immediately, disposed of, and replaced.

9. Contractor shall ensure that his personnel do not eat or smoke in contaminated areas.

10. Contractor shall ensure that personnel working in contaminated areas wash their hands thoroughly with soap or mild detergent and water before eating, smoking or using toilet facilities.

2.4 Occupational Health and Safety Plan

1. This Occupational Health and Safety Plan establishes guidelines and requirements for safety of personnel during the conduct of construction activities associated with the cleanup of PCB contamination at _____ _____. All employees of the Contractor and any subcontractors involved in construction activities are required to abide by the provisions of this plan. Each person working on the site is required to read the plan and sign the attached Compliance Agreement.

2. The Occupational Health and Safety guidelines and requirements presented herein are based on a review of available information and an evaluation of potential hazards. Because of the variety of possible work activities and site conditions which may be encountered, and the uncertainties associated with potential health effects from exposures to PCBs (and other contaminants which may be present) no guarantees can be made regarding the potential for health effects associated with activities on this site. This plan outlines the health and safety procedures and equipment required for activities at this site to minimize the potential for exposures of all personnel.

3. The contaminants of greatest health concern associated with activities at this site are: Polychlorinated Biphenyls (PCBs) and associated chlorinated benzenes. Other chlorinated solvents have been used at the site, such as Trichloroethane (TCA) although none has been determined to be on or in the ground, to date. PCB contamination at the site has been found to occur as various phases:

   - a denser than water PCB oil phase
   - a lighter than water PCB contaminated mineral oil phase
   - a dissolved phase in groundwater.

The site levels (concentrations) of PCBs found in soils and fluids at the site range from trace amounts to about 65% pure PCBs.

4. The major routes of potential exposure are inhalation, skin absorption, and ingestion. Where absorption through the skin is a likely route of exposure, appropriate clothing is considered to be an effective barrier to PCBs in liquids, soil or as airborne particles. Ingestion would only occur if food became

contaminated or if airborne particles were inhaled, trapped by mucous membranes, and subsequently ingested. Inhalation of small airborne dust particles could occur during earth moving activities, which generate dust.

5. The proposed layout of site facilities is shown on Figure B-1, at the end of this section. Part of the contaminated work area on owner's property is indicated. Surface and subsurface contamination is known to be present at various locations in all work areas of the site.

6. The site facilities provided by the property owner include:

   - car parking area
   - hookups to sanitary sewer, water and electric at proposed trailer locations
   - a number of 25 000 L (5 500 gal) storage tanks for water from excavations and drainage control
   - sample storage area
   - water treatment system (granular activated carbon)
   - water and electric supplies

   Facilities to be provided by the Contractor include:

   - wash trailer (toilets, wash basins, showers, with storage areas for outer protective clothing)
   - office/change/lunch trailer
   - vehicle decontamination pad
   - boot wash area

7. Entrance to the site is via the car park on the west side of the plant. All personal vehicles are to be left in the car park. A project safety log book is to be provided and maintained by the Contractor, in the site office. All persons entering the site must log-in indicating name, company, date and time. When leaving the site all persons must log-out in a similar manner.

8. The use of the trailers must be conducted as follows:

   - Following log-in, use Change area to dress in work clothes. Street clothes are to remain in the Change area.
   - Protective outer clothing (i.e., coveralls, rubber boots, rubber gloves, hard hats, respirators, eye guards, etc.) are to be stored and donned in the Wash Trailer.
   - Only when persons are properly dressed in outer protective clothing, are they to enter the contaminated work area through the gate adjacent to the wash trailer.
   - Before leaving the contaminated work area all personnel must wash outer protective gear, particularly boots, gloves and rain gear in the boot wash area.
   - Upon exiting the contaminated work area, all persons are to use the Wash Trailer to remove and store outer protective clothing, and to wash/shower before entering the Change/Lunch area.
   - Before leaving the site, all persons are to change into street clothes, leave their work clothes in the Change area, and log-out.

9. Before commencing work, the Contractor may consider having employees undergo a medical examination. The requirements of a medical examination can be provided to the Contractor's physician by Monenco's corporate medical officer.

10. Before work commences the Contractor shall provide copies of the Occupational Health and Safety Plan to all employees. The plan shall be reviewed and discussed and questions answered. Signed Compliance Agreements forms shall be collected by the Contractor and returned to Monenco. Individuals refusing to sign the form will not be allowed to work on the site. Subcontractors and subcontractor personnel involved in site activities are also required to comply with the provisions of this plan. However, the Contractor and subcontractors are considered separately responsible for enforcement and/or modification of safety measures applied to their employees.

11. The personal protective equipment specified in this plan (see .15) must be provided to all personnel. In addition the following requirements must be met:

    - facial hair that interferes with proper fit of respirators must be removed.
    - contact lenses must not be worn.

12. A Project Safety Log will be maintained at the work site by the Contractor. The Engineer, or his designate, will review and sign the safety log at the completion of each work day. The project safety log will be used to record entry and exit dates and times of all personnel, and of project site visitors. Any accidents, injuries, and illnesses; incidents of safety infractions by field personnel; and other information related to safety matters are to be recorded. All accidents, illnesses, or other incidences are to be reported to the Engineer, or his designate.

13. The area around intrusive site activities such as excavating, will be designated as potentially contaminated work areas. Within the work areas, protective clothing and equipment as specified in this Safety Plan must be worn. Whenever possible, personnel should work from a position upwind of earth-moving operations. Upon leaving the work areas, all personnel will follow the decontamination procedure (see .18). Before leaving the site, all personnel will change and wash/shower in the trailer facilities on site.

14. Smoking, eating and drinking will not be permitted on the work site except in the lunch room provided. Good personal hygiene must be practiced by all personnel to avoid ingestion of contaminants or spread of contaminated materials.

15. The following protective equipment must be provided by the Contractor, and must be worn by all personnel.

    - Head Protection

      Hard hats must be worn by all personnel working on the site.

    - Eye Protection

      Safety goggles, glasses, or face shields must be worn by all personnel working close to heavy equipment or performing activities where potential for eye or face exposure exists due to splash, dust, or vapour, etc.

    - Skin Protection

      Waterproof and solvent-resistant gloves must be worn by all personnel. In areas where heavy contamination may be encountered, inner gloves (surgical latex type gloves) should also be worn. Personnel should discard gloves and other skin protection equipment which becomes torn, punctured or appears to deteriorate under chemical action (in the latter case, the Engineer should be notified). Appropriate waste disposal containers (steel drums) will be provided on site.

- Foot Wear

  Waterproof and solvent-resistant neoprene safety boots (with steel toe caps and shank) must be worn by all personnel while on the site.

  BOOTS MUST BE PROPERLY DECONTAMINATED BEFORE LEAVING THE CONTAMINATED WORK AREA.

- Clothing

  Polycoated Tyvek disposable coveralls or (if conditions are wet) waterproof pants must be worn by all personnel.

- Respiratory Protection

  Half mask respirators with organic vapour cartridges and high-efficiency dust filters should be worn by all personnel where heavy dust or vapour conditions are encountered. It is expected that in open outdoor situations (away from earthmoving activities) respirators will not generally be required. All personnel should be fit tested for the specific brand of respirator to be used. In the case of PCBs, a M.S.A. Comfo II black silicone respirator (with appropriate organic vapour and dust cartridges) or equivalent, is recommended.

- Ear Protection

  Ear protection must be worn during activities which cause excessive noise. The recommended maximum exposure is 85 decibels.

16. All personnel must thoroughly wash their hands and face with soap and water before eating, drinking, smoking or going to the toilet. Meals must only be eaten in the designated lunch area of the trailers, and protective equipment must be removed before entering the lunch area. Smoking is prohibited on the work site, except in the lunch area of the trailer.

17. At the end of each shift all field personnel will wash or shower. Any areas of skin which may have come into contact with PCBs must be thoroughly washed with soap and water. It is recommended that work clothes (worn beneath protective equipment) be frequently laundered.

18. The process of decontamination involved removal of waste stained clothing and equipment during work and particularly at the end of the workday. Care should be taken to avoid skin contact with waste materials during removal of protective clothing. Drums will be provided for disposal of contaminated clothing. The proper decontamination procedure is as follows:

    - Wash and rinse boots and outer gloves with long handled brushes, using water, in the decontamination pad.
    - Proceed to the wash trailer and remove heavily contaminated suits and gloves and place in a disposal drum.
    - Re-usable suits and gloves should be stored in the trailer with other protective equipment (boots, respirators, etc.)
    - Once all the protective equipment has been removed, wash thoroughly (or shower) before proceeding to the Change area.

    All waste material collected as a result of decontamination will remain on the site (in the contaminated work area) and will be stored in an area designated by the Engineer.

COMPLIANCE AGREEMENT

I have received a copy of the Occupational Health and Safety Plan for the Cleanup of PCB Contamination at _____ Avenue, Toronto (Monenco Project No. _____ 8287-9). I have read the plan, and understand that I could be prohibited from working on the site for violating any of the safety requirements in the plan.

Signed _____ Date _____

Print Name _____

Position _____

Company _____

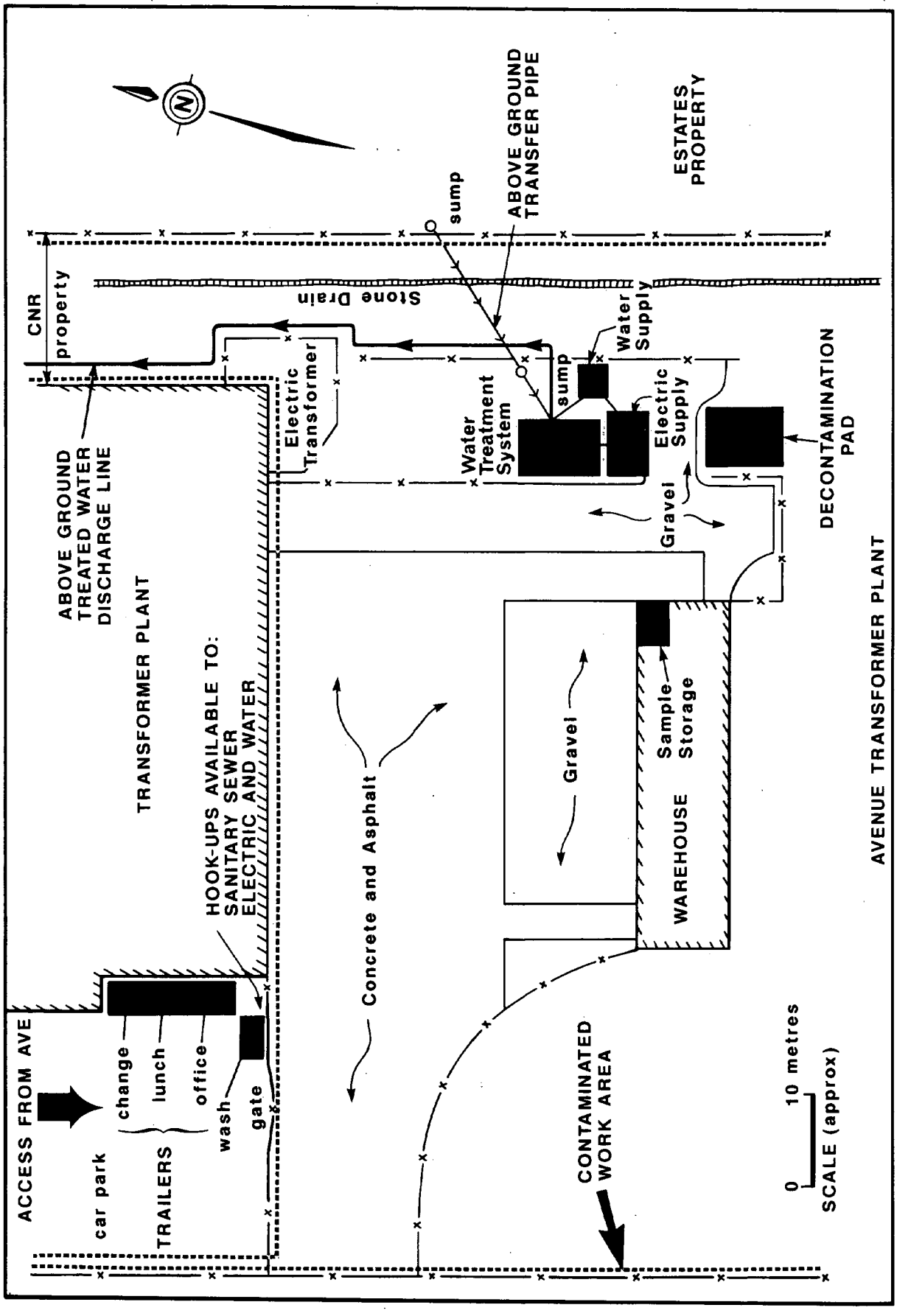

Fig. B-1 CLEAN-UP OF PERIPHERAL PCB CONTAMINATION
PROPOSED LAYOUT OF SITE FACILITIES.

Appendix C

Summary of Guidelines for the Decommissioning and Cleanup of Sites in Ontario, February 1989

The Province of Ontario has issued a decommissioning and cleanup guide for the restoration and rehabilitation of contaminated industrial sites. This document (Guidelines for the Decommissioning and Cleanup of Sites in Ontario, MOE 1989) provides details of the data and information required by the Ontario Ministry of Environment (MOE) for the approval of any cleanup plan. In principle, remedial action will be required wherever contaminants are present at concentrations above ambient background levels.

The MOE already has existing objectives for permissible concentrations of contaminants in the air and water. Where appropriate, these objectives can be used for final cleanup criteria at a contaminated site.

In addition, the guidelines list cleanup guideline limits for 18 elements, oil and grease, pH, electrical conductivity and sodium absorption ratio in soils (Tables C-1 and C-2). These guidelines are based on phytotoxicity and the future land use of the site. For contaminants not addressed in the guide, guidelines must be developed on a site-specific basis. If large numbers of organic contaminants are present, specific indicator or representative compounds may be used for the entire assemblage.

Contaminant cleanup concentrations (not addressed in the guideline) must be developed in consultation with the Phytotoxicology Section of the Air Resources Branch (MOE) and with the consideration of:

- environmental and human health toxicology of the contaminants;
- mobility of specific contaminants or contaminant groups present and migration pathways;
- synergistic contaminant effects;
- physical and chemical features specific to the site;
- future site and adjacent land use; and
- aesthetic considerations.

A risk assessment analysis may be conducted to assess the foregoing considerations as inter-media transfer is not considered in the existing criteria for air, soil or water. Land use plays a major role in the formulation of cleanup criteria, with the resulting criteria becoming less strict (in terms of acceptable residual contamination) for each of the following land uses:

- agriculture, residential or parkland/recreational development; and,
- commercial or industrial development.

Although the existing Ontario Ministry of the Environment (MOE) criteria for permissible concentrations of contaminants in air and water are applied on a province-wide basis, each set of final cleanup criteria can be considered on a site-specific basis with the overall objective of establishing stringent criteria that are fully protective of human health and the environment.

Two examples where site-specific cleanup criteria have been derived in Ontario are the Texaco -- Port Credit and Shell -- Oakville refineries.

Table C-1 Cleanup Guidelines for Soils

	Criteria for Proposed Land Use [a,c]			
	Agricultural/Residential/ Parkland[d]		Commercial/Industrial	
Parameter[b]	Medium and Fine Textured Soils	Coarse-Textured Soils[e]	Medium and Fine Textured Soils	Coarse-Textured Soils[e]
pH (recommended range)	6 to 8	6 to 8	6 to 8	6 to 8
EC (mS/cm)[g]	2	2	4	4
SAR[h]	5	5	12	12
Arsenic	25	20	50	40
Cadmium	4[a*]	3[a*]	8[a*]	6[a*]
Chromium (VI)	10	8	10	8
Chromium (total)	1000	750	1000	750
Cobalt	50	40	100	80
Copper	200[a*]	150[a**]	300	225
Lead	500[a*]	375[a*]	1000[a*]	750[a*]
Mercury	1[a*]	0.8[a*]	2[a*]	1.5[a*]
Molybdenum	5[a*]	5[a**]	40	40
Nickel	200	150	200	150
Nitrogen (%)	0.5[i]	0.5[i]	0.6[i]	0.56[i]
Oil and Grease (%)	1[f]	1[f]	1[f]	1[f]
Selenium	2[a**]	2[a**]	10	10
Silver	25	20	50	40
Zinc	800	600	800	600

Notes:

a Cleanup guidelines recommended by the Phytotoxicology Section, Air Resources Branch, Ministry of the Environment. The guidelines are based primarily on phytotoxicity except for (a*) based on human health; and (a**) based on health of grazing animals.

b All units are in ppm (µg/g), dry weight, unless otherwise stated.

c For comparison with these guidelines, analyses for metal and metalloids must be conducted using an approved strong, mixed-acid digestion procedure. Contact the Laboratory Services Branch of MOE if in doubt about acceptable methods.

d Guidelines have been endorsed by the OMAF/MOE/MOH Sludge Utilization Committee.

e Defined as > 70 % sand and < 17 % organic matter.

f Guideline given is for fresh oil; for weathered oil (min. 2 yr. exposed on site), the guideline is 2 %

g EC = electrical conductivity (saturation extract).

h SAR = sodium adsorption ratio.

i If nitrogen levels exceed the guidelines, the mineralization of the soils should be evaluated. Additions of

Table C-2 Provisional Cleanup Guidelines for Soils

	Criteria for Proposed Land Use[a,c,d]			
	Agricultural/Residential/ Parkland		Commercial/Industrial	
Parameter[b]	Medium and Fine Textured Soils	Coarse-Textured Soils[e]	Medium and Fine Textured Soils	Coarse-Textured Soils[e]
Antimony	25	20	50	40
Barium	1000	750	2000	1500
Beryllium	5	4	10	8
Vanadium	250	200	250	200

Notes:

[a] These guidelines are tentative: actual permissible levels of parameters in other situations may vary according to site-specific circumstances. Further information on the application of these guidelines may be obtained from the Phytotoxicology Section of Air Resources Branch, Ministry of the Environment.

[b] All units in ppm (μg/g), dry weight.

[c] For comparison with these guidelines, analyses must be conducted suing an approved strong, mixed-acid digestion procedure. Contact the Laboratory Services Branch of MOE if in doubt about acceptable method.

[d] These provisional guidelines apply to soil of minimum pH 6.

[e] Defined as > 70 % sand and < 17 % organic matter.

In both cases, portions of the land occupied by the refineries were to be developed for residential dwellings. This change in land use was complicated by the former use of the properties for landfarming of various refinery wastes with the subsequent contamination of the soil by a variety of inorganic and organic contaminants. To obtain MOE's approval, a cleanup plan was designed to lead to the release of the landfarming areas for redevelopment. The MOE soil criteria for pH, electrical conductivity, sodium absorption ratio, nitrogen, oil and grease, and metals were used for these parameters. However, as many as 43 organic chemicals were suspected of being present on site and were deemed by the MOE as being a potential hazard to individuals inhabiting the site. To eliminate this hazard, cleanup criteria for these organic chemicals had to be developed.

The first step toward these site-specific criteria required a review of the chemical, physical, and toxicological properties of the 43 suspect organic chemicals. Similarities among the 43 chemicals with regard to their properties allowed the selection of ten organic chemicals to represent the entire group of 43. Acceptable daily intakes of the ten representative organic chemicals were prepared from their respective toxicological profiles.

To estimate the potential exposures of future site residents to the ten representative chemicals, a pathways model was developed. The various pathways examined in this model were:

- ingestion of contaminated soil and dust;
- inhalation of vapours;
- dermal absorption; and
- ingestion of contaminated plants grown on site.

The acceptable concentrations (i.e., cleanup criteria) for the ten representative organic chemicals (and by implication the entire group of 43) in the soil were derived from the calculated acceptable daily intake, by working "backwards" through the various pathways of human exposure to the concentration in the soil producing the calculated acceptable daily intake.

The development of cleanup criteria for soils is ongoing in Ontario. The guidelines will be updated by MOE as new criteria are developed. For further information, the decommissioning proponent should contact the MOE.

Appendix D

Summary of Contaminated Sites Rehabilitation Policy, Environment Québec, February, 1988

The province of Quebec uses an approach based on both the Netherlands system and the system developed by France to evaluate soil and groundwater contamination. This system defines three levels of contamination as a guide for contaminant assessment and restoration. In qualitative terms the levels are:

- contaminants present at the background or detection limit levelá(A);
- contaminants present at "moderate" levels (B); and
- contaminants present at "severe" levels (C).

The actual quantitative values provided by the province of Quebec (Table D-1), as modified from the Netherlands criteria, are for a relatively large number of compounds and elements. This system provides absolute numbers to assist in decision making regarding the need for cleanup and the extent of cleanup. Specific soil contaminants of concern to the Quebec government were added to those provided by the Netherlands and specific groundwater criteria were modified to make them more applicable to the province. Previously established Quebec criteria for heavy metals and mineral pollutants in groundwater (Level "B") and storm sewers (Level "C") were inserted within the Netherlands' general strategy, Table D-1. U.S. EPA estimated permissible concentrations of certain organic compounds have also been used to make the Quebec document more applicable to the particular needs of that province.

Concentrations of the listed contaminants (Table D-1) which equal or exceed level "B" values would require detailed analysis and some restorative or reclamation procedures would be necessary for agricultural and residential uses. Concentrations which meet or exceed level "C" contaminant values may require corrective measures and restrictive land uses until such time as reclamation techniques lower the contaminant values.

The document, as presented by the government of Quebec, is intended to be used as a guide to the management of contaminated soils and ground water. Specific cleanup criteria are not given.

In principle, the objective of site cleanup is to totally restore the integrity of the degraded media. A restored site should not be subject to any use restriction, should not contaminate the environment, should not threaten human health or damage adjacent property, should not be phytotoxic or biotoxic, and should be aesthetically acceptable. The Quebec Ministry of the Environment recognizes that difficulty may occur in practically obtaining the foregoing objectives on all decommissioned sites. Experience demonstrates that the determination of the appropriate cleanup criteria is based on many factors, including multiple use, background levels, aesthetic factors, future land use, risks to human health, environmental sensitivity of the site, public perception, remedial costs and the existence of suitable treatment technology. A risk assessment approach may form a component of the overall evaluation of factors determining suitable site cleanup criteria.

Table D-1 Quebec Groundwater and Soil Contamination Indicators

		Soil (mg/kg of dry matter) (ppm)			Groundwater (µg/L) (ppb)		
		A	B	C	A	B	C
I -	**Heavy Metals and Elements**						
	Ag	2	20	40	5	50	200
	As	10	30	50	5	50	100
	Ba	200	500	2000	50	1000	2000
	Cd	1.5	5	20	1	5	20
	Co	15	50	300	10	50	200
	Cr	75	250	800	15	40	500
	Cu	50	100	500	25	500	1000
	Hg	0.2	2	10	0.1	0.5	1
	Mo	2	10	40	5	20	100
	Ni	50	100	500	10	250	1000
	Pb	50	200	600	10	50	100
	Se	1	3	10	1	10	50
	Sn	5	50	300	10	30	150
	Zn	100	500	1500	50	5000	10 000
II -	**Mineral Pollutants**						
	Br	20	50	300	100	500	2000
	NO_2 (as N)				20	1000	-
	NO_3 (as N)	-	-	-	10	100 000	0
	NH_4 -	-	-	200	500	1500	
	CN, free (total)	1	10	100	40	200	400
	CN, complex (total)	1	50	500	40	200	400
	F (total)	200	400	2000	300	1500	4000
	PO_4 (as P)	-	-	-	50	100	700
	S (total)	500	1000	2000	-	-	-
	Hydrogen Sulphide (H_2S)	-	-	-	10	50	500
III -	**Monocyclic Aromatic Hydrocarbons (MAH)**						
	Benzene	0.1	0.5	5	0.5	1	5
	Ethylbenzene	0.1	5	50	0.5	50	150
	Toluene	0.1	3	30	0.5	50	100
	Styrene	0.1	5	50	0.5	40	120
	Xylene (total)	0.1	5	50	0.5	20	60
	Monochlorobenzene	0.1	1	10	0.2	2	5
	Dichlorobenzene (any one of)	0.1	1	10	0.1	2	5
IV -	**Phenolic Compounds**						
	Phenols	0.1	1	10	1	3	20
	Chlorophenols (each)	0.1	0.5	5	1	2	5
	Chlorophenols (total)	0.1	1.0	10	1	4	10
V -	**Polycyclic Aromatic Hydrocarbons (PAH)**						
	Anthracene	0.1	10	100	0.2	7	30
	Benzo *(a)* anthracene	0.1	1	10	0.1	0.2	1
	Benzo *(c)* phenanthrene	0.1	1	10	0.1	0.5	2
	Benzo *(a)* pyrene	0.1	1	10	0.1	0.2	1
	Chrysene	0.1	1	10	0.1	1.0	5
	Dibenzo *(a, h)* anthracene	0.1	1	10	0.1	0.2	1
	Dibenzo *(a, h)* pyrene	0.1	1	10	0.1	1.0	5
	Dibenzo *(a, i)* pyrene	0.1	1	10	0.1	1	5
	Dimethylbenzo *(a)* anthracene	0.1	1	10	0.1	0.2	1
	Fluoranthene	0.1	10	100	0.1	2.0	10
	Fluorene	0.1	10	100	0.1	2	10
	Benzo *(b)* fluoranthene	0.1	1	10	0.1	0.2	1
	Benzo *(j)* fluoranthene	0.1	1	10	0.1	0.2	1

Table D-1 Quebec Groundwater and Soil Contamination Indicators (Cont'd)

	Soil (mg/kg of dry matter) (ppm)			Groundwater (µg/L) (ppb)		
	A	B	C	A	B	C
Benzo *(k)* fluoranthene	0.1	1	10	0.1	0.2	1
Indano *(1, 2, 3, c, d)* pyrene	0.1	1	10	0.1	1.0	5
Naphthalene	0.1	5	50	0.2	10	30
Phenanthrenef	0.1	5	50	0.1	1	5
Pyrene	0.1	10	100	0.2	7	30
Total PAH	1.0	20	200	0.2	10	50
3-methylocholanthrene	0.1	1	10	0.1	0.2	1
Acenaphthene	0.1	10	100	0.5	20	30
Acenaphthylene	0.1	10	100	0.5	10	20
VI- Chlorinated Hydrocarbons						
Aliphatic chlorinated hydrocarbons (each)	0.3	5	50	1	10	50
Aliphatic chlorinated hydrocarbons (total)	0.3	7	70	1	157	0
Chlorobenzene (each) except hexachlorobenzene	0.1	2	10	0.3	2	5
Chlorobenzene (total)	0.1	4	20	0.3	4	10
Hexachlorobenzene	0.1	2	10	0.1	0.5	2
Polychlorinated biphenyls (total)	0.1	1	10	0.1	0.2	1
VII - Pesticides						
Organochlorinated						
Aldrin and Dieldrin	-	-	-	0.05	0.7	2
Chlordane (total lsomers)	-	-	-	0.05	0.7	2
DDT	-	-	-	0.05	30	60
Endrin	-	-	-	0.05	0.2	0.5
Heptachlor epoxide	-	-	-	0.05	3	5
Lindane	-	-	-	0.05	4	10
Methoxychlor	-	-	-	0.05	100	200
Carbamates						
Carbaryl	-	-	-	0.05	70	150
Carbofuran	-	-	-	0.05	70	150
Chlorophenoxycarboxylic Acid Derivatives						
2, 4-D	-	-	-	0.05	100	200
2, 4, 5-T	-	-	-	0.05	10	20
Organophosphorus						
Diazinon	-	-	-	0.05	14	30
Fenitrothion	-	-	-	0.05	7	20
Parathion	-	-	-	0.05	35	70
Parathion-methyl	-	-	-	0.05	7	20
Pyridynium Derivatives						
Diquat	-	-	-	0.05	50	100
Paraquat	-	-	-	0.05	7	20
Trichloroacetates						
Picloram	-	-	-	0.05	1	2
Pesticides (Total)	0.1	2.0	20	0.05	100	200

Table D-1 Quebec Groundwater and Soil Contamination Indicators (Cont'd)

	Soil (mg/kg of dry matter) (ppm)			Groundwater (µg/L) (ppb)		
	A	B	C	A	B	C
VIII - Other Pollutants						
Gasoline	100	150	800	1000	1500	3000
IX - Indicators						
Minerals Oils	100	1000	5000	100	1000	5000

Note: - means no criteria established

Appendix E

Summary of Environmental Regulations in Canada

E.1 Alberta

In Alberta, at the present time there are no specific guidelines pertaining to plant site cleanup. Instead, the government relies on existing environmental legislation and discussions with proponents to solicit cooperation from industries whose plants have shut down and require cleanup. Further control is exercised through local planning authorities who can withhold land use rezoning if site conditions and proposed uses are considered imcompatible by the Department of the Environment.

The *Agricultural Chemicals Act* (R.S.A. 1980, C. A-6), the *Clean Air Act* (R.S.A. 1980.c.C-12), the *Clean Water Act* (R.S.A. 1980.c.C-13), and the *Department of the Environment Act* (R.S.A.1980.c.D-19) generally provide to the Minister of the Environment the power to require that every person who deposits, adds, emits or discharges a contaminant (or agricultural chemical) or a substance or thing on or into the natural environment in non-compliance with regulations or licenses in a manner that:

1) causes, or is likely to cause, injury or damage to, or impairment of the quality of the natural environment, or

2) causes, or is likely to cause, injury or damage to plant, animal or human life and health, or

3) is, or is likely to, adversely affect property,

notify the Minister immediately, and take all measures ordered or prescribed with respect to the stopping of such discharge, and the cleaning or decontamination of the natural environment.

Should the Minister's orders not be followed, the Minister may carry out the necessary measures and recover the costs of remediation from the responsible person(s).

In 1980, the Government of Alberta enacted the "*Land Surface Conservation and Reclamation Act*" (LSCRA), R.S.A. 1980, C.L-3, (as amended). The Act applies to all lands within Alberta except for subdivided residential land and agricultural land. Under the Act, the government may issue a reclamation order to the operator of a "designated" surface operation to:

- condition, maintain or reclaim the land or any part of it and land adjacent to it;
- prevent, contain, control, remove or remedy any contamination, degradation or deterioration of the land surface;
- remove or remedy any hazard to human life, domestic livestock or wildlife or to the conduct of agricultural or other operations, and so on (s. 42(1)).

Part 2 (s.23) of the LSCRA lists a number of operations (paper, pulp, fertilizer, oil and gas, chemicals, petrochemicals, steel, cement, etc.) that may be designated as Regulated Surface Operations. At present the reclamation order has only been applied to land use in connection with wells, pipelines, battery plant, transmission lines, mines, quarrys, pits, waste disposal sites or landfill sites, and any other designator operations. Section 23 also gives the Lieutenant Governor in Council the power to designate by regulation any kind of operation or activity as a Regulated Surface Operation if the operation or activity involves the construction, operation or abandonment of a plant for any other industrial, manufacturing

or processing purposes. To date regulations have been issued for:

- Regulated Coal Surface Operations;
- Regulated Oil Sand Gas Pipeline Surface Operations; and
- Regulated Oil Sands Surface Operations.

Under Section 7.1 of the *Hazardous Chemical Act* R.S.A. 1980, CH-3 (as amended), where an unlawful or accidental discharge, emission, escape or spill of a hazardous chemical occurs at a facility for the storage, treatment or disposal of hazardous chemicals, the person responsible for the chemicals is required, immediately on becoming aware of the occurrence, "to take all reasonable emergency measures consistent with public safety to repair, remedy and confine the effects of and remove the hazardous chemicals in such a manner as to effect maximum protection to human life, health and the environment". The Act also instructs the Director of Pollution Control as to the appropriate action to protect human life, health or the environment and charge the cost of such action to any one or more of the persons responsible for the hazardous chemical. The government may also require similar cleanup measures under Section 10(1) of the *Transportation of Dangerous Goods Control Act.*, S.A. 1982, c.T-6.5.

E.2 British Columbia

In British Columbia there are no specific regulations that mandate plant site cleanup if the waste was deposited in compliance with a permit, and is properly contained and monitored. For facilities that are closed, the recourse is industry cooperation, land use restriction registered against the land title or a refusal by the municipality to either rezone the land or issue an occupancy permit. The province has recently released (April 17, 1989) site-specific guidelines for the cleanup of contamination at the Pacific Place site in Vancouver.

For existing operations, if a waste is a "special" waste under the *Waste Management Act* (S.B.c. 1982, c.41) then the Minister can order the operator to take appropriate steps to remove the "special" waste and render the area harmless. In the case of a spill or accidental discharge, a Minister may order the responsible party to implement the necessary measures to prevent or abate contamination where it may cause pollution.

Under the *Environment Management Act* S.B.C. 1981, C.14 the Minister can issue an environmental protection order if he considers that an existing or proposed work may cause detrimental environmental impact.

Spills are reportable under the *Pesticide Control Act*, R.S.B.C. 1979, C.322 and *Pesticide Control Regulations* B.C. Reg. 319/81 for pesticides and the *Transport of Dangerous Goods Act* S.B.C. 1985, C.17 for all dangerous goods. The responsible party is required to take appropriate measures to remedy the situation.

Finally, under the *Health Act* R.S.B.C. 1979, C.161, the Minister of Health may require removal or termination of a health hazard by the responsible party (S.78).

E.3 Manitoba

Manitoba has not enacted specific legislation to require industries to decommission and clean up contaminated plant sites. For plants which have already shut down, Manitoba relies on industry cooperation to carry out plant site cleanup.

Under the new *Environment Act* (S.M. 1987-88, C.26) a valid and subsisting license is required from the Ministry before a person can proceed with construction, alteration, or operation of a plant that may likely cause significant adverse environmental effects (S.10, S.11, S.12 and S.14). A similar license is also required for a plant to close down.

The *Licensing Procedures Regulation Manitoba* Reg. 163/88 enacted under the

Environment Act requires a proponent of a development to submit a description of the proposed environmental management practices to be employed to prevent or mitigate adverse effects, having regard for, where applicable: contaminant handling, monitoring, storage, treatment, and final disposal of pollutants; conservation and protection of natural or heritage resources; environmental restoration and rehabilitation of the site upon decommissioning; and protection of environmental health (S.1(k)).

The *Environment Act*, if properly applied, can ensure that industry operates in a manner that minimizes contaminant discharges into the environment, therefore, minimizing cleanup requirements at decommissioning necessary to permit another land use.

For spills and accidents, both the *Environment Act* and the *Dangerous Goods Handling and Transportation Act* C.C.S.M. D12 (as amended) give the Minister broad powers to take or ask the responsible parties to take counter measures as reasonable to control discharges, protect property and the environment and, where necessary, to recover the costs of cleanup from the responsible parties.

E.4 New Brunswick

New Brunswick does not have any guidelines or regulations pertaining specifically to the decommissioning and cleanup of industrial sites.

The Clean Environment Act
R.S.N.B.1973.C-6 (as amended), Section 5, provides powers to the Minister of the Environment as follows:

5. (1) The Minister may issue a control order requiring the person to whom it is directed to do one or more of the following, namely:

(a) to limit or control the rate of discharging, emitting, leaving, depositing, or throwing of any contaminant or waste into or upon the environment, or any part thereof, in accordance with the directions set out in the order;

(b) to stop the discharging, emitting, leaving, depositing or throwing of any contaminant or waste into or upon the environment, or any part thereof;

(i) permanently,

(ii) for a specified period, or

(iii) in the circumstances set out in the order;

(c) to alter the manner of discharging, emitting, leaving, depositing or throwing any contaminant or waste into or upon the environment, or any part thereof, in accordance with directions set out in the order;

(d) to alter the procedures to be followed in the control or elimination of the discharging, emitting, leaving, depositing or throwing of any contaminant or waste into or upon the environment, or any part thereof, in accordance with directions set out in the order;

(e) to install, replace or alter any equipment or thing designed to control or eliminate the discharging, emitting, leaving, depositing or throwing of any contaminant or waste into or upon the environment, or any part thereof, in accordance with directions set out in the order; and

(f) where a contaminant or waste has been discharged, emitted, left, deposited or thrown into or upon the environment or any part thereof, to carry out cleanup, site rehabilitation or other remedial action, including the provision of water by means of the installation of a water-supply system or by other means, in accordance with directions set out in the order.

Clean Environment Act provides that, should the requirements of the control order not be followed by the responsible person, the Minister may take such action as necessary to implement the control order and recover the costs of implementation from the responsible person(s).

The *Health Act* R.S.N.B.1973, c. H-2, (as amended) permits the Minister of Health to make rules, orders and regulations for the prevention, treatment, mitigation, and suppression of disease, and the conservation of human health and life. The Act provides for and regulates, amongst other things:

1) the prevention, abatement, and removal of nuisances;

2) the method of operating factories, trades or businesses so far as it relates to human health;

3) the prevention of the pollution, defilement, discolouration or fouling of lakes, rivers, streams, pools, springs, wells, and waters, and waterworks;

4) the prevention of pollution of a public conveyance by any nuisance or filth;

5) generally all such matters, acts and things as may be necessary for the protection of public health.

The *Health Act* allows the ordering of control measures to prevent or stop contraventions of the regulations, and permits recovery of costs by the Minister should control measures be undertaken by the government on behalf of the responsible person.

Pesticide chemicals that are used, stored, transported, or disposed of in a manner contrary to the regulations, or that are dangerous to the health of a person or animal, or harmful to soil, crops, or plant life, are similarly controlled under the *Pesticides Control Act* R.S.N.B.1973,P-8, (as amended). In addition, the *Unsightly Premises Act* R.S.N.B.1973, c. U-2, (as amended) requires that on land within 500 feet of the right-of-way, on either side, of a highway:

1) No person shall permit premises owned or occupied by him to be unsightly by permitting to remain, on any part of such premises, any ashes, junk, rubbish, refuse, residue of production or construction, bodies or parts of automobiles or other vehicles or machinery or a tumbledown building.

2) No person shall permit a building or structure owned or occupied by him to become a hazard to the safety of the public by reason of dilapidation or unsoundness of structural strength.

E.5 Newfoundland and Labrador

Newfoundland and Labrador do not have guidelines or regulations specific to the phaseout and monitoring of industrial sites or waste disposal sites.

The province solicits the cooperation of industry under the regulations of existing Acts such as:

1) *Department of Environment Act* (S.N.1981 c. 10)

2) *Pesticides Control Act* (S.N.1983,c 52)

3) *Waste Material (Disposal) Act* (S.N.1973 c. 82)

4) *Dangerous Goods Transportation Act* (S.N.1982 c. 45)

5) *Department of Health Act* (R.S.N.1970 c. 83)

These Acts provide the government with the power to make and enforce regulations as necessary:

a) to provide for the prevention or removal or both of all matters, things and conditions on public or private property which constitute or are likely to constitute a menace to public health (R.S.N.1970, c. 83, s.23(1d));

b) to take all reasonable measures consistent with public safety to repair or remedy any dangerous condition or reduce or mitigate any danger to life, health, property, or the environment that may result from discharge, emission or escape of a dangerous good (S.N. c. 45, s. 16(2));

c) to ensure that, subject to the regulations, no person discharges or deposits any material of any kind into a body of water or on any shore or bank thereof or in any place that may cause pollution or impair the quality of water for any beneficial use;

d) to prevent, restrict or prohibit any condition which is causing or which may cause pollution of the air, soil or any body of water; (R.S.N.1970, c. 10, s. 27(1)); and

e) to require any person who has caused any body of water or part thereof, or soil on any area of land to become polluted or unwholesome to cleanse, disinfect, or purify the same at his own cost and expense, and prescribe how and when such remedial actions are to be carried out (R.S.N.1970, c. 10, s. 32(l)k).

E.6 Nova Scotia

Nova Scotia does not have guidelines or regulations specific to the decommissioning and cleanup of industrial sites. The government relies on existing environmental legislation to control the handling and cleanup of dangerous goods, hazardous wastes, and contaminated lands.

The *Environmental Protection Act* (R.S.N.S. 1989, c. 150), the *Dangerous Goods and Hazardous-wastes Management Act* (S.N.S. 1989, c. 118), the *Oil and Gas Production and Conservation Act* (R.S.N.S. 1989, c. 326), the *Petroleum Storage Regulations* (N.S. Reg. 33/88 under the *Dangerous Goods and Hazardous-wastes Management Act*), and the *Health Act* (R.S.N.S. 1989, c. 195) generally provide to the Minister the power to require that every person who deposits, adds, emits, or discharges a contaminant (or chemical) or a substance or thing on or into the natural environment in non-compliance with regulations or licenses in a manner that:

1) causes, or is likely to cause, injury or damage to, or impairment of the quality of the natural environment, or

2) causes, or is likely to cause injury or damage to plant, animal or human life and health, or

3) is, or is likely to, adversely affect property,

notify the Minister immediately, and take all measures ordered or prescribed with respect to the stopping of such discharge, and the cleaning or decontamination of the natural environment. Should the Minister's orders not be followed, the Minister may carry out the necessary measures and recover the costs of remediation from the responsible person(s).

Section 7 of the *Dangerous Goods and Hazardous-wastes Management Act* (S.N.S.

1986, c.7) empowers the Minister of the Environment to direct any persons responsible for dangerous goods or hazardous wastes to:

a) take specified precautions with respect to the treatment or decontamination of an area affected by dangerous goods or hazardous wastes;

b) take specified precautions with respect to the future use of the site;

c) prepare and submit a written contingency plan in case of spills or leakage; and

d) undertake investigations, tests, surveys or other action from time to time.

Section 31 (1) of the *Petroleum Storage Regulations* (N.S. Reg. 33/88), pertains to the decommissioning of unused and abandoned underground storage tank systems, and states that the owner shall:

a) remove all underground piping or purge the piping of flammable product and permanently seal the ends of the pipe by capping;

b) remove all underground tanks; and

c) remove any contaminated soil to a location acceptable to the Minister of the Environment.

The *Mineral Resources Act* (R.S.N.S., 1989, c. 286) was enacted to control the disposal of tailings substances to the environment and also to regulate the restoration, reclamation and rehabilitation of mines and/or mining lands. Under Part III, Section 83 of this Act, the applicant for a lease to operate or work a mine must provide the Minister of Mines with a detailed plan showing the location of all surface buildings, installations, tailings and waste disposal areas. This plan must also outline the proposed method of restoration, reclamation and rehabilitation of the surface lands.

The *Oil and Gas Production and Conservation Act* (S.N.S. 1984, c.9) enables the Minister of Mines and Energy to prescribe the minimum acceptable standards for the methods, tools, equipment and materials to be used in drilling, completing, operating, suspending, and abandoning any wells.

E.7 Ontario

Ontario has enacted the following legislation and regulations which have provisions for the remediation of sites contaminated by chemical spills or improper material handling practices:

1) *Environmental Protection Act* (EPA) (R.S.O. 1980, c. 141);

2) General - Waste Management, (R.R.O. 1980, Reg. 309, as amended by O.Reg. 464/85 under the EPA);

3) *General - Air Pollution, Regulation* 308 (R.R.O. 1980 as amended by O.Reg. 107/85 under the EPA) and currently being revised (1989) under the Clean Air Program (CAP);

4) *Hauled Liquid Industrial Waste Disposal Sites* (O. Reg. 808/81, under the EPA);

5) *Mobile PCB Destruction Facilities Regulation* (O. Reg. 148/86, under the EPA);

6) *Lakes and Rivers Improvement Act* (R.S.O. 1980, c. 229);

7) *Mining Act* (R.S.O. 1980, c. 268);

8) Ontario Water Resources Act (OWRA) (R.S.O. 1980, c.361, as amended by S.O. 1983, c.51, s.5);

9) *Pesticides Act* (R.S.O. 1980, c.376); and

10) *Environmental Assessment Act* (EAA) (R.S.O. 1980, C.140).

Part II S.13 of the *Environmental Protection Act* prohibits the deposition, addition, emission, or discharge of a contaminant into the natural environment that:

a) causes, or is likely to cause, impairment of the quality of the natural environment for any use that can be made of it;

b) causes, or is likely to cause, injury or damage to property or to plant or animal life;

c) causes, or is likely to cause, harm or material discomfort to any person;

d) adversely affects, or is likely to, adversely affect the health of any person;

e) impairs or is likely to impair, the safety of any person;

f) renders, or is likely to render, any property or plant or animal life unfit for use by man;

g) causes, or is likely to cause, loss of enjoyment of normal use of property or (S.O. 1983, c.52, s.4); or

h) interferes, or is likely to interfere, with the normal conduct of business (S.O. 1983, c.52, s.4).

There are a number of specific legislative requirements under the *Environmental Protection Act* which can require a proponent to decommission or clean up a site. However, the last resort in all cases is Part II, S.16 of the Act which empowers the Minister to order any person who causes or permits the deposit, addition, emission or discharge of a contaminant into the natural environment to do all things and take all steps necessary to repair the injury or damage.

Part V, S.40 of the EPA states that no use shall be made of land or land covered by water which has been used for the disposal of waste within a period of twenty-five years from the year in which waste disposal ceased unless the approval of the Minister has been given for the proposed use.

Part IX, S.85 of the Act states that in the event of a spill, the Minister may order anyone involved with the spill either directly or indirectly to take any action necessary to ameliorate the adverse effect of the spill and to restore the natural environment.

The *Environmental Protection Act* has provisions such that if the requirements of any cleanup or control orders are not followed by the responsible person, the Minister may take any action necessary to implement the order, and recover the costs of implementation from the responsible person(s). Similar requirements and powers exist under the other Acts referred to previously.

In 1984, Environment Ontario (MOE) introduced the *Guidelines for Decommissioning (Shutdown) of Major Industrial Sites in Ontario*. These generic Guidelines were the first to be introduced in Canada and were developed to provide Ministry staff involved in closure of industrial sites with a systematic approach to decommissioning. The following considerations were outlined in the document:

a) the importance of an in-depth background knowledge of plant operations;

b) the selection of a shutdown category (i.e., temporary, permanent where the plant is mothballed with no planned startup in the foreseeable future, or permanent where the plant is dismantled and the land redeveloped);

c) development of a site closure plan;

d) management of on-site waste treatment facilities during the shutdown;

e) conducting hydrogeological and soil investigations;

f) disposal of materials accumulated on site;

g) on-site supervision, inspection and government liaison;

h) provision for air quality monitoring; and

i) confirmatory testing to ensure the site is environmentally secure.

The 1984 decommissioning guidelines document has been revised, and in January 1989 the MOE released *Guidelines for the Decommissioning and Cleanup of Sites in Ontario*. The new guidelines detail a process for meeting MOE site decommissioning and cleanup requirements and outline management and technical procedures.

The objectives of the 1989 guidelines are to:

1) ensure that the decommissioning and cleanup of sites is completed in an environmental acceptable manner;

2) communicate to decommissioning and site cleanup proponents and the public the requirements and policies of MOE, and identify potential involvement of other agencies;

3) ensure that the decommissioning and cleanup of sites in Ontario proceeds in the most efficient, fair, and consistent manner possible; and

4) ensure public involvement in the decommissioning and site cleanup process.

In principle, the guidelines require remedial action where on-site contaminants are present at concentrations above background levels. Soils cleanup criteria are presented for a selection of primarily inorganic chemical parameters that may remain as a residual soil concentration for a specific land use after decommissioning. Flexibility with respect to site-specific requirements is encouraged, permitting the development of site-specific criteria above background levels, or application from other jurisdictions, providing the criteria are protective of human health and the environment.

The MOE generally co-operates closely with the Ontario Ministry of Labour and municipal authorities controlling land zoning (Official Plan review process) to ensure notification of proposed industrial decommissionings or site cleanups. The MOE may in certain cases require a decommissioning proponent to post financial assurance with the Ministry (Part X, EPA) to ensure that terms or conditions of a decommissioning will be adequately carried out. If all contaminants on the site are not removed to specified or background levels, the MOE will require a deposition or caveat registered on title (under the *Registry Act*) outlining any land use restrictions or outstanding concerns with respect to future use of the property.

E.8 Prince Edward Island

Prince Edward Island has not enacted specific legislation requiring industries to decommission and clean up contaminated plant sites. If an industrial plant is to be decommissioned, the Province relies on industry cooperation and discussion with the regulatory agency for preparation of site-specific cleanup plans.

The *Environmental Protection Act* (R.S.P.E.I. 1988, c. E-9) prohibits the pollution or impairment of land, air, and water and gives the Minister the authority to order remedial action to combat, eliminate or mitigate a cause of pollution and then seek damages against the polluter for expenses incurred in cases where the polluter fails to comply with a cleanup order.

The *Petroleum Storage Tanks Regulations* (P.E.I. Reg. EC435/86, under the *Environmental Protection Act*) regulates the operation and maintenance of underground storage tanks, and specifies that abandoned tanks must be removed, underground pipes must be removed or purged and capped, and

contaminated soil must be removed to the satisfaction of the regulatory agency (S.17).

The *Public Health Act* (R.S.P.E.I. 1988, c. p-30) defines as a nuisance anything which is directly or potentially injurious to public health and offensive to the general community (S.6(1)) and empowers the Chief Health Officer to investigate and take such steps as he considers necessary to abate or remedy the same (S.6.(2)).

The *Unsightly Property Act* (R.S.P.E.I. 1985, c. u-5), allows an inspector to issue a cleanup order to the owner or to the person in control of the property to remedy the condition of the property in a manner and to the extent directed by the order, or structures or parts thereof, or to remove any rubbish, refuse, garbage, waste materials, etc. causing or contributing to the unsightliness of the property. The content and nature of the cleanup orders are decided by the Lieutenant Governor in Council.

E.9 Quebec

In Quebec, the *Environment Quality Act* (EQA) (R.S.Q. 1977, c. Q-2) and its Regulations prohibit the deposition of wastes to the environment and under the Act, any person(s) responsible for any contamination may be forced to implement any corrective action deemed necessary by the Ministry to protect the environment and public health. The Act also provides that where the person(s) responsible for the contamination fail to implement the corrective measure, the Minister has the power to carry out these works and then recover the cost of these works from whoever was responsible for depositing, issuing or discharging contaminants into the environment. (S.25, S.114.1, S.115, and S.115.1). Several Regulations under the Act pertain to the management of wastes, contaminants, spills and hazardous materials during specific operations.

Section 65, EQA, states that no land used as a site for the elimination of waste, which is no longer in use, may be used for construction purposes for a period of 25 years without the written permission of the Minister. Prior to giving permission, conditions may be imposed, particularly, the deposit of a guarantee.

Section 81 of the *Hazardous Waste Regulation* (O.C. 1000-85 under the *Environment Quality Act*), regulates the reporting and cleanup of spills during transportation.

The restoration and reclamation of pits and quarries after operations have ceased is regulated under Division VII of the *Regulation Respecting Pits and Quarries* (R.R.Q. 1981, c.Q-2, r.2, under the *Environment Quality Act*).

The restoration and closure of pulp and paper mill waste landfill sites is governed by Sections 43, 44 and 45 of the *Regulation Respecting Pulp and Paper Mills* (R.R.Q. 1981, c.Q-2, r.12, as amended, under the *Environment Quality Act*).

The *Regulation Respecting Solid Waste* (R.R.Q.1981, c.Q-2, r.14, as amended, under the *Environment Quality Act*) addresses the closing down or suspension of activities at dry material disposal sites (S.89, S.90, and S.92); at waste disposal sites (S.89, S.90, and S.92); at waste disposal sites in the North (S.100.6); and the closing down of dumps or other open-air solid waste disposal sites (S.126).

In 1988, the Ministère de l'Environnement du Québec (MENVIQ) released the *Contaminated Sites Rehabilitation Policy*, which is intended to:

a) prevent the use of contaminated land to the detriment of health, the environment and property;

b) promote the recovery of resources by facilitating the redevelopment of

contaminated land in so far as the degree of decontamination achieved is compatible with the use contemplated and is safe for users and the environment; and

c) ensure that contaminated soil is handled safely.

To prevent the indiscriminant redevelopment of contaminated land, this Policy requires development proponents to conduct a characterization study of any site where contamination is suspected, and to submit the results of the study along with plans for remediation and redevelopment to both MENVIQ and the municipality for review. Under this Policy, MENVIQ examines the developer's proposal for compatibility of the project with the degree of contamination of the soil and the groundwater. MENVIQ then makes its recommendation to the municipality and monitors the implementation of the remedial measures by the proponent. The Policy also contains cleanup criteria for organic and inorganic contaminants in soil.

In 1988, MENVIQ also issued the following documents and technical guides related to the restoration of contaminated land:

1) *Guide Standard de Caractérisation de Terrains Contaminés* (QEN/SD-2) (Standard Guide for Characterization of Contaminated Lands). This guide outlines procedures which landowners should follow in preparing the characterization of a lot (i.e., historical research, sampling, analysis of soil and ground water, and the final report).

2) *Terrains contaminés -- Les municipalités, des yeux sur leur territoire* (Contaminated Sites -- Municipal Jurisdiction Surveillance) outlines the municipal role in the management of contaminated land and the assessment process under the Contaminated Sites Rehabilitation Policy.

3) *Guide technique des mesures de contrôle à effectuer lors des travaux d'excavation de sols contaminés* (QEN/SD-3) (Technical Guide to Control Measures for Excavating Contaminated Soils) is a reference guide for consultants and contractors to ensure that all contaminated soil has been removed.

4) *Guide d'Implantation et de gestion de lieux d'enfouissement de sols contaminés* (SD-7) (Guide to Establishing and Managing Landfill Sites for Contaminated Soils) is a technical guide which addresses construction and design of secure landfill cells for contaminated soil isolation and containment.

MENVIQ is currently preparing the following documents which would be applicable to decommissioning:

a) *Procédure pour le choix d'un mode d'intervention sur les sols contaminés* (Procedure for Choosing the Response to Soil Contamination) documents options for the treatment, storage or elimination of various types and levels of contaminants and provides developers with a decision-making tool for the selection of the most environmentally acceptable restoration option.

b) *Guide des méthodes de prélèvement des échantillons d'eau et de sol* (Guide to Water and Soil Sampling);

c) *Guide des méthodes de conservation et d'analyse des échantillons d'eau et de sol* (Guide to Preserving and Analyzing Water and Soil Samples); and

d) *Guide d'évaluation des techniques de traitement des sols contaminés* (Guide to Evaluating Soil Treatment Techniques).

E.10 Saskatchewan

At the present time, Saskatchewan does not have any specific regulations or formal policies on industrial site decommissioning. Decommissioning issues are addressed only on a project-specific basis by Saskatchewan Environment.

Under the current *Environmental Management and Protection Act* (S.S. 1983-84, C.E-10.2) a permit is required to cause or allow any contaminants to be discharged, deposited, drained or released when there is a reasonable possibility that such an action may change the quality of any water or cause water pollution (S.17). Under section S.4 of the Act, the Minister of the Environment may order an owner or a person responsible for control of the pollutant to investigate and remedy any adverse effect of the pollutant on the environment and restore the area affected by the pollutant to a condition satisfactory to the Minister. However, the order is subject to the terms of licence, permit or any other privileges granted by the Minister and is effective only if the discharge is unauthorized.

A number of other Acts and regulations such as the *Mineral Industry Pollution Prevention Regulations,* (C.D-14, R.2), the *Public Health Act* (R.S.S. 1978, C.P37) and the *Waste Management Regulations* (S.R. 198/72) (as amended) require a polluter to obtain approval before waste is to be discharged.

In cases where a major spill has occurred or where contamination originally from on-site activities has spread off-site, Saskatchewan Environment has the authority to address the problem through the *Environmental Spill Control Regulations* (S.S. 1983-84, C.D-14.1). The Regulations do not require industry to prepare for decommissioning in advance but allows Saskatchewan Environment to be involved after a plant has closed down. This is the main vehicle which has been used in the past by Saskatchewan Environment to require plant site cleanup.

E.11 Canada

The Canadian Government has proclaimed several Acts and Regulations for the protection and preservation of the natural environment and which prohibit the deposition, emission or spillage of wastes and industrial chemicals. On June 30, 1988, the *Environmental Contaminants Act* (S.R.C., 1985, c. E-12), the *Clean Air Act* (S.R.C. 1985, c. C-32) (as amended), Part III of the *Canada Water Act* (S.R.C. 1985, c. C-11 and Section 6(2) of the *Department of the Environment Act* (S.R.C. 1985, c. E-10) were repealed and replaced with the *Canadian Environmental Protection Act* (CEPA) (S.R.C. 1985, c. 16 (4th Supp.).

Under the old *Environmental Contaminants Act*, there were no powers to compel polluters to clean up controlled toxic chemicals released into the environment. The new CEPA provides either the Minister of the Environment or the Minister of National Health and Welfare with the authority to do so. In addition, if the polluter fails to comply with a cleanup order, the government has the authority to take remedial actions and recover the costs from the polluter (s. 36-40).

Section 136 of the CEPA allows any person who has suffered loss or environmental damage to his person or property to engage in civil action against the polluter.

The CEPA also gives the government the power to temporarily halt any action which might result in chemical pollution of the environment, and it allows the Minister of the Environment and other ministers to cooperatively set up regulations to protect federal lands and waters from pollution.

The CEPA contains provisions to control all aspects of the life cycle of toxic substances

including: development, manufacture, transport, distribution, storage and use, release into the environment, and their disposal as waste. Authority is also provided to regulate emissions and effluents, waste handling and disposal practices of federal departments, boards, agencies, and Crown corporations. The CEPA also permits the federal government to create guidelines and codes for environmentally sound practices and establish objectives which set desirable levels of environmental quality (such as site decommissioning guidelines and drinking water quality objectives). Under CEPA, the federal government has the authority to enter into agreements with provincial governments to administer promulgated regulations or policies.

The *Fisheries Act* (S.R.C. 1985, c. F-14) (as amended) prohibits the deposit or discharge of pollution, industrial wastes or other environmental contaminants of any type into waters frequented by fish that would result in the destruction of fish or the loss of fish habitat. This Act further states that anyone who deposits such deleterious substance(s) is liable for all costs and expenses incurred to counteract or mitigate any adverse effects s. 34-43.

The *Arctic Water Pollution Prevention Act* (S.R.C. 1985, c. A-12), the *Northern Inland Waters Act* (S.R.C. 1985 c. N-25), the *Northern Inland Waters Regulations* (C.R.C. 1978, c.1234) (as amended), and Part VI of CEPA prohibit anyone from discharging any wastes or environmental contaminants unless specifically authorized to do so by a licence or permit issued by the Minister of the Environment.

The *Territorial Land Use Regulations* (S.R.C. 1978, c.1524) under the *Territorial Lands Act* (S.R.C. 1985, c. T-7) applies to Crown lands in the Yukon and Northwest Territories, and specifies that after completion of a land use operation, the permit holder must restore the permit area as nearly as possible to the same condition as it was prior to commencing the land use operation (s.18, s.19).

Spills of chemicals or wastes are reportable under the *Canadian Environmental Protection Act* (S.C. 1988, c.22, S.36), *The Canada Shipping Act* (S.R.C. 1985, c. S-9 s. 655(2)), the *Canada-Newfoundland Atlantic Accord Implementation Act* (S.C. 1987, c.3, S.161) and the *Transportation of Dangerous Goods Act* (S.R.C. 1985 c. T-19).

Appendix F

Review of Approaches Used to Establish Cleanup Guidelines in Various Jurisdictions

F.1 General Types of Approaches

The various approaches that have been developed or suggested for setting cleanup guidelines can be grouped under the following general headings:

- *ad hoc* practices;
- restoration to ambient or "background" or pristine levels;
- technology-based standards (best available technology or best engineering judgement);
- national goals for residual contamination;
- cost-benefit approach;
- site-specific risk assessment; and
- site classification and restoration relative to current and future land use.

The U.S. Office of Technology Assessment (OTA) recently reviewed these types of approaches and concluded that the *ad hoc* practices of the past are no longer acceptable, and that cleanup guidelines based on "background" conditions alone do not make environmental, technical, or economic sense. It was further concluded that technology-based approaches do not offer levels of human health and environmental protection comparable to the costs of implementation, while the setting of national goals, the cost-benefit approach, and site-specific risk assessment can be used but pose considerable problems and substantial limitations. Of all the approaches, the U.S. OTA concluded that guidelines and criteria based on site classification seemed to be the most beneficial strategy. However, given the diversity of site conditions and potential future uses of sites that must be addressed, the optimum course is to combine the best features of site classification, risk assessment, cost-benefit analysis, and existing environmental criteria.

F.2 Specific Approaches

The approaches being considered or used by selected regulatory agencies in North America and Europe are described in the following. Each approach is evaluated in terms of four attributes that were identified during workshops held in 1985 and 1986 under the direction of the Decommissioning Steering Committee as part of efforts to describe a "preferred" approach:

- it should be sufficiently flexible that site-specific information can be considered;
- consideration should be given to the various compartments of the environment and the relationships between compartments;
- it should be capable of addressing all types of contaminants; and
- there should be provision for examining various levels of protection for human health and the environment.

In addition, comments are offered on the ability of each approach to provide the following capabilities or features:

- incorporate risk assessment;
- consider various routes of exposure;
- consider the effects of exposure to more than one contaminant;

- incorporate various types of future land use; and
- ability to cope with missing data through use of default values.

The Province of Ontario issued guidelines for the restoration and rehabilitation of industrial sites in February 1989. The guide identifies the information required for regulatory approval of any cleanup plans. Numerical guidelines (concentrations) have been recommended for some inorganic substances and "indicator" parameters. Comments on specific attributes include:

- site-specific information is not included in the guidelines but must be taken into account when trying to set site-specific guidelines;
- the guidelines are based on toxicological concerns related to human, animal, or plant health for a number of inorganic parameters;
- relationships between environmental compartments must be addressed if site-specific guidelines are developed;
- current guidelines address a few indicator parameters, such as pH, conductivity and SAR;
- no provision for examining various levels of protection for human health and the environment;
- risk assessment techniques can be used to develop site-specific cleanup guidelines for other contaminants;
- various routes of exposure must be considered in developing site-specific guidelines;
- the effects of exposure to more than one contaminant must be addressed in developing site-specific guidelines;
- the guidelines address several types of future land use; and
- unable to cope with missing data.

The Ontario guidelines do not recommend a specific process for establishing a site-specific criteria, but do require on-going consultation with the Ministry of the Environment (MOE) during the criteria development process.

A summary of the Environment Ontario decommissioning guidelines is presented in Appendix C.

The Province of Quebec has established three levels of chemical-specific concentrations in soil and groundwater that define background, a threshold for in-depth site investigations, and a threshold for immediate corrective action. It incorporates elements of the approaches used by The Netherlands and France. The three levels are intended to be used as a guide only, but are rigourously applied. To establish specific cleanup guidelines, risk assessment techniques and various site-specific factors need to be considered. Comments include:

- does not use site-specific information;
- considers only soil and groundwater compartments;
- inorganic substances and organic compounds are addressed;
- three types of values are defined but these do not provide various levels of protection for human health and the environment;
- does not incorporate risk assessment;
- does not appear to consider various routes of exposure;
- does not consider the effects of exposure to more than one contaminant;
- does not incorporate various types of future land use; and

- unable to cope with missing data.

A summary of MENVIQ's decommissioning guidelines is reproduced in Appendix D.

The Province of Alberta does not yet have a systematic approach to setting cleanup guidelines, but it does require the responsible company to identify all site contaminants, the contaminants of concern, and proposed cleanup levels to obtain government approval. The proposed cleanup levels must be supported by appropriate, scientifically defensible data. Since there is no systematic approach per se, comments on specific attributes and desirable features are inappropriate.

The State of California utilizes a standardized, systematic and integrated set of tasks (the Site Mitigation Decision Tree) to set site-specific cleanup criteria at any abandoned or uncontrolled waste site. The process involves six steps:

(1) preliminary site appraisal;

(2) site assessment;

(3) risk appraisal;

(4) environmental fate and risk determination;

(5) development of mitigation strategies; and

(6) selection of remedial action.

The approach has extensive data requirements. Comments on this standardized approach include:

- uses site-specific information;
- considers relationships between environmental compartments;
- addresses all types of contaminants;
- incorporates risk assessment;
- being based on risk, there is provision for examining various levels of human health protection;
- considers various routes of exposure;
- considers the effects of exposure to more than one contaminant;
- incorporates various types of future land use; and
- ability to cope with missing data unknown.

The State of New Jersey derives site-specific, acceptable soil contaminant levels as the end-product of calculations that determine human exposure to contaminated soil and groundwater (as a result of contact with contaminated soil). The system also quantifies the exposure of aquatic organisms to contaminated surface water. A recent presentation described efforts to identify state-wide, "acceptable" soil concentrations for twelve contaminants by considering five endpoints: health effects associated with ingestion of contaminated groundwater; health effects associated with ingestion of contaminated soil; background concentrations; analytical detection limits; and adverse effects other than human health (Garie *et al.*, 1988). Comments on specific attributes and desirable features include:

- capable of using site-specific information;
- limited consideration of relationships between environmental compartments;
- few contaminants have been investigated to date, but approach can address all types;
- provision for examining various levels of protection for human health and the environment;
- recent applications have included risk assessment;
- considers various routes of exposure;

- does not consider the effects of exposure to more than one contaminant;
- possible to consider various types of future land use but not yet done; and
- unable to cope with missing data.

The State of Washington uses existing state and federal guidelines and criteria to derive cleanup levels. Background concentrations can be used if there are no guidelines. For example, a soil cleanup level for a specific chemical may be expressed as a multiple of the water quality guideline for that chemical. If multiples of guidelines or background concentrations do not provide an appropriate cleanup level, site-specific information and predictive environmental models are used. Comments on specific features include:

- uses site-specific information if other guidelines do not exist;
- considers relationships between environmental compartments to a limited extent;
- can address all types of contaminants;
- no provision for examining various levels of protection for human health;
- does not incorporate risk assessment;
- does not consider various routes of exposure;
- does not consider the effects of exposure to more than one contaminant;
- does not incorporate various types of future land use; and
- ability to cope with missing data unknown.

The U.S. Environmental Protection Agency (U.S. EPA) has a specific set of procedures (the Superfund Public Health Manual) for deriving cleanup criteria that prevent adverse human health effects.

The main features of the system are the quantification of the migration of contaminants among environmental compartments and detailed human exposure assessment. Comments on specific features include:

- can use site-specific information;
- considers relationships between environmental compartments;
- address all types of contaminants;
- provides for examining various levels of protection for human health and the environment;
- incorporates risk assessment;
- considers various routes of exposure;
- can consider the effects of exposure to more than one contaminant;
- incorporates various types of future land use; and
- able to cope with missing data to an extent.

The Netherlands has established a list of contaminants (approximately fifty organic and inorganic chemicals and chemical mixtures) and associated concentrations in soil and groundwater. Three levels or categories of contamination are defined: normal or background; moderate contamination; and severe contamination. The numerical criteria appear to be based on various factors including detection limits (and multiples thereof), and general opinions as to values for ambient or background concentrations. The guidelines do not appear to be scientifically determined. The criteria are used as an initial method for evaluating sites. Site-specific information is considered when establishing cleanup levels. The usefulness of this approach has been proven on a large number of investigations. Comments on features include:

- site-specific information is considered where cleanup is necessary;
- only soil and groundwater compartments considered;
- addresses all types of contaminants;
- no provision for examining various levels of protection for human health and the environment;
- does not use risk assessment;
- does not consider various routes of exposure;
- does not consider the effects of exposure to more than one contaminant;
- considers type of future land use; and
- not able to cope with missing data.

The United Kingdom has published a list of soil contaminant values ("trigger concentrations") below which a site is regarded as uncontaminated. The triggers vary with the proposed future use of the site and have been adapted from existing guidelines developed for other purposes or based on professional judgement. Comments on specific features include:

- little use made of site-specific information;
- does not explicitly consider relationships between environmental compartments;
- can address all types of contaminants but has focussed on metals to date;
- no provision for examining various levels of protection for human health and the environment;
- does not incorporate risk assessment;
- various routes of exposure not considered explicitly;
- does not consider the effects of exposure to more than one contaminant;
- considers future land use; and
- ability to cope with missing data unknown.

France has published a list of values for four levels of contamination (threshold values) which, once reached, require a response. The four levels are: background (no response needed); investigation threshold (further studies required before disposition of the contaminant is determined); treatment threshold (soil must be treated to reduce contamination); and emergency threshold (immediate and decisive action is needed to remove contamination). Comments on specific features include:

- does not use site-specific information;
- little consideration of relationships between environmental compartments;
- can address all types of contaminants;
- no provisions for examining various levels of protection for human health and the environment;
- does not incorporate risk assessment;
- does not consider various routes of exposure;
- does not consider the effects of exposure to more than one contaminant;
- does not consider future land use; and
- ability to cope with missing data unknown.

The approaches adopted by the U.S. EPA and the State of California come closest to having all of the desirable attributes and features. In view of the current lack of consensus as to the approach that should be used and the preliminary nature of many of the strategies that have been put forward, a

previous review prepared for the Decommissioning Steering Committee recommended that Canadian agencies investigate a combined approach that would incorporate the best elements of several approaches in an effort to identify the most effective and efficient ways of decommissioning industrial sites (Monenco, 1990).