Guide to the Environmental Aspects of Decommissioning Industrial Sites

May 1985

GUIDE TO THE ENVIRONMENTAL ASPECTS OF DECOMMISSIONING INDUSTRIAL SITES

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GUIDE TO THE ENVIRONMENTAL ASPECTS OF DECOMMISSIONING INDUSTRIAL SITES

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EXECUTIVE SUMMARY

Companies who operate industrial facilities are continually evaluating their profitability. Evaluations may result in decisions to shutdown uneconomic, inefficient and often old production facilities. It is estimated that during the years 1984 to 1990 approximately 20% of existing Canadian industrial capacity will be shutdown for economic reasons. This massive plant closure program will be brought about largely by the obsolescence and age of industrial facilities constructed in the 1940's, 1950's and 1960's. Certainly, changes in industry from manufacturing to a more service-based economy will have a major impact on decisions regarding plant closure. This situation will be further exacerbated by the impact of high technology.

In preparation for the decommissioning of a plant site, the economic, human and political aspects are stressed; however, often the environmental implications of closing a plant, particularly the need for and cost of site clean-up, are not normally included in the initial planning. This guide will assist industry and government by identifying and discussing the many environmental issues associated with industrial site decommissioning. Planning and implementing clean-up of a decommissioned industrial plant site requires detailed assessment, investigations, interpretation and review of alternatives, conducted in a phased and logical sequence.

The general principles outlined in the guide may be applied to the decommissioning of any industrial plant site; however, the guide is specifically aimed at the oil, gas and chemical industries including oil refineries, natural gas processing plants, and organic and inorganic chemical plants.

Clean-up activities vary from site-to-site; in fact, activities are specific to industry type, products and by-products, age of the

plant, location of the site (geography, geology, hydrogeology, climate), waste management practices and proposed future use. Also, approaches by regulatory agencies vary from province to province and local government concerns are not consistent throughout Canada. While the guide identifies and describes in detail the activities associated with the planning and implementation of a cost-effective program, it is not a blueprint - a program must be designed to address individual site conditions. The approach to decommissioning must be flexible and responsive to specific site conditions.

Important factors to be considered in planning and implementing clean-up of industrial sites are summarized as follows:

1. **Decommissioning Planning**

The clean-up of an industrial plant site is not unlike plant design, construction and commissioning as the clean-up requires conceptual and detailed planning, management systems, site investigations, design, cost controls and approvals. Accordingly, the clean-up program requires a significant commitment of corporate resources.

2. **Plant Site Assessment**

Detailed plant site assessments should be conducted prior to field sampling and analysis to clearly identify possible types and extent of contaminant concerns. The preparation of an operations history of the plant (which focuses on waste management practices and chemical handling over the operating life of the plant) is a key component of site assessment. Much of the background information can be assembled through formal interviews and informal discussions with key employees (present and past).

3. **Site Investigations**

Site investigations should be designed and conducted by personnel who have experience in conducting contaminant investigations. An effective method for industrial site assessment is to conduct the investigation in phases, with initial or reconnaissance work followed by detailed testing in areas of concern.

4. **Clean-up Criteria**

Clean-up criteria are benchmarks which define the extent and significance of contamination on the site and are subsequently the 'numbers' which define the extent of site clean-up. Criteria are directly related to future use of the site and geologic, hydrogeologic and other site-specific factors, and must be developed on a sound scientific basis to protect future users of the site.

5. **Site Clean-up**

Site clean-up is governed by an all-encompassing clean-up plan which thoroughly defines clean-up actions, measures for worker health and safety, and treatment and disposal of wastes. Sampling and analysis carried out during site clean-up will ensure an effective program.

6. **Confirmatory Analysis**

When planned clean-up activities are completed, confirmatory sampling and analysis is required to ensure that site clean-up was effective (i.e. no residual contaminants in excess of clean-up criteria).

7. **Long-Term Monitoring**

Long-term monitoring of the site may be required to measure the effectiveness of site clean-up. Monitoring may include sampling groundwaters or surface waters downgradient of the site, measuring the integrity of on-site containment facilities, monitoring the degradation of hydrocarbons or measuring metal uptake in agricultural crops.

8. **Regulatory Agency Involvement**

Environmental regulatory agencies have the responsibility of ensuring that clean-up of the plant site is sufficient to protect the environment and future uses of the site. Therefore, an effective two-way communication network between regulatory agencies and the company should be established early in the decommissioning program and should continue through all phases. Approvals from regulatory agencies may be required for the clean-up criteria and for the planned clean-up program as well as upon completion of confirmatory testing.

9. **Public Relations**

While public interest will vary from site-to-site, public concerns related to site clean-up and re-development should be addressed at the design stage of sampling programs as well as during preparation and implementation of clean-up plans. By keeping concerned members of the public informed of progress and by maintaining good communications, many public concerns, fears and speculations will be alleviated, thus assisting the successful completion of plant site decommissioning.

10. Preventive Measures

The cost and complexity of eventual site clean-up can be significantly reduced by instituting preventive measures such as the consideration of decommissioning factors at the site selection stage, the implementation of specific operating procedures and the preparation of an annual environmental information report.

This guide will assist government and industry in the development of appropriate guidelines for decommissioning industrial plant sites. While the Province of Ontario has published guidelines (June 1984) and other provinces are studying possible guidelines, most industrial site clean-up projects are dealt with on an ad hoc basis.

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PART 1

INTRODUCTION

PART 1 - INTRODUCTION

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1.1 INTRODUCTION

A company decision to shutdown an industrial plant is based almost exclusively on economics. Generally, in preparation for a senior management decision regarding plant shutdown, a significant planning exercise is completed. The economic, human and political aspects of a plant closure are normally stressed; however, to this point in the planning process, company management has probably not had a proper basis to adequately consider the environmental implications of closing a plant, particularly the need for a clean-up program.

Plant shutdown is more extensive than simply shutting down the process and dismantling and removing the equipment, buildings and attendant facilities. Years of plant operations have frequently resulted in accumulations of liquid and solid wastes, as well as sludges and sediments from wastewater treatment and product storage. In addition, during the operating life of a plant, spills and leaks of process chemicals, products and by-products may have caused contamination in the area of the plant. As a result, the over-all plant shutdown program must include consideration of probable contaminated soils, sludges, sediments, surface waters and groundwaters, and the subsequent formulation of a clean-up program aimed at leaving the site in an environmentally safe condition consistent with the proposed future use of the site.

1.2 PLANT SHUTDOWN OPTIONS

When a decision is made to shutdown an industrial plant, there are four available shutdown options, as follows:

- o mothballing;
- o partial plant shutdown;
- o abandonment; and
- o decommissioning.

The differences in these available options are summarized below.

121 MOTHBALLING

Mothballing is carried out with the expectation of reactivating the industrial plant at some time in the future. There are important distinctions between mothballing, abandonment and decommissioning as they apply to site clean-up.

Activities associated with mothballing include:

- o depletion of feedstock materials;
- o process shutdown;
- o draining vessels, equipment and piping;
- o cleaning and purging vessels, equipment and piping;
- o lubricating rotating equipment;
- o filling piping and equipment with inert gas;
- o maintaining temperature and humidity control; and

- retaining staff for on-going maintenance, monitoring, management of surface runoff, access control and security.

A limited amount of site clean-up may be required as part of mothballing activities in order to render the plant site safe. However, mothballing should not require the type of intensive studies and clean-up associated with partial plant shutdown or complete site decommissioning.

122 PARTIAL PLANT SHUTDOWN

In some instances, companies may decide to shutdown only a portion of an industrial plant. Three examples are:

- shutdown refinery processing and convert tankfarm areas into a product marketing terminal;

- shutdown mercury cell chlor-alkali operations (which produced chlorine normally for pulp and paper mills) with the continued operation of the mill; and

- shutdown of sour gas processing with continued operation of the facility as a compressor station, transferring sour gas to another gas processing plant.

Companies are encouraged to initiate clean-up plans for the area of the plant which has been shutdown. The exact nature and extent of the clean-up plan will depend on:

- the extent to which the facilities left in operation interact with the shutdown portion of the plant;

- the type and extent of contamination; and

- the proposed future use of the land.

123 ABANDONMENT

Shutting down a plant (with no expectation of reactivation) and securing the plant site from entry may appear to be an economically viable alternative, given the costs associated with the planning and implementation of a proper site decommissioning program. However, there are long-term problems associated with continued ownership of steadily deteriorating buildings, contaminated liquid and solid wastes which may eventually pollute off-site areas, and the ever-increasing costs of an environmentally acceptable clean-up program. Problems will arise from:

- complaints from the local community;
- investigations by government regulatory agencies;
- legal action against the company by federal or provincial agencies; and
- adverse corporate publicity in the media.

There are increasing concerns of plant site abandonment from the public sector and regulatory agencies, brought about in part from relatively recent and extensive contaminant investigations of abandoned landfill and industrial sites in the United States. As a result, abandonment of an industrial plant is not a viable alternative in the long term. The potential cost of legal action, adverse publicity and eventual site clean-up will considerably outweigh the cost of a proper decommissioning program. Plant site abandonment is generally not environmentally acceptable.

Shutdown and abandonment of an industrial plant may occur as a result of bankruptcy of a company. As no viable corporate entity exists in this case, it is incumbent on the receiver of the industrial plant to initiate a site clean-up program and on the regulatory agencies to ensure that it is done.

124 DECOMMISSIONING

The objective of decommissioning a plant site is to leave the site in an environmentally safe condition consistent with the proposed use of the site. In addition to meeting this objective, decommissioning provides a further benefit to the company through the sale or reuse of the site for industrial or other land uses.

In the broad sense, decommissioning an industrial plant is similar to plant construction and commissioning, requiring significant planning and management commitments, field studies, regulatory agency and potential public involvement and on-site construction (dismantling and materials handling). As a result, similar management systems and activities are applied to the planning and implementation of plant site decommissioning. Factors which are often considered in planning for site decommissioning are as follows:

- management, planning, scheduling and cost estimating;
- shutdown of process equipment;
- disposal of excess raw materials, intermediates and final products as well as other supplies;
- lay off, transfer or retirement of plant site employees;
- assessment of the nature and extent of contamination;
- development of the clean-up criteria;
- development and implementation of a site clean-up plan;
- dismantling and disposal of equipment and other on-site facilities;
- future use or disposal of the plant site; and
- liaison with the public, government and the media.

1.3 PURPOSE OF THE GUIDE

This guide focuses on the environmental aspects of decommissioning, specifically the planning and implementation of a site clean-up plan. The objective of a clean-up plan is to provide for clean-up of on-site (and possibly off-site) contamination to the extent required to safeguard future users of the site. Figure 1-1 provides a suggested outline of the steps that are normally required to ensure the successful completion of the environmental aspects of plant decommissioning. The need to complete the steps outlined in Figure 1-1 is based on concerns with respect to contamination at a particular plant site and the probable extent of the required clean-up program.

Because there is currently only limited information to draw on when planning and implementing a plant site decommissioning program, there has been a tendency to "re-invent the wheel" when a plant site is decommissioned. Within the context of the site-specific nature of the clean-up plan, the purpose of the guide is to:

- identify basic approaches which can be used in the development and implementation of a clean-up plan;

- identify information needed to develop the clean-up plan;

- discuss the sequence of activities in the development and implementation of a site clean-up plan; and

- outline potential preventive measures which may be taken during plant site selection, construction and operation to significantly reduce the need for and extent of site clean-up.

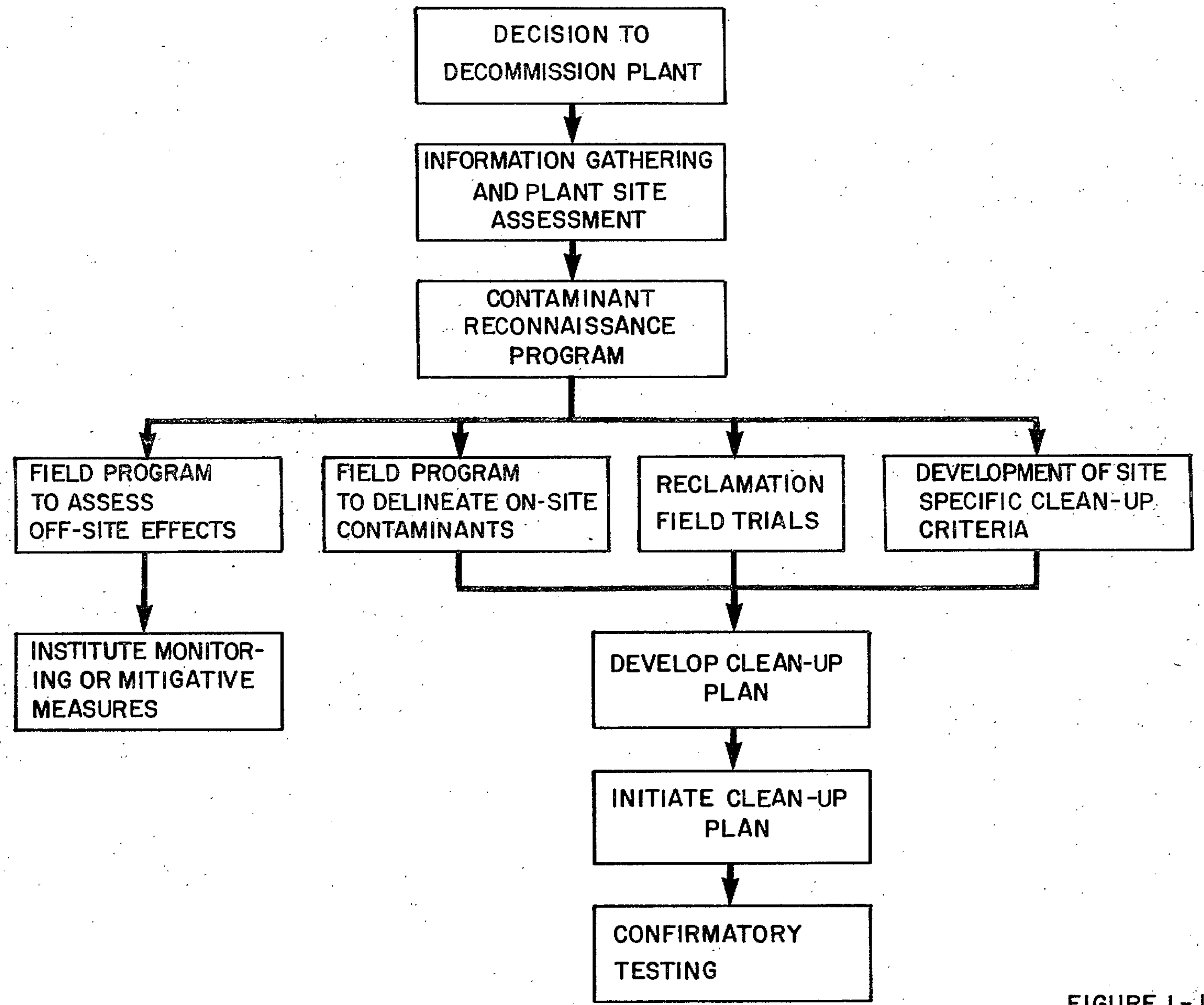

FIGURE 1-1

ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA
DECOMMISSIONING GUIDE

STEP-WISE APPROACH TO THE CLEAN-UP ASPECTS OF DECOMMISSIONING PLANNING

The guide will assist those involved in site decommissioning by addressing the myriad of details required in the planning and implementation of a clean-up program. The site-specific nature of a clean-up plan will require judgment decisions regarding the application of the details in the guide to a particular plant site.

The general principles outlined in the guide may be applied to the decommissioning of any industrial plant site; however, the guide is specifically aimed at the oil, gas and chemical industries including oil refineries, natural gas processing plants (both sweet and sour gas), and organic and inorganic chemical plants.

1.4 FORMAT OF THE GUIDE

The guide is structured to present information in an orderly sequence as follows:

Part 1 - the background to and concept of decommissioning as well as the purpose and format of the guide;

Part 2 - a review of approaches taken by regulatory agencies in Canada and the United States with respect to the environmental aspects of decommissioning;

Part 3 - details and sequence of activities for an all-encompassing decommissioning program;

Part 4 - approaches taken at industrial plant sites which have recently shutdown, with particular emphasis on the methodology used to develop clean-up criteria;

Part 5 - an outline of preventive measures which may be taken during plant siting and subsequent plant operations to significantly reduce costly and extensive clean-up programs when a plant is decommissioned; and

Part 6 - conclusions.

PART 2

APPROACHES TAKEN BY REGULATORY AGENCIES

PART 2 - APPROACHES TAKEN BY REGULATORY AGENCIES

CONTENTS

2.1 INTRODUCTION

In North America there are few legal statutes which apply specifically to the decommissioning of industrial plant sites. This paucity of specific legislation is due to the fact that relatively few major industrial plants have been decommissioned and that circumstances differ at sites. However, plant decommissioning activity is increasing both in terms of numbers and complexity and this will require a carefully considered framework of legislation and guidelines.

2.2 LEGISLATION AND REGULATIONS IN NORTH AMERICA

In both Canada and the United States, all-encompassing environmental legislation can generally be applied to abandonment, mothballing and decommissioning of industrial plants. This legislation provides the mandate to regulatory agencies to control contamination or pollution of water and soil, and to develop regulations to control practices or activities such as the closure of an industrial plant. Few regulations implicit to decommissioning exist and most regulatory activities rely on the application of guidelines or site-specific approaches.

A brief outline of legislation, regulations and guidelines related to industrial plant decommissioning in the United States and Canada follows.

221 APPROACHES IN THE UNITED STATES

There are few federal or state regulations implicit to the decommissioning of industrial plants. The approach taken in the United States is directed more specifically to the clean-up of hazardous waste sites. The Resource Conservation and Recovery Act (RCRA) and Title 40 of the Code of Federal Regulations can be applied to plant decommissioning operations where facilities and affected land and water areas can be considered hazardous waste sites.

The RCRA, enacted by the Congress in 1976, established guidelines related to the management of hazardous waste as well as the transport, treatment and disposal of hazardous waste. The regulations to enforce these guidelines were established by the Environmental Protection Agency (EPA) between 1976 and 1981 and are covered under Title 40 of the Code of Federal Regulations. These regulations have no provision for state involvement, but by agreement a state can enforce these regulations. A state may also pass its own regulations and enforce such, but they must meet the minimum standard of the Title 40 federal regulations.

Several states, including Illinois, Michigan and Texas, now act as the enforcement agency rather than the EPA.

Groundwater investigations upon closure of plant sites are required in some states. The criteria which groundwater must meet varies from state-to-state, but in general, groundwater must be scanned for the EPA priority pollutants. In some cases, only total organic carbon (TOC) analysis must be performed. If a groundwater problem is discovered, the state can require remedial measures before the site is abandoned.

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) established regulations and guidelines for the clean-up of hazardous waste sites. The Act, also known as Superfund, established a fund and imposed financial requirements to responsible parties for the clean-up of hazardous wastes sites. To be applied to a closed industrial plant site, however, it must be demonstrated that the site contains hazardous wastes and the site must be priorized as a significant hazard. While CERCLA is a federal statute, the state government must be satisfied with the level of clean-up and it may impose more extensive requirements under state legislation.

The State of New Jersey has enacted a most comprehensive act which applies to the closure of industrial plants. The Environmental Cleanup Responsibility Act (ECRA), which came into effect on December 31, 1983, imposes conditions on the sale (for continued operations) or closure of industrial plants where hazardous substances or wastes were utilized, manufactured or generated. Important provisions of ECRA and regulations thereunder are summarized as follows:

- by providing for notification and assessment of industrial plant sites prior to their sale for continued operation, the Act provides protection to unsuspecting purchasers of a plant site;
- similar notifications and assessments are required for sites that will be closed;
- the Act specifically identifies industries that fall under its provisions by the Standard Industry Classification system (SIC);
- the Bureau of Industrial Site Evaluation assesses notifications and determines if further action is required;
- applications must include such items as:
  - a detailed scaled site map,
  - a detailed description of operations,
  - descriptions of the types and locations of hazardous waste storage facilities,
  - a complete inventory of hazardous substances and wastes,

- a detailed sampling plan, and
- a decontamination plan;

o the Bureau provides guidance to the required elements of the sampling plan and must approve the plan prior to implementation;

o the Act requires the submission of a clean-up plan for plants that are closing aimed at returning the site to an environmentally acceptable condition. The clean-up plan, which must be approved by the Bureau, must contain:

- a detailed description of the activities that will take place to eliminate the presence of hazardous substances or wastes which have been identified as needing remedial action,
- a description of the location, types and quantities of hazardous substances and wastes that will remain on the site,
- the results of the detailed sampling program,
- an evaluation of alternative clean-up methods,
- recommendations for the most practicable method of clean-up,
- detailed cost estimates, and
- an implementation schedule;

o the Bureau evaluates the plan, approves it or identifies deficiencies in the plan;

- when the plan is approved, the company is required to obtain a surety bond, letter of credit or other financial security for the full amount necessary to complete the clean-up; and

- upon completion of site clean-up, the Bureau conducts a final inspection of the site to ensure compliance with the approved plan and issues a final approval which will authorize the sale, transfer or closure of the plant.

222 APPROACHES IN CANADA

In Canada, jurisdiction for decommissioning activites is primarily a provincial concern. While certain provincial and federal environmental regulations respecting discharges of wastewaters to surface waters and the operation of landfill sites can be applied to the clean-up of industrial plant sites, only the Province of Ontario has developed guidelines specific to the decommissioning of industrial plant sites. Quebec and Alberta are presently studying possible guidelines. Generally, regulatory agencies approach plant decommissioning on a case-by-case basis.

The Ontario Guidelines for Shut Down of Industrial Sites are comprehensive and are presently being applied to the decommissioning of refineries and chemical plants. These guidelines provide a mechanism for continuing communication between the company and the regulatory agency throughout the decommissioning project and address:

- on-site waste treatment facilities;

- hydrogeological and soil investigations;

- o disposal of materials accumulated on-site; and

- o end land use.

With regard to on-site waste treatment facilities, the guidelines require that during decommissioning, there can be no discharges to the environment in excess of that allowed in the plant's operation license. The guidelines outline the main elements to be included in soils and hydrogeologic investigations and specify that contaminated soils (levels of chemical substances exceeding phytotoxicological guidelines) must be cleaned up and properly disposed. Materials which have accumulated on-site may be sold for use in other plants, or properly disposed, but they cannot be left on site. The end land use will determine to what degree the land must be rehabilitated.

In general, the regulatory aspects of closure and clean-up of industrial plant sites are dealt with on a case-by-case basis in Canada. To avoid this ad hoc approach, there is a need to develop guidelines for clean-up and reclamation of shutdown industrial plant sites.

PART 3

SITE CLEAN-UP: PLANNING AND IMPLEMENTATION

PART 3 - SITE CLEAN-UP: PLANNING AND IMPLEMENTATION

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Figure

3.1 INTRODUCTION

The objective of planning and implementing clean-up of an industrial plant site is to provide a site that is environmentally secure and safe for another land use. To achieve this objective, there are a wide variety of activities which must be carefully planned and carried out, from the initial decision to decommision a plant to the successful completion of site clean-up. This section discusses these activities in detail.

Determination of the need for and extent of clean-up of a decommissioned industrial plant site requires the sequential completion of clean-up activities. Figure 3-1, which is a model flow diagram of activities and information needs associated with plant site clean-up, conceptualizies clean-up activities in a logical sequence. By following the sequence of activities in a step-by-step manner, the assessment of plant site conditions and the design of necessary clean-up programs will be all-encompassing and cost-effective, to permit the successful clean-up of the site. Site conditions will dictate the level of effort required for each activity.

This part of the decommissioning guide is organized into sections which discuss the following major planning, investigative and clean-up activities:

- o Decommissioning Planning;
- o Plant Site Assessment;
- o Reconnaissance Testing Program;
- o Development of Clean-up Criteria;

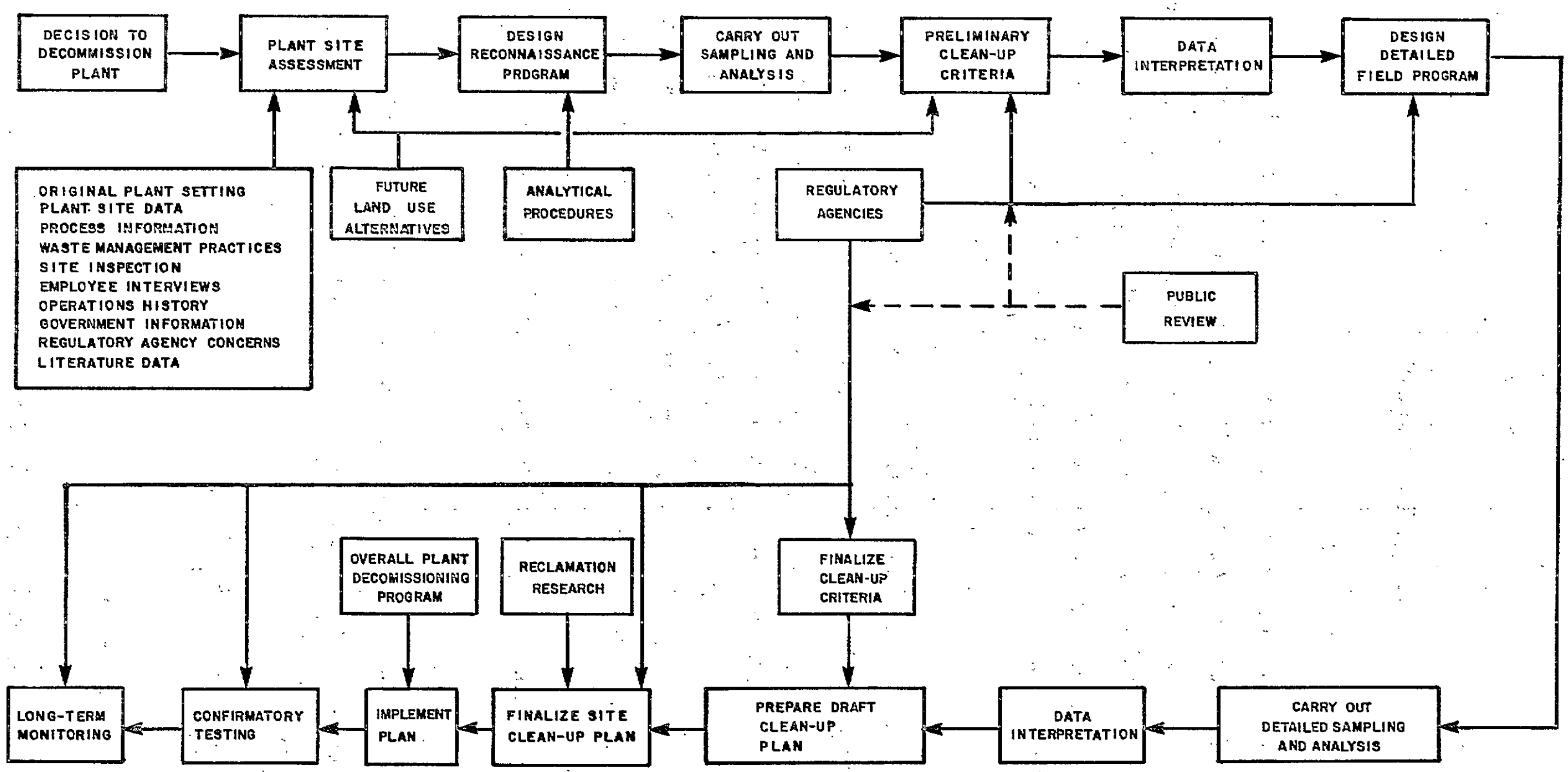

FIGURE 3-1
ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA
MODEL FLOW DIAGRAM OF ACTIVITIES AND INFORMATION NEEDS ASSOCIATED WITH PLANT SITE CLEAN-UP

- Detailed Testing Program;
- Preparation of Clean-up Plan;
- Implementation of Clean-up Plan;
- Confirmatory Testing; and
- Long-term Monitoring.

These major activities are discussed in detail by identifying the objectives of the activity, its importance to the over-all site decommissioning program, major informational needs and items to be evaluated and a suggested approach to carry out the activity.

The planning and implementation of site clean-up requires the involvement of regulatory agencies throughout all phases. Public interest in plant site clean-up and re-development will vary from site-to-site. The importance of and suggested approaches to regulatory agency and public involvement in site clean-up are provided in Sections 3.11 and 3.12.

3.2 DECOMMISSIONING PLANNING

Planning for the shutdown of an industrial plant and the clean-up requires a commitment on behalf of the corporation to provide the necessary organization and resources to manage the project. The major factors that play a rôle in taking a decision to decommission an industrial plant and in establishing the infrastructure required to carry out a clean-up program are shown in Figure 3-2.

321 DECISION TO DECOMMISSION

The decision to shutdown an industrial plant is usually based on economics and may be the result of an overall economic down-turn, market changes, depletion of feedstock to the plant, process technology inadequacies, or environmental concerns. In taking their decision on the future of an industrial plant, the company will weigh the economics of updating the plant, upgrading environmental control facilities, conversion to a new product, or transporting raw materials from another source (as the case may be) against the cost and implications of decommissioning the facility.

A decision to permanently shutdown an industrial plant is usually made well in advance of actual turndown. It is at this point that planning of the decommissioning program should commence.

Severe economic conditions may have led to the bankruptcy of a company and subsequent closure of an industrial plant. A third party, possibly the receiver or the government, is then faced with implementing a decommissioning program.

Decommissioning planning factors (and hence the guide) may also be applicable to an industrial plant site that was shutdown some years

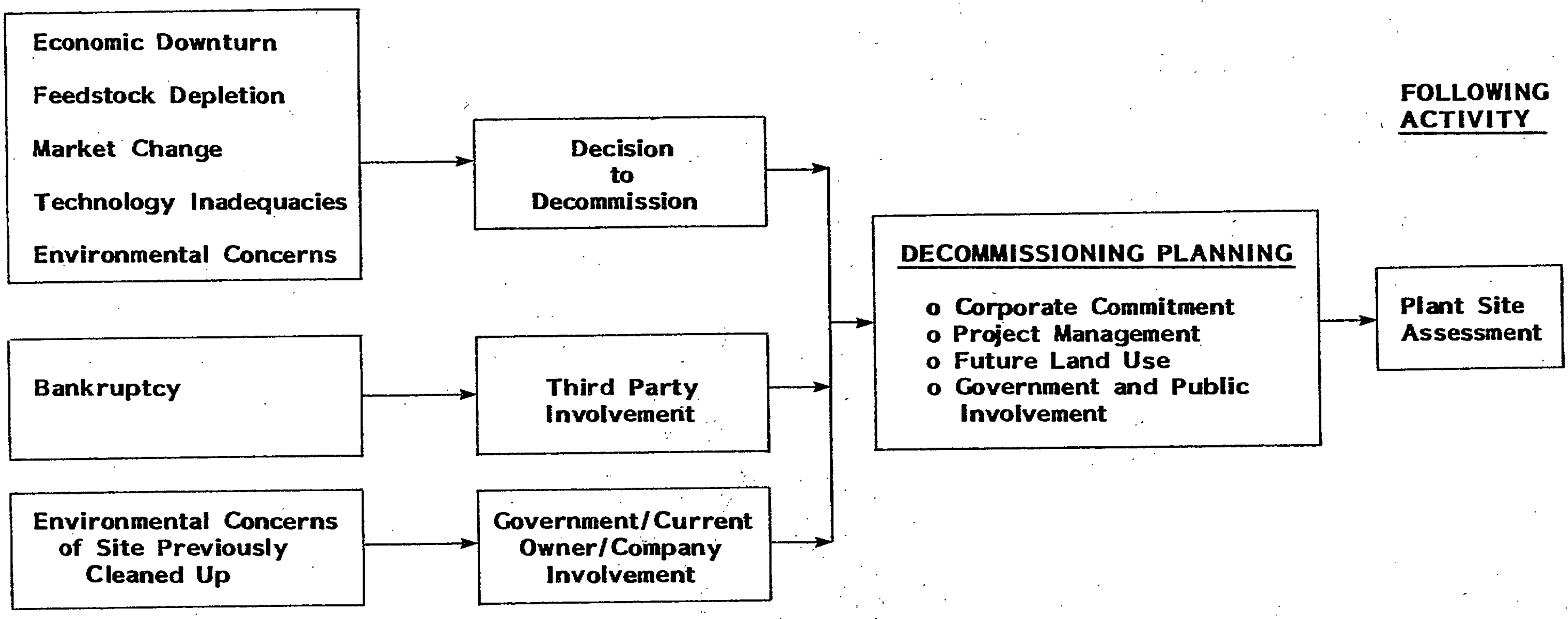

FIGURE 3-2

DECOMMISSIONING PLANNING

earlier and was cleaned up to the then current standards of the regulatory agency. However, as a result of investigative advances, there may now be a concern over the concentration of a particular chemical or other conditions on-site.

Faced with the closure of an uneconomic industrial plant, the company may evaluate site abandonment, mothballing and partial site decommisioning as alternatives to decommissioning the facility.

.1 Abandonment

It is highly unlikely that a viable company would simply shutdown an industrial plant and 'walk away' from the site. If this were to occur, the long-term costs would be considerable. From an environmental point of view, abandonment of an industrial plant is clearly unacceptable. In addition to the loss of revenue from possible sale of the site as well the process equipment, other factors that will add to the direct and indirect costs associated with abandonment of the site include:

- liabilitis with respect to site access and contaminants;
- court action;
- negative publicity; and
- ever-increasing costs for eventual clean-up.

.2 Mothballing

If a decision is made to permanently shutdown a plant, there are few advantages to mothballing the site (as opposed to decommissioning). Mothballing simply defers the task (and costs) of decommissioning. Further, there will be additional costs associated with monitoring the site, maintaining security and managing surface runoff.

.3 Partial Decommissioning

If only a portion of an industrial process is shutdown, the site (shutdown portion) may be decommissioned or it may be desirable to defer decommmissioning until the entire plant is closed. Under some circumstances, regulatory agencies may encourage decommissioning of the shutdown portion (partial decommissioning). The principles of decommissioning described herein may also apply to a partial decommissioning project.

.4 Decommissioning

Decommissioning of the plant site is carried out to provide a site that is environmentally secure and that can be safely re-developed for other defined land uses.

322 CORPORATE COMMITMENT

Preparation and execution of site clean-up plans requires a significant commitment in terms of time and resources. Accordingly, the decommissioning of the industrial plant should be managed by a person who has direct input to company policy and financial matters which govern the decommissioning project.

323 PROJECT MANAGEMENT

It is essential that the decommissioning project be planned and implemented in a logical manner, guided by an over-all decommissioning master plan. The project is not unlike the design, construction and commissioning of the industrial plant, in that it must be organized, monitored and managed by a project management system (CPM or other). Just like the design of the industrial plant was based on site-specific geological and geotechnical information, process design criteria, end product specifications and waste treatment/disposal standards, the design of the site clean-up and reclamation plan is based on levels of contaminants in soils, sediments, groundwaters, etc., end land use and clean-up criteria.

324 FUTURE LAND USE

Future land use of the plant site may not be established prior to implementing the decommissioning program. Environmental conditions on-site may, in fact, limit the end use alternatives. However, the end use alternatives should be established early in the program since these significantly affect the nature of investigations on-site and the extent of site clean-up.

325 GOVERNMENT AND PUBLIC INVOLVEMENT

Involvement of regulatory agencies throughout the plant site decommissioning program is essential to the clean-up and re-development of the plant site. Further, involvement of local governments and the public in the program can be beneficial and, in some cases, may be required. Major roadblocks in the approval of clean-up plans can be avoided by encouraging input at all stages of the program, by soliciting comments and suggestions, and by presenting results of investigations, proposed clean-up criteria and proposed clean-up plans.

3.3 PLANT SITE ASSESSMENT

331 OBJECTIVES

The objectives of conducting an assessment of the plant site are to identify potential environmental concerns associated with plant operations, and accordingly, to provide the basis for the design of sampling and analytical programs. As shown in Figure 3-3, the plant site assessment includes an analysis of all available background, process and waste management information.

The assessment needs to be of sufficient detail to guide the design of any sampling and analytical programs by identifying possible types, locations and extent of contamination. It should be carried out by individuals who are experienced in contaminant investigations so that all possible sources and avenues of site contamination are identified. In assembling information for the assessment, the investigating team should undertake detailed inspections of the site, and should discuss plant operations with key personnel from all levels of plant management and operations to gain an understanding of processes and waste management practices. The plant site assessment should also consider concerns of regulatory agencies with respect to possible site contamination and should include a review of the literature.

332 INFORMATION NEEDS

The assembly of all available background and process information is required to identify the possible types of contaminants and areas or locations that may require clean-up. The information needed to carry out a plant site assessment is discussed in the following subsections.

FOLLOWING ACTIVITY

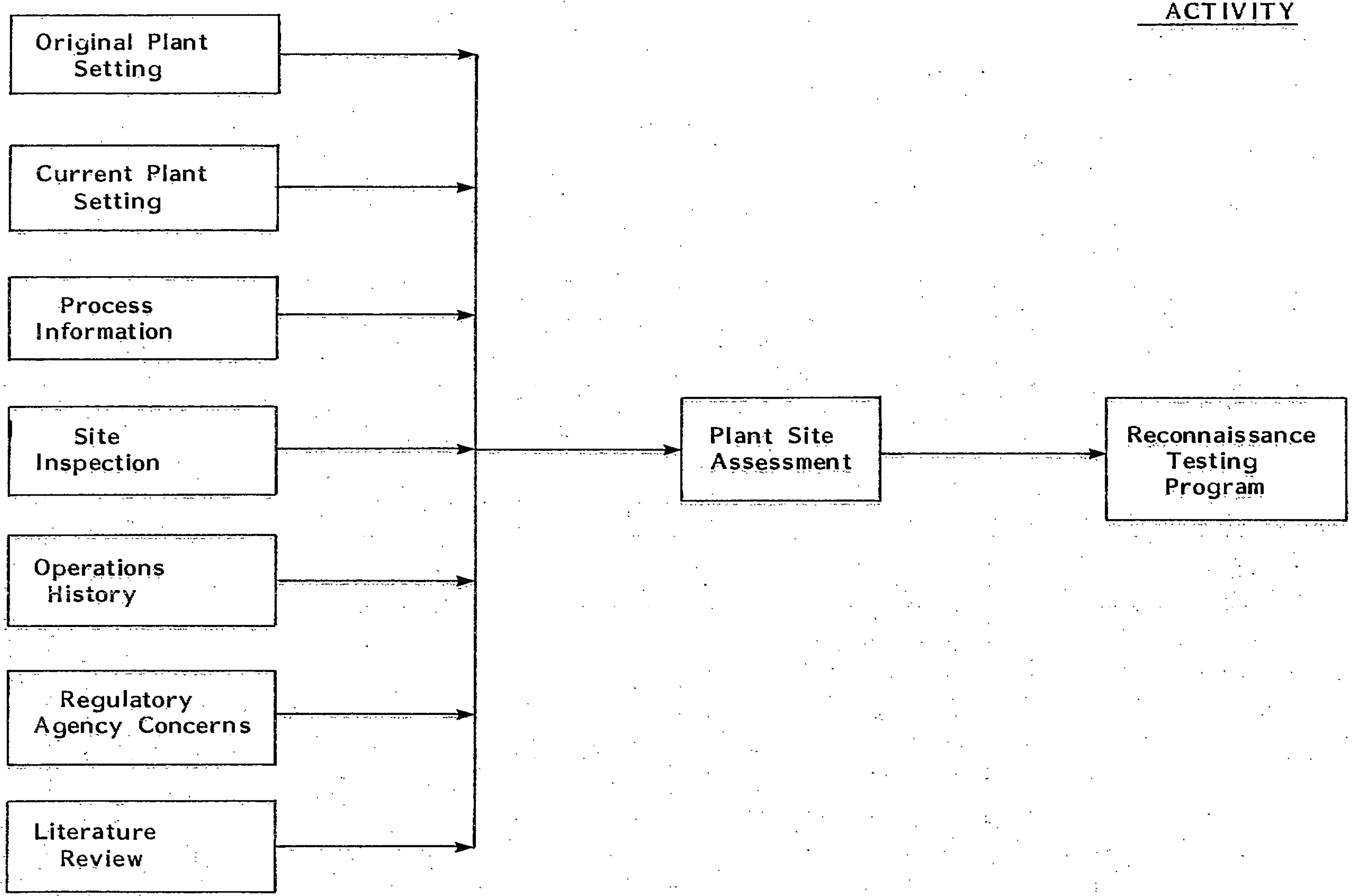

FIGURE 3-3

PLANT SITE ASSESSMENT

.1 Original Plant Setting

The vast majority of plant sites have been substantially modified since start-up. A detailed knowledge of the original environmental setting of the plant is useful in determining changes in the environment which have occurred as a result of plant construction and operation. The changes might impact plant clean-up. For instance, knowledge of the surface drainage in the area of the proposed plant site would indicate those drainage channels affected by possibly contaminated plant site surface runoff.

As shown in Figure 3-4, the physical description of the plant site should include information concerning drainage patterns, topography, geology, hydrogeology and vegetation. Much of this information may be available in preliminary site evaluations completed prior to construction of the plant. Other possible sources of pre-construction environmental information of the plant site area are:

- o environmental impact statements or assessments completed for the plant or in the area of the plant prior to construction;

- o environmental baseline surveys completed prior to plant construction;

- o government soil, vegetation or surface water quality surveys predating plant construction;

- o government fish and wildlife files or surveys concerning the fauna and flora of the region prior to construction;

- o records of well drilling logs from the vicinity of the plant site;

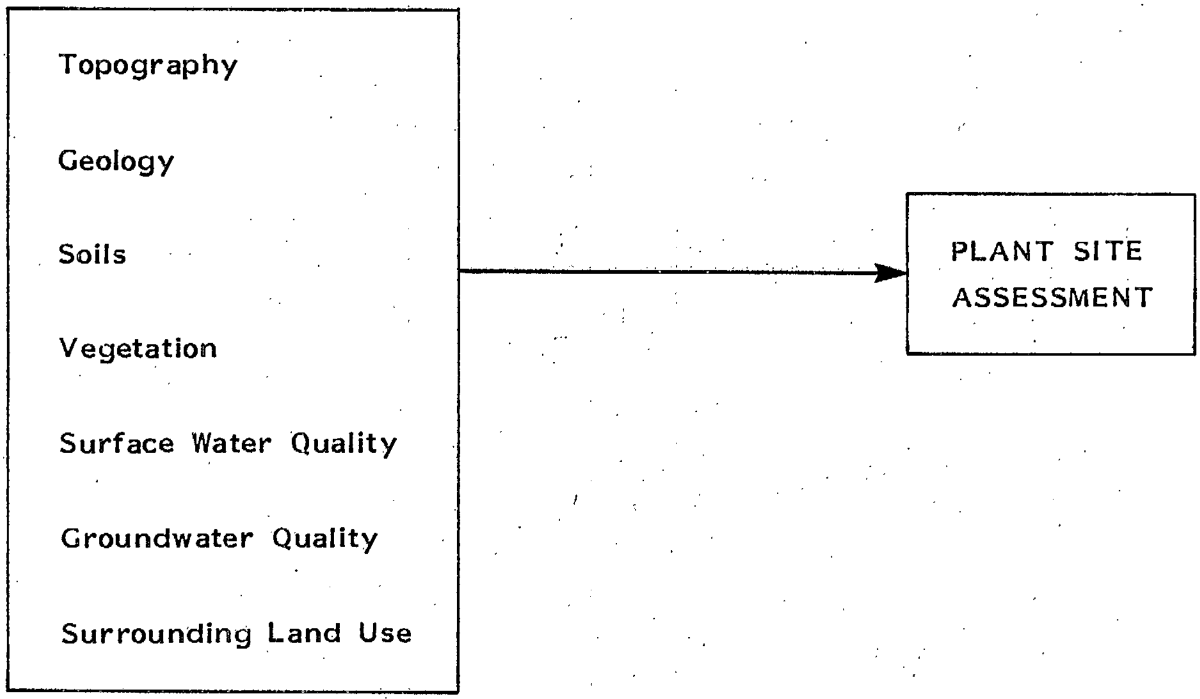

FIGURE 3-4
ORIGINAL PLANT SETTING

- groundwater quality information which may been collected from subsurface drinking water supplies in the area, or from specific baseline surveys;

- aerial photographs of the plant site predating plant construction;

- interviews with company personnel who were involved in plant construction or initial operation; and

- interviews with individuals who lived in the area prior to plant construction.

The data obtained from various sources should be reviewed and summarized to outline the current state of knowledge concerning the plant site prior to construction. The report should address the following factors:

- topography;
- geology;
- soils;
- vegetation;
- surface water quality;
- groundwater quality; and
- surrounding land use.

.2 Current Plant Setting

By comparing the present-day and original plant settings, changes which have occurred during the plant's operating life can be identified. Changes may be the result of plant operations and thus may indicate areas of concern from a clean-up standpoint. Features of the plant site which are important to the plant site assessment are shown in Figure 3-5. This activity is particularly important where extensive site

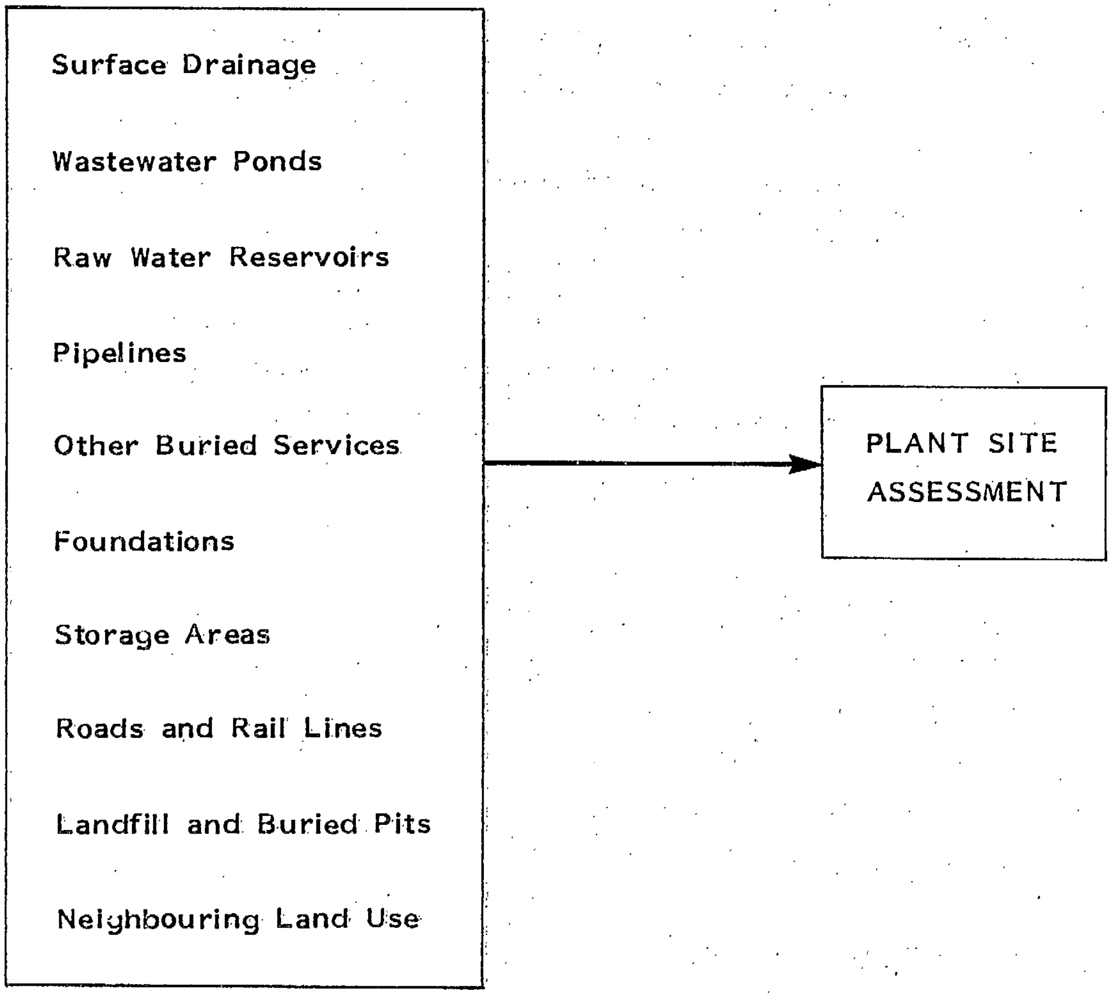

FIGURE 3-5
CURRENT PLANT SETTING

modifications have occurred during the plant's operating life but which are not evident from surface disturbances; for instance, buried pits and landfills, buried sloughs or altered drainage channels.

Information on the current setting of the plant may be obtained from a number of sources. For an over-all picture of the plant site, current aerial photographs should be used to delineate such facilities as:

- process areas;
- raw materials storage;
- reservoirs;
- product or by-product storage areas;
- drainage areas;
- waste storage, treatment and disposal sites;
- effluent discharge points;
- ancillary and support plant facilities;
- product loadout areas; and
- connecting pipelines for feedstock, products, intermediates, or raw materials.

In addition, information from construction drawings, process flow diagrams and plot plans will be of value in defining the current setting of the plant site and the immediately surrounding area.

On a more specific basis, information concerning the depth of foundations, depth and configuration of trenches dug for pipelines, location of underground storage tanks, liners used for wastewater ponds or coatings used on buried metal tanks on the plant site should also be obtained. This information may be obtained from:

- plant construction plans, specifications and as-built drawings;
- borehole logs;
- piping schematics and plans;

- o construction specifications for wastewater ponds;
- o construction specifications for structures; and
- o construction specifications for buried storage facilities.

Compiling and analyzing information on the current plant setting should result in a thorough knowledge of plant process facilities, ancillary or support facilities and the surrounding land uses. By comparing this information with the original plant site setting, it will be possible to identify the following:

- o the potential for on-site contamination;
- o the potential for the spread of contamination;
- o changes in topography which might result in contaminant accumulations;
- o the potential for changes in surface water and groundwater quality; and
- o changes in land use surrounding the plant.

.3 Process Information

Knowledge of the plant processes as well as feedstock qualities, chemicals used and manufactured on-site, and process wastes and by-products will assist in establishing potential sources and types of contaminants, and areas of the plant where clean-up may be required. Figure 3-6 highlights the process-related factors needed for the plant site assessment. Related information on sewer lines, sumps, separators and other treatment works for wastes from individual plant processes will assist in providing an understanding of normal waste management practices.

Each process within the plant should be reviewed in detail with regard to:

- o the purpose and type of process;

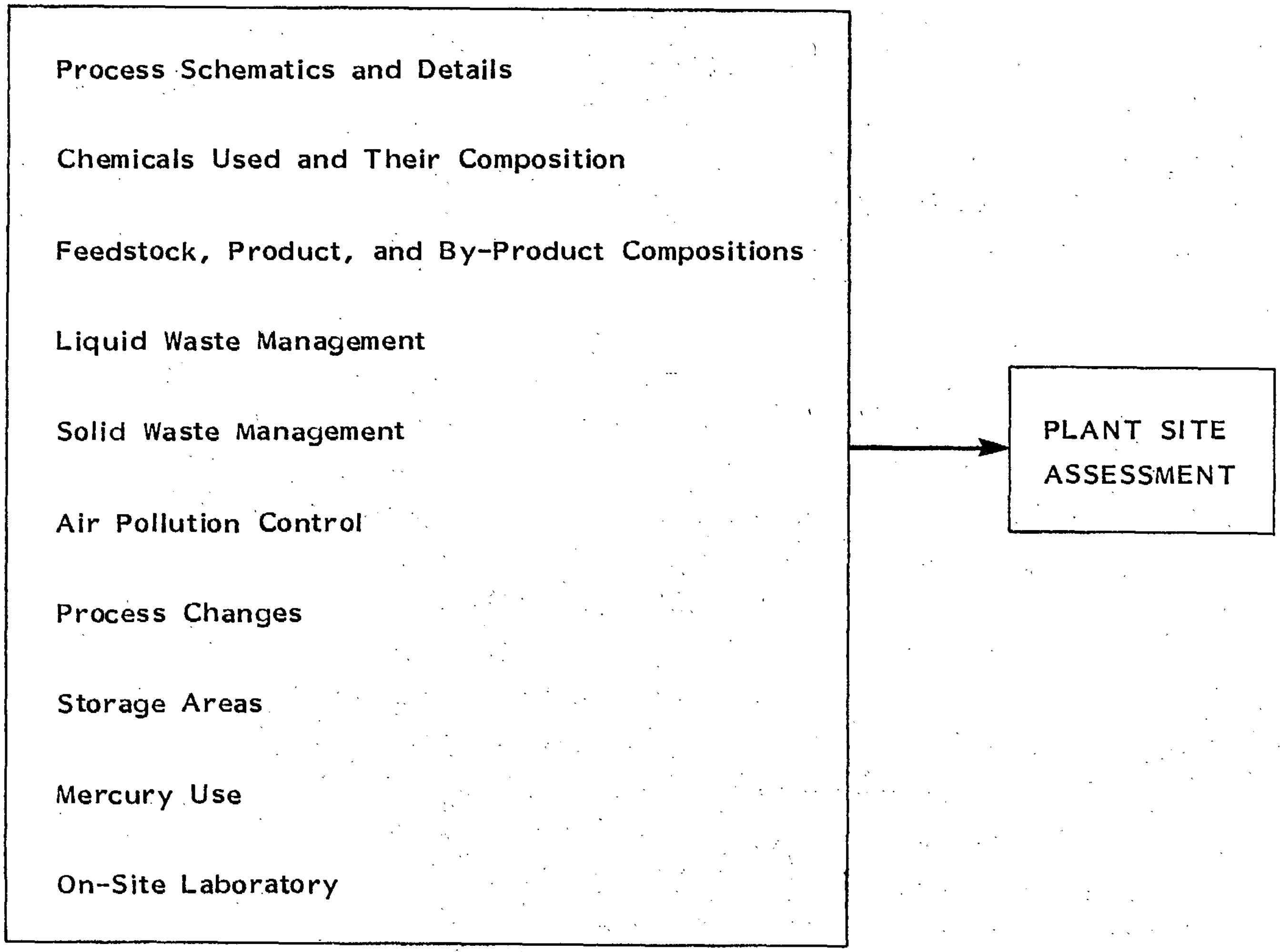

FIGURE 3-6
PROCESS INFORMATION

- the composition of the feedstock or other raw materials;
- the composition of the product;
- the composition of catalysts or additives used in the process;
- the physical process conditions (e.g. temperature and pressure);
- the composition of by-products and solid wastes;
- the composition and method of treatment of air emissions;
- the volume, method of treatment and quality of water used;
- the volume and quality of wastewater generated;
- waste management practices; and
- changes in each process since plant start-up.

Descriptions of the individual processes within the plant should be accompanied by process schematics. This information may be obtained from:

- special chemical analyses of feedstock and raw materials;
- routine chemical analyses performed for process control on raw materials, products, by-products or wastes;
- manufacture's analyses of catalysts, chemical additives, or fluids used on the plant site;
- special analyses of solid, semi-solid, liquid or gaseous wastes produced in the plant;
- waste treatment records on the quantity and quality of waste;
- plant records documenting changes in process since start-up;
- equipment maintenance or operating manuals;
- chemical engineering manuals showing schematics of individual processes; and
- mass balance sheets for quantification of chemicals imported to the plant versus products and wastes leaving the plant or placed in storage on the plant site.

Degradation of stored products by physical/chemical or microbial action may result in contamination of storage sites. An example is the sulphur block area of sour gas plants. Over the years of storage, small quantities of elemental sulphur are microbially converted to sulphate and sulphuric acid. This can increase the sulphate level and reduce the pH of both soil, groundwater and surface runoff in the vicinity of the sulphur block. In some instances alterations in soil and water quality may be sufficient to require clean-up during decommissioning activities. The compilation of process information should therefore include storage areas and should identify construction details of base pads and underdrain systems.

In the past mercury was widely used in plant instrumentation, for instance in pressure measuring gauges. Spillage of mercury from breakage of manometers or maintenance of gauges (instrument shop) may be a significant clean-up concern. Attempts would be made to recover as much of the spilled mercury as possible but residual amounts would find their way into drains and sumps and possibly into the plant's sewer system. Mercury accumulates in the sludges and sediments in drainage ways, sewer systems and wastewater treatment systems. Given concerns regarding mercury contamination, it is important to determine mercury usage throughout the plant and attempt to determine the fate of spilled mercury at each location. Information on mercury usage within the plant should be available from purchase orders and plant maintenance reports. Another excellent source of information is the individual reponsible for maintaining the plant's instrumentation.

Electrical transformers and capacitors, electromagnets and other equipment may have dielectric fluids containing polychlorinated biphenyls (PCB's). These fluids are usually identified under a variety of trade names, and it is essential to clearly determine the make-up of dielectric fluids. Spills of PCB fluids may have occurred, or oils may have been changed and disposed of on the plant site. Possible PCB contamination presents a significant clean-up concern for the plant site, hence, locations of these electrical devices should be identified. It is noted that it is not unusual to detect low levels of PCB's in older transformers designed as non-PCB units.

Many plants possess their own analytical laboratory for determination of product composition, standards, or process efficiency. Inventories of the quantities of chemicals used and information on laboratory waste disposal practices should be obtained. While the volume of chemicals used in the laboratory is usually small by comparison to the operation of the plant, the year-after-year disposal of potentially hazardous chemicals from the plant laboratory may culminate in the contamination of wastewater sumps, sewers and treatment systems.

Information on the use and disposal of chemicals in laboratories should be available from:

- o purchase orders;
- o a list of chemical tests performed and reagents required;
- o interviews with laboratory personnel; and
- o documentation concerning laboratory waste handling practices.

Information on process details, products, by-products, and wastes generated should be summarized for each major process within the plant. Lists of potential contaminants and their likely location should be prepared for each process. This should be repeated for each of the support facilities such as cooling towers, steam generators, wastewater and water treatment facilities, and laboratories. This summary is a major input to the plant site assessment.

.4 Site Inspections

Detailed site inspections are aimed at obtaining an estimate of areas of the plant site where contamination may have occurred and thus where clean-up and reclamation programs may need to be focused. Site inspections (Figure 3-7) will allow information concerning the original

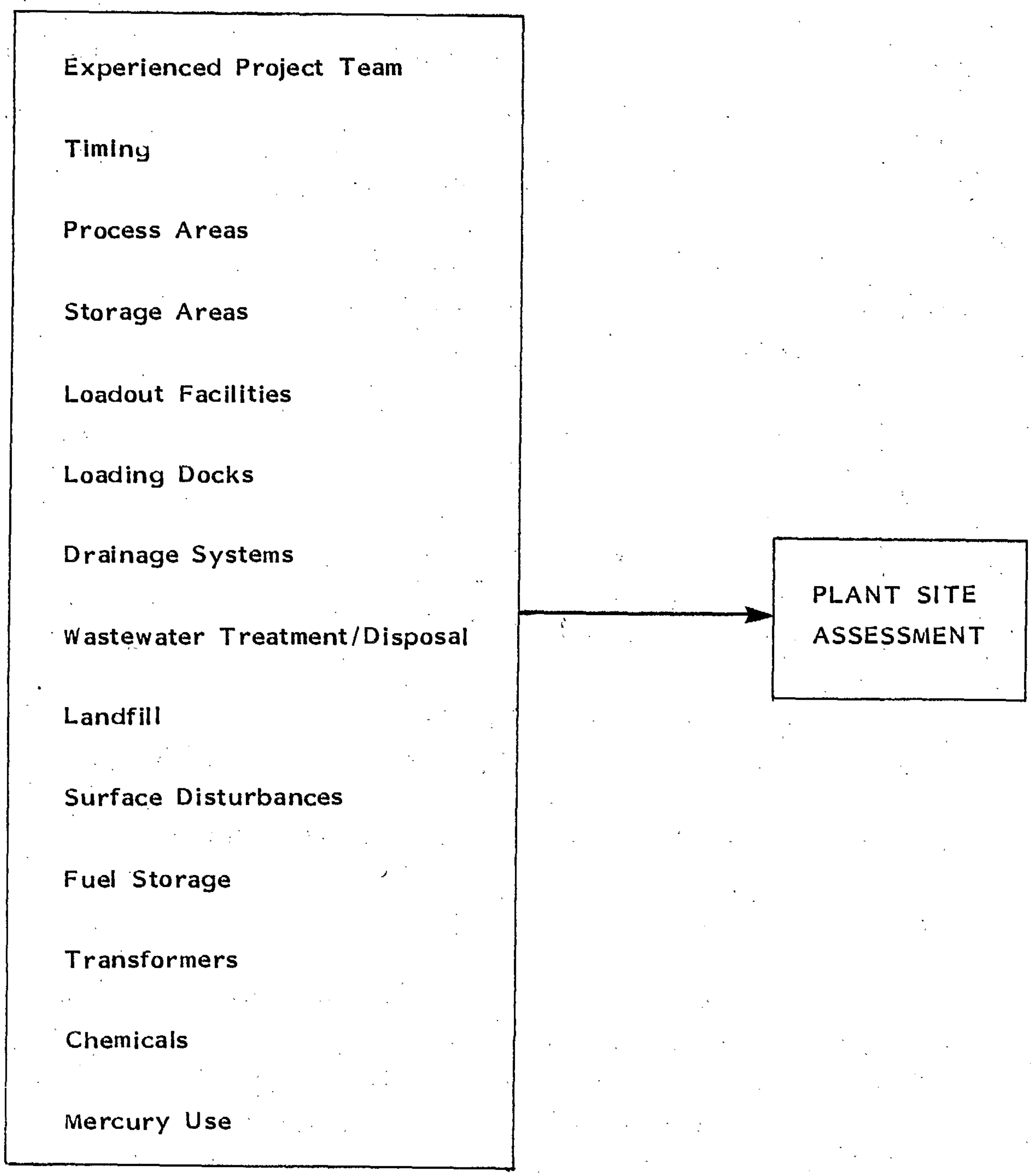

FIGURE 3-7
SITE INSPECTIONS

and current plant setting and the plant process information to be put in perspective relative to possible plant site contamination. This section will describe when the initial site inspection should take place, what preparations are necessary, who should undertake the inspection and what specific areas should be examined.

.41 Site Inspection Team and Preparation for Inspections

Once the decision to decommission a plant has been made, a qualified team should be formed for planning and implementing the clean-up program. This team may include:

- plant process personnel;
- waste management specialists;
- chemical engineers;
- environmental contaminant specialists;
- hydrogeologists; and
- analytical chemists.

Prior to the actual site visit, the inspection team should, as a group, review in detail the information from the original and current plant setting as well as the process information. Available information on major plant upsets or past operating problems should also be reviewed.

.42 Timing of Site Inspections

It is important that site inspections take place before the commencement of equipment dismantling. The location and orientation of process equipment can significantly assist in identifying possible areas and types of contamination (e.g. transformers, process vessels containing catalysts etc.). In addition, heavy earthmoving or construction equipment may spread contamination as well as introduce other contaminants not associated with plant operation onto the site.

.43 Inspection Sequence, Priorities and Suggestions

The site inspection should be conducted by process area or sub-area in a sequence which begins with feedstock introduction onto the plant site and ends with the product loadout facility. In addition to the major process areas of the plant site, the following areas should be critically examined during the plant inspection:

- raw materials, by-product and product storage areas;
- loading and unloading facilities;
- liquid waste and sludge disposal operations;
- solid waste disposal sites;
- surface drainage systems;
- electrical substations or transformer storage areas;
- fuel storage areas (above and below ground);
- maintenance facilities; and
- laboratory facilities.

Drainage ditches or other surface runoff retention areas are also important. If plant wastewater or surface runoff discharges into a receiving stream or river, inspection of both the upstream and downstream portions of the stream or river, relative to the discharge point, should be made. Discharges to lakes, ponds or other static water bodies should also be inspected.

Obvious contamination of surface soils or water may be identified by:

- surface discolouration;
- surface films;
- odour;
- textural anomalies; and/or
- lack of or changes in vegetative cover

If the plant has wastewater or surface runoff treatment or holding ponds, the use of surface geophysical techniques (for instance electromagnetic induction) are recommended as a cost-effective procedure for identifying possible leakage. Leakage could affect groundwater quality.

Areas of the plant site requiring particular attention are detailed below.

- **Process Area**

The following should be identified during the site visit:

- process vessels containing catalysts;
- processes particularly susceptible to spills or leaks; and
- the location of filters and other equipment requiring frequent maintenance.

Information on the procedures used during annual maintenance should also be reviewed.

- **Landfill Sites**

Landfill sites are frequently located on or near the plant site. In some cases disposal sites were originally natural depressions or gullies on or near the plant site. The sites should be inspected to determine possible contaminant movement either into surface waters or groundwater. The method of operation of the disposal site (i.e. sanitary landfill or open dump) should be reviewed.

- **Chemicals and Chemical Storage Areas**

Chemicals use on the plant site should be reviewed with particular emphasis on storage areas and chemical feed systems. In addition to chemical additions and catalysts used in the industrial processes, other chemicals are used in the treatment of potable and boiler feed water, cooling water and wastewaters. Loading docks, storage areas, feed systems, and locations for storage/disposal of spent chemical containers should be inspected for signs of spillage. The use of herbicides on the plant property should also be reviewed.

- **Mercury Use On-Site**

While mercury may have been used in the industrial process (mercury cell chlor-alkai plants, mercury seed dressing plant, etc.), mercury use in other industrial plants was common. Manometers, float valves and other monitoring devices may contain mercury, or mercury may have been used in the past. Also, mercury may have been used for analytical determinations in the on-site laboratory. Use of mercury on-site should be reviewed with emphasis on identifying locations where spilled mercury may be concentrated (sumps, gutters, or drains near process vessels and boilers, drains in the instrument maintenance shop, sump in the laboratory etc.)

- **Electrical Substations or Transformer Storage Sites**

Electrical substations or transformer storage areas are frequently suspected of being contaminated with polychlorinated biphenyls (PCB's) due to spills and leaks of dielectric fluids. Non-PCB transformers cannot be excluded as a possible source of PCB contamination, since these units may contain 50 ppm or more PCB's in the fluid.

- **Fuel Storage Areas**

Fuel storage areas, especially underground tanks, are historically noted for leaks and contamination of adjacent soil and groundwater. Contamination from these tanks may generally not be apparent at the surface. The older the storage tank, the more likely that contamination is present. In addition, these underground tanks are usually coated with tar prior to installation and leaks of fuel may leach contaminant organics from the tar coating. Some effort should be made by the inspection team to determine the age of underground fuel storage tanks and any measures taken in the past to determine if leaks had occurred. Fuel storage tanks frequently have small areas of contamination at the outlet due to spills when transferring product.

- **Ancillary and Support Facilities**

Motor pool, machine shops or other maintenance facilities within the plant are also potential sources of contaminants such as used fuels, oil, transmission fluids, grease and other lubricants, solvents, paints and pesticides. Generally, contaminated areas in the vicinity of these facilities are small, however, the type of contaminant may be considered particularly hazardous thus requiring special attention during a clean-up program.

- **Drainage Ditches**

Because drainage ditches collect surface runoff from wide areas of the plant and may also receive wastewaters, as well as process spills or leaks, they can be highly contaminated with a wide variety of possible contaminants. Knowledge of the plant's wastewater handling and drainage system will assist in determining the likely areas and types of contamination. Subsurface sediments in the drainage ditches, especially in areas where runoff has pooled, should be identified during the site inspection. This action may reveal, either by odour or visual examination, the possible presence of severely contaminated sediments.

- **Wastewater Discharges**

Wastewater discharges into a stream, over the years of plant operation, may have affected the composition of downstream sediments.

Since sediments are generally a sink for many contaminants in the aquatic environment, inspection of sediments upstream and downstream from the wastewater discharge point is recommended. Reservoirs or surface water retention structures further downstream are likely candidates for this sediment examination. Where discharges of wastewater occur into a lake or other static body of water, examination of the sediments should occur at some distance from the discharge point sufficient to allow for settling of particulate material.

.44 Site Inspection Report

Notes from the site visit should be compiled and drafted into a brief report, which should detail possible problem areas on a process-by-process or facility-by-facility basis. Possibly contaminated areas should be identified on a plot plan, together with likely contaminants. This report can then be integrated with other background information as input to the plant site assessment.

.5 Operations History

During a plant's operating life (often in excess of 25 years), numerous changes may have been made to the processes, to operating practices and to the methods of handling, treating and disposing of wastes. These changes will have a major impact on plant site contamination and thus clean-up plans. Establishment of a historical sequence of plant operations will therefore account for:

- changes in the source and composition of raw materials;
- changes in storage sites for raw materials, by-products, or products;
- changes in chemical or physical manufacturing processes; and
- changes in waste management and disposal practices

Areas of the plant site associated with these changes should be identified and examined with regard to their potential for contamination.

The initial source of information concerning the operations history of the plant will come from current plant management and operating personnel. To efficiently integrate this information with other sources (Figure 3-8), a standard questionnaire should be prepared. This will ensure consistency of questions and allow for confirmation during the compilation of information. In order to obtain information, it is recommended that the questionnaire be used as a basis for interviewing both current and former employees. Care should be exercised to select interviewees who:

- represent as much of the operating life of the plant as possible, and
- are familiar with those aspects of plant operations likely to cause problems from a contamination standpoint.

The questionnaire used in interviewing key personnel should be subdivided into three broad areas:

- raw materials, process and product management;
- waste management; and
- spills, leaks and other upset conditions.

The questionnaire should also address concerns arising from any ancillary or support facilities on the site. Examples are:

- welding and machine shops,
- maintenance areas,
- paint, pesticide and solvent storage areas, and
- electrical substations

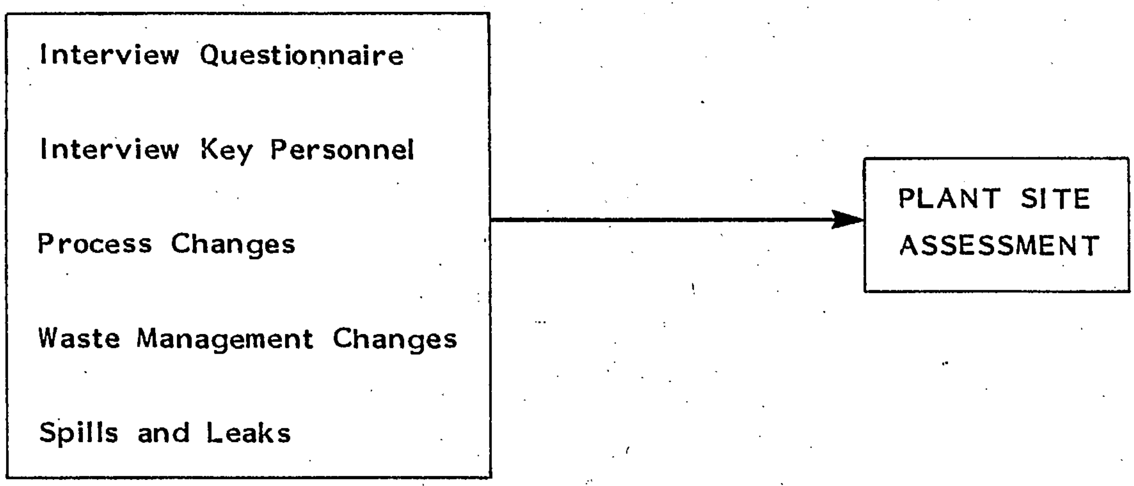

FIGURE 3-8
OPERATIONS HISTORY

Details of construction practices can frequently be obtained from employees who were involved in plant start-up. Every effort should be made to confirm responses in critical areas, particularly when attempting to address activities which may have occurred 10 or more years ago.

Historical operations information may also be obtained from regulatory licences or government approvals for construction and operation of plant processes or their associated discharges to the environment. Spill or regular monitoring reports can provide additional useful information as can consultant's reports prepared over the life of the plant.

After compiling and cross-checking the information derived from the questionnaires and any additional information sources, a complete chronological history of plant operation should be prepared making extensive use of charts and tables. Potential contamination problems should be clearly identified together with spills, leaks and plant upset conditions. In preparing this report, it should be remembered that plant operating practices are being reviewed in order to determine possible contaminant problems (where, what, when and how much).

.6 Regulatory Agency Concerns

A working relationship between the regulatory agencies and the company is necessary for the orderly completion of the various tasks involved in decommissioning of a plant (see Section 3.11). Regulatory agency approval will be required for the over-all decommissioning plan as well as for the clean-up criteria and the clean-up plan. Finally, on completion of the clean-up plan, the regulatory agency should be prepared to certify that the site is decontaminated to the extent required by the clean-up criteria.

The decommissioning of any plant should be viewed as part of an on-going relationship between the plant management and the regulatory agencies. This relationship was initiated at the point of approval for construction of the plant and has progressed, over the years of plant operation, through the various licences and permits required for the operation of various chemical processes, discharges or emissions until the point where the plant has come to the end of its operating life. Just as the regulatory agencies approved the construction of the plant, so they must be involved in the approval of the overall decommissioning and clean-up plans.

At the plant assessment stage of the decommissioning program, it is important to establish the concerns of the regulatory agencies. As shown in Figure 3-9, factors or issues from a regulatory viewpoint which will assist in assessing the plant site include:

- o government policies (regulations or guidelines) applicable to the clean-up of industrial sites;

- o results of studies carried out on or near the plant site;

- o concerns with respect to soil or water contamination; and

- o other information which may be applicable from government involvement in other decommissioning projects.

While the regulatory agency will be formally and informally involved throughout the decommissioning program, it is recommended that discussions be held at the plant site assessment stage to clearly identify the concerns regulatory agencies may have with conditions on site. This information would then be integrated with other factors used to assess the plant site.

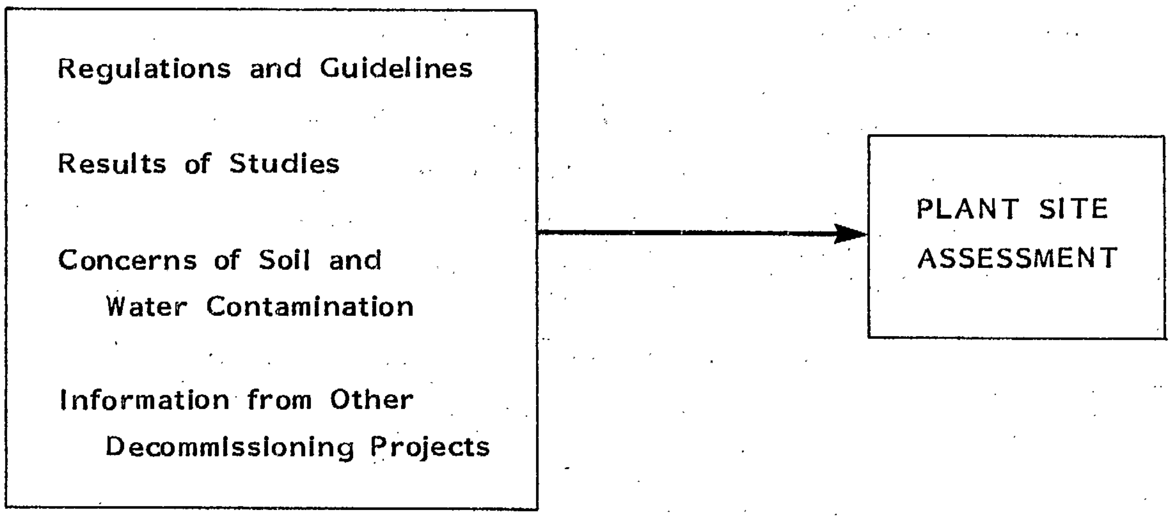

FIGURE 3-9
REGULATORY AGENCY CONCERNS

.7 Literature Review

A literature review will identify information on the environmental effect of plant operations, details of plant site decommissioning activities including pertinent studies and clean-up and reclamation options. Literature-based information concerning the impact of plant operations on the environment, sources of specific contaminants, their locations on the plant site and clean-up and reclamation options will assist in the development and implementation of clean-up plans, including plant site assessments, reconnaissance and detailed field programs and development of site specific clean-up criteria.

Literature relevant to plant decommissioning should include technical reports concerning decommissioning activities at other similar plant sites. These reports will be especially valuable in determining the type and level of contaminants associated with individual process areas within the plant, and the migration of contaminants off the plant site (Figure 3-10). There is currently limited information concerning specific plant site clean-up operations; however, other types of reports which will assist in determining the impact of plant operation include:

- investigation and clean-up of landfills;
- clean-up activities related to chemical spills;
- impacts of specific chemical process on the environment;
- analytical methodologies for hazardous substances;
- restrictions on future land use imposed by plant operations; and
- contaminants in emissions from plant operations (normal and upset conditions).

Technical Reports On:

- Plant Decommissioning
- Clean-up Programs
- Landfill and Industrial Site Investigations
- Sampling Methodologies
- Analytical Methodologies
- Process Information
- Waste Characterization
- Contaminant Migration
- Clean-up Options
- Costs

→ PLANT SITE ASSESSMENT

FIGURE 3-10
LITERATURE REVIEW

A number of technical reports are available from government and industry which will help in establishing the types and concentrations of contaminants found in association with refining, natural gas processing or chemical processes. To obtain available reports, contact the Environmental Protection Service of Environment Canada, provincial environmental agencies and the United States Environmental Protection Agency. Other sources of technical information are:

Petroleum Association for Conservation of the
Canadian Environment
Suite 400, 130 Albert Street
Ottawa, Ontario K1P 5G4
Canada
(613) 236-9122

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005
U.S.A.
(202) 682-8000

Canadian Petroleum Association
15th Floor,
633 - 6th Avenue S.W.
Calgary, Alberta
Canada
(403) 269-6721

Canadian Chemical Producers' Association
Sutie 805
350 Sparks Street
Ottawa, Ontario K1R 7S8
Canada

Chemical Manufacturers Association
2501 M Street, Northwest
Washington, D.C. 20037
U.S.A.
(202) 887-1100

A systematic review of the literature will also provide information useful to further activities of the decommissioning program (clean-up options, criteria, costs, etc.). Pertinent literature on the environmental effects of plant operations, decommissioning activities, clean-up and reclamation procedures should be documented in a brief report. The report should contain for each literature source:

- a summary of the report findings; and
- the meaning or application of its findings for the plant site being decommissioned.

333 ASSESSMENT

The assembly of pertinent background site and process information (discussed in the foregoing sections) will provide the investigative team with sufficient data to assess site conditions. An analysis of the available information will enable the investigative team to:

- identify the possible types of contaminants of concern;
- identify the possible problem areas of the site; and
- estimate the possible extent of subsurface concerns.

The plant site assessment, which places into perspective the environmental concerns associated with clean-up and reuse of the site will be used to determine the nature and extent of field investigations on the site.

3.4 RECONNAISSANCE TESTING PROGRAM

Environmental investigations which involve extensive sampling and analysis are more effective if they are undertaken in phases. The first phase is a reconnaissance program which is designed to provide indications of contamination and to provide the basis for detailed investigations in certain areas. The reconnaissance program may, in some cases, show that subsequent detailed investigations may be very limited or may not be required.

There are cases where a single field program can be conducted to provide sufficient information to design a clean-up program. These may include relatively small chemical plants where few contaminant concerns are associated with the process, or other plants where considerable information on the geologic and hydrogeologic setting, waste management practices and contaminated areas is known. However, for most sites, a phased approach consisting of an initial or reconnaissance program followed by detailed testing, is practical, cost-effective and acceptable to regulatory agencies.

Field sampling and analytical programs may, in some cases, need only be limited to confirm known conditions of the site. In the majority of industrial plants, however, field programs should be more extensive and should include known areas of contamination, suspected areas of contamination and areas believed to be unaffected by plant operations. By choosing to conduct only limited investigations of a site, there may be an increase in overall costs for the program, or other concerns may become apparent at some future time.

The degree of investigation required is site-specific (the plant site assessment has identified the required nature and extent of field investigations) and various modifications to methodologies suggested herein may be required to effectively and efficiently determine the extent of contamination at a particular site. However, the detailed and practical approach suggested in the following subsections will guide an investigative team in the field investigation of a site. The approach to designing and carrying out the reconnaissance testing program is shown in Figure 3-11.

341 OBJECTIVES

The main objectives of the reconnaissance testing program are:

- o to identify the types of contaminants, range of contaminant concentrations and general locations of contaminant problems; and
- o to clarify the geologic and hydrogeologic conditions of the site and surrounding area.

Individuals who are experienced in assessing and analyzing contaminant problems are required to design the program. Fields of expertise may include:

- o hydrogeology;
- o soil science;
- o waste management;
- o analytical chemistry; and
- o process engineering.

Other expertise would provide input to program design as required, such as organic chemical specialists and workplace health and safety specialists.

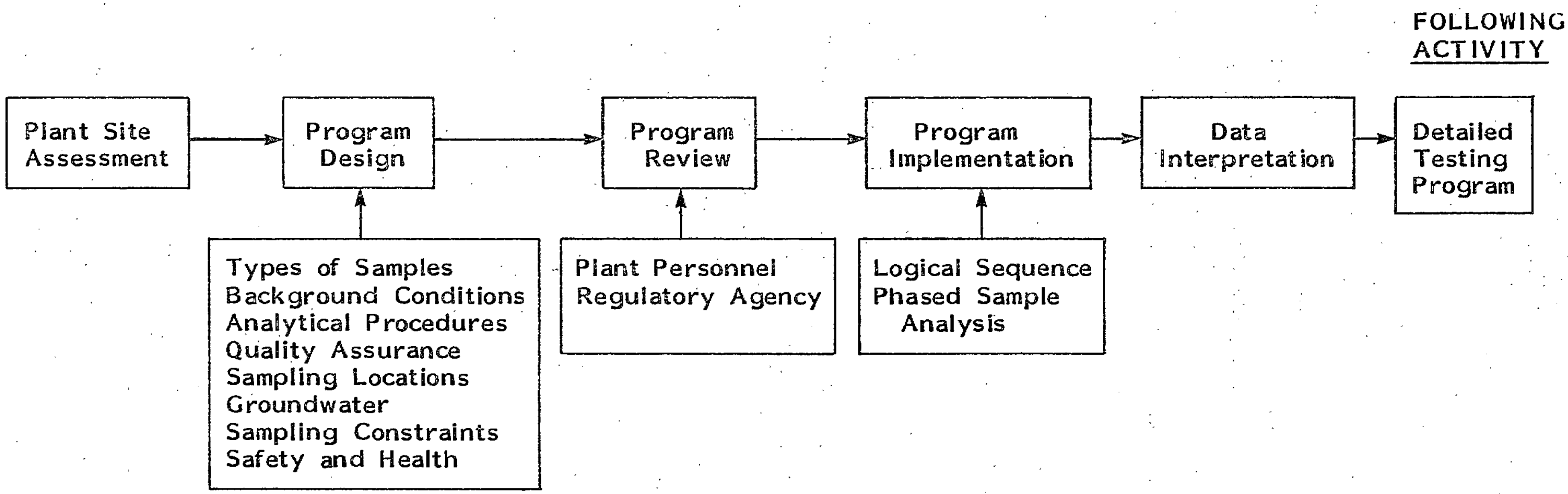

FIGURE 3-11

RECONNAISSANCE TESTING PROGRAM

342 INFORMATION NEEDS

A variety of factors are to be considered by the investigative team in the design (and costing) of an effective reconnaissance program. These factors, when considered at the design stage, will assist in the evaluation of the testing results and ultimately in meeting the program objectives. Information needed to conduct a reconnaissance program is identified and discussed in the following subsections.

.1 Types of Samples

The areas of concern will vary from site-to-site, as will the types of samples to be collected. These will have a marked effect on sampling equipment, resources and costs. There are a number of different types of contaminants produced in the oil and gas processing and organic/inorganic chemical industries. The different physical and chemical properties of the contaminants usually mean different routes of dispersion and retention in the environment for each type of contaminant. It is important that all types of environmental samples (soils, surface waters and groundwaters, etc.) and sludges/residues from the plant are analyzed for the range of possible contaminants established by process information, operations history and the review of relevant studies. Sample types may include:

- soils;
- overburden;
- surface waters;
- groundwaters;
- sediments in drainage ditches and wastewater ponds or lagoons;
- sludges in building drains, sumps and gutters, and in separators and classifiers;
- residues in process vessels:
- construction materials;
- feedstocks;

- by-products; and
- chemicals.

.2 Background Conditions

In order to assess the degree of contamination on the plant site, there is a need to establish the natural levels of constituents in the environment away from the influences of the plant and away from other sources of contaminants in the area. Important factors required to establish background conditions are as follows:

- background conditions should be established for soils, overburden, sediments, groundwater and (possibly) upstream surface water quality;

- the number of background sampling sites - needs to be sufficient to provide a statistical range;

- access to background sites (approval from landowner) is required;

- sites should be located of the same geologic origin as the plant site (with regard to soils, overburden, pond/lake/river sediments and groundwater); and

- published background information will assist in the design of the background sampling program.

.3 Analytical Procedures

The ultimate basis for determining the type and extent of contamination on a plant site is the accurate identification and quantification of specific substances. The analytical program is the key element within the field studies and great care must be exercised during the planning of analytical programs to ensure results are of value in the development and implementation of the clean-up program. Figure 3-12 summarizes the major facets of establishing analytical procedures for the decommissioning project.

The laboratory selected to conduct analyses of environmental samples collected from on and off the plant site must have a good reputation for accuracy and precision, as well as for promptness in analyzing samples and reporting results. The laboratory should:

- o routinely participate in round-robin inter-laboratory comparisons of contaminants in environmental samples;
- o be staffed by qualified personnel;
- o possess state-of-the-art analytical equipment and procedures;
- o maintain internal quality control procedures;
- o have a good working relationship with another laboratory of similar quality for external quality control; and
- o be able to obtain and analyze standardized environmental samples (i.e. soils, water, sediments, tissue, etc.) for substances of likely concern in the clean-up of the plant site.

The laboratory should be thoroughly conversant with the analytical procedures used by regulatory agencies concerned about the environmental aspects of the decommissioning program. Given the wide variety of possible analyses required, it may be necessary to use two laboratories for the regular analytical program.

Specific types of contaminants of concern were identified in the plant site assessment, and these contaminants will form the basis of

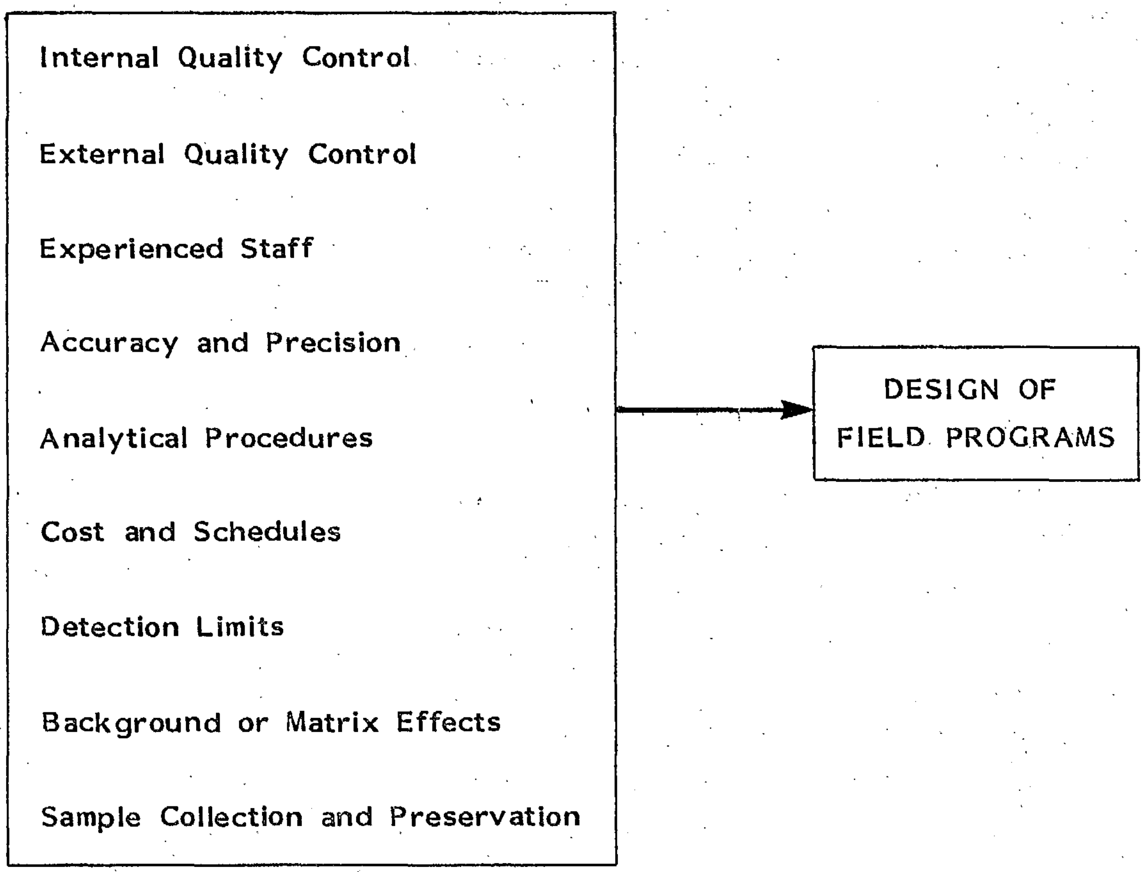

FIGURE 3-12
ANALYTICAL PROCEDURES

analytical determinations to be made. However, other constituents and indicators of contamination should be included in the analytical suite for the reconnaissance program. Multi-element scans (when used cautiously) provide a relatively inexpensive and timely measure of element concentrations.

The specific analytical parameters will vary from industry-to-industry and may range from a few parameters at a lead-acid battery plant (lead and possibly other metals) or at a wood preserving plant (arsenic, creosote, pentachlorophenol) to 20 or more parameters at a more complex sour gas plant or oil refinery. Sample pH and salinity should always be measured as these are indicators of conditions on-site and are integral in planning clean-up and reclamation programs. Further, analysis for mercury should be specified, particularly in sediments and sludges. The analytical program must be tailored to the specific industry, and within the industry, to the types of processes and chemicals used or produced.

For the reconnaissance program, specific design considerations for the analytical program include:

- 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.

The selected analytical laboratory must be required to account for possible interferences in the analyses of environmental samples and be prepared to compensate for background matrix effects which might result from the digestion, extraction, clean-up, or separation procedures used during preparation of the sample for analysis.

Detection limits for each substance must be set to establish the level at which the substance can no longer be detected with certainty in an environmental sample. The detection limit for a given substance is also important the development of clean-up criteria. For example, a clean-up criterion of 2.5 ppm for a given substance is meaningless if the detection limit for that substance is greater than 2.5 ppm.

The logistics of analyzing samples in phases within the reconnaissance program, should be reviewed with laboratory personnel at an early stage. Phased analysis (in terms of both numbers of parameters and numbers of samples) can be a cost saving measure, but has implications in terms of sample size, preservation and management.

For those industries processing hydrocarbons (oil refineries, gas plants, organic chemical plants), indications of hydrocarbon contamination can be determined by oil and grease measurements (waters) and oil determinations (soils, sediments, sludges). Alternatively, organic carbon measurements may be used as indicators. Similar determinations can be made on samples from other industries where spillage from fuel storage areas occurred. There are increasing concerns of the effects of the organic constituents of hydrocarbons in the environment. Therefore, identification of the organic compounds in selected samples collected during the reconnaissance program, utilizing gas chromatography/mass spectrometry (GC/MS) should be part of the reconnaissance program. Selection of sample for GC/MS analyses should be based on measurements of organic carbon or oil content. GC/MS analyses can also be undertaken in phases to reduce costs. Once the initial extraction is made and the sample is run, output from the analysis can range from identification of specific target compounds, to specific groups of compounds, to EPA Priority Pollutants, to a complete scan of all known organic compounds. If further information on the sample is required at any point, it can be obtained and interpreted from the computer-stored chromatogram.

For chemical plants utilizing or producing specific organic compounds, a series of target organic compounds could be established for analysis by GC or GC/MS. These target compounds could include the compound utilized or produced, its degradation products, and organic contaminants that may be produced in the industrial process.

The selection of analytical procedures must be documented in order that these procedures are rigorously adhered to throughout the entire decommissioning program. The documentation should be supplied to all laboratories selected for the analysis of environmental samples and to regulatory agencies involved in the decommissioning.

.4 Quality Assurance

A quality assurance program, conducted in concert with the internal quality control measures at the analytical laboratory (identified in the foregoing section), is that portion of a comprehensive analytical program which assures the reliability of analytical data. A second (quality assurance) laboratory would be given the responsibility to analyze duplicate samples from the site.

While a number of random duplicates can be selected for analysis at the quality assurance laboratory, a more meaningful program is described as follows:

- o the selection of a finite number of samples spanning all sample types and matrices and the systematic duplication (blind) of the samples with due regard to sample homogeneity;
- o providing for at least triplicate analysis of each selected sample at both the main laboratory and the quality assurance laboratory (triplicate analyses will provide a mean and standard deviation for each chemical parameter at both laboratories);

- ensuring the utilization of the same procedures and analytical instrumentation at both laboratories as far as is possible with available equipment; and

- utilizing the same standards at both laboratories for their internal quality control checks.

.5 Sampling Density and Sampling Site Locations

Establishing the number, density and locations of sites for the sampling of soils, overburden and sediments, and for the installation of groundwater monitoring wells is critical to a successful program and should be based on the judgement of the experienced investigative team in order to meet the objectives of the reconnaissance program. Factors for consideration in establishing sampling site locations are identified in the following paragraphs.

.51 Soils and Overburden The number and location of sampling sites for soils and overburden will depend to a large extent on anticipated or suspected concerns (plant site assessment). As well, sampling density will vary across the site and will be more intense in areas suspected to be contaminated. For the reconnaissance program it is also important to establish sampling sites in areas which are not expected to be contaminated to ensure that the plant site assessment was accurate.

It is not the intent of the reconnaissance program to precisely define boundaries of contaminated areas; however, certain factors should be considered in the program design which would provide general indications of areal extent. Examples of these methods are as follows:

- establishing a grid (spacing is site-specific) over the suspected and adjacent area. A grid is useful in locating sampling sites, aids in the presentation of analytical results and is essential in future delineation of areas to be cleaned-up;

- establishing sampling sites on concentric circles moving outward from the source into adjacent non-contaminated areas; and

- sampling several sites on the grid or concentric circles with phased analysis of samples from the source towards the non-contaminated area.

In this way, a general estimate of the areal extent of contamination can be made (precision of the estimate depends on grid size or interval of concentric circles).

On a similar basis, sampling intervals with depth at each site can be determined; however, actual sampling intervals should be based on the experience of the personnel in the field. It is suggested that at least two samples per site should be submitted for analysis. For the reconnaissance program, these samples may include the surficial sample (0 to 15 cm) and a sample from a deeper horizon (site-specific). It is both logical and cost-effective to collect at least two other soil samples from each site (above and below the deeper sample submitted for analysis) for possible future analysis.

Further overburden sampling at depth would be undertaken as part of the hydrogeological aspects of the reconnaissance program.

Compositing of samples is often used to establish "average" conditions in an area. For a reconnaissance program, composite sampling may be appropriate for characterizing certain areas believed to be of uniform chemical composition (for example, landfarm areas or uncontaminated areas). By sampling these areas on a grid with systematic compositing of samples, the area can be characterized relatively economically. Interpretation of the analytical results of composite samples may be more difficult since:

- o the presence of clean areas may be masked by contaminants introduced to the composite with contaminated subsamples; or conversely

- o the impact of highly contaminated areas may be masked by clean subsamples.

Samples of soils can be collected from boreholes augered by hand (depth is usually limited to 1 m), from test pits excavated with a backhoe (maximum depth is usually 3 to 4 m), or from boreholes augered by a mobile drill rig equipped with a spilt spoon or Shelby tube sampler (much greater depth). The use of the drill rig will be less costly if a large number of sites is involved; however access constraints may necessitate other methods.

Given the nature of this initial reconnaissance program, it may not be efficient or practical to use computer interpolation techniques to predict contaminant distribution in soils. However, in some situations (for instance, lead contamination of soils due to fallout from stack emissions), the distribution of a contaminant may be relatively uniform permitting the use of spatial statistics and computer interpolation of data to specifically delineate contaminated areas. The intended use of these techniques should be determined early in the program design as minimum sampling densities are required.

Further information on the design of soil sampling programs may be found in McKeague (1978), Mooij and Rovers (1976), Mason (1983) and Barth and Mason (1984). It is emphasized that design of the soils and overburden sampling program (and the associated analytical program) should be undertaken by individuals experienced in contaminant investigations.

.52 <u>**Sediments**</u> Sediments in drainage ditches are likely to be contaminated if the ditches carried process wastewaters or surface runoff from process or storage areas, or were impacted by spills or leaks. For the reconnaissance program, sediments in all drainage ditches should be sampled as well as sediments in downstream surface runoff or wastewater ponds. Candidate locations in drainage ditches are areas where water tends to pond, or locations where frequent spills or discharges have occurred.

For the reconnaissance program, sediment samples are usually collected to a depth of 15 to 25 cm utilizing a sampling trowel or shovel, or with a dredge. If deeper sampling is desired, a sediment coring device (ponds), or a drill rig or backhoe (ditches) would be used.

.53 <u>**Groundwater/Hydrogeologic Study**</u> A hydrogeologic study or assessment of groundwater conditions at a plant site is an essential part of determining whether or not plant operations had an effect on the local environment. In general, these studies involve determining the nature of local groundwater occurrence as well as its movement and quality. After review of the type of operational facilities and potential problems at a site, a field program (part of the reconnaissance program) is usually then required to determine the general soils and geologic setting of the area and the likely pathways for significant groundwater movement. These activities involve drilling a number of geologic testholes and installing and testing of a series of piezometers (small diameter monitoring wells). The number and depth of these piezometers often depends upon the complexity of the geology. However, the piezometer network must be sufficient to provide a three-dimensional picture of groundwater flow rates and direction.

Piezometers can also be sampled to determine any anomalies in groundwater quality on-site. Contaminated zones of groundwater often migrate in distinct "plumes" but the effectiveness of detecting these plumes on-site depends upon whether piezometers have been properly located downgradient from problem areas and at suitable depths for the expected contaminants.

Plant site seepage may contain a variety of contaminants that may only be partially miscible in water and may have different densities than local groundwaters. Soluble components from seepage may be easily dissolved and transported with groundwaters but lighter petroleum products tend to accumulate near the water table. Denser products generally migrate much deeper. Further, variations in contaminant distribution in groundwaters may also occur due to geochemical transformations or interactions with subsurface materials.

Hydrogeologic studies must be carefully designed and carried out by experienced personnel. However, useful summaries dealing with many of the general principles involved may be found in Freeze and Cherry (1979), Gillham et al. (1983), Houghton and Berger (1984), Drever (1982), Scalf et al. (1981) and Fenn et al. (1977).

.54 **Other Sampling** Other sampling on the site, as part of the reconnaissance program, may include raw materials, by-products, products, and chemical used in the process, if these have not previously been sufficiently characterized. As these materials are the primary sources of the various types of contaminants on-site, plans should be made to sample and analyze these materials early in the reconnaissance program. Analytical results may necessitate modifications to the planned analytical program for other samples.

For the purposes of defining disposal requirements of sludges and residues contained in drains, sumps, gutters, process vessels and treatment facilities, representative samples should be collected for analysis. As well, fluids from electrical transformers should be sampled for PCB analysis. Considerable planning may be required for collection of these samples (access, personal protection, sampling devices, etc.) and accordingly, interaction and assistance from plant operating personnel may be required.

.6 Sampling Constraints

There are many factors, some of which are unique to a particular plant or setting, that may affect sampling methodology and the nature of the program. These are:

- o access to some sites may be restricted due to vessels, overhead or underground piping, ditches, electrical services, etc.;
- o safety concerns such as high pressure lines, explosive vapours and embankments;
- o health aspects such as the nature of waste compounds in sludges, sediments, etc.; and
- o compatability of materials due to contaminants, i.e. PVC, steel, or stainless steel piezometers.

Sampling constraints can all be overcome, i.e. the investigation near process facilities and underground services could be postponed until the plant is shutdown, or exceptional safety and protective measures could be incorporated (skin and breathing protection). At the design stage, it is important to identify any sampling contraints and to document special mitigative or other measures required.

.7 Health and Safety

Safety and health protection measures are established from the list of known or suspected contaminants which may be encountered by the project team, from industry-specific safety measures (i.e. protocols for work undertaken with materials of high H_2S content) and from well-established industrial safety measures (working in confined areas, drilling or excavation near buried services, etc.). Appropriate measures that may be formulated as a site-specific safety and health program (which would govern all field work on the site) may include:

- o medical checks before, during and after field work;
- o provision of skin protection and other safety wares;
- o provision of breathing protection in the form of canister-type respirators or a continuous air supply;
- o explosive vapour measurements prior to and during drilling or excavation; and
- o ensuring all field personnel are advised of in-plant safety protocols.

.8 Sampling Methodology

The investigative team, on the basis of the preceding information, would then establish sampling methodology which would include the following:

- o depth of investigation;
- o sampling equipment;
- o size of samples;
- o sampling intervals;
- o borehole logs and visual observations;
- o sample identification;
- o sample containers, storage and preservation;
- o personal protection;
- o cleaning and decontamination of equipment;
- o logistics;
- o sample transportation to laboratory;

- o duplicate samples; and
- o field organization.

343 PROGRAM DESIGN AND REVIEW

A proposed reconnaissance testing program would be developed on the basis of the foregoing factors to meet the program objectives. The program will determine the types of contaminants, the range in contaminant concentrations and the general areas affected. Further, the program will clarify the geologic and hydrogeologic conditions of the site and surrounding area.

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 knowledgable of 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 safety and health 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. Suggested modifications should be incorporated to ensure completeness.

344 PROGRAM IMPLEMENTATION

Just as the plant site assessment and reconnaissance program design were carried out by experience personnel, the field reconnaissance 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. Further, 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 plant site assessment and reconnaissance program design should 'overlap' into the field program to ensure continuity.

Key items for successfully completing the reconnaissance sampling program are shown in Figure 3-13. There are a variety of ways to execute the reconnaissance sampling program; however, a suggested sequence is as follows:

- Establish on-site investigation office;
- Provide for storage of samples;
- Review program safety and health concerns with plant personnel;
- Sample feedstocks, products, by-products and chemicals and immediately transport to the laboratory for analysis. The results of these analysis may affect future analytical programs;
- Sample background soils, overburden and sediments and install background piezometers;
- Initiate drilling of boreholes for hydrogeology study and commence installation of piezometers. Deeper boreholes should be drilled first to increase knowledge of the site;
- Commence soil sampling (boreholes, test pits and hand augers);

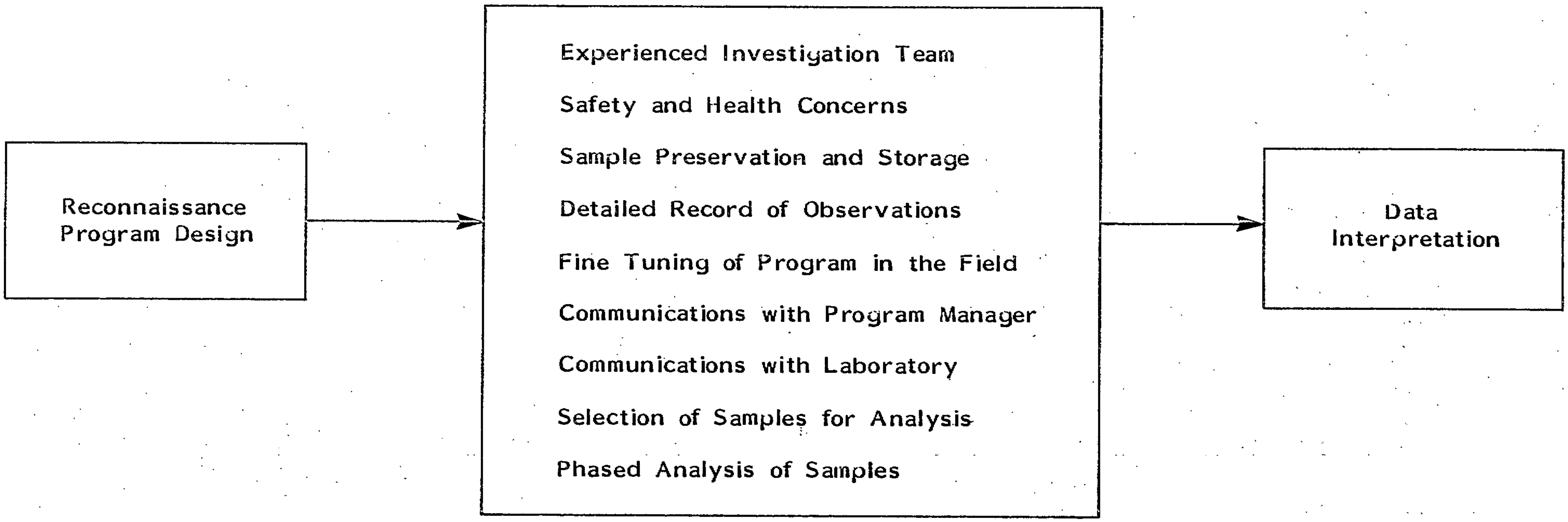

FIGURE 3-13

RECONNAISSIANCE PROGRAM IMPLEMENTATION

- 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; and
- Survey all sampling locations.

Constant communication should be maintained with the decommissioning program manager to report on progress and identify program changes as a result of information gained while sampling.

Management of the significant numbers of samples can become a problem. To overcome these problems, constant communications with the laboratory are necessary, a well-organized sample storage and transportation system is required, and a detailed sample logging system is necessary. If possible, a computer terminal in the field (linked to the laboratory) will expedite sample descriptions and fix analytical requests to the laboratory.

To meet the objectives of the reconnaissance program, it is prudent to undertake the analysis of samples in phases. For a marginal increase in sampling costs, additional samples would be collected and stored. If further information is required to define the types of contaminants, range in concentrations, or general boundaries of contaminated areas, these samples would be taken out of storage for analysis. [Further, these samples may be used in subsequent analytical programs.]

345 DATA INTERPRETATION

To meet the objectives of the reconnaissance program, interpretation of the analytical data and observations from field work (Figure 3-14) includes:

- a review of quality control checks to ensure that the analytical data is within the desired accuracy and precision;

- an interpretation of geologic and hydrogeologic data generated from the drilling of boreholes and testing of piezometers to identify the hydrogeologic setting of the plant site and to identify possible pathways of contaminant movement (or conversely, barriers which have retarded movement);

- an estimation of groundwater flow rates and direction of flow;

- an evaluation of data from the chemical analysis of samples by identifying the types and concentrations of contaminants in soils, overburden, sediments and groundwaters on-site (and possibly off-site) that are a direct result of plant operations; and

- a review of the composition of sludges, building materials and residues (usually wastes which are confined in concrete sumps and vessels) and identification of possible disposal methods.

The evaluation of chemical data can be undertaken in the absence of preliminary clean-up criteria (see Section 3.5), or by comparison to the criteria. If criteria are not yet developed, the data would be compared to the natural constituents (mean ± confidence limits) in the environment from background sampling sites. Because a particular substance exists on-site above background may have little significance to the future use of the site. Further, it is unlikely that clean-up of the

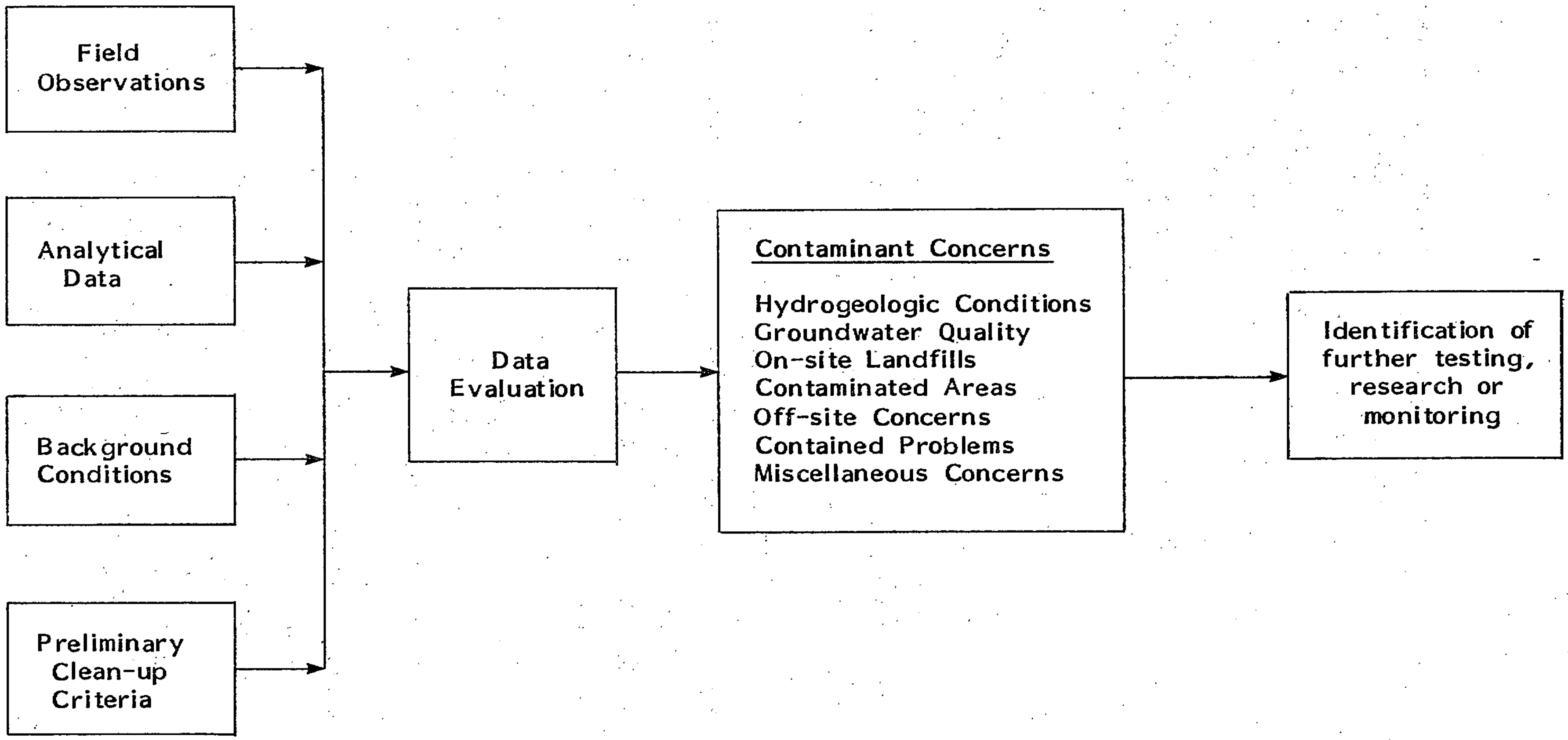

FIGURE 3-14

DATA INTERPRETATION
(RECONNAISSANCE PROGRAM)

site to background would be required by regulatory agencies, or desired by the company. Clean-up criteria for some heavy metals (i.e. chromium and zinc) may be an order of magnitude greater than background concentrations, while for other compounds (i.e. mercury or certain organics), the criterion value may be at or near background levels. It is important to place the conditions on-site into proper perspective by relating concentrations to safe levels. It is therefore desirable to have the preliminary clean-up criteria in place to properly evaluate the analytical data.

Since there is usually a significant amount of analytical data associated with a reconnaissance program (each sample may have 20 or more data attributes), the use of a computer to assist in the evaluation and presentation of results is essential. Data can be directly inputted to a computer data base in the laboratory as analytical determinations are completed. Subsequent use of the computerized data base may include:

- o preparation of data presentation tables;
- o plot or otherwise identify contaminant levels above background, or greater than clean-up criteria; and
- o delineation of problem areas through plotting of isopleths of specific contaminants.

A report on the reconnaissance program would include details of the hydrogeologic conditions and would address contaminant concerns by grouping of contaminant concerns by their severity and extent such as:

- o groundwater quality concerns (on-site and off-site);
- o conditions in the on-site landfill;
- o large areas contaminated with metals, organics, or other compounds;
- o isolated contaminant concerns;
- o off-site concerns (i.e. sediments in drainage channels);

- o contained problems (i.e. sludges, residues, building materials); and
- o miscellaneous concerns (i.e. PCB's in transformer oils, asbestos insulation, etc.)

The report should also document non-contaminated areas of the plant site.

At this point, the need for additional work should be identified. This may include an identification of the need for and specific details of further sampling and analysis (detailed field program), research requirements for site clean-up and reclamation, or long-term monitoring requirements. Conversely, the results of the reconnaissance program may indicate that further testing is not required.

The results of the reconnaissance program should be presented to the regulatory agencies in order to make these groups aware of conditions on-site and to solicit input to the planning of further work.

3.5 DEVELOPMENT OF CLEAN-UP CRITERIA

Clean-up criteria should be developed for a particular plant site to determine whether or not clean-up of specific areas of the site is required. Criteria which are site-specific, will determine the necessary reduction of contaminant levels to allow the safe re-use of the site.

351 OBJECTIVES

The main objectives for the establishment of clean-up criteria are:

- o to provide levels of chemical parameters on the site which are considered safe for the proposed future land use; and
- o to provide a means to judge the severity of contaminants on the site to enable the development of a clean-up plan.

For each environmental medium of concern (groundwater, surface water, soils and sediments) concentrations of substances exist which are considered "normal" or "background" for the area in question. These background values should be established for each site subject to decommissioning and will be specific for that site. The background values for substances of concern (e.g. problem contaminants including trace metals, hydrocarbons, etc.) should be obtained from the analyses of environmental samples collected from areas in the vicinity of the plant site which are known to have been unaffected by plant operations. Concentrations of particular substances in environmental samples taken on-site, which are significantly above background levels (mean ± confidence limits) must be considered a sign of on-site contamination. However, clean-up of contamination will depend to a large extent on:

- the future land use of the site;
- the criteria used to judge whether or not a particular area is contaminated to the extent that it will interfere with the intended land use; and
- the extent and degree of contamination based on the criteria.

The clean-up criteria are "benchmarks" that are adopted in relation to the future use of the site and are used to judge the severity of contamination and thus the need for clean-up.

Reconnaissance level and detailed field testing programs determine the spatial extent and nature (concentration) of contaminants. Clean-up criteria will then provide "benchmarks" against which the level of contamination of various parts of the plant site can be compared. Concentrations of contaminants above their identified "benchmark" values indicates a potential concern.

The development of clean-up criteria could be undertaken at the same time as data from the reconnaissance program are being reviewed and assessed; however, it is useful to have the criteria developed in preliminary form to evaluate the data. The factors important to the development of clean-up criteria are shown in Figure 3-15. Clean-up criteria are site-specific and are related to:

- future land use;
- future resource use (i.e., groundwater);
- the nature of soils, sediments and groundwater in the area;
- climatic factors; and
- the form of contaminants on-site.

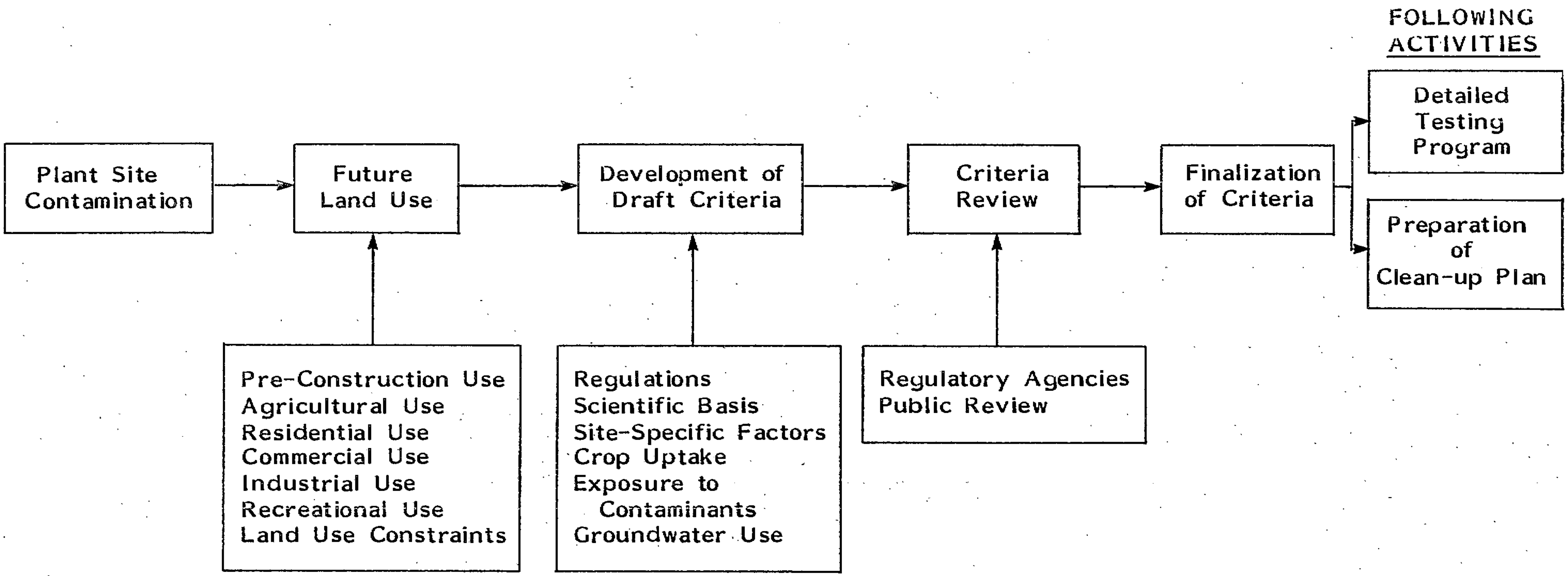

FIGURE 3-15

DEVELOPMENT OF CLEAN-UP CRITERIA

352 FUTURE LAND USE

The proposed future land use of a decommissioned industrial plant site has a direct impact on the degree of required site clean-up. If an industrial plant site is to be re-developed for residential use, clean-up criteria will be very stringent. However, if industrial zoning remains, criteria will be less stringent.

Generally, decisions regarding the proposed future land use of the plant site will be made by the company, with input from various levels of government (mainly provincial and local). Options available for the future land use of the site are discussed in the following sub-sections.

.1 Pre-Construction Use

Returning the land of the decommissioned plant site to its former, pre-construction use may not always be possible or desirable. Since plant construction, the land surrounding the plant site may have undergone a change in use and the original land use may no longer be compatible. For example, if the plant was originally built on agricultural land but at the time of decommissioning was surrounded by residential developments, it makes little sense to return the plant site to an agriculture land use. A use more compatible with the surrounding land such as residential or light industrial development would be a more appropriate choice.

.2 Agricultural Use

Use of the plant site for agriculture either as crop land or pasture may have a significant effect on the clean-up criteria. Concentrations of trace organics, metals, or other contaminants in the soil, must be such that they will not effect crop productivity or accumulate in edible portions of the plants to levels considered harmful to animal or human health. This does not necessarily mean that the concentration of various contaminants must be reduced to background levels. It does mean that the clean-up criteria for this land use must have a sound scientific basis to ensure the safety to crops and to animals or humans who consume the crops.

.3 Residential Use

Residential development, including rural residential, single unit subdivision or multi-family developments, adds a further dimension to the clean-up criteria for decommissioned industrial plant sites. While criteria must address uptake of contaminants in edible fruits and vegetables grown in residential garden plots, residential development brings with it unlimited public access and possible concerns such as ingestion of soils (a concern with young children) and respiratory intake of dusts and certain volatile compounds. Also, increased concerns of groundwater quality will be apparent if individual or community wells will supply water to the development.

.4 Commercial Use

Commercial development of the decommissioned industrial site may have reduced human health concerns (as compared to residential uses); however, these are dependent on the nature of the development. Criteria, which consider potential interaction between contaminants and those accessing the site as well as groundwater use, are required and these must be specific to the type of commercial development proposed.

.5 Industrial Use

Industrial development, while it will require less stringent clean-up criteria than other land uses proposed for the decommissioned plant site, must still take into account the potential human health effects associated with the long-term respiratory intake of contaminants from the contaminated soils on-site, and potential groundwater use. In addition, continued development of the decommissioned plant site for industrial purposes must avoid the mobilization of any remaining on-site contamination.

.6 Recreational Use

Recreational development may take a number of varied forms. These may include buldings to be used as indoor recreational centres, outdoor amusement parks or natural areas requiring the revegetation of the area, building of trails or paths and perhaps day-use facilities. The various options available for recreational development will profoundly effect the clean-up criteria for the proposed development. Large sports or convention arenas would have less stringent clean-up requirements than recreational developments which might entail direct contact with soils such as hiking, picnicking or similar activities.

.7 Constraints on Land Use

Although there are a number of options available for the future land use of the site, the final choice will be determined by two interacting factors:

- o the costs of clean-up of the plant site to suit the desired land use; and
- o the desires of the future land owners and concerned citizens.

Future land uses of a decommissioned plant site are subject to the constraints placed on them by the economic feasibility of a particular clean-up plan. A future land use which would require the removal of millions of cubic metres of soil, its appropriate disposal and its replacement with uncontaminated soil may be economically unfeasible. Such uses must be discarded early in the clean-up planning for more realistic alternatives.

Public and private interests, in the choice of a future land use, must also be taken into consideration. This is especially true when the plant site is adjacent to or within municipal boundaries. Where these interests are already focused on a particular future land use, the need to evaluate other options may be greatly reduced or eliminated. The formulation of specific clean-up for the intended land use can then proceed at an earlier stage in the overall decommissioning plan.

The choice of a proposed future land use will depend on:

- o regulatory agency concerns (provincial and local);
- o concerns of the local communities;
- o the economic feasibility of attaining the clean-up criteria necessary for a proposed land use;
- o the wishes of future owners of the plant site; and
- o the attitude of the present plant site owner.

The proposed land use should then be integrated into the development of clean-up criteria.

353 CRITERIA DEVELOPMENT

To date there is a very limited plant site clean-up experience to draw on and, therefore, information to set criteria or "benchmark" values must be drawn from:

- o the limited experience to date;
- o available literature;
- o government regulations and guidelines; and
- o discussions among industry, regulatory agency personnel and the public.

Criteria are developed for the proposed land use of the site as well as specific site conditions which influence the severity of the contamination. As there is little precedence established for the development of clean-up criteria (particularly related to potential health effects of contaminants in soils), the scientific basis for criteria development must be well-founded. Dependent on future use, consideration may include: soil/crop relationships with respect to crop phytotoxicology and to animal grazing or the production of feed or food crops; the potential effects of ingestion, inhalation, or dermal exposure of wind blown contaminated dusts or vapours; the potential effects of inadvertent ingestion of contaminated soils (such as may occur with children at play); the biodegradability of organics in soils or groundwaters; and the potential effects of contaminants on construction materials.

Possible options for future land use of the decommissioned plant site will involve different demands on the plant site resources. Establishment of clean-up criteria will be a direct result of the future land use demands of site resources. For each proposed land use, clean-up criteria must take into account the relative importance of:

- the uptake of contaminants by plants growing on contaminated soils;
- the passage of contaminants up the food chain by grazing animals or use of vegetation for human consumption;
- potable well water contamination;
- surface water quality; and
- the potential for exposure to contaminant losses (wind blown dusts or vapours) from contaminated soils.

For example, an agricultural land use would demand soils which are either uncontaminated or sufficiently low in contaminants that utilization of plants grown on these soils would present no health risk to animals or humans. An industrial use for the decommissioned site would ave less stringent clean-up criteria for contaminants than would the agricultural use, but human exposure to contaminated dust might be of concern and appropriate clean-up criteria would have to be formulated. As well, for industrial re-development of the site, possible chemical reactions of soil contaminants on construction materials, may necessitate criteria considerations. If the groundwater resource on-site is to be used for drinking water supplies, the appropriate clean-up criteria could be the Canadian Drinking Water Standards. If not defined by standards, criteria for groundwater contaminants may involve the establishment of action levels which are based on chemical toxicities for a given use.

The formulation of clean-up criteria might not be necessary for some contaminants if government regulations or guidelines already specify levels of these contaminants which are deemed unacceptable. If no regulations or guidelines exist, the scientific literature must be searched for information concerning the environmental behaviour of contaminants found on the plant site. A rationale will be drawn from this information for the proposed clean-up criteria. The scientific basis for the rationale should be presented, along with the clean-up criteria, to regulatory agencies for their review, comment and approval. The clean-up criteria developed for the intended future land use of the decommissioned plant site should be documented with its supporting information as a formal report. In this format it can be submitted to government regulatory agencies for their review, comment and ultimate approval and to various concerned citizens or environmental groups.

Even though permissible contaminant levels may have been addressed and the rationale for the clean-up criteria explained, there may yet be concerns over the levels of some contaminants on the plant site. These concerns may have to be countered with field or laboratory studies demonstrating the acceptability of the proposed clean-up criteria levels.

The clean-up criteria, if established prior to any detailed testing of the site, will guide the design of further testing programs. However, the future use of the plant site may not be known at the time clean-up is being planned. If this were the case, draft criteria in the form of ranges of contaminant concentrations would be developed for alternative end uses.

Examples of the development of clean-up criteria for industrial sites recently decommissioned are provided in Part 4 of this guide.

3.6 DETAILED TESTING PROGRAM

The reconnaissance testing program provided data on the types of contaminants, ranges in concentration and generalized locations of contamination. If contamination concerns are identified on-site, a further investigation is required to provide details for clean-up and reclamation of the site. The detailed investigation will key on those concerns that are judged to be significant in terms of the clean-up criteria, and will provide additional reclamation-related information required to identify clean-up and reclamation alternatives (Figure 3-16). Many of the aspects of the detailed testing program are similar to those of the reconnaissance program (Section 3.4).

361 OBJECTIVES

The objectives of the detailed testing program are:

- to precisely define boundaries of contaminated areas (areal and depth);
- to clarify surface and subsurface anomolies with respect to pathways for contaminant movement;
- to identify potential mobility of contaminants under probable future conditions; and
- to identify physical parameters for clean-up, or other factors required for design of site clean-up and reclamation.

To meet these objectives, the types of analysis of samples will change to determine reclamation requirements and the form and mobility of contaminants. Accordingly, interaction with the laboratory is required

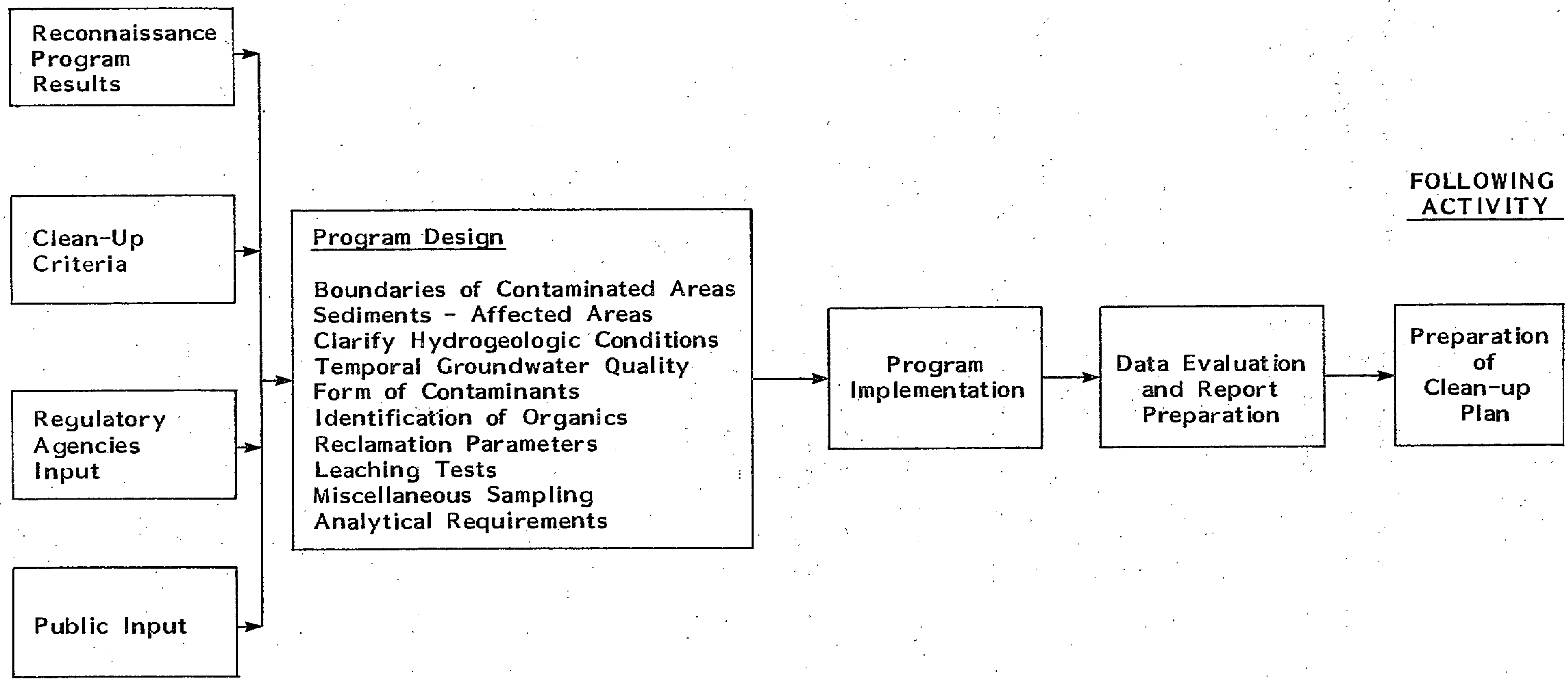

FIGURE 3-16

DETAILED TESTING PROGRAM

at the design stage to establish methodologies, detection limits, sample size, and quality control for these new sets of analysis. While it is desirable to utilize the same laboratory to maintain continuity, a specialist laboratory may be required to undertake some tests (i.e. leaching tests).

362 PROGRAM DESIGN AND REVIEW

The tasks associated with the design of the detailed testing program may include those identified in the following subsections.

.1 Boundaries of Contaminated Areas

- o the need to precisely define boundaries (areal extent and depth) to enable volume calculation;
- o use of computer interpolation programs may assist; however, ensure that minimum amount of data is available; and
- o plan to take more samples than necessary, and analyze in stages to define a clean-line. The additional samples collected during the reconnaissance program will minimize field work for this task.

.2 Extent of Contamination Beneath Ditches, Ponds and Lagoons

- o sediments in these facilities may be contaminated with certain metals and organic compounds;
- o need to identify the depth of contaminant movement beneath the ponds or ditches and the adjacent area of influence; and

- sampling and analysis in sufficient detail to determine the homogeneity of the sediments and to determine the volume of contaminated sediments.

.3 **Groundwater**

- additional drilling and piezometer installation to clarify anomolies in the subsurface formations and to further identify (if required) the hydrogeologic conditions of the area; and

- further groundwater sampling and analysis to assess temporal groundwater conditions.

.4 **Sludges and Residues**

- further characterization may be required to define disposal requirements (i.e., leaching tests).

.5 **Evaluation of Contaminants**

- determination of the form (species) of contaminants, particularly related to the mobility of contaminants;

- further GC/MS determinations for organics;

- reclamation parameters such as buffering capacity, exchange capacity, sodium absorption ratio, and other parameters; and

- mobilization of contaminants - soluble fraction,
  - extractable fraction,
  - leaching tests.

.6 Other Work

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

- analysis of soils and sediments near transformers or other electrical equipment found to contain PCB's;
- analysis of construction materials which may be contaminated to define health-related controls to be applied to dismantling, reuse or ultimate disposal. These may include concrete cores from sumps and gutters, wood from cooling towers, contaminated equipment, piping, etc;
- a further evaluation of waste materials in the on-site landfill to determine future remedial measures, given the more extensive knowledge of subsurface conditions; and
- the tracking of specific contaminants of concern identified in unusual locations on-site, where the source has not been determined.

363 PROGRAM IMPLEMENTATION

The detailed testing program should be carried out by the experienced team in a manner similar to the reconnaissance program (Section 344), governed by the established safety and health, sampling, analytical and quality assurance protocols. More is now known about the site and the detailed program can be undertaken more efficiently.

The emphasis of work in the field (and the subsequent analytical work) is defining the extent of contamination with respect to cleanup criteria. With respect to soils, visual observations in the field coupled with the sampling and analysis of soils collected from intermediate locations (sampled radially and downward from a known contaminated area) will assist in defining a "clean line". Strategic placement of additional piezometers or piezometer nests will allow clarification of hydrogeoloic anomolies and assist in locating the extent of groundwater contaminant plumes.

As with the reconnaissance program, it is prudent to analyze samples in stages. Additional samples, collected during the reconnaissance program and placed in storage, may now be analyzed to provide some of the detailed information.

364 DATA INTERPRETATION

With the completion of the analytical portion of the detailed testing program, the investigation team is now in a position to conclude the investigation. In consideration to the clean-up criteria, the analytical results will be reviewed to:

- delineate those areas of the plant site with contaminant levels greater than clean-up criteria. The extent of the data will be sufficient to precisely define the boundaries of these areas, and to determine the depth of disturbance;

- determine the volume of contaminated sediments in drainage ditches, lagoons and ponds, and to delineate the areas adjacent to these facilities which have been affected by seepage;

- identify the extent of groundwater contamination that has occurred from plant operations and its regional implications;

- evaluate the potential for mobilization of contaminants in soils, sediments and sludges;

- characterize contaminated sludges, residues and other materials from process components that will have to be removed and disposed;

- identify off-site contamination concerns; and

- identify miscellaneous concerns associated with decommissioning of the plant, such as:

  - asbestos insulation,
  - removal of catalysts, residue, sludge or fluids from process vessels,
  - clean-up and disposal of PCB-contaminated transformer fluids,
  - removal of contaminated structures,
  - disposal of chemicals,
  - etc.

3.7 PREPARATION OF CLEAN-UP PLAN

The completion of detailed testing of the site and finalization of clean-up criteria will permit an evaluation of clean-up options for the site and subsequently the development and submission of a site clean-up plan. The evaluation of options may necessitate a change in the desired future use of the site if clean-up to established criteria cannot be achieved due to technical or economic reasons.

371 OBJECTIVES

The main objectives of the clean-up plan are:

- o to develop and evaluate options for site clean-up, together with their associated costs;
- o to identify acceptable methods to remove or contain contaminants or otherwise remediate the effects of contamination;
- o to identify acceptable disposal methods on-site or disposal sites off-site for contaminated materials removed from the site; and
- o to provide a site, through a series of planned clean-up and reclamation actions, that will be safe for the proposed future use.

Figure 3-17 shows the major factors involved in the development and finalization of the clean-up plan.

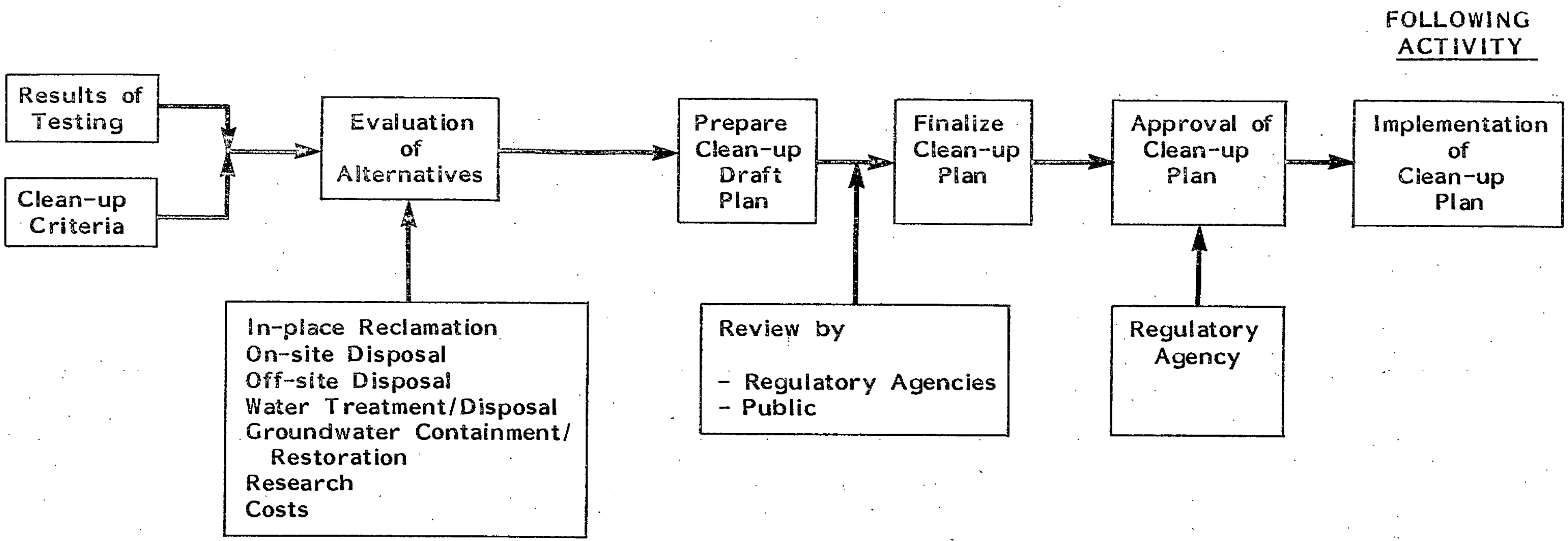

FIGURE 3-17

PREPARATION OF CLEAN-UP PLAN

372 CLEAN-UP AND RECLAMATION OPTIONS

To provide environmentally safe conditions for the future land use at the plant site, certain clean-up and reclamation methods may be used to reduce contaminant levels to concentrations below those defined by the clean-up criteria. Clean-up and reclamation options for a particular area will depend on the type and degree of contamination of the area and the proposed future land use. Where contaminated materials are identified, a decision should be made regarding the practicality of reclaiming these materials in place or whether selective handling and moving of the materials is required. Reclamation options are aimed at improving soil properties to levels suitable for plant growth, or at changing soil properties (for example, soil pH) to protect groundwater or structures.

Ultimately, approval of clean-up and reclamation plans will have to be obtained from the appropriate regulatory agencies. Requirements vary from province-to-province, and some provincial regulatory agencies may support a particular method while others may not. For example, deep well injection of wastewaters is accepted in at least three provinces; however, other provinces and the federal government do not approve of this disposal method. When examining options for clean-up and reclamation, it is essential to be aware of regulatory policies.

A number of clean-up and reclamation options are discussed in the following subsections.

.1 In-Place Reclamation Options

In-place reclamation options include:

- the addition of soil amendments such as limestone to neutralize acid soils and/or organic matter (such as manure or straw) to improve soil quality for plant growth;

- o use of irrigation and subsurface drainage, as required, to enhance the leaching of salts;

- o cultivation and addition of amendments (i.e. limestone to improve soil pH, nutrients, manure, straw, etc.) to enhance biological breakdown of organics and hydrocarbons; and

- o the growing of vegetation which is not used for human or animal consumption, such as trees (a caveat placed on the land title would ensure this use).

In-place reclamation options will, in most cases, require continued management and monitoring over the long term.

.2 On-Site Disposal of Contaminated Materials

On-site disposal options are intended for materials which cannot be reclaimed using existing reclamation techniques because of chemical or physical characteristics. Various options include:

- o capping of contaminated soils, pond sediments and sludges with 1.2 to 1.5 metres of clay material;

- o solidification using fly ash, flue dust, cement, sodium bentonite clay or proprietary solidification methods to prevent the leaching of metals;

- o on-site containment in a clay lined excavation, with a leachate collection system and additions of amendments to control/prevent leaching; and

- o on-site isolation in a specially designed and constructed vault using secure encapsulation techniques.

Disposal of contaminated materials in on-site facilties requires the installation of monitoring devices with respect to the long-term integrity of the facilities.

.3 Off-Site Disposal of Contaminated Materials

Disposal of contaminated materials off-site in approved facilities will normally eliminate the need for long-term monitoring of the site. The company should, however, investigate the liabilities associated with disposal of wastes in an off-site treatment/disposal facility. Options for disposal of waste materials off the site are subject to the approval of regulatory agencies and include:

- o disposal of waste materials in a local or regional landfill. Only mildly contaminated materials may be considered for disposal in local or regional landfills since few sites in Canada are approved for more highly contaminated or hazardous wastes;

- o disposal of waste materials in an approved hazardous or special waste disposal facility; and

- o disposal (storage) in an approved hazardous or special waste storage facility for materials which cannot be routed to disposal facilities (for example, PCB's).

Since there are few facilities in Canada for the disposal of hazardous or special wastes, inter-provincial or trans-boundary transport of waste materials will likely be required. Accordingly, transport requirements, import restrictions, regulatory agency approvals (for transport and disposal) and their associated costs enter into the evaluation of off-site disposal alternatives. Usually, samples of the waste materials have to be submitted for independent analysis.

.4 Other Disposal Alternatives

Other disposal alternatives for waste materials from the site may include:

- o incineration in an approved mobile incineration unit;
- o land application of waste materials to agricultural soils using methods similar to the application of municipal sludges where controls are established to restrict heavy metal uptake in crops; and
- o landfarming of oily sludges to reduce levels of hydrocarbons through biological breakdown, as is common in the oil refining industry.

.5 Treatment/Disposal of Surface Waters

Options for the treatment/disposal of surface waters include:

- o treatment to provincial government effluent standards and discharge off-site (batch treatment in ponds or the use of mobile wastewater treatment units); and
- o treatment and pump to deep well injection if acceptable to regulatory agencies.

.6 Containment/Restoration of Groundwaters

Options for the containment or restoration of groundwaters include:

- o installation of recovery wells for oil removal and reclamation;

- collection and treatment of contaminated groundwaters with discharge to surface waters or to deep injection wells, consistent with regulatory standards;

- installation of slurry trenches and other containment facilities to act as physical barriers to groundwater movement; or

- addition of amendments (especially nitrogen and phosphorous) for the in-situ biodegradation of organic contaminants by the natural groundwater microflora.

373 CLEAN-UP AND RECLAMATION RESEARCH

To fully evaluate clean-up and reclamation options, research may be required to enhance the scientific basis for evaluations. Research may take the form of laboratory tests or field trials to measure the effectiveness of a method for contaminant removal, isolation or immobilization and its technical feasibility and costs.

Research programs may include:

- measurements of the rate of biodegradation of contaminants by natural micro-organisms or the degradation of organics by sunlight;

- measurements of the uptake of heavy metals in crops grown in contaminated soils;

- evaluations of the application of sludges to agricultural soils;

- testing of soils on the site with respect to abilities to contain contaminants;

- evaluations of various solidification or fixation methods;
- measurements of the chemical compatibility of liners with respect to conditions on-site;
- assessment of the feasibility of isolating and immobilizing contaminant plumes; and
- treatability studies for leachates, wastewaters or groundwaters.

Results of research programs, together with information on the technical feasibility and costs, are a direct input to the evaluation of clean-up and reclamation alternatives.

374 PREPARATION OF DRAFT CLEAN-UP PLAN

The clean-up plan for the site should be all-encompassing and must address the following issues:

- the types and levels of contaminants measured on the site;
- the clean-up criteria;
- the effectiveness of proposed clean-up methods; and
- the future use of the site.

Further, the plan must be responsive to concerns expressed by the public and regulatory agencies.

Normally, a clean-up plan is prepared initially in draft form for review by regulatory agencies. Depending on the level of public concern associated with the clean-up and re-development of an industrial site, it may be advantageous to present the draft plan to the public. However, if a public presentation is not held, it is important to keep those concerned with the project informed of its status.

The draft plan which is submitted to regulatory agencies for review should include:

- a summary of the levels of contaminants on the site and in particular, contaminants which are present at levels greater than or equal to clean-up criteria;
- the identification, delineation and quantification of materials to be removed;
- a summary of the alternatives for site clean-up and a brief evaluation of each;
- assessment of alternatives for disposal of contaminated materials (on-site or off-site);
- a detailed description of the methods proposed for site clean-up including technical feasibility and approximate costs;
- a proposed schedule for the work;
- a discussion on how the clean-up plan is integrated with other decommissioning measures such as dismantling of process components and final contouring of the site;
- a discussion of the 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 or will be affected by future developments on the site; and

- identification of proposed long-term monitoring provisions.

375 FINALIZATION OF CLEAN-UP PLAN

Comments from regulatory agencies and concerns of the local government and public interest groups are major inputs to the finalization of the clean-up plan. Detailed design and planning of specific clean-up provisions for the site will proceed when the results of reclamation research (if any) are available and a thorough assessment of the benefit/cost relationship of various clean-up options is completed. For example, it may be less costly in the short-term to construct waste contaminant facilities on-site, however, long-term monitoring needs and costs as well as associated liabilities may encourage a company to dispose of wastes in an off-site government-approved facility. On a similar basis, remedial measures and monitoring requirements for the plant's on-site landfill may justify moving wastes off-site, or implementing exceptional containment facilities.

The final plan, which is submitted for government review, should contain detailed design of all clean-up, reclamation, containment and monitoring plans. The plan should be integrated with all other decommissioning activities (removal of buildings, equipment, etc.) and should contain provisions for the health and safety workers undertaking the clean-up, measures to treat wastewaters during the project, and other measures to minimize potential spread of contaminants.

3.8 IMPLEMENTATION OF CLEAN-UP PLAN

When approval of the clean-up plan is received, clean-up of the site can commence. Depending on site conditions, it may be undertaken over several years, or may be a relatively simple and straightforward program involving the removal of processing components and disposal of sludges.

While clean-up activities vary from site-to-site, important factors which must be considered in the implementation of a clean-up plan (Figure 3-18) include the collection and treatment of wastewaters during the clean-up program, provisions for worker safety and health, and the sequence of clean-up activities. These are discussed in the following subsections.

381 WASTEWATER TREATMENT

Wastewaters which are generated as a result of clean-up activities must be collected and treated prior to discharge from the site. These may include wastewaters from the dewatering of sludges, from the cleaning of sumps, gutters, drains, etc., from washdown of transport vehicles, and sewage from washrooms and shower facilities. As well, surface runoff from the site should be monitored and treated as required. Usually, the dismantling and clean-up of wastewater treatment facilities is undertaken near the end of the clean-up program.

382 WORKER SAFETY AND HEALTH

The handling of contaminated and hazardous materials during the clean-up project may require exceptional personal protection provisions. These may include breathing and skin protection, the provision of 'clean'

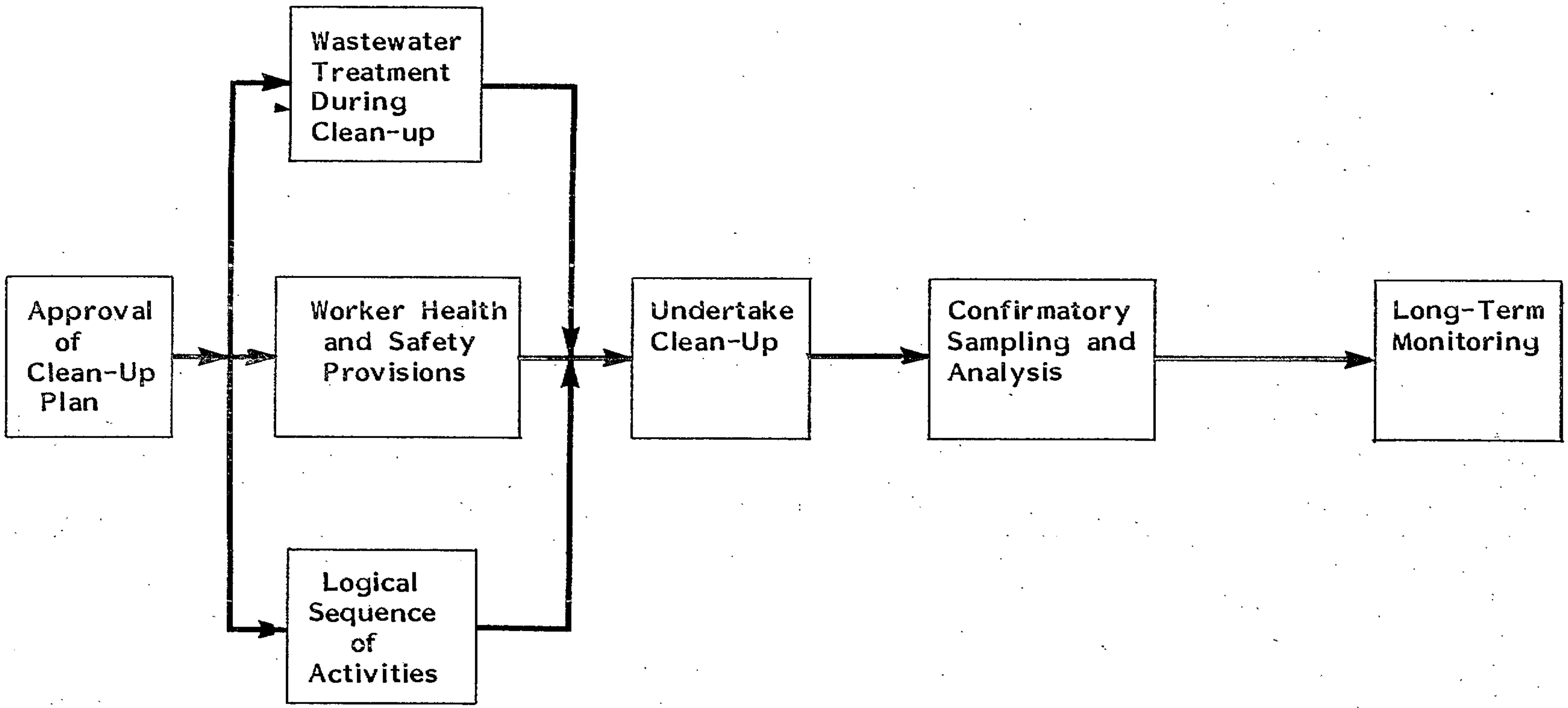

FIGURE 3-18

IMPLEMENTATION OF CLEAN-UP PLAN

and 'dirty' areas, shower facilities and detailed safety and health protocols. Depending on the nature of contaminants, comprehensive medicals for all workers may be required with regular checks throughout the program.

383 SEQUENCE OF CLEAN-UP ACTIVITIES

Successful completion of the clean-up program requires detailed planning of the various tasks in order to minimize the spread of contaminants. A suggested sequence of clean-up activities is described in the following paragraphs.

.1 Removal and Disposal of By-products and Chemicals

- o chemicals returned to suppliers, reused at another plant, or disposed of in government-approved facilities;

- o by-products removed from the plant site as sales or to storage elsewhere; and

- o avoid spillage and dusting of by-products when loading and transporting by-products. Removal of sulphur from the sulphur block at a sour gas plant may be handled as a liquid or as a solid to complete the task in a timely manner. Controls such as breathing protection for workers, and water sprays and wind speed limits should be applied to minimize sulphur dusting of adjacent areas. Transport vehicles should be thoroughly washed before leaving the site. Similar provisions should be applied to the removal of other materials.

.2 **Construction of On-site Containment Facilities**

- o if wastes from the site are to be disposed of on-site, specially designed and approved facilities would be constructed prior to removal of any wastes;

- o long-term monitoring devices should be installed at the time of construction of containment facilities; and

- o other containment facilities on-site may include leachate control and collection systems for the on-site landfill or groundwater containment and recovery systems.

.3 **Diversion of Surface Drainage**

- o while surface water control and treatment systems should remain operational throughout the site clean-up program, clean surface runoff should be diverted from the area.

.4 **Removal and Disposal of Sludges and Other Residues**

- o sludges may be highly contaminated requiring special handling methods;

- o drying or otherwise dewatering sludges will reduce bulk and disposal costs;

- o any wastewaters generated from sludge dewatering and cleaning of sumps and gutters will have to be treated in the plant's wastewater system or transported off-site for treatment and disposal; and

- o sludges would be transported in specially equipped vehicles to the planned disposal facility (on-site or off-site)

.5 Removal of Process Equipment

- o equipment may be removed from the site for use elsewhere or sold as scrap if uncontaminated;
- o contaminated equipment should be handled and appropriately disposed of as part of the planned clean-up program;
- o cutting torches for dismantling equipment should be used cautiously to avoid explosions and fire and the volatilzation of contaminants (i.e. mercury);
- o removal of asbestos insulation requires special protection measures consistent with government regulations; and
- o any equipment that contains or previously contained PCB fluids (i.e. transformers, capacitors) must be handled as hazardous materials. Currently, there are no ultimate disposal facilities in Canada for PCB's, hence, secure storage is required.

.6 Cleaning of Building Interiors

- o if process buildings are to be converted for another use (i.e. industrial or commercial), extensive cleaning of the building interior and exterior is required;
- o may involve vacuuming, washing down and cleaning of walls, floors, ceilings, ducting, sumps and drains;
- o special attention should be given to the building's heating and ventilating system;
- o clean-up of dusts from the building roof may also be required; and

- workplace health and safety regulations will govern the extent of clean-up prior to reuse of buildings.

.7 Dismantling of Buildings

- relatively straightforward task, however, avoid possible spread of any contaminants;

- concrete sumps, gutters or drains may be contaminated and may have to be removed and disposed of as part of the planned clean-up of the site; and

- structures such as cooling towers may be contaminated with chromium and other metals, which will necessitate special procedures for dismantling, loading and transport to disposal facilities.

.8 Removal of Buried Services

- if buried services are to be removed, they should first be drained and purged. Excavation of pipes should be undertaken concurrently with the excavation of contaminated soils. Bedding materials around pipes may have been a pathway for contaminant movement, hence, some sampling and analysis may be required during clean-up to determine required action; and

- if buried services are to be left in place, pipes should be drained, purged and capped; filled with concrete; or maintained in a manner consistent with future developments.

.9 Excavation of Contaminated Soils and Sediments

- the excavation program will be planned in detail with respect to estimated areas and depths;

- excavation should proceed in 'lifts' with periodic sampling and analysis to measure progress of contaminant removal. This will serve to minimize the amount of materials for disposal and will ensure an effective clean-up;

- undertake excavations in a logical sequence to avoid possible disturbances by vehicles in completed areas;

- if contaminants are primarily contained in the soil fines, screening of the soils (with appropriate dust controls) will reduce volume of materials for disposal;

- the concentrations of contaminants in soils and sediments will determine the method of disposal (see Section 372). As contaminated soils and sediments will not be homogeneous, selective handling of materials during excavation will reduce disposal costs; and

- do not backfill excavations until confirmatory sampling and analysis is completed (see Section 3.9).

.10 Reclamation Measures

- for those areas where soil amendments are to be applied including landfarm areas, access and surface drainage controls should be established prior to implementing the planned program.

.11 Confirmatory Sampling and Analysis

- confirmatory analysis is an essential component of any clean-up project and should be completed prior to backfilling and final grading (and prior to dispersal of clean-up personnel, equipment and facilities);

- confirmatory analysis measures the success of the clean-up program, identifies further clean-up requirements and provides a final record of site conditions; and

- it is suggested that a third party be utilized to select sampling locations and to collect samples.

.12 Installation of Long-Term Monitoring Facilities

- depending on the nature of required monitoring for the site, long-term monitoring facilities (i.e. piezometers near containment facilities or downgradient of the site) would be installed when appropriate during the clean-up program.

.13 Shutdown and Clean-up Wastewater and Sewage Treatment Works

- while these facilities may be shutdown in phases during the clean-up program, treatment facilities must be operable to treat surface runoff, wastewater generated from clean-up operations and sewage generated from the workforce involved in clean-up;

- monitoring of influent and effluent should be undertaken throughout the process, and when it can be demonstrated that treatment facilities are no longer required, shutdown and clean-up can proceed; and

- for those plant sites where groundwater and leachate collection systems are installed for recovery and/or treatment of contaminants, or where runoff from soil reclamation areas remains contaminated, wastewater treatment systems may have to be operated for a number of years.

3.9 CONFIRMATORY TESTING

When site clean-up is completed, or when phases of a multi-phase clean-up program are completed, confirmatory testing is required to ensure that the task of removing contaminants from the site or reclaiming contaminated soils has been effective.

With respect to the excavation of contaminated soils, the confirmatory testing program would involve sampling of soils within and nearby excavated areas and analysis of samples with respect to clean-up criteria. Usually, an independent contractor who has not been involved in site investigations and clean-up would conduct the confirmatory testing program. However, it is essential that methods used in the confirmatory program are the same as those used in investigative programs. Confirmatory testing would be carried out prior to backfilling.

Other confirmatory testing would likely be carried out in conjunction with long-term monitoring of the site.

3.10 LONG-TERM MONITORING

Requirements for long-term monitoring of site conditions will vary from site-to-site, and will provide assurances that clean-up and reclamation programs have been effective. The following long-term monitoring programs may be required.

- o monitoring of groundwater downgradient from the site;
- o monitoring of the integrity of on-site containment facilities; and
- o monitoring of site reclamation programs such as
  - reclamation of contaminated soils,
  - landfarming of sludges, and
  - metal uptake in crops.

Monitoring of the site may continue for several years and may be gradually phased out when sufficient monitoring data demonstrates the integrity of the site.

3.11 REGULATORY AGENCY INVOLVEMENT

Regulatory agency involvement will continue throughout the entire decommissioning program. An effective two-way communication network between government agencies and the company is a key factor of the program.

The prime concerns of the regulatory agencies are:

- ensuring that the site is cleaned up to a level which will provide long-term environmental protection and which will be safe for future users;
- ensuring that future uses of the site are compatible with the clean-up measures and do not affect the integrity of containment facilities;
- ensuring environmental protection while the site is being decommissioned; and
- ensuring that contaminated materials removed from the site are safely transported and disposed of in approved facilities.

Once a company has made a decision to decommission a plant, it should inform the relevant local, provincial and federal regulatory agencies of this decision. However, it is recommended that the notice of the intent to decommission the plant should not be provided to regulatory agencies until the objectives of the decommissioning plan have been developed by the company and approved by company management. At this stage it is important that the company take the initiative in terms of planning the entire decommissioning exercise. Further, the company will need to address concerns regarding their employees, shareholders, local and provincial politicians and the media.

Several provincial and local regulatory agencies may be involved in various aspects of the decommissioning program. These may include environment, health, and workplace health and safety ministries; municipal or regional waste disposal and land development authorities; utility boards or commissions; local boards of health; and land use planning and approval agencies. There are advantages from the perspective of both the company and the regulatory agencies to establish a lead government agency whose role is to be the sole contact on matters of the plant decommissioning program. The lead agency would ensure that all appropriate regulatory agencies are apprised of decommissioning plans, and that all governmental concerns are addressed in the clean-up plan.

In addition to providing a listing of government concerns with respect to conditions on the site and reviewing results of testing programs, regulatory agencies will be deeply involved in the development of clean-up criteria. As the criteria are the numbers which will be used to ensure the long-term safety of the site, it is incumbent on the regulatory agencies to ensure that the criteria are sufficient to meet the objectives for the site.

While regulations, guidelines and government policy may specify criteria for some contaminants, considerable discussions and negotiations will be required in the development and finalization of criteria. Regulatory agency approval of the criteria is required to permit development of the site clean-up plan.

Regulatory agencies should be prepared to approve the detailed decommissioning plan once they have an opportunity for review and comment. However, the regulatory agency and the company must remember that a key to a successful decommissioning is flexibility and thus changes in the plan may be required as implementation proceeds. Once the regulatory agency is satisfied with the plan, written approval should be provided to the company. If the plan requires a number of years for completion, periodic review meetings (possibly every 6 months) should be held between the regulatory agency and the company to assess progress.

When the plant site has been cleaned up in accordance with the approved plan, the regulatory agency should then issue a clean-up certificate to that effect.

3.12 PUBLIC REVIEW PROCESS

Public interest in plant site decommissioning will vary with location. In many cases, there will be few public concerns with respect to the clean-up and re-development of the plant site. A company should, however, be prepared to address public concerns.

The local community often has a large stake in an oil, gas, or chemical production plant in terms of employment, corporate taxes, and local community benefits. The reasons for decommissioning should be adequately explained in order that the local community fully appreciates and understands the need to decommission the plant. This aspect of the decommissioning plan should be considered a natural extension of the on-going corporate-community relationship.

On a similar basis, the local community has a large stake in the future use of the plant site. The community may be concerned with public exposure to contaminants on the site, and the community needs to be advised of clean-up plans and to be assured that site clean-up will be undertaken.

After the notice of intent to decommission is announced, some members of the local community may have concerns over the future of the site and public committees or environmental groups may form with the express purpose of monitoring the decommissioning activities. These concerns must be adequately addressed in the decommissioning program. Further, the public sector may have ideas or development schemes for the decommissioned plant site which should be actively pursued by the plant owner as options for the future land use of the plant site. Wide spread community support for a particular development scheme will reduce the time necessary to develop and evaluate a wider variety of development options.

Public attitudes and emotions of sufficient magnitude to cause the formation of special committees or result in the intervention of existing environmental groups should be a top priority in dealing with the public. One of the chief problems in dealing with these groups are misconceptions of the company's objectives in their decommissioning plan. It is important that the decommissioning plans are presented in as open and honest manner as possible. Where specific details of the decommissioning plan cannot be presented, the reasons for this omission should be clearly stated and, if appropriate, the omission rectified at a later, specified date.

It may be desirable during the decommissioning plan to present to the public the results of chemical analyses, clean-up criteria and other quantitative environmental data. To relay this information effectively and have it understood by the public, careful preparation of meeting documents is required. As well, times and locations of public meetings should be specifically designed around the normal work routines of the community. The purpose of each presentation (both oral and written) should be clearly and concisely stated at the beginning of the presentation. It is essential that the results of technical studies are effectively translated to lay personnel. Explanation of terminology is extremely important.

Where appropriate the following terms should be defined in a concise and accurate manner in documents presented to the public:

- reclamation;
- decommissioning;
- hydrogeology;
- heavy metals;
- organics;
- wastewater ponds;
- process area;
- sediments;

- parts per million/parts per billion
- toxicity;
- clean-up criteria;
- groundwater monitoring; and
- background levels.

Other terms should be added to this list to fit the specific type of facility to be decommissioned and the specific type of problems encountered.

Explanation of the steps to be taken in the decommissioning plan as well as other actions or options should be presented in the form of easily understood flow charts, figures or graphs.

At the conclusion of an oral or written presentation, it is necessary to request questions or statements concerning the presentation from the public. This feed-back is essential in establishing the local community's attitudes concerning the decommissioning program. In this way, the public sector will have an integral role in decommissioning planning.

Because the decommissioning is part of the on-going relationship between the company and the local community, the manner in which the decommissioning exercise is conducted will be coloured by the past relationships formed during operation of the plant. Where community relations have been good, it can be expected that decommissioning relationships will proceed in the same manner. Considerably more effort will be required for decommissioning activities, especially those involving public review and input, if past relations between the company and the local community have been less than cordial.

Public Relations Manager

Good public relations throughout the development and implementation of the decommissioning plan will expedite various activities within the plan and bring the plant decommissioning to a satisfactory conclusion for all concerned parties.

By maintaining good relationships with the media, the public and environmental groups, factual information can be effectively disseminated and translated to assist in alleviating concerns and minimizing negative publicity or misconceptions.

With the notice of intent to decommission should come the appointment of a public relations manager. The manager should:

- be the only source of information concerning plant decommissioning to the news media and public;
- act as chairman of all meetings with the public, citizens, or environmental groups;
- have the ability to obtain input from all company management levels;
- review and edit all documents prepared for public presentation;
- maintain a consistency in relations with the public sector in accordance with corporate policy; and
- be responsible for inputting public concerns about clean-up plans and activities to corporate management and decommissioning staff.

Because the decommissioning of a plant site is part of the natural sequence of events in industrial operations, the positive aspects of the decommissioning plan should be stressed. The fact that the plant site will be left in an environmentally acceptable condition for a future land use is the focal point for positive public relations. An approach that is honest and open, with respect to conditions on-site, planned clean-up of the site and possible future use, has significant benefits in successful decommissioning programs.

PART 4

CASE HISTORIES

PART 4 - CASE HISTORIES

CONTENTS

CONTENTS (Cont'd)

TABLES

4.1 INTRODUCTION

In previous sections of this guide, information is provided on the activities that are required to successfully complete the clean-up of a decommissioned plant site. Clearly from a decommissioning standpoint all sites are not created equal. Investigations and clean-up may be minimal at some sites while clean-up activities may be very complex at other sites, particularly those industries that have been in operation for a number of years, operations that handled large volumes and many types of chemicals, plants where spills and leaks were extensive, or operations that generated large or complex waste volumes and disposed of the materials on-site. Each decommissioned site has specific requirements and the key is to tailor the over-all program to site-specific problems.

A number of refinery, natural gas processing and chemical companies in Canada and the United States have recently been involved with decommissioning pItÖ? sites. Representatives of these companies have kindly provided details of the environmental aspects of their programs, together with comments on changes that would be made in hindsight to improve these programs. Information provided is summarized in the following sections:

- o Decommissioning Planning;
- o Plant Site Assessment;
- o Field Investigation Programs;
- o Development of Clean-up Criteria;
- o Clean-up Programs; and
- o Disposition of Sites (after decommissioning).

4.2 DECOMMISSIONING PLANNING

Senior management's decision to shutdown a plant is based almost solely on economic grounds. In recent years industrial plants have been closed as a result of market changes, depletion of plant feed-stock, process inefficiencies, and environmental concerns. Until recently, these corporate economic decisions were based solely on consideration of the costs for continued operations or costs of modifications for continued viable operations. Dismantling of equipment and structures and clean-up of the site were generally undertaken for the recovery of scrap and salvage values, or the requirements of a specific future user of the site (usually another industrial user).

There is now a greater awareness of potential long-term environmental problems associated with abandoned industrial sites, and concerns by regulatory agencies and the public sector which are consistent with demands for improved hazardous waste management systems. With some exceptions, companies who are closing industrial plants are aware of long-term environmental concerns and their associated liablities, and have generally accepted the responsibility to clean-up sites to the satisfaction of regulatory agencies. In fact, companies who are presently involved in the decommissioning of several hydrocarbon processing plants have implemented detailed planning exercises, and extensive sampling and analytical programs leading up to site clean-up and re-development.

The following items detail some of the planning approaches taken at industrial plants recently decommissioned:

<u>Types of Shutdown</u>

- industrial plant sites were either mothballed, partially decommissioned or completely decommissioned;

- the disposition of plant sites ranged from the sale of plant sites with plans to re-start chemical processing to complete decommissioning and clean-up;

- in response to environmental concerns with respect to mercury cell chlor-alkali plants, several facilities were closed and cleaned up with either conversion to other processes or complete facility closure;

- refineries were closed with decommissioning and clean-up of the hydrocarbon processing components with continued (in some cases, short-term) operations of the tankfarm and marketing terminals; and

- a gas plant was decommissioned and cleaned up with subsequent operation as a compressor station.

Planning

- circumstances varied at each closed facility and, accordingly, decommissioning planning was not consistent;

- most companies completed decommissioning planning studies prior to announcements of plant closure;

- some companies gave little consideration to the environmental implications of decommissioning at the planning stage; and

- at one chemical plant, very little initial planning was undertaken and decisions were made as site clean-up programs proceeded.

Personnel Management

- most companies considered the dispersal of plant emloyees to be a major consideration in plant closure;
- in most cases, plant employees were advised of plant closure prior to any public anouncements;
- plant employees were transferred to other company plants, received layoff notices, or retired;
- many companies provided assistance to employees who were terminated or retired;
- one company hired a human resource management company to assist in personnel management functions;
- many companies realized the importance of maintaining key management and operating staff on-site during the decommissioning program;
- one chemical company formed committees of plant management and operating personnel to plan and implement various activities associated with the decommissioning program; and
- other companies made available key personnel to assist in defining plant site contaminant problems.

Relationships with Regulatory Agencies

- with few exceptions, input from regulatory agencies was not solicited until initial investigations were completed and clean-up plans were formulated; and

- in most cases, however, regulatory agencies were advised of plans to undertake investigations.

Public Involvement

- the involvement of the public sector varied from no involvement to extensive discussions and input to all aspects of decommissioning; and

- generally, public involvement has been a function of existing neighbouring land use (i.e. an industrial plant being decommissioned in an area extensively populated with other industrial facilities usually received little public attention)

Comments

Specific comments received from companies contacted with respect to suggested changes in the approach used to plan a decommissioning program are as follows:

- ensure that senior management are aware of the environmental implications and costs of the decommissioning program;

- assign a senior person as the decommissioning manager;

- obtain corporate commitment for resources to undertake required assessments, investigations and clean-up;

- clearly define realistic concerns of regulatory agencies early in the project;

- if plant site employees are transferred, terminated or retired when the plant is shutdown, a wealth of information leaves with them;

- utilize, as much as possible, staff from the plant to plan and execute site clean-up; and

- do not underestimate the 'people problem' associated with dispersal of staff from the plant.

4.3 PLANT SITE ASSESSMENT

As indicated in Part 3, the objective of completing a plant site assessment is to identify potential environmental concerns associated with plant operations and thus to provide a basis for the design of the sampling and analytical programs. This assessment is particularly important when it is remembered that:

- the plant may have operated in excess of 25 years;
- environmental requirements have become substantially more stringent in the last 10 years; and
- a more cost-efficient sampling and analytical program can be designed on the basis of a thorough plant site assessment.

However many companies involved in decommissioning activities have committed few resources to performing a detailed plant site assessment.

Plant site assessments undertaken prior to any field investigations or clean-up programs varied considerably in their extent as follows:

- in some cases, assessments consisted of identifying known areas of contamination;
- preparation of detailed operating histories were not commonly undertaken;
- one gas processing company conducted a detailed plant site assessment prior to field studies, but prepared an operations history later in the program when the need became apparent;

- several clean-up programs were initiated without complete assessments and, as a result, numerous 'surprises' were found during the clean-up program;

- assessments in some cases did not include discussions with regulatory agencies and thus government concerns were not known until testing programs were completed;

- a number of chemical companies completed detailed inventories of chemicals and interviewed long-term employees to complete a limited plant site assessment;

- a number of refinery operators gathered information on current plant operations prior to field program design; and

- prior to the shutdown of a refinery, a company is preparing a detailed waste management history to identify contaminant concerns.

Comments

Specific comments received from those companies contacted with respect to plant site assessments are as follows:

- conduct a thorough assessment of potential problems before commencing sampling and analytical programs, and before site clean-up;

- if a thorough assessment of the plant site is not completed, subsequent testing programs may be misdirected;

- utilize key management and operations staff from the site to assist in the plant site assessment;

- consider subsurface conditions at the plant site as an essential component of decommissioning planning;
- have a thorough knowledge of potential problem areas prior to formulating clean-up plans; and
- develop objectives for the clean-up and future use of the site on the basis of contaminant concerns identified in the assessment.

4.4 FIELD INVESTIGATIONS

As discussed in earlier sections, there are distinct advantages in conducting field investigations in phases. The initial phase, a reconnaissance program, provides fairly general information on the types and ranges in concentrations of contaminants, provides indications of the areal extent of contamination and provides site geologic and hydrogeologic information. The results of the reconnaissance program are used to identify the need for and nature of any further, more detailed investigations.

Generally, investigations undertaken at industrial plant sites have not specifically included reconnaissance level programs, however, often a second phase of field work was required to delineate specific problem areas. This was not always efficient or cost-effective.

Approaches to field investigations for the identification of contaminants at various industrial plant sites are summarized as follows:

- initial or reconnaissance level programs were viewed as the first major step at some refineries, gas plants and larger chemical plants;

- at some refineries, the initial work concentrated in landfarm and processing areas, and did not include waste storage and treatment areas;

- at one large gas plant, a reconnaissance program was conducted; however, safety requirements limited investigations in the process area (the plant was still operating). When the plant was shutdown, detailed investigations (designed on the basis of the plant site asesssment and results of the reconnaissance program outside the process area) were undertaken in the process area;

- at two gas plants, reconnaissance programs were first conducted with results used to design a detailed hydrogeologic study to define and assess groundwater conditions;

- a refinery operator, in preparation for closing the refinery, is initiating a very specific reconnaissance program to be followed with additional work if required;

- for chemical plants, there have been a wide variety of investigative approaches taken, given the diversity of chemical plant operations;

- at one large chemical facility, clean-up programs were implemented after a limited plant assessment and sampling program; however, a number of 'surprises' were found during clean-up, necessitating considerable additional sampling (and costs);

- clean-up of one chemical plant was done on the basis of no field investigations, with work undertaken primarily to remove sludges and clean sewers, etc.;

- at many chemical plants, results from the initial sampling programs led to further sampling to specifically delineated problem areas. These secondary programs were not initially planned or budgeted;

- some secondary sampling programs have been integrated with planned clean-up options to provide additional information on controls required;

- usually, regulatory agencies were advised of the intent to conduct investigations; however, often their input was not solicited until after the initial field work was completed.

- a regulatory agency was directly involved in assisting one chemical company to complete field investigations;

- in some cases, regulatory agency concerns necessitated further investigations after planned testing programs were completed; and

- future use of the site, or future land use options were not often finalized prior to reconnaissance or detailed field work.

Comments

Field investigations, whether undertaken in stages or as one major program, were generally sufficient to provide the basis for the design of clean-up programs. Specific comments received from those companies contacted with respect to field investigations are as follows:

- a preliminary or reconnaissance level investigation is useful in defining the types, ranges in concentration and approximate areal extent of contamination;

- regulatory agency involvement is essential; however, in the view of some companies, has necessitated some unnecessary testing; and

- future use of the site (and clean-up criteria) largely affect field investigations, and should be established early in the program.

4.5 DEVELOPMENT OF CLEAN-UP CRITERIA

The establishment of clean-up criteria for decommissioned industrial plant sites has normally involved considerable discussions with regulatory agencies. In some cases, the regulatory agencies imposed criteria and in others, companies decommissioning industrial plants developed preliminary criteria, followed by regulatory agency review, discussions and negotiations to establish final criteria. Recently, criteria development associated with clean-up of industrial sites involved extensive literature reviews and interpretation and considerations of potential health effects to future users of the sites. This methodology was applied to the clean-up of a shutdown lead-acid battery plant, and is being applied to the clean-up of a sour gas plant and a refinery.

In general, there are no regulations in Canada with respect to defining the level of clean-up required when an industrial plant is shutdown. There are many reasons why criteria cannot and should not be established on a universal basis. These centre mainly on the interactive relationships between site-specfic factors and the future use of the site. Clearly, health-related standards for contact with hazardous chemicals (ingestion, inhalation, dermal exposure) should be used to provide baseline criteria, but site-specific factors must be used to answer the question "how clean is clean" with respect to soils, sediments and groundwaters.

Comments

Comments from companies who have recently been involved in the establishment of clean-up criteria are as follows:

- clean-up criteria are the most significant factors in a clean-up program;

- criteria must be established on a scientific and rational basis with the full understanding of the cost implications associated with the numerical values (i.e. a slight change in a criterion may have a significant effect on the extent and costs of clean-up); and

- regulatory agencies should, in addition to providing guidance to the development of criteria, have in place a mechanism to establish criteria on a case-by-case basis.

Further information on criteria development is provided in Section 4.8, Case Histories.

4.6 SITE CLEAN-UP PROGRAMS

The details of site clean-up programs vary considerably from site-to-site, from industry-to-industry and from province-to-province. It is beyond the scope of this guide to provide specific details of clean-up programs; however, with some exceptions, it can be stated that site clean-up programs completed in recent years have generally been to the satisfaction of regulatory agencies.

The following items summarize some of the approaches being taken at decommissioned plant sites:

- considerable discussions and negotiations between companies and regulatory agencies to establish clean-up criteria;
- public hearings to discuss and establish clean-up criteria, and to review clean-up plans;
- at some plants, contaminated materials were contained on-site in specially designed vaults, while at others, large volumes of contaminated soils, sediments and sludges were transported to off-site disposal sites;
- off-site disposal included disposal in municipal or regional landfills, disposal in hazardous waste landfills in the United States, incineration and storage;
- at some refinery sites, recovery wells have been installed to remove hydrocarbons from the water table;
- soil amendments were applied to improve soil quality for crop growth;

- cover material was applied to contaminated surface soils to minimize possible exposure to contaminants; and
- long-term monitoring facilities were installed at some sites (usually groundwater monitoring wells) to monitor site conditions.

4.7 SITE DISPOSITION

Re-development of decommissioned industrial sites in recent years has included a number of uses such as reuse of the site and some process facilities for chemical production, conversion to light industrial and commercial uses, recreational development (parkland), and plans for residential developments. In some cases, residual contamination on-site and related concerns of regulatory agencies have prevented re-development schemes planned by site purchasers. The following summarizes some re-development uses implemented or planned at industrial sites recently decommissioned:

- plans to establish a commercial development on the site of a former chemical plant (by the new owner of the site) have been delayed due to contaminants on-site;

- a chemical plant site, after clean-up, is presently for sale in an area zoned for commercial and light industrial uses;

- a major chemical production plant site was cleaned up and is presently being developed as an extensive residential subdivision with recreational facilities including a golf course;

- a chemical plant was sold (prior to clean-up) to a developer for residential use. Delays in the site clean-up (by the chemical company) and concerns by the regulatory agency are modifying re-development plans;

- a chemical plant site was was deeded to the local government for future industrial development;

- several decommissioned chemical plant sites have changed ownership for use for chemical production;

- a number of refineries have been closed down with continued operations of tankfarms and marketing terminals. With closure of the terminals, site re-development plans include residential development, combined residential/commercial development, combined agricultural/industrial development and industrial development;

- a sour gas plant site which is presently being cleaned up will be used for both industrial (including continued operation of the compressor station) and agricultural uses;

- two sour gas plants, which will soon be shutdown, will be cleaned up to facilitate re-development to uses compatible with neighbouring land uses. (i.e. residential/commerical in one case and agricultural in the other case); and

- the possible sale and re-development of a large refinery site is being delayed by environmental and land use authorities due to residual hydrocarbons in soils and groundwaters.

4.8 CASE HISTORIES

The decommissioning of three industrial plant sites are described in the following sections to identify successful approaches taken to alleviate environmental concerns and to permit re-development. These plants are a lead-acid battery plant, a large refinery and a major sour gas processing facility. The discussion of these projects focuses on the establishment of clean-up criteria.

481 LEAD-ACID BATTERY PLANT

The battery plant was located in an industrial area of a large urban community and was in operation for approximately 30 years, producing wet-cell lead batteries. The plant was shutdown and mothballed in 1982 and, approximately one year later, decisions were made to decommission the facility and to sell the site.

The plant site was relatively small in area (2.2 hectares) with the surface cover consisting of the battery plant and loading docks, paved parking and storage areas, rail spur, landscaped area and unattended buffer zones.

The company contracted with a consultant to determine conditions on the site and to define clean-up requirements, and with a contractor experienced in cleaning up contaminants. The following paragraphs highlight the significant aspects of the clean-up project.

.1 Background Information

- o background information on the extent of lead contamination on the plant site was very limited and consisted of:

- the results of a broad lead-in-soil survey by the regulatory agency associated with other larger secondary lead smelters in the vicinity, and
- the results of very limited on-site soil sampling by the company;

o data indicated elevated lead concentrations above background; however, sampling intensity was limited.

.2 **Testing Programs**

o testing programs were designed on the basis of:

- the above limited background information,
- a detailed inspection of the site, and
- discussions with a former employee of the plant;

o potential sources of lead in soils on the site included:

- fall-out from emissions to the atmosphere,
- dust from outside storage areas and from the building roof,
- waste management and housekeeping practices, and
- emissions from automobiles travelling on nearby roadways;

o sampling and analytical programs were undertaken in two phases as follows::

Phase 1

- an initial or reconnaissance program conducted on a grid over the entire site,

- focused on surficial soil sampling (0 to 5 cm and 5 to 10 cm) at nodes of the grid with deeper sampling at a limited number of locations,
- additional sampling sites were selected in locations where lead contamination was likely (near loading docks, near the baghouse, etc.),
- samples of dust and sludge from the interior of the battery plant were also collected to define clean-up and disposal requirements, and
- as lead contamination was expected on the building roof (flat roof of tar/gravel construction), samples of dust were collected for analysis.

Phase 2

- a more detailed program undertaken to define contaminant profiles in certain areas of the site to determine to extent of clean-up required.

.3 Results of Testing

- o over most of the site, lead contamination existed in surface soils with values ranging from background levels to a high of about 16,000 ppm. Lead concentrations reduced sharply with depth to background levels;

- o on one side of the building, near loading docks, lead levels were much higher, ranging up to 200,000 ppm (20%) near the surface. Backfilling of a low lying area had resulted in high lead levels below the surface to depths ranging from 30 to 45 cm;

- o while lead analyses by atomic absorption spectrophotometry were performed on all soil samples, ICP scans for metals were undertaken on selected samples. The ICP scans showed no anamolous concentrations of other metals; and

- computer interpolation techniques (including kriging) were utilized to identify the spatial distribution of lead in soils. These techniques were successful over most of the site; however, near the loading docks, rail spur and backfilled areas, there was no spatial dependence of lead concentrations.

.4 Clean-up Criteria

- at the time of clean-up, there were no criteria in place for lead in soils in industrial locations;

- a lead criterion in surficial soils from other jurisdictions was used:

  - as a result of hearings of the Environmental Hearing Board on Lead Contamination in the Metropolitan Toronto area, a criterion of 3000 ppm ± 13% measured in the top 5 cm (2 inches) of soil, was established as the level for excavation and/or paving of the surface. The criterion was established after consideration of possible re-entrainment of lead dust and possible health effects due to ingestion of lead contaminated soils, and
  - in Winnipeg, the same criterion (3000 ppm ± 13%) was used in a soil and sod removal program in residential areas bordering a secondary lead smelter;

- since the battery plant site would remain zoned for industrial use, the value of 2600 ppm (3000 ppm - 13%) was established as the clean-up criterion. The criterion was subsequently accepted by the regulatory agency.

.5 Site Clean-up

- on the basis of the established criterion, soils on the plant site to be excavated and removed were delineated using computer interpolation techniques and the areas to be excavated were marked;

- a backhoe with a modified bucket was used to excavate soils in lifts. Samples were collected from the base of excavated areas for analysis to measure the progress of clean-up. Composite samples of soils excavated were analyzed to identify the disposal location, as follows:

  - soils with an average lead concentration of less than 4000 ppm were transported to a regional landfill for disposal, and
  - soils with greater than 4000 ppm lead were transported to a hazardous waste facility in the United States for disposal;

- dust and gravel were removed from the building roof by vacuum and screened. Gravel was returned to the roof; and

- the building interior was also cleaned as follows:

  - removal of all equipment,
  - removal of sludge from sumps,
  - vacuuming of dust from floors, walls, beams, etc.
  - cleaning of the building ventilation system, and
  - final washdown.

.6 Confirmatory Testing

- upon completion of the soils excavation program, confirmatory sampling and analysis was carried out. As a result, some additional excavation was required in certain areas; and

- inside the building, a testing program was undertaken (dust and air testing) following a stress test on the ventilation system.

.7 Site Disposition

- Approximately one year after completion of site clean-up, the plant site is still for sale.

482 REFINERY SITE

The development of clean-up criteria for a decommissioned refinery site is discussed in the following paragraphs.

.1 Site Conditions

- the refinery site included the refinery processing area, tankfarm and marketing area, landfarm area where oily sludges were applied to agricultural land, waste disposal area, and wastewater treatment facilities;

- the company contracted with a consultant to undertake a sampling and analytical investigation of the site, to include soils and groundwaters;

- the results of the investigation indicated elevated levels of hydrocarbons and certain heavy metals at some locations of the refinery site;

- soils in the area of the refinery site consist of clay loam till over bedrock with a soil pH greater than 6.5; and

- intended future use of the site was established to be compatible with the surrounding area (urban and industrial).

.2 Initial Communications with Regulatory Agency

- when the decision was taken to decommission the refinery site, the regulatory agency was advised of the planned decommissioning program including plans to conduct soil and groundwater investigations;

- the regulatory agency was provided with results of the soil and groundwater investigations for review; and

- the regulatory agency was advised of plans to have a consultant develop clean-up criteria for the site.

.3 Criteria Development

- the company contracted with a second consultant to develop clean-up criteria for soils specific to the site and its intended future use;

- the development of criteria included an extensive review of the literature with emphasis on phytotoxic effects, safe levels of trace compounds in food and fodder, uptake of metals in crops, and, in the case of certain metals, potential human health effects;

- contaminants addressed in the development of criteria included:

  - soil pH and salinity,

- plant nutrients (nitrogen compounds),
- hydrocarbons, and
- heavy metals;

o with respect to soil metal levels, data from experiments and studies on soils with characteristics similiar to soils on the refinery site were used;

o the following provide details of the development of the criteria:

1) **soil pH and salinity**

o a criterion value for soil pH was developed to ensure crop growth, reduce the potential for corrosion of concrete and other construction materials, and to prevent the solubilization of soil metals.

o a value for salinity (electrical conductivity) was developed to limit effects on crop growth. Further, because of the high precipitation in relation to evaporation or evaportranspiration in the area, it was expected that soil salinity would tend to decrease by leaching.

o to limit the effects of sodium ions on soil stability and permeability, a sodium absorption ratio was established for soils in the landfarm area.

2) **plant nutrients (nitrogen compounds)**

o a criterion value for total Kjeldahl nitrogen was established to limit concerns with respect to possible high nitrate levels in plants and nitrate impacts in groundwater in the landfarm area.

3) **hydrocarbons**

o for the landfarm area, a criterion value for the oil and grease content of soils was based on degradation rates of oily wastes and other hydrocarbons in soils.

4) **heavy metals**

o criteria development for heavy metals in areas of the site proposed for industrial uses was based on the assumption that soils with levels of contaminants that do not result in phytotoxic effects on fodder or grain crops, or levels in the resultant vegetation that are above levels chronically tolerated by domestic animals, are suitable for industrial use.

o criteria development for heavy metals in areas of the plant site proposed for urban use was based on the use of soils for growing vegetables in home gardens. More specifically, metal uptake in leafy vegetables was used to establish criteria.

o site conditions and projected land use play a large role in criteria for metals; hence, several restrictions were applied to literature searches in order to make the clean-up criteria as specific to the refinery site as possible. These were:

- data was restricted to field plot experiments or studies, as greenhouse and nutrient solution experiments are known to exaggerate plant uptake of metals;

- data was restricted to soils with a pH value greater than 6.5;

- data was restricted to field crops (grass, cereal leaves and straw and corn leaves); and

- data was restricted to medium and fine textured soils.

o data from the appropriate literature sources was plotted (soil metal level vs. vegetation metal level), and criteria were established from interpretation of statistical relationships, phytotoxic levels, and accepted metal levels in animal feed.

.4 <u>Presentation of Proposed Criteria to Regulatory Agency</u>

o the proposed criteria were presented to the regulatory agency and as a result of their review, there was acceptance of the methodology and basis for the criteria development. The regulatory agency agreed with criteria values for most parameters, however, suggested lower levels for certain metals.

.5 <u>Finalization of Clean-up Criteria</u>

o a re-evaluation of outstanding criteria was undertaken by the company and a final submission was made to the regulatory agency;

o final approval of the criteria was received, and planning for site clean-up was initiated; and

- Table 4-1 summarizes the clean-up criteria for the refinery site. It must be stressed that these criteria are specific to the refinery site and cannot be applied without detailed studies to other areas.

483 SOUR GAS PROCESSING PLANT

A major sour gas processing facility which operated for approximately 25 years was shutdown due to declining gas reserves. Facilities for the removal of acid gases from the raw gas, the sulphur plant, hydrocarbon processing facilities, storage and loadout and related utilities were shutdown; however, compression facilities remain in operation with transport of sour gas and liquids by pipeline to a nearly sour gas plant for processing.

In anticipation of decommissioning the plant site, the company initiated a series of studies to define conditions at the site and to provide the necessary information to initiate site clean-up. These studies included:

- a general resisitivity survey of the plant site to identify and map areas of possible surface and subsurface chemical contamination and to locate and map buried pipelines;

- a reconnaissance sampling and analytical program for soils, underlying drift material, surface waters, groundwater and pond drainage ditch sediments on the plant site (excluding the main process area which was still in operation);

- a survey of possible off-site impacts associated with discharges of surface waters from on-site wastewater ponds;

TABLE 4-1

Example of Clean-up Criteria for Soils on a Refinery Site[a]

Parameter	Criteria: Industrial	Criteria: Residential
pH	6 to 8	6 to 8
Electrical Conductivity (mS/cm)	2	2
Sodium Absorption Ratio	15	15
Total Kjeldahl Nitrogen (%)	0.6	0.6
Total Cadmium (ppm)	8	4
Trivalent Chromium (ppm)	1000	1000[b]
Total Copper (ppm)	300	300
Total Lead (ppm)	1000	500
Total Mercury (ppm)	2	1
Total Molybdenum (ppm)	40	40[c]
Total Nickel (ppm)	200	200
Total Zinc (ppm)	800	800
Oil and Grease (%)	2	2

a Clean-up criteria are provided as an example only and are site-specific. The values cannot be applied to other areas without detailed studies.

b Reduce to 400 ppm if hexavalent chromium is detected.

c Reduce to 5 ppm if land used for grazing of ruminants or growing of forage for ruminant consumption.

- a detailed hydrogeology study to define the geologic and hydrogeologic regimes in the vicinity of the plant to identify possible comtaminant plumes;

- preparation of an operational history of the plant based on interviews with a number of former employees;

- a detailed investigation of soils beneath and adjacent to the sulphur block; and

- a detailed investigation of soils, sediments, groundwater and sludges within the process area (after shutdown of major process facilities).

Future uses of the plant site include the proposed re-development of the process area for construction of an anhydrous ammonia plant and the reclamation/clean-up of peripheral areas including wastewater ponds and lands affected by the storage of elemental sulphur for agricultural uses, consistent with neighbouring land use (growing of forage crops).

Clean-up of the site is being conducted in stages as detailed testing programs are completed and to permit the timely re-development of the process area.

Significant aspects of the site decommissioning program are identified in the following subsections.

.1 Site Conditions

- the geologic setting of the gas plant consists primarily of a thick sequence of silty clay till overlying a broad, relatively thin, preglacial gravel over silty shale bedrock. The till is approximately 40 m thick beneath the site;

- the water table is located within 1 to 3 m of the ground surface;

- movement of groundwater in the till is very slow, in the order of 0.02 to 0.08 m per year due to very low hydraulic conductivities;

- the site slopes across the process area to the lowlying wastewater pond area. Surface runoff, along with some process wastewaters, were carried by drainage ditches to a series of natural sloughs which were enlarged and dyked to provide for storage, settling and evaporation of wastewaters;

- drainage from the sulphur block and neighbouring lands was collected in a separate wastewater pond; and

- solid wastes and sludges from the process were disposed of in a landfill on-site.

.2 Reconnaissance Testing Program

- the reconnaissance testing program was initiated approximately 8 months before shutdown. Because of safety concerns associated with the operation of sampling equipment in the process area, the reconnaissance program was concentrated in other areas of the site;

- prior to finalizing the reconnaissance testing program long-time employees were interviewed, aerial photographs were examined, and past studies and company files were reviewed to identify areas that may be contaminated;

- soils and underlying drift materials were sampled at the surface and at various depths from approximately 100 sampling sites;

- piezometers were installed throughout the site to define groundwater conditions and to collect groundwater samples;

- surface waters in various wastewater ponds and sediments from the ponds and associated drainage ditches were sampled;

- samples were analyzed for general indicators of contamination such as pH, soil salinity, hydrocarbon content, total organic carbon and total Kjeldahl nitrogen. Total and soluble sulphur, soluble calcium and magnesium and soil buffering capacity were measured in soils suspected of sulphur contamination;

- trace elements such as barium, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel and zinc were measured by Atomic Absorption and on selected samples, ICP scans were performed;

- for some soils and sediments, comprehensive organic analyses were performed by GC/MS;

- background sampling and analysis of soils, underlying drift materials, groundwaters and pond sediments was also undertaken;

- results of the reconnaissance testing program included:

  - heavy metals including chromium, cadmium, and mercury in the sediments of certain ponds and the plant landfill;
  - organic compounds including polycyclic aromatic hydrocarbons, benzothiophenes and phthalates in pond sediments and surface soils;

- low pH and high total sulphur, sulphates and salinity in soils near the sulphur block;
- anomolous sulphate levels in groundwater in certain areas; and
- low pH in the surface water within the pond collecting runoff from the sulphur block;

o the reconnaissance testing program indicated that, because the site is underlain by relatively impermeable till, contamination was contained on-site and was limited to the near-surface; and

o sources of contaminants included:

- metals including mercury which were used in the process area;
- hydrocarbons which were either processed by the plant or used in the process area, and
- sulphur from the past and (then) present sulphur block.

.3 **Off-Site Impacts**

o when the reconnaissance testing program was completed, an off-site sampling and analytical program was initiated;

o the program focused on sampling sediments from drainage ditches and receiving waters down-gradient of the site, with analysis of the samples primarily for the heavy metals and organic compounds (plant site target compounds) detected in the reconnaissance program on the site; and

o no significant levels of plant site target compounds were detected off-site.

.4 Detailed Hydrogeology Study

- the detailed hydrogeology study was conducted primarily to define geologic and hydrogeologic regimes in the vicinity of the plant for the purposes of determining groundwater flow rates and direction and to design a long-term groundwater monitoring network;

- to supplement the groundwater monitoring network installed during the reconnaissance testing program, testholes were drilled and piezometers were installed at 28 locations on and off the site, including a number of background locations;

- the study confirmed the presence of up to 45 m of glacial tills beneath the site; however, silt deposits occur in the upper portions of the tills in one area of the site;

- plant site operation affected shallow groundwater quality in the process area, beneath wastewater ponds and in the landfill area. Poor quality groundwaters to depths of 12 m in these areas have elevated dissolved solids and sulphate levels. Various organic parameters are also present in shallow groundwaters in certain areas; and

- the study concluded that the low permeable tills have restricted contaminant movement in groundwater, thereby isolating poor quality groundwaters to shallow isolated locations. An apparent anomoly exists in one area (possibly due to the aforementioned silt deposits) where sulphate levels tend to be higher just offsite. Further studies (now underway) will determine if the sulphate is a natural occurrence or if it originated on the site.

.5 Operational History

- o to assist in defining the source of contaminants identified in the reconnaissance testing program, an operational history of the plant site was prepared;

- o an interview questionnaire which focused on waste management and spill control practices over the life of the plant was used as the basis for interviewing 14 persons who had worked at the site (as employees or contractors). Efforts were made to select a range of personnel (from labourers to plant managers) covering the construction and operational phases of the plant;

- o a chonological history of plant construction and operations (with an emphasis on those practices that might impact on site clean-up) was prepared;

- o the operational history was useful in identifying the following:

  - the location of buried tanks and pits,
  - chemicals used, storage areas, etc.,
  - modifications to drainage channels,
  - significant spills and leaks,
  - operational details of the process,
  - waste management practices, and
  - waste materials that were landfilled; and

- o the operational history was used extensively in the design of detailed testing of the site.

.6 Detailed Testing in the Process Area

- o when the major gas processing facilities were shutdown, a detailed testing program in the process area was initiated;

- o the program was designed on the basis of the reconnaissance testing program (contaminants detected in wastewater pond sediments and drainage ditches originated in the process area), the operational history and detailed inspections of the site;

- o the sampling program included;

  - the collection of soil samples from 186 boreholes and testpits,
  - the collection of ditch sediment samples throughout the process area,
  - the installation of piezometers and piezometer nests for groundwater sampling,
  - the collection of sludge and residue samples from in-building gutters and sumps,
  - the collection of miscellaneous samples including chemicals used in the process, wood from the cooling tower, transformer fluids, etc.

- o sampling of soils and sediments was concentrated in areas of suspected contamination with sufficient samples collected with depth and from sites located gradually more distant from the apparent source;

- o samples were analysed in phases (in terms of both numbers of samples and numbers of parameters) with additional analyses performed as required to sufficiently define the extent of contamination;

- since criteria were not yet established, results of testing were compared to background conditions. Significant results are summarized as follows:

  - elemental sulphur in the upper few centimeters of surface soils near the sulphur plant and sulphur handling facilities. Oxidation of sulphur has raised the salinity of these surface soils and, in a few locations, lowered the soil pH. The natural buffering capacity of the soils has neutralized the sulphuric acid, limiting low soil pH to the upper 15 to 20 cm of the soil profile,

  - elevated concentrations of cadmium, chromium, lead and zinc in certain areas, but limited to the upper 25 cm of the soil profile,

  - elevated mercury concentrations in surface soils and sediments near process facilities where mercury was used in pressure gauges,

  - hydrocarbons levels and nitrogen compounds in soils near faciliites where condensate and amines were stored or handled,

  - low levels of PCB contamination in surface soils near the bottom drain valves of electrical transformers (the transformer fluids contained up to 61 ppm PCB's), and

  - sulphates, ammonia, and hydrocarbons and their associated organic components in shallow groundwaters near process facilities,

- analysis of in-building sludges and residues indentified significant levels of certain metals (mercury, chromium, zinc), hydrocarbons and associated organic compounds; and

- wood from the cooling tower contained moderate levels of cooling chromium and zinc, and sludges beneath the tower contained high metal concentrations .

.7 Quality Control

Throughout all testing programs at the site, comprehensive quality control measures were applied to analysis of samples by duplicate analyses at an outside laboratory.

.8 Criteria Development

- while future uses of the site will include both industrial and agricultural, the company decided to develop criteria based on agricultural use (more stringent criteria than industrial use);

  - the development of criteria for soil/plant/livestock relationships proceeded in a manner similar to methodology described in Section 482,

  - the criteria were based on an extensive review of available literature from North America, Europe, Israel, Australia and New Zealand; however, only those studies which included field trial experiments on soils and climate similar to conditions at the gas plant site were used,

  - for metals, a relationship between soils metal levels to crop metal levels was established from the above literature, and conservative (lowest) phytotoxic limits and lowest tolerable concentrations for livestock were identified for each heavy metal of concern,

- the recommended maximum soil metal concentrations were determined from evaluation of the phytotoxic limits (plants), tolerable concentrations (livestock) and soil/crop metal levels.

o the criteria were presented in draft form to the regulatory agency, and after considerable discussions were approved. Finalized criteria are presented in Table 4-2. It is emphasized that the criteria are specific to the sour gas plant site and cannot be applied to other areas without detailed studies.

.9 Site Clean-Up

o with the clean-up criteria finalized, clean-up of the site is currently underway;

o the sulphur block base pad was cleaned up by removing sulphur-contaminated soils and incorporating limestone to neutralize acids;

o the cooling tower was dismantled and the contaminated wood was disposed of in a regional landfill by layering with high carbonate clay till;

o planning for clean-up of the process area is completed and clean-up will commence in the spring of 1985. Significant aspects of the clean-up program include:

- removal of all in-building sludges and residues,

TABLE 4-2

Example of Clean-up Criteria for Soils on a Sour Gas Plant Site[a]

Parameter	Criteria Industrial
pH	GT 6.5
Total nitrogen (%)	0.6
EC (mS/cm)	4.0
Total hydrocarbons (%)	2
Total copper (ppm)	400
Total zinc (ppm)	1200
Total lead (ppm)	1000
Total nickel (ppm)	300
Total chromium (ppm)	1000
Total cadmium (ppm)	4.0
Total mercury (ppm)	2.0

[a] Clean-up criteria are provided as an example only and are site-specific. The values cannot be applied to other areas without detailed studies.

GT- greater than.

- excavation of soils and sediments with contaminants at levels greater than criteria, and
- removal of transformer fluids with detectable PCB's.

o disposal of waste materials will include:

  - disposal of special wastes in a special waste facility in the United States,
  - disposal of moderately contaminated materials (levels near criteria) in a regional landfill, and
  - specialized treatment of PCB-contaminated fluids,

o clean-up programs for remaining areas of the site (wastewater pond area, landfill, and soils affected by sulphur) will be developed when detailed testing is completed.

PART 5

PREVENTIVE MEASURES

PART 5 – PREVENTIVE MEASURES

CONTENTS

FIGURES

5.1 INTRODUCTION

The development and implementation of a clean-up plan associated with plant site decommissioning can be a costly and extensive undertaking. There are, however, a number of preventive measures which can be addressed during plant construction and operation to minimize eventual clean-up requirements and their associated costs. These measures (Figure 5-1) fall into three broad categories as follows:

- siting criteria for new plants;
- changes in plant operating procedures; and
- preparation of annual environmental information reports.

Each of these issues is discussed in detail in the following sections.

PREVENTIVE MEASURES

- o Site Selection
  - consider site decommissioning factors at the site selection stage

- o Operating Procedures
  - spill prevention, clean-up and reporting
  - sludge handling, treatment and disposal
  - inventory of chemicals
  - solid waste disposal/landfill operations

- o Annual Environmental Information Report
  - permanent waste management record
  - implement mitigative measures during operations

FIGURE 5-1
PREVENTIVE MEASURES

5.2 SITING CRITERIA

The majority of provincial environmental agencies require proposed new plants to prepare some type of environmental impact assessments (EIA). These EIA's can be relatively straightforward for small projects but can be complex documents for larger projects. An integral part of an EIA (no matter how small) is a discussion of the possible siting alternatives for the plant. A site selection exercise normally includes:

- o a list of criteria used in the siting process and the weighting factors used to rank the sites;

- o a comparison of regions examined by the proponent in selecting the preferred area for the project location and the basis for any rankings or assessments that were carried out; and

- o a comparison of individual sites within the preferred region with regard to siting criteria used by the proponent, the method of site comparison and the basis for site rankings (or assessments)

There are usually few specific requirements in the site selection exercise to determine the ability of a proposed plant site to degrade, neutralize, contain or disperse contaminants resulting from plant operations. These factors, however, are important in determining the nature and cost of waste management facilities for a proposed site and will have a direct impact on the type and cost of clean-up programs required when the plant is ultimately decommissioned. Planning for site decommissioning at the site selection stage should address the following factors:

- o groundwater depth and movement (lateral and vertical);

- soil chemistry (e.g. pH, buffering capacity and ion exchange capacity);

- soil contaminant neutralization or retention capacity;

- climatic conditions affecting contaminant dispersal from the plant site;

- receiving waters for wastewater discharged off-site; and

- acceptability of basins or ditches for on-site containment of process wastewaters and/or surface drainage.

Each of the above factors should be addressed relative to the potential for contaminant behaviour (e.g. movement, degradation, etc.), and should be weighted and ranked in the same manner as other siting criteria.

521 GROUNDWATER

Alternative sites may be ranked according to the existence, depth and movement of groundwater. If the potential exists for groundwater contamination from the industrial plant, sites with little or no groundwater movement would receive a score appropriate for the reduced potential for off-site groundwater contamination. Groundwater quality should also be taken into account, with non-potable groundwater being favoured for plant site construction and good quality groundwater being least favourable.

522 SOIL

The soil at alternate sites should be ranked in terms of soil type, pH, buffering capacity, permeability, ion exchange capacity or contaminant retention capacity. For instance, for soils likely to receive acidic contaminants, sites with highly alkaline and well-buffered soils would be given preference over sites with low pH and poorly buffered soils. Soils containing either large concentrations of organic matter or clay are much better suited for retaining water insoluble organic compounds (e.g. halogenated organics, polycyclic aromatic hydrocarbons) than low organic or sandy soils. The retention of these types of contaminants in the upper soil layers would provide for a less extensive site clean-up.

523 CLIMATIC FACTORS

Climatic factors can play a significant role in the movement of contaminants both on and off the plant site. For instance, precipitation, evaporation and wind speed may be ranked if alternative sites differ significantly in these factors.

524 RECEIVING WATERS

The quality and quantity of receiving waters (streams, lakes and rivers) for plant wastewater discharges are potentially important in minimizing the impact of these discharges on the environment. Appropriately higher rankings would be given to receiving waters with sufficient assimilative capacity to minimize impacts on downstream water uses.

525 ON-SITE DRAINAGE DITCHES AND HOLDING PONDS

The on-site soil material available for construction of ditches and wastewater ponds must also be ranked in terms of permeability and contaminant retention. Also considered in this ranking must be the cost of lining ditches or ponds to produce the desired permeability and contaminant retention capability.

These and possibly other factors which might impact ultimate plant site decommissioning should be ranked. The weighting (ranking) of each factor based on its importance in terms of the potential movement of contaminants will allow consideration of the factors important to ultimate clean-up requirements at the site selection stage. To date, the site selection process has generally not considered criteria which might impact decommissioning and possible clean-up programs.

In addition to ranking the above factors during the site selection process, consideration should be given to contaminant containment procedures or techniques for the chosen site. The techniques or procedures should ensure containment of possible contaminants from:

- spills or leaks;
- plant site surface runoff;
- wastewater ponds;
- raw materials or product storage areas; and
- solid waste disposal areas (landfills).

Plant site surface runoff and wastewater ponds should be prevented from contaminating subsurface soils and groundwater by proper lining with man-made or natural materials. In addition, sufficient retention times should be allowed for settling of contaminated particulate material in appropriate sumps or sediment collection areas.

Raw materials or product storage areas and landfills can also be prevented from contaminating the surrounding environment by the proper construction of base pads and liners.

These techniques and procedures should be contained in either a waste management or environmental management plan as part of the EIA for the selected plant site location.

A number of provincial environmental agencies have guidelines on the preparation of environmental impact assessments (EIA). Where necessary these guidelines should require a discussion of decommissioning and clean-up plans associated with the proposed new plant. As decommissioning activities increase in number and the need for development and implementation of clean-up programs becomes more evident, government agencies are likely to request proponents of new facilities to realistically address this issue in an EIA.

5.3 PLANT OPERATING PROCEDURES

Plant operating procedures have a direct effect on the extent and degree of plant site contamination and thus the cost of clean-up when the plant is shutdown. Management of wastes on the site (disposal of sludges, landfill operations, spill clean-up and control, management of wastewaters, maintaining records, etc.) have a significant impact on the nature of investigations and site clean-up when the plant is shutdown. Changes in waste management practices at operating plants and establishment of up-to-date procedures for new or proposed plants will decrease plant site contamination and ultimately the extent of site clean-up.

Examples of factors to consider when reviewing or establishing operating procedures are provided in the following sections.

531 SITE ENVIRONMENT MANAGEMENT

Each operating facility should have an environmental manager normally reporting to the plant manager. In the case of a large plant, the environmental manager will be a full-time position (with necessary support staff). For smaller plants, the environmental manager's role may be a part-time function. The environmental manager should be appointed prior to the time of plant construction. His function and responsibilities would include:

- over-all responsibility for environmental matters arising from plant site operations;
- liaison with the corporate environmental group;

- preparation of all relevant applications for permits and licences for the plant;

- environmental work contracted to consultants and others;

- spill response and reporting measures;

- relevant routine monitoring programs and preparation of necessary reports for submission to government agencies;

- routine inspection of drains, sumps, wastewater and air emission treatment and solid waste handling systems;

- maintaining plant site chemical and waste disposal inventories;

- preparation of annual environmental information reports; and

- liaison with the local community and government agencies.

The environmental manager should have the full support and commitment of the plant manager and company management to undertake activities in the environmental area which are consistent with over-all corporate environmental policy. In this regard the corporation should have a written policy on environmental matters. Company employees should be thoroughly conversant with this policy, copies of which should be made available to the general public.

532 SPILL RESPONSE AND REPORTING

An up-to-date spill response procedure should be in place for industrial plants. The procedure should clearly identify staff responsibilities and contain an action plan to stop a spill or control a leak, recover lost product and remove and dispose of contaminated soils or other materials. Disposal of contaminated materials should be undertaken at government-approved incineration or landfill facilities.

In developing the action plan, potential spill scenarios should be identified, prevention and control equipment installed and inventory control procedures implemented. Consideration should be given to diversion of surface runoff and containment/recovery systems. It may also be necessary in some situations to install groundwater monitoring wells and subsurface recovery systems.

The plant site should be equipped with equipment and supplies for use in controlling and cleaning up spills and leaks. Equipment could include absorbent materials, booms, pumps, skimmers, portable tanks, etc. Also, an up-to-date list of other equipment, which would be readily available for use in spill situations, should be maintained.

Aside from reporting of spills to regulatory agencies (most provinces have manditory spill reporting requirements), reports on all spills should be prepared and reviewed periodically to indicate possible problem areas requiring attention. The spill reports will also assist in the development and implementation of future clean-up programs.

533 INVENTORY OF CHEMICALS

An inventory of all chemicals, feedstocks, and products used or produced on the plant site should be maintained. During a plant's operating life changes will be made in the type and volumes of chemicals, feedstocks and products purchased, used or produced and, since each is a potential contaminant, an inventory will assist in planning future clean-up programs. The inventory should include as much chemical data as available and should identify the purpose of each chemical and storage locations.

534 LABORATORY OPERATIONS

The methods of handling and disposing of spent reagents and out-dated chemicals from the plant laboratory should be reviewed. In some cases, these wastes should not be disposed of in the plant wastewater system or solid waste disposal site. Special containers should be used for disposal at a facility approved for this purpose.

535 WASTEWATER MANAGEMENT

Most industrial plant sites have separate collection/treatment systems for managing clean and contaminated surface runoff and process wastewaters. The effectiveness of these systems should be reviewed in detail. Inefficient or ineffective operation of treatment systems may be resulting in gradual build-up of contaminants in the sediments of receiving water bodies off-site. During decommissioning activities, it may be required to clean-up contamination in the receiving environment; for example, river sediments where heavy metals and hydrocarbons tend to accumulate.

536 GROUNDWATER MONITORING

A series of piezometers (small diameter groundwater monitoring wells) installed at predetermined locations on the plant site will be capable of defining groundwater flow conditions and water quality. Periodic monitoring of the groundwater quality will provide indications of concerns during plant operations and will enable mitigative action to be taken.

537 **SURFICIAL SOIL MONITORING**

A similar program for collecting surficial soil samples downwind of the plant site should also be implemented. Soil sampling and analysis are particularly important for industrial plants with stack emissions (i.e., secondary lead smelters) or where by-products are stored in the open (i.e., sulphur at sour gas plants). A systematic recording of soil sample results will form the basis for remedial actions to be taken and will assist in the assessment of site conditions during decommissioning activities.

538 **SOLID WASTE DISPOSAL PRACTICES**

The disposal of waste materials such as spent catalysts, pond sludges, tank bottoms, separator sludges, contaminated soils and other materials from spills and leaks, spent filters, waste chemicals, below-specification products, and other solid and semi-solid wastes to on-site landfills, pits, or dump sites should be critically reviewed. Often, on-site landfill sites were not planned as such and may originally have been simply a low-lying area of the plant site.

During decommissioning activities, it may be required to:

o seal the landfill/dump site, install leachate collection and treatment systems and maintain a long-term (perhaps in excess of 25 years) groundwater monitoring system; or

o remove all waste materials from the landfill/dump site and transport to a government-approved facility for disposal.

Both options can be costly. Clearly, operating an on-site landfill/dump site brings with it some long-term liabilities and costs. Therefore, the option of utilizing an off-site government-approved disposal facility as an alternative to an on-site landfill should be reviewed and analyzed very carefully. If an on-site landfill is required, the following items should be incorporated to effectively manage solid wastes:

- government approval of the location and operation of the site should be obtained in writing (this may be a requirement in some jurisdictions);
- utilize incineration (again government-approved) wherever possible and use the landfill for disposal of ash and other non-combustible materials;
- maintain records of the precise locations of landfills;
- maintain a detailed inventory (date, volume, chemical composition, etc.) of wastes disposed of in the landfill;
- appoint a plant employee, responsible for the operation of the landfill site, to report directly to the plant's environmental manager; and
- maintain the landfill in accordance with sound and well-established operating practices.

5.4 ANNUAL ENVIRONMENTAL INFORMATION REPORT

Over the operating life of an industrial plant, an enormous amount of data related to environmental matters is collected. In order to allow for the orderly assessment of these data in the future; for instance, during the design of a clean-up program associated with decommissioning activities, an annual environmental information report should be prepared by the plant's environmental manager. The information contained in this report should include the following:

- the results of any on-site and off-site monitoring programs such as groundwater, air emissions, wastewater discharges, water quality (in the receiving environment), etc., and analytical procedures used in the monitoring programs;
- spill reports;
- inventory information on chemicals, feedstocks and products;
- inventory information of wastes disposed of in any on-site landfill;
- relevant site inspection reports;
- documentation (with process diagrams) of changes in plant production techniques, operating procedures, processes or equipment, with an assessment of any environmental implications;
- information on identified plant site (and off-site) contamination problems;

- information on meetings with government agencies and the public (e.g. minutes of meetings and supporting documentation such as letters, memoranda and reports); and

- identification of problem areas and details of corrective action (together with the results of the corrective action).

Given the amount of information in the annual environmental information report, an executive summary should be prepared, which should include a check list of problems still requiring action. In order to maintain a complete information record, annual environmental information reports should be placed in a box file together with:

- all reports to government or regulatory agencies for the time period covered by the information report;

- all relevant internal and consultant's reports;

- copies of all government licences, permits, approvals, etc.; and

- an up-to-date process flow diagram, plot plan and aerial photograph (if available). Any other relevant photographs should also be included.

The annual environmental information report and supporting documentation will be a permanent, well-documented record of plant activities as they affect the environment. As such, the information will be invaluable during the design of clean-up programs associated with plant decommissioning activities.

The relevant plant operating procedures and production of the annual environmental information report should be clearly documented in the plant's standard operating procedures manual. The success of the environmental activities will depend to a large extent on the willingness, cooperation and understanding of the operating staff at a plant site. Educational programs may be required to inform operating personnel of their role and to solicit their cooperation in operating plant facilities in an environmentally acceptable manner.

PART 6

CONCLUSIONS

PART 6 – CONCLUSIONS

CONTENTS

6.1 CONCLUSIONS

This guide is of interest to those involved in the environmental aspects of decommissioning industrial plant sites. While the general principles outlined in the guide may be applied to the decommissioning of any industrial plant site, it is specifically aimed at oil, gas and chemical industries.

There are important factors involved in decommissioning industrial plant sites which should be considered by industry and regulatory agencies. These are identified in the following concluding remarks.

DECOMMISSIONING PLANNING

- the clean-up of an industrial plant site is not unlike the design, construction and commissioning of industrial plants as it requires detailed planning, management systems, design, costing and approvals;
- clean-up programs require a significant corporate commitment in terms of resources and time;
- clean-up programs are site-specific and must be tailored for each plant site; and
- the program should proceed under the direction of a senior manager.

REGULATORY AGENCY APPROACH

- o regulatory agencies having jurisdiction over the clean-up and future use of decommissioned industrial sites should have in place a formal procedure for providing input to the development of clean-up plans and to facilitate the approval of the plans. Guidelines, developed cooperatively by government and industry, would define roles and responsibilities; and

- o because of the site-specific nature of contaminant concerns and future site use, it is not feasible to specify clean-up criteria for many contaminants in regulations or guidelines.

PLANT SITE ASSESSMENT

- o detailed plant site assessments should be conducted prior to any field sampling and analytical programs to clearly identify possible types of contaminant concerns and their likely extent; and

- o plant site assessments should include the preparation of a detailed operations history which considers waste management practices and chemical use over the operating life of the plant. Formal interviews and informal discussions with key employees (both present and former) provide the basis for the operations history.

FIELD PROGRAMS

- o field programs should be conducted by professionals and technical personnel who are experienced in conducting contaminant investigations; and

- o to be effective, field programs should be conducted in phases, with initial or reconnaissance work followed by detailed testing in certain areas.

CLEAN-UP CRITERIA

- clean-up criteria are benchmarks for reviewing contaminants on-site and hence, in defining required clean-up programs; and
- criteria are site-specific and must have a sound scientific basis to ensure that a site, when cleaned up, is safe for intended future uses.

SITE CLEAN-UP

- the site clean-up plan must be all-encompassing in the definition of clean-up actions, measures for worker safety and health, and treatment and disposal of waste generated during site clean-up; and
- sampling and analysis during clean-up will ensure an effective and efficient program.

CONFIRMATORY ANALYSIS

- confirmatory sampling and analysis, conducted after planned clean-up actions are complete, measures the effectiveness of clean-up and is a final record of conditions on-site.

LONG-TERM MONITORING

- long-term monitoring may be required to determine the effectiveness of on-site containment or reclamation measures.

PUBLIC INVOLVEMENT

Public concerns about the clean-up of industrial sites and public interest in site re-development should be addressed in the planning and implementation of site clean-up.

PREVENTIVE MEASURES

The cost and complexity of eventual site clean-up can be significantly reduced by instituting preventive measures such as the consideration of decommissioning factors at the site selection stage, the implementation of specific operating procedures, and the preparation of an annual environmental information report.

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