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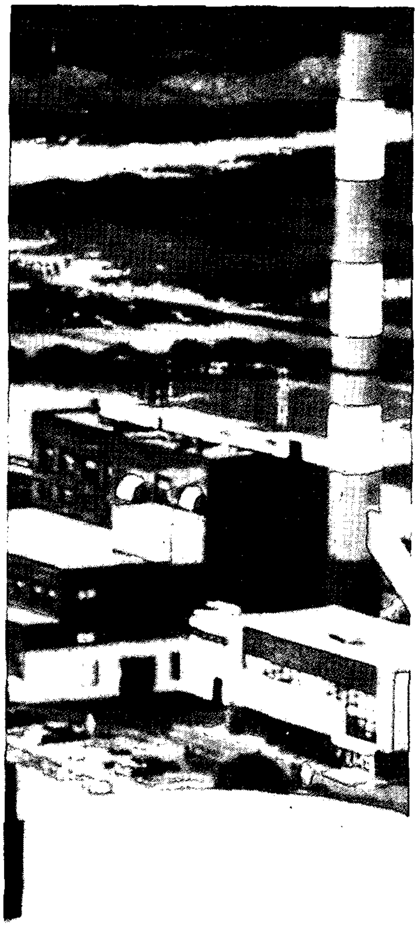

Environmental Codes of Practice for Steam Electric Power Generation - Decommissioning Phase

Report EPS 1/PG/6
November 1992

Canada

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ENVIRONMENTAL PROTECTION SERIES

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Abstract

The Environmental Codes of Practice for Steam Electric Power Generation - Decommissioning Phase is the fifth in a series of five documents developed for the steam electric power generation (SEPG) industry under Part I, Section 8 of the Canadian Environmental Protection Act. *This industry includes fossil-fuelled stations (i.e., those powered with wood, coal, oil, or gas) and nuclear powered stations. However, the Codes are only applicable to the non-radioactive aspects of nuclear-powered stations.*

This report outlines environmental concerns related to the decommissioning of SEPG stations and recommends practices intended to provide a framework for:

a) assessing the nature and extent of contamination, if any, to be considered in the development of a site decommissioning strategy;

b) evaluating alternatives for site remediation activity that will mitigate or eliminate the adverse environmental impacts associated with the decommissioning of SEPG facilities in whole or in part; and

c) ensuring that the decommissioned site is left in a condition suitable for future land use.

This Code was developed by a federal-provincial-industry Working Group and was subjected to a multi-stakeholder review before its publication. It is intended as an environmental standard for governments, industry, and the public.

Résumé

Le Code de recommandations techniques pour la protection de l'environnement applicable aux centrales thermiques - Phase de la mise hors service *constitue le dernier d'une série de cinq documents élaborés à l'intention de ces centrales thermiques conformément à l'article 8 de la partie I de la* Loi canadienne sur la protection de l'environnement. *Ces guides sont destinés tant aux centrales alimentées aux combustibles fossiles (c.-à-d. au bois, au charbon, au mazout ou au gaz) qu'aux centrales nucléaires. Toutefois, les codes s'appliquent seulement aux aspects non radioactifs des centrales nucléaires.*

Le présent code décrit des préoccupations environnementales en ce qui concerne la désaffectation des centrales thermiques et recommande des pratiques qui visent à assurer un cadre de travail en vue :

a) *de déterminer la nature et l'étendue de la contamination, le cas échéant, qui sera examinée dans le cadre de l'élaboration d'une stratégie de désaffectation d'un site;*

b) *d'évaluer les possibilités de rechange relativement à des activités de remise en état des sites qui serviront à atténuer ou à éliminer les effets environnementaux adverses liés à la mise hors service des installations thermiques en tout ou en partie;*

c) *de s'assurer que le site mis hors service est laissé dans un état convenable en vue de l'utilisation future du sol.*

Un groupe de travail constitué de représentants des gouvernements fédéral et provinciaux et de l'industrie a élaboré le présent document, qu'il a soumis à divers intervenants en la matière préalablement à sa publication. Ce code devrait servir de norme environnementale aux gouvernements, à l'industrie et au grand public.

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Glossary

The following definitions are valid for the purposes of this Code.

Aesthetic relates to the perception of a site as determined with the natural senses, i.e., sight, sound, taste, and odour.

Assess or Assessment means such investigations, monitoring, surveys, testing, and other information-gathering activities that are undertaken to identify:

(i) the existence, source, nature, and extent of contamination resulting from the placement or release of a hazardous material or chemical substance into the environment; and

(ii) the extent of danger to public health, safety, and welfare, as well as to the environment.

Background Concentration is the concentration of a chemical substance occurring in media removed from the influence of a steam electric power station at a specific site.

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

Contaminant means any solid, liquid, gas, or odour, or a combination of any of them that, if released or emitted in an uncontrolled manner, may have an adverse impact on the environment.

Criteria are numerical standards that are established for concentrations of chemical parameters in various media to determine the acceptability of a site for a specific land use.

Decommissioning is the closure of a facility, taking into account the long-term protection of the environment. This may include, on a site-specific basis, the removal of process equipment, buildings, and structures in an environmentally acceptable manner. Decommissioning may involve all or part of a steam electric power station. Remediation may be required to remove or contain chemical substances and hazardous materials from the environment or to render the site safe and aesthetically acceptable. Decommissioning may (but will not necessarily) result in a change in land use.

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

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

Hazardous Material is material that, because of its quantity, concentration, chemical composition, or corrosive, flammable, reactive, toxic, infectious, or radioactive characteristics, either individually or in combination with any other substance or substances, constitutes a substantial present or future threat to human health, safety, or welfare, or to the environment, if improperly used, stored, treated, handled, transported, disposed of, or otherwise managed.

Mothballing is the process of placing a facility in a protective state to enable its future reactivation. Mothballing may involve all or part of a steam electric power station.

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

Remediation means any measure or combination of measures proposed or undertaken to prevent, minimize, or mitigate damage to the public health, safety, and welfare, and to the environment, that could result from the presence of chemical substances, hazardous material, buildings, services, or structures located on a site. Remediation is carried out to render the site suitable for specified future land use(s).

Site means any land, buildings, structures, and associated pipelines, storage areas, production areas, shipping areas, and disposal areas where steam electric power is generated.

Synergistic Effect means the simultaneous action of individual contaminants which, together, have a greater total effect than the sum of the individual contaminant effects.

3R Management means following the principles of waste reduction, reuse, and recycling.

Section 1

Introduction

The Environmental Codes of Practice for Steam Electric Power Generation (SEPG) consist of a series of reports that identify good environmental protection practices for various stages of a steam electric power project. The Codes of Practice encompass the siting, design, construction, operations, and decommissioning phases of a project and deal with multi-media (air, water, and land) considerations. The Design Phase Code, however, deals only with water and land considerations; air emissions guidelines for new fossil-fuelled stations are included as an appendix in that report.

1.1 Scope

The steam electric power generation industry includes all facilities that use a steam cycle to produce electricity. This includes both fossil-fuelled (wood, coal, oil, and gas) and nuclear (CANDU) generating stations.

The Codes of Practice outline environmental concerns and alternative methods, technologies, designs, practices, and procedures that will minimize or eliminate the adverse environmental effects associated with steam electric generating stations. They also contain recommendations that Environment Canada considers to be reasonable and practical measures to preserve the quality of the environment which is affected by these stations. These recommendations may be used by the electric power industry, regulatory agencies, and the general public as sources of technical advice and assistance in the development and implementation of environmental protection practices and requirements.

The Codes are not regulations. They are being developed under the objectives, guidelines, and codes of practice provisions of Part I, Section 8, of the *Canadian Environmental Protection Act* (CEPA). While the Codes will help to achieve the CEPA objective of protecting Canada's natural environment, consistency with them does not remove obligations to meet other federal, provincial, or municipal standards.

1.2 Development

The Decommissioning Phase Code was developed in consultation with a federal-provincial-industry Working Group established by Environment Canada. The members of this Working Group were selected to provide appropriate expertise on SEPG decommissioning and environmental protection practices. The members are listed in Appendix A.

1.3 Code Structure and Application

The Decommissioning Phase Code outlines decommissioning activities (Section 2) and related environmental concerns (Section 3), such as waste containment, groundwater contamination, and the removal of buried services. Site remediation technologies and alternatives are outlined in Section 4 and an overview of the approach to developing site remediation criteria is given in Section 5. Specific recommendations regarding the mitigation of environmental impacts are presented in Section 6, as is the rationale for each of the recommendations. The recommendations are summarized in Section 7.

The Decommissioning Phase Code applies to all on-site facilities and many off-site activities (e.g., groundwater monitoring) associated with the decommissioning of steam electric power stations. It does not, however, address the decommissioning of off-site transmission and transportation systems or mining facilities that may have been associated with the station.

The fundamental principles embodied in the Decommissioning Code have been drawn directly from guidelines published by the Canadian Council of Ministers of the Environment (CCME, 1991). The Code is to be applied to all aspects of decommissioning fossil-fuelled steam electric power stations and to the non-radioactive aspects of decommissioning nuclear steam electric power stations. Radioactivity concerns are regulated by the Atomic Energy Control Board (AECB, 1988).

For the purpose of this Code, the decommissioning phase begins with the decision by the utility company to retire the station in question and continues through to the completion of all site remediation activity. *Planning for decommissioning* can begin at the early design stage in the life cycle of the station (e.g., by taking ecosystems into account when developing the site layout) and can continue throughout the construction and operations phases (e.g., by ensuring that appropriate waste disposal procedures are followed).

While Code recommendations are intended to be clear and specific about objectives, they have been formulated to facilitate the application of alternative technologies and practices that can achieve an equivalent or better level of environmental protection. They are not intended to stifle technology, creativity, or the benefit of experience with existing methodology. Indeed, continuing research, development, and demonstration of innovative and improved environmental protection practices are strongly encouraged by Environment Canada.

Section 2

Decommissioning Activities

2.1 Introduction

Fossil-fuelled steam electric power stations (SEPSs) generate electricity through the combustion of wood, coal, oil, or gas to produce steam, and then the conversion of energy. In 1989, 24.7% of the electricity generated in Canada originated at these facilities (CEA, 1990). Nuclear SEPSs accounted for 15.8% of electricity generated during the same period. All these facilities are listed in Appendix B.

While they are normally designed for an operating period of 30 to 40 years, the life span of SEPSs may be considerably extended by the operating history, fuel conversion, or upgrading activities. Nonetheless, a utility company will ultimately decide to shut down and retire the facility permanently.

The storage and handling of fuel and process chemicals, the generation and disposal of solid wastes (predominately coal ash), and the long-term operation of such station facilities as cooling water systems and buried services may introduce contaminants to site soils, sediments, surface water, and groundwater. The concentration of some contaminants may be significant enough to represent a risk to human health and safety and the environment, if a different land use were permitted before site remediation.

All site areas can be remediated to a level that will ensure the protection of public health, safety, and welfare as well as the environment. It may not be practically possible, however, to remediate the entire site to a level that would permit totally unrestricted land use, e.g., the relocation of an ash disposal area would not generally be a realistic expectation. For this reason, steps would have to be taken to ensure that appropriate restrictions are well documented and enforced.

When the decommissioning of a SEPS has been decided, the utility company should begin a logical process of evaluation and decision-making that will ultimately lead to a site which:

(i) minimizes risk to human health and safety;

(ii) minimizes environmental impacts;

(iii) complies with all applicable laws and regulations, i.e., is consistent with all applicable codes, guidelines and recommended practices, and complies with provincial and municipal land use requirements;

(iv) is suitable either for unrestricted land use or for the proposed land use;

(v) does not represent an unacceptable liability to present and future owners; and

(vi) is aesthetically acceptable.

The activities required to achieve these objectives are summarized in Subsections 2.2 to 2.8 (see also Figure 1).

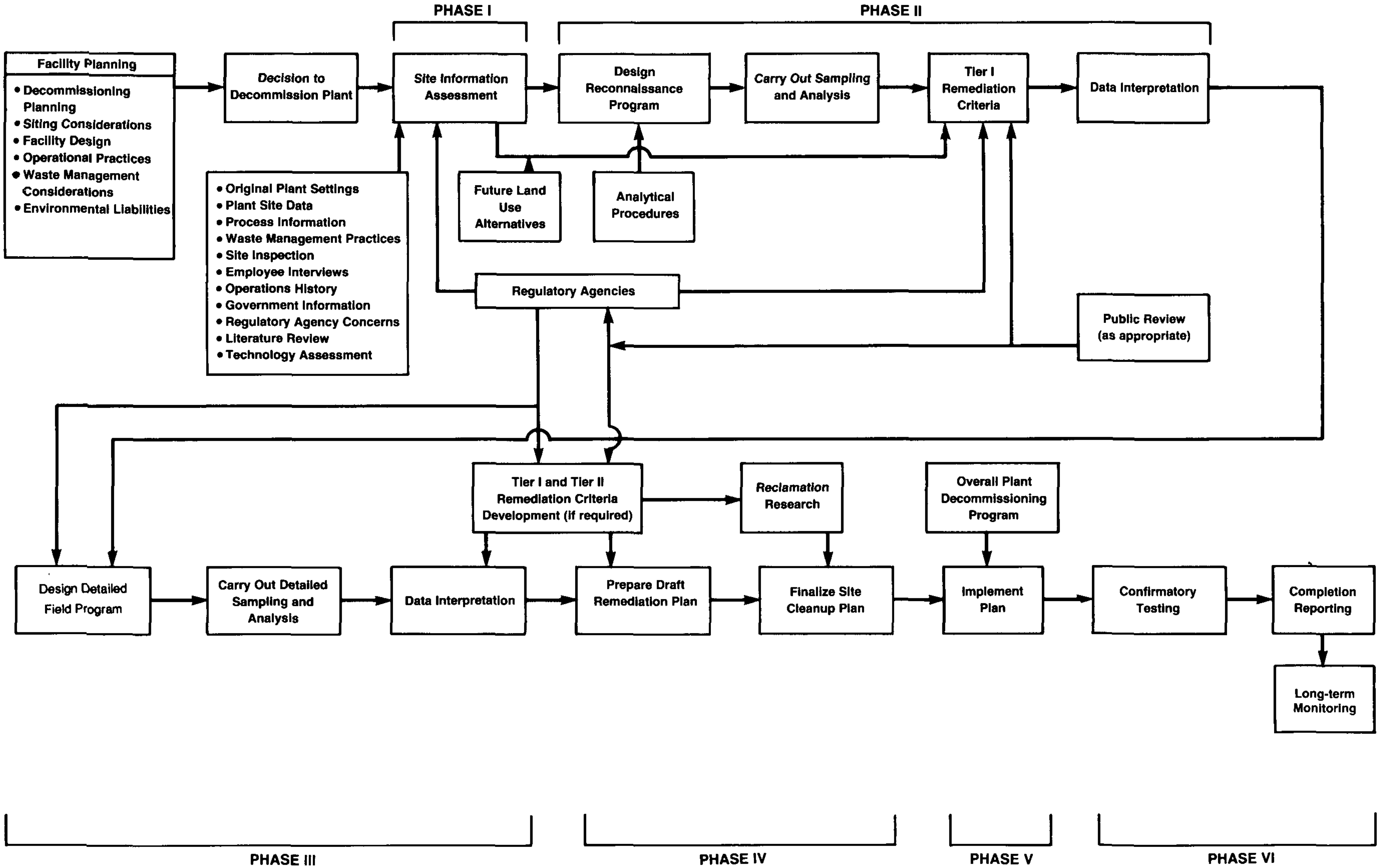

Figure 1 Overview of the Site Decommissioning and Remediation Planning and Implementation Process (Source: CCME, 1991)

2.2 *Decommissioning Planning*

The decommissioning of all SEPSs requires site remediation which follows the principles of waste reduction, reuse, and recycling in combination with the removal, treatment, and disposal of materials with levels of contaminants that exceed defined criteria. The level of cleanup is very site-specific and depends upon the operating history of the facility and regulatory requirements. In all cases, however, the fundamental objectives are to protect human health, safety, and welfare and to minimize adverse environmental effects.

Ideally, planning for decommissioning should begin at the Environmental Impact Assessment stage of a project so that early attention is paid to the development of facilities and procedures that provide for effective environmental protection throughout the entire life cycle of the station. However, it must be recognized that many of the Canadian SEPSs likely to be decommissioned over the course of the next two decades were constructed when environmental knowledge, concerns, and mitigation technologies were much less developed than they are today. In such cases, detailed planning can only be undertaken in the later operating life of the facility.

Regardless of when planning is initiated, its objective is to assess the existing environment and the options available for decommissioning so that preliminary estimates of the necessary work and time required to remediate the site can be developed. This, in turn, enables the utility company to plan for and commit the required organization and resources to manage the project.

The amount of work required to develop a decommissioning plan and undertake a decommissioning project depends on the age and operating history of the facility, the extent of (potential) site contamination, and the sensitivity of the local environment.

2.3 *Site Information Assessment*

The assessment of site information involves the evaluation of all available information related to the siting, design, construction, and operation of the station to determine areas of potential environmental concern. This includes a review of former site uses.

The assessment generally includes the collection and review of information related to the original and current plant setting, the design, and the operating history of all on-site facilities, material storage, handling and disposal practices, environmental incidents, and regulatory concerns.

The objective is to produce a site assessment report that can be used to establish a reconnaissance testing program.

2.4 *Reconnaissance Testing Program*

The main objectives of the reconnaissance testing program are to:

(i) identify the types of wastes and contaminants, as well as their quantities, range of concentration, and general location on the plant site;

(ii) identify potential off-site sources of contamination that may affect decommissioning;

(iii) clarify soil, geological, hydrogeological, and hydrological conditions of the site and surrounding area;

(iv) determine concentrations of contaminants in all media; i.e., air, water, and soil;

(v) investigate structures and facilities on site that, due to their physical dimensions, cannot be removed but require specific remedial measures to make the site safe for future beneficial land use;

(vi) identify materials that can be readily reused, recycled, or reduced in volume before disposal (3R management);

(vii) identify structures, process, or generating equipment that requires decontamination before removal, reuse, recycling, or disposal; and

(viii) provide the initial inputs to the assessment and identification of preliminary site remediation criteria.

Completion of the reconnaissance testing program generally represents a major decision-making point for the utility company in that it indicates both the degree of site contamination and the associated decommissioning cost. It defines the requirements of the detailed testing program.

2.5 Detailed Testing Program

A detailed testing program is required at most SEPSs to determine the degree and extent of site contamination. A follow-up may also be required to define special handling, cleanup, stabilization, or reclamation procedures for such on-site facilities as effluent treatment lagoons.

The primary objectives of the detailed testing program are to:

(i) quantify all wastes suitable for 3R management;

(ii) delineate the boundaries of areas found to be contaminated;

(iii) further define the physical, subsurficial (water and soil), and meteorological conditions of the site to assess contaminant movement along various pathways;

(iv) examine and define areas of unknown subsurface anomalies identified by remote-sensing or geophysical techniques;

(v) collect the structural and soil data required to clean, demolish, stabilize, and isolate site structures and deposits;

(vi) provide information about areas that were not accessible during the reconnaissance testing program;

(vii) provide more detailed data to assess the validity of the preliminary remediation criteria; and

(viii) provide the information necessary to assess the feasibility of various decommissioning and clean-up options available or required to attain the preferred land use.

The approach to the detailed testing program is similar to that of the reconnaissance program. However, since it is aimed at focussing on identified areas of contamination, more samples are typically collected from fewer locations. The series of contaminants for which the samples are analyzed is also likely to be scaled down as the field team focusses on site-specific parameters of concern.

The aims of the detailed test program are the resolution of site contamination, the definition of remediation criteria, and the preliminary identification of remediation technology options. However, generic Tier-I remediation criteria provided by the regulatory authority could offer a first and potentially feasible alternative to the development of site-specific criteria. The application of Tier-I and Tier-II criteria is discussed in greater detail in Subsection 5.2.

2.6 *Preparation of Decommissioning and Remediation Plan*

The decommissioning and remediation plan is a study of site remediation requirements and alternatives, each of which is evaluated in terms of effectiveness, practicality, and cost. The available alternatives and preferred approach are documented in a manner similar to that used for an environmental impact assessment report. They are generally circulated to interested parties in draft form. The final plan details the design of the actual facilities and procedures to be used in implementing the preferred approach and is subject to approval by regulatory authorities.

Preparation of the decommissioning and remediation plan can begin immediately upon completion of the site information assessment at plant sites where comprehensive waste management and site remediation activities have been conducted throughout the operating life of the station. At many sites, however, the lack of sufficient information may prevent the development of such a plan before completion of the detailed sampling program.

2.7 *Implementation of Decommissioning and Remediation Plan*

The relative complexity of implementing the site remediation and decommissioning plan depends on the nature and extent of site contamination and the defined site remediation criteria. This means that implementation of the plan must be adapted to each site.

Basic considerations and issues in the implementation of all plans are:

- permission by the appropriate regulatory authority for contractors involved in the handling of contaminated material to do so;
- a worker health and safety monitoring program;
- construction of containment and treatment facilities;
- management of surface drainage and wastewater;
- control of fugitive dust emissions;
- material removal and disposal following the principles of 3R management;
- removal and disposition of plant equipment following the principles of 3R management;
- cleaning and demolition of buildings;
- removal of buried equipment and services;
- excavation and disposal of contaminated soil and sediments;

- feasibility of *in-situ* stabilization of contaminated material;
- detailing of reclamation measures;
- in-program monitoring of contaminants; and
- post-remediation requirements, e.g., monitoring if contaminants have been left in place.

(Recommendations specific to each of these basic considerations and issues are presented in Section 6.)

2.8 Confirmatory Sampling and Completion Reporting

The final phase of plant decommissioning and remediation involves two principal activities:

(i) confirmatory testing of all areas to demonstrate that contamination has either been removed or effectively stabilized in accordance with the remediation criteria approved for the site; and

(ii) preparation of a project completion report that documents all of the decommissioning and remediation activities carried out as well as relevant monitoring data; it also includes as-built drawings for all completed works.

Owners of sites on which potentially hazardous material remains will likely be required to plan and implement a risk management program as well as a monitoring program which can demonstrate that the management objectives are being met.

The completion report is submitted to the regulatory authority for review and acceptance. Its acceptance means that the plant site has been remediated according to the remediation criteria and is at least acceptable for future land use.

Environmental Concerns

3.1 Introduction

The areas of potential contamination at a typical fossil-fuelled and a nuclear SEPS are shown in Figures 2 and 3. As noted earlier, both the number and significance of decommissioning issues that arise during the course of the process will be highly site-specific. However, it is possible to discuss approaches to general issues. For example, it is reasonable to assume that concerns about the integrity of waste disposal facilities justify carrying out site-specific investigations to demonstrate otherwise.

Some general environmental issues are discussed in this section.

3.2 Ash Disposal Areas

The generation of electricity from wood, oil, or coal produces fly ash, bottom ash, and boiler slag as by-products of the combustion process. Fly ash is a fine-grained, relatively light material that is discharged from the boiler as a component of flue gas and subsequently captured by some combination of mechanical cyclones, electrostatic precipitators, or baghouses. The larger, heavier ash particles either fall to the bottom of the boiler or are deposited on furnace walls and heat exchanger surfaces; ultimately they may be removed either in a molten state or in granular form. Molten materials are referred to as boiler slag, whereas the solid granules are called bottom ash. Generally, all of these materials derive primarily from the non-combustible mineral matter present in the original fuel. Fly ash generated by oil-fired plants, however, may contain unburned carbon concentrations of up to 50% or more.

Ash production and disposal are not issues of concern with gas-fired generating stations because there is virtually no incombustible matter in the fuel.

By-products of combustion are generally conveyed to a disposal area by way of either a wet (hydraulic) or a dry (pneumatic) ash-handling system. In wet systems, ashes are conveyed as a slurry to a settling lagoon where they separate by gravity, and the supernatant is either discharged (once-through system) or recirculated. In dry systems, the material is generally transported by conveyor or pipeline to a silo from where it is trucked to a landfill or exhausted mine pit or sold which is the case, for example, with fly ash used as an additive to cement.

The reclamation of ash-handling and disposal areas is one of the major concerns to be addressed during the development and implementation of decommissioning strategies for coal- and oil-fired power plants. Because ash is a high-volume solid waste that cannot be (practically) removed from the disposal area, it must be stabilized and secured on-site. Canadian electrical utilities produced approximately 55 Mt of coal ash between 1958 and 1986, virtually all of which was directed to disposal areas (Dearborn, 1989).

The primary concern associated with the decommissioning of ash disposal facilities

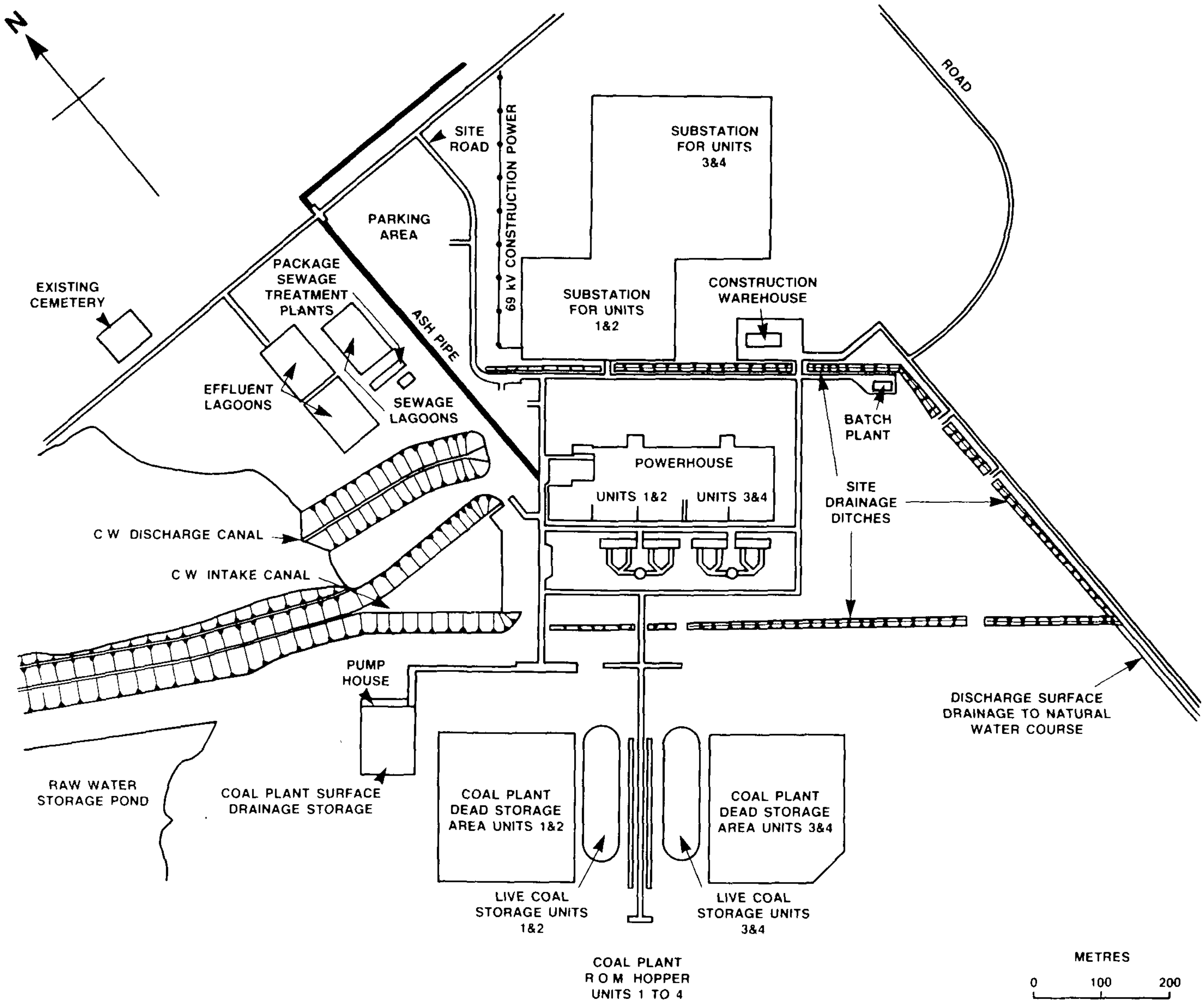

Figure 2 Typical Site Plan for a Fossil-fuelled Power Station

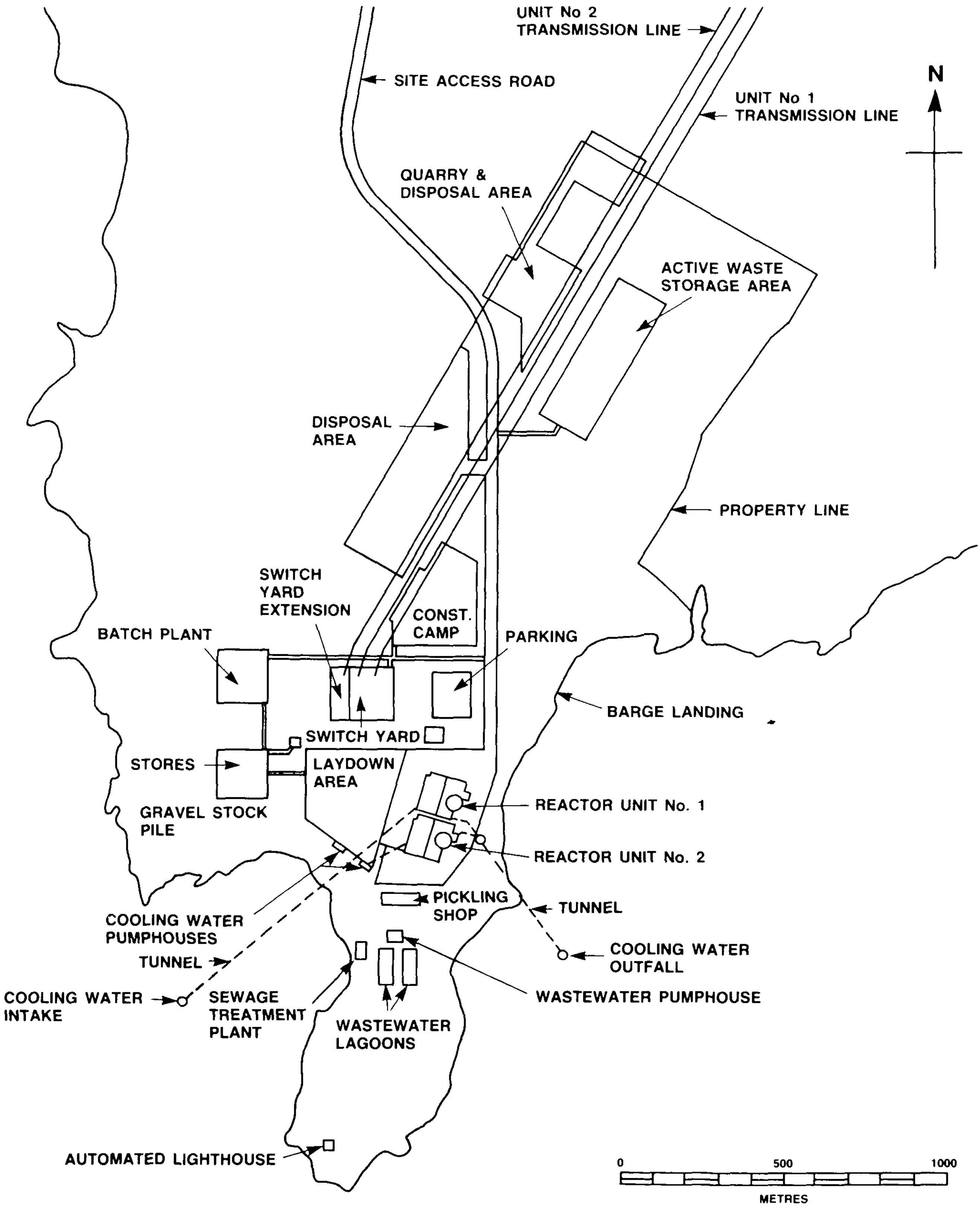

Figure 3 Typical Site Plan for a Nuclear Power Station

relates to the long-term potential of the materials to leach contaminants, most notably such heavy metals as copper, nickel, and zinc to local soil and groundwater. However, the contamination of surface water by site runoff, the lateral migration of contaminated leachate, or the continuing discharge of ash pond effluents must also be addressed, as must the physical stability of large ash deposits. Stability is of particular significance at plant sites with wet lagoons, since these deposits are often saturated, poorly compacted, and incapable of supporting building loads without excessive settlement.

Reclamation of at least the on-site disposal area(s) assumes a high priority in the development of a decommissioning strategy. The definition of future land use may be particularly significant in this regard, since these facilities typically occupy much more land than the operating station itself.

3.3 Solid Wastes from Sulphur Dioxide Control Systems

Flue gas desulphurization (FGD) systems are designed to remove sulphur dioxide (SO_2) from flue gas by its reaction with an alkaline reagent (sorbent) such as lime, limestone, or sodium compounds. The compounds formed in this reaction are either recycled to produce such marketable by-products as wallboard gypsum, or they are disposed of as waste containing some combination of calcium- or sodium-based reaction products, excess scrubbing agent, and fly ash. The disposal operations used at any individual site are generally similar to those used for the disposal of ash.

Although no FGD systems were operating in Canada when this Code was prepared, one unit was under construction as part of a new generating project in New Brunswick and three FGD units were being retrofitted to existing stations: one in New Brunswick and two in Ontario. High-calcium wastes can also be produced by the Furnace Sorbent Injection and Circulating Fluidized Bed Combustion SO_2 control technologies, facilities for which are now under construction in Saskatchewan and Nova Scotia, respectively. All of these systems either produce a marketable by-product or use dry waste-handling and -disposal operations.

The environmental concerns associated with the decommissioning of FGD waste disposal facilities are similar to those described in Subsection 3.2 for ash disposal, i.e., leaching of contaminants to soil and groundwater and contamination of surface water by site runoff. Two factors, however, should greatly decrease the significance of those concerns:

(i) Because of the relatively low concentrations of heavy metals of environmental concern, FGD wastes have a much lower leaching potential than most fuel ashes.

(ii) Perhaps most importantly, Canadian utility companies are now designing and constructing these disposal facilities in a manner consistent with Environment Canada's Codes of Practice (Environment Canada, 1985b and 1989), meaning that the above-noted environmental concerns should be addressed in the pre-operational stage of disposal site development.

Even though contaminant migration may not be a major issue for FGD disposal areas, the volume of waste involved could significantly affect future land use considerations for the plant site. For example, it has been estimated that a 500-MW coal-fired generating station could produce anywhere from 0.05 million and 6.9 million m^3 of waste over a 20-year period depending on coal characteristics and the type of FGD process used (Environment Canada, 1985a). Therefore, the environmental concerns associated with the volume of FGD wastes present on the site could be of the same general magnitude as those related to ash disposal.

3.4 *Waste Impoundments*

Various aqueous wastes are discharged from thermal generating stations, including metal-cleaning and water treatment wastes; boiler, ash-handling, and cooling system blowdowns; laboratory, floor, and yard drains; wastewater treatment effluents and sludges; and sanitary sewage and sludge.

In some cases, these wastes are directed to common or dedicated impoundments where solids settle as sludge and ultimately become a source of environmental concern when the station is decommissioned.

Although these concerns vary from one impoundment to another, the decommissioning of these facilities generally requires the appropriate handling and disposal of sludge, the protection or rehabilitation of groundwater, and the remediation of the underlying (contaminated) soil. Abandonment is not an option due to the chemical characteristics of most sludges and sludge-related wastewaters. Testing is required to determine whether the sludge(s) is (are) hazardous as defined by federal or provincial legislation.

3.5 *Fuel Storage Areas*

Coal-fired SEPSs maintain both "live" and "dead" coal-handling and storage areas on site. "Live" coal is used to meet the immediate and short-term fuelling needs of the plant, whereas "dead" coal is stockpiled for use when the fuel supply to the plant is interrupted for any reason. The areal extent of coal storage areas at Canadian plants typically ranges from 30 to 70 m^2/MW depending on the proximity of the station to the coal source. Compared to stations that rely on a remote fuel supply, mine mouth operations generally maintain much smaller on-site stockpiles (Monenco, 1988).

At oil-fired SEPSs, all fuel storage needs are typically provided by tank farms, the volume and area of which depend on the size of the station, its capacity factor, and the reliability of the source of supply. Most of these facilities consist of a series of above-ground vessels surrounded by perimeter dykes to contain spills and leaks. Many fuel storage and delivery systems, however, are supplemented by below-ground tanks and supply lines.

All SEPSs use various other petroleum products ranging from lubricating oils to boiler ignition and vehicle fuels. These systems frequently incorporate underground storage vessels and supply lines.

Soil and groundwater contamination that may result from coal pile runoff or leakage from underground petroleum storage tanks and lines are the major concerns related to the decommissioning of fuel storage systems. The extent of contamination associated with coal pile leachate and runoff is related primarily to:

(i) the nature of the coal stored, e.g., high-sulphur coals generally produce a more contaminated leachate than low-sulphur coals do;

(ii) whether the pile was underlain by an impervious liner; and

(iii) whether runoff collection and treatment facilities were operated throughout the existence of the station.

If the utility company has made a reasonable effort to clean up spills throughout the operating life of a station, oil contamination associated with above-ground storage systems is most likely confined to isolated pockets of relatively shallow soil. Contamination associated with underground storage systems has the potential to be much more significant, however, since relatively small leaks may have gone undetected for a considerable length of time and resulted in the sub-surface migration of a contaminant plume.

Also requiring attention are:

- contamination of soil in above-ground tank farms, particularly in those that were constructed with relatively permeable material such as sand;
- removal and disposition of any fuel stocks that remain after the plant has been shut down;
- removal and disposition of hydrocarbon sludge from heavy oil storage tanks;
- decontamination of storage tanks before their removal and disposition, and the handling of wastewater generated by this activity.

Once again, on-site testing will be required to determine the relative significance of these concerns.

3.6 Landfills

At many generating stations, one or more on-site landfills are maintained throughout their operating lives for solid waste disposal. These sites generally consist of unlined fill areas that are used until the space has been exhausted or is required for another purpose. At that time, the landfill is covered with native material and a new disposal facility is developed elsewhere on the site.

Landfill contents are often highly variable, particularly at older station sites, and may include domestic refuse; waste impoundment sludges; scrap equipment, piping, and construction debris; empty chemical containers; and small volumes of coal, ash, and oil-bearing waste.

The main concerns associated with the decommissioning of landfills are the determination of the exact nature of wastes that were placed in the facility throughout its operating life and the assessment of soil and groundwater quality in the site area. The contents of some landfills may require removal, segregation, treatment, or long-term monitoring. Even locating all of the landfills could prove to be a challenge at some station sites since record-keeping of this type was relatively poor before the 1970s.

Estimates of typical landfill volumes are extremely difficult to develop, given the wide variety of possible inputs, but a range of 1 to 10 m^3/MW/a has been predicted for a western Canadian coal-fired plant (Moneco, 1988). The lower end of this range is based on waste inputs consisting primarily of domestic refuse, empty chemical containers, and scrap steel, while the upper end is based on the assumption that most clarification/filtration sludges will also end up in the landfill site.

3.7 *Cooling Water Intake and Discharge Structures*

Cooling water is withdrawn from and returned to the water source (once-through systems) or evaporative heat exchanger (ponds or towers in recirculating systems) through intake and discharge structures. These structures may be located on the shoreline of the water body or may take the form of canals, channels, tunnels, or large-diameter buried conduits.

The primary environmental concern associated with the decommissioning of intake and discharge structures relates to the accumulation of sediment and its effect on biota and water quality. This is especially true of outfall structures and adjacent areas, since many wastewater streams may have been discharged through the cooling water system throughout the operating life of the station.

However, the high flow velocities that typify cooling-water outfall structures substantially limit solids accumulation at most plants. Therefore, limiting the impact of physical demolition activities is likely the only significant issue remaining after completion of on-site test work.

3.8 *Cooling Ponds*

Many generating stations in western Canada withdraw the main condenser cooling water (CCW) from a man-made reservoir or cooling pond. In most cases, the CCW is returned to the reservoir or cooling pond, which acts as an evaporative heat exchanger, for recirculation to the CCW intake of the station. However, there are also reservoirs that have been designed solely for the purpose of supplying water to the station. At these locations, CCW is continuously recirculated through a cooling tower and separate recirculating pond rather than through the supply reservoir. In both cases, CCW is discharged to the environment only as blowdown, evaporation, and seepage.

Sludge-like deposits eventually accumulate in these cooling and recirculating ponds as a result of the introduction of solids associated with make-up water, chemicals used for cooling water treatment, and wastewater streams that are discharged either to the CW outfall or to the pond itself.

It is difficult to generalize about the nature of these deposits since their composition depends on the number and type of wastestreams that were discharged at a particular pond location throughout the operating life of the station. The rate of solids deposition is also a factor, e.g., low velocity or dead areas of the pond may become sinks for wastewater solids. Characterization of the nature and extent of cooling pond sludge and the identification of specific environmental concerns requires a site sampling and analysis program. At a conceptual level, however, these concerns are similar to those associated with the decommissioning of waste impoundments.

Station decommissioning could very well result in the reservoir or cooling pond being retained in essentially the same state, at the same elevation, and with the same water volume as when the station was in operation. Even if this is the case, however, a concern that may arise at some locations is the impact of decreased water circulation, aeration, and heat input on the habitat and fishery that established itself in the reservoir during the operating life of the station.

3.9 Buildings

The disposition of buildings and other structures as part of the decommissioning process depends very much on the intended future land use and the level of contamination found during the sampling and analysis program. For example, structures such as the boiler house, turbine hall, cooling water pumphouse, water treatment plant, and administrative building may be demolished or simply cleaned in preparation for another utility occupant.

Whatever the intended use, however, several areas require investigation. Unused chemicals and reagents, petroleum products, and drums of waste material may be stored at various locations throughout site buildings. Many plant gutters, floor drains, sumps,.and underground services could contain residues that could pose a threat to human health or the environment in the event of an uncontrolled release or inappropriate disposal procedure. The same holds true of some process piping and equipment, e.g., that associated with the turbine lubrication and governing systems. Asbestos insulation was widely used in plants built during the 1940s, 1950s, and 1960s. Even the foundation backfill is a potential concern because it is generally a very porous material, such as gravel, that could provide a conduit for the migration of contaminants to groundwater.

The general condition of the structures and their associated services and foundation materials must be assessed to determine the nature and extent of required remedial measures.

3.10 Electrical Equipment

Much of the electrical equipment associated with the operation of a SEPS (breakers, transformers, capacitors, switchgear, etc.) contains a liquid dielectric. Some of this equipment may contain polychlorinated biphenyls (PCBs), particularly that manufactured before the 1979 Canadian ban on the sale of PCB fluids.

Clearly, the most significant concern associated with the decommissioning of electrical equipment in pre-1980 stations is the inadvertent handling or disposal of PCB-contaminated material and equipment. It is important, however, that all electrical equipment that contains a liquid dielectric be disposed of so as to minimize the potential for an accidental release to the environment. In most cases, this requires the verification of PCB content and the draining and rinsing of the equipment before disposal.

3.11 Miscellaneous Soil Contamination

Many areas around the general plant yard may have been contaminated as a result of inadvertent leaks and spills throughout the life of the station. This is particularly true of soil close to chemical and fuel transfer areas, yard drainage ditches, and any area used for interim outdoor storage of drummed materials.

Also of potential concern is (surficial) soil contamination associated with fugitive dust emissions from coal- and ash-handling and storage facilities, particularly if it involves off-site property.

All of these areas would normally be evaluated as part of the site-specific test program.

3.12 Site Restoration

This Subsection outlines concerns related to the dismantling and restoration of "clean" plant structures and equipment, i.e., it assumes that all of the contamination and land use concerns noted earlier have been addressed before restoration activities are initiated.

At most plant sites, restoration begins with the removal of process and generation equipment, piping, etc. and is followed by the dismantling of above-ground structures. Once the superstructures have been cleared away, the above-ground portion of foundations and stacks is demolished to grade by blasting. Below-grade foundations, structures, and services may be removed depending on the future land use. Those not removed are delineated on a revised site plan. The final step in the process is site levelling or recontouring.

The above processes generate various relatively inert waste materials, including assorted types of wire, structural steel, piping, metal cladding, insulation, and concrete rubble. Much of this material is potentially reusable or recyclable. Some of the process equipment may be relocated for use elsewhere in the utility, but most of it will probably be sold as scrap along with the waste steel. Most of the remaining material will be disposed of as waste in an approved landfill.

The restoration of sites close to populated areas may generate some secondary concerns related to the dust, noise, and vibration produced by the dismantling or demolition of structures. Increased road traffic, particularly that associated with the trucking of material to off-site salvage and disposal areas, may prove to be of concern to local residents.

While these concerns are relatively minor within the context of the overall decommissioning process, they are important components of the site decommissioning plan.

Remediation Technologies and Alternatives

4.1 Introduction

Site remediation technologies vary greatly in terms of the level of sophistication and cost required to achieve the specified level of remediation. An integral component of these remediation initiatives is the delineation of site contamination through the compilation and assessment of detailed site data.

4.2 Ash Disposal Areas

While the extent of remedial work required at ash disposal sites varies widely, most regulatory authorities require, at a minimum, that the site be revegetated, have stable slopes, and exhibit bearing capacities appropriate for the future land use. Clearly, additional measures are required if sampling data indicate that the existing site poses a threat to the quality of groundwater, surface water, or soil.

The potential for contamination of groundwater by ash site leachates can be minimized throughout the operating life of the station by ensuring that facilities are designed, constructed, and operated in a manner consistent with the Environmental Codes of Practice for SEPSs. The potential for contamination can be further reduced or eliminated by constructing an impervious cap over the site, collecting and treating contaminated groundwater, and containing the site.

Capping of the ash site with an impervious material would greatly reduce leachate volumes by preventing the infiltration of precipitation and, if supplemented by a soil cap, would also improve the bearing capacity and trafficability of the reclaimed surface. A vegetative cover could be added by seeding of the cap material to further reduce infiltration and prevent erosion. In some instances, it may be possible to establish a vegetative cover directly on the ash surface and thus realize both a sufficient reduction in leachate and an improvement in site stability.

If capping does not prove to be adequate with respect to the generation of leachate, it may be necessary to collect and treat leachate or contaminated groundwater. This could be accomplished by installing a series of interceptor drainage lines and recovery wells around the perimeter of the site and directing the leachate to an on-site treatment facility. Design of the treatment facility would be based on the contaminant(s) of concern but could include one or more of such methods as flocculation/precipitation, sedimentation, filtration, neutralization, and ion exchange (see Figure 4).

Containment could be achieved by:

(i) constructing an impervious slurry wall around the down-gradient perimeter of the site to the depth of the shallowest, naturally occurring impervious stratum (see examples in Figure 5); or

(ii) relocating the ash to an engineered, secure landfill.

The application of any containment alternative to a large ash disposal area would be very expensive and would normally only

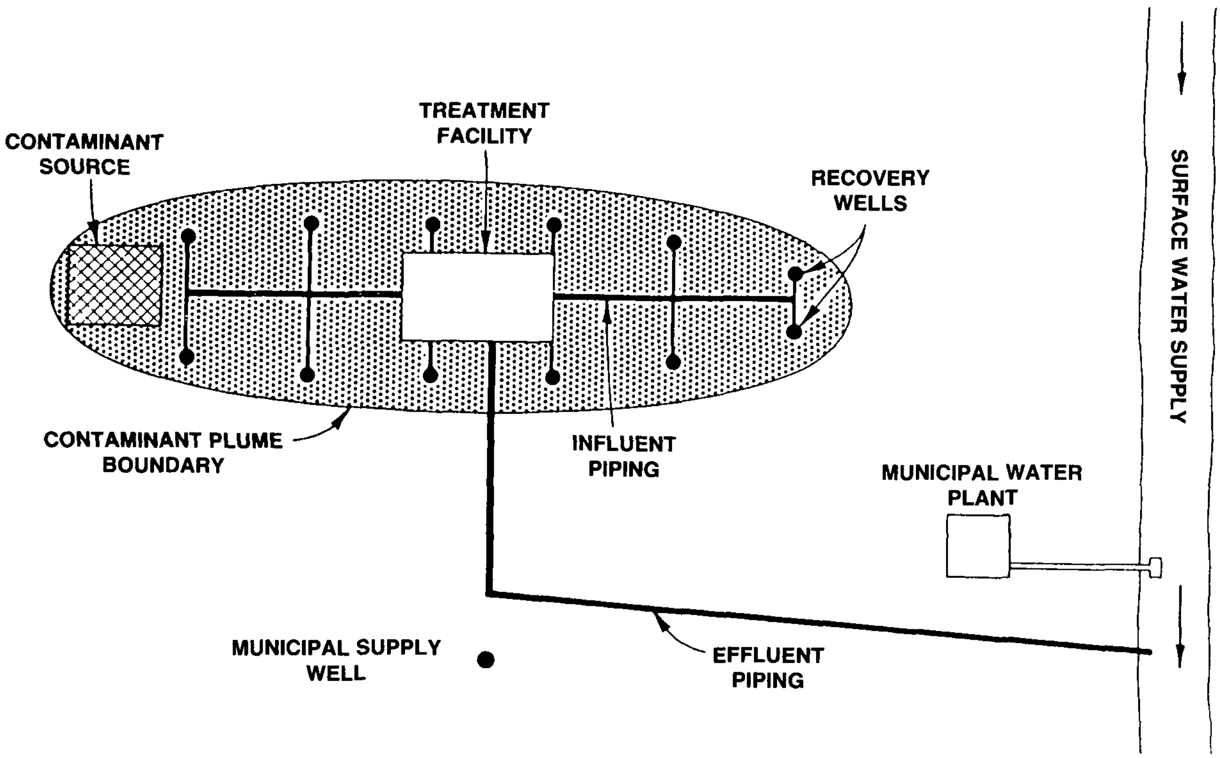

Figure 4 Conceptual Illustration of Groundwater Collection/Treatment System

be considered where problematic leaching is occurring in sensitive areas.

Surface runoff that contacts ash deposits has the potential to contaminate the natural drainage system, but can be effectively reduced by recontouring the site surface, constructing civil works that divert runoff around the site, and capping.

All visible accumulations of ash around the periphery of the site are normally removed and transported back to the disposal area. In some cases, the upper layer of the remaining soil may have to be amended to re-establish vegetation. A vegetative cover over the disposal site prevents further contamination of peripheral soils.

4.3 FGD Waste Disposal Areas

Decommissioning options for FGD disposal areas are very similar to those outlined for ash disposal. In both cases, the decommissioning strategy is directed toward the elimination of the site as a source of contamination, its physical stability, and the reclamation of groundwater, surface water, and soils affected by its operation. Again, the contamination potential can be minimized by measures implemented during the design, construction, and operating phases of the life cycle of the station, e.g., by using a dry- stacking rather than a wet-ponding disposal operation for FGD waste.

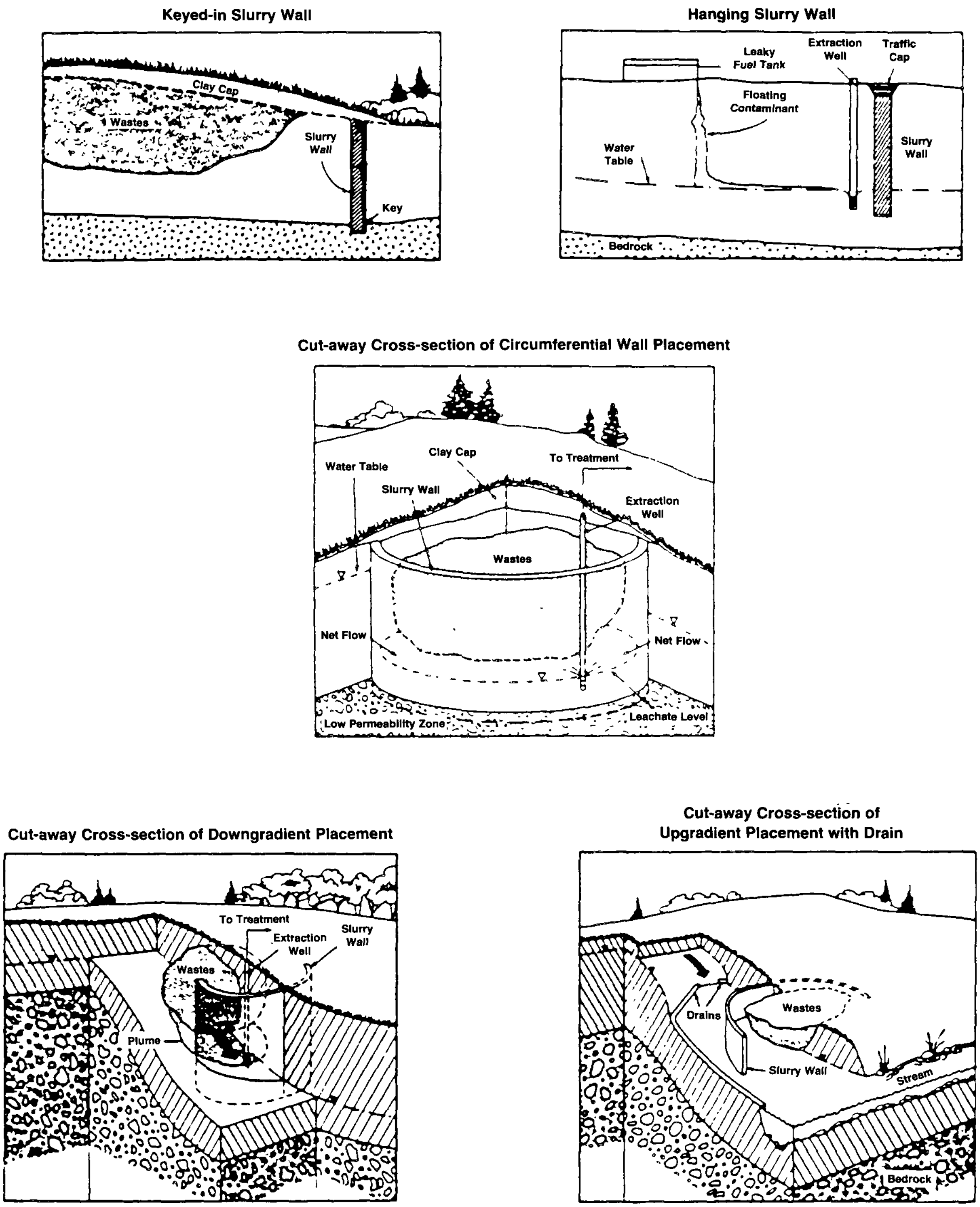

Figure 5 Slurry Wall Placement Options

4.4 *Waste Impoundments*

4.4.1 Sludge

A number of remedial measures can be applied to contaminated and thixotropic sludges. The method used depends on the nature of the contaminants, local groundwater and soil characteristics, and regulatory requirements. Bearing capacity and trafficability requirements of the proposed future land use would be additional considerations for thixotropic materials.

Possible options include excavation and movement of the material to an on-site containment cell or secure landfill, *in-situ* treatment, treatment followed by disposal in an on-site landfill, off-site disposal, treatment followed by off-site disposal, and excavation and incineration.

On-site disposal options are generally the most cost-effective in the short run but may leave the utility with an undesirable long-term liability.

At sites with favourable soil and groundwater conditions, it may be possible to dispose of lightly contaminated or thixotropic sludges in a common containment cell. The cell would be lined and capped with an impervious material, such as clay, and would be constructed so that its base would be above the maximum elevation of the groundwater table. This approach, although generally the least expensive of the on-site options, may not be appropriate for all sites and sludges.

Secure landfills are similar conceptually to containment cells but incorporate design features for the positive control of leachates. These features normally consist of multiple liners and leachate collection and treatment through a drainage layer placed between the waste material and the liner, or between the two liners. The choice of liner system is based on the nature of the waste, the consequences of a leachate breakthrough, regulatory requirements, and economics. Three possible liner concepts are shown in Figure 6.

Properly designed, installed, and maintained secure landfills could be used to dispose of most power plant sludges. However, sludges with a significant free-water content or high concentrations of mobile heavy metals may require treatment before disposal.

The treatment of sludges requires mixing of the material with a binding agent to reduce the leaching potential of undesirable contaminants. Treatment may also increase the bearing capacity of the sludge, e.g., admixing fly ash with other binding agents may resolve the concern about the stability associated with the disposal of most thixotropic wastes. Numerous fixation and solidification techniques could be used, but the cement- and lime-based processes are generally the most appropriate for power plant sludges, given their relatively proven performance, simplicity, and low cost.

In cement-based processes, Portland cement is added to the waste to produce a solid material with low permeability and high compressive strength. These processes are generally tolerant of chemical variations in the waste and particularly well suited to sludges with a high moisture content, since water is required for the reaction. Lime-based techniques combine lime, pozzolanic materials, and water with the sludge to produce a product similar to that produced by the cement-based processes. The potential advantage of this technique is that it may be possible to use fly ash as the pozzolan and thereby reduce treatment costs.

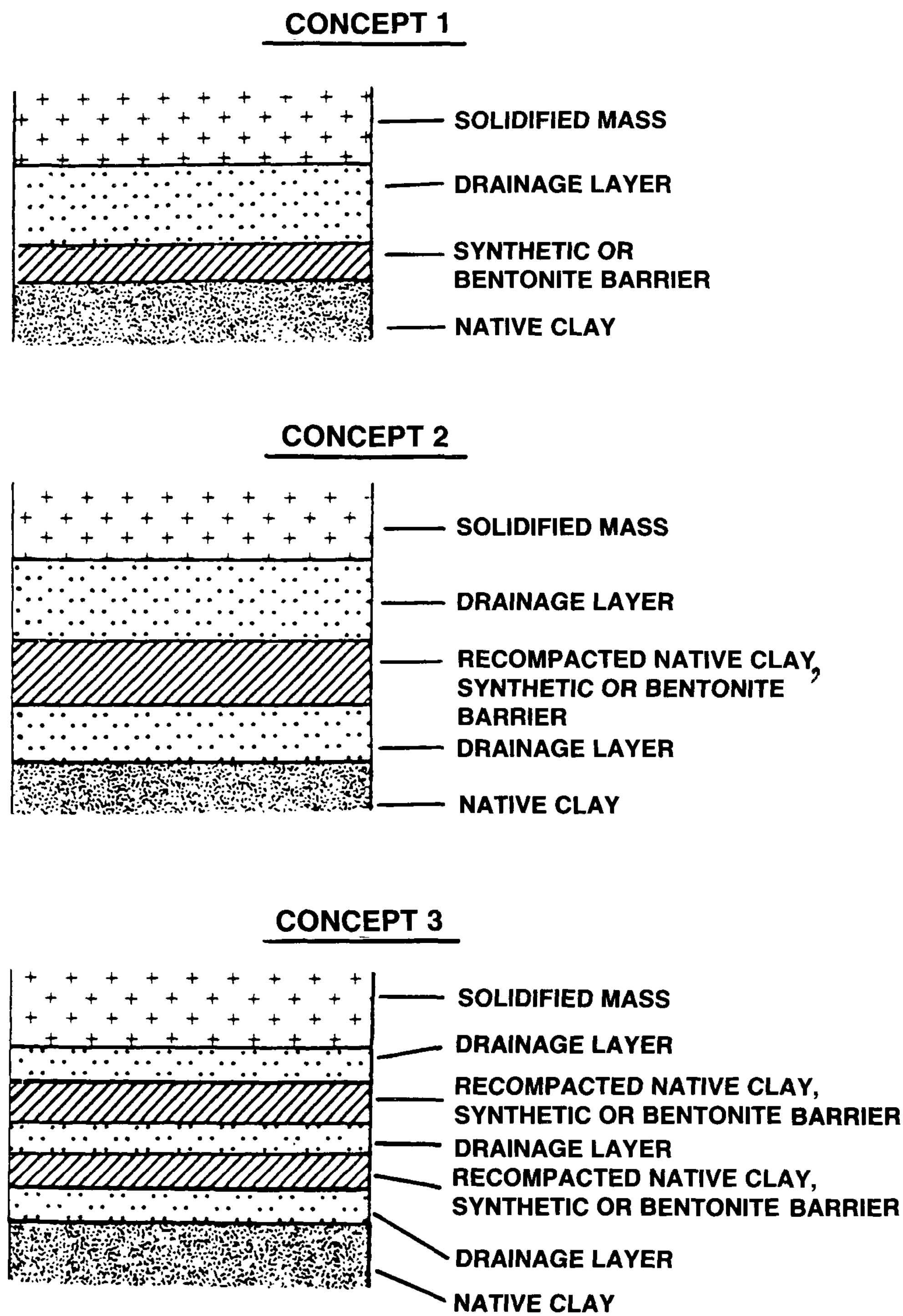

Figure 6 **Secure Landfill Liner Concepts**

Both techniques are effective for sludges with high heavy-metal contents.

In-situ treatment of sludge involves the use of specialized injection and mixing equipment at each impoundment. This equipment is generally provided and operated by a contractor who adjusts the treatment process for each individual sludge. *In-situ* treatment is appropriate where the resulting reduction in leachate volume and toxicity affords sufficient protection to groundwater without an impermeable liner. It may not be suitable for sludge that is underlain by permeable soil or situated in an area with a high water table.

Incineration is a process that involves high-temperature oxidation under controlled conditions to change hazardous substances into water vapour, CO_2, NO_x, HCl gases, ash, and slag. It requires flue gas treatment to prevent the release of potentially hazardous incineration products, such as particulate matter and HCl. Portable incinerators could be located on site to deal with organic wastes; however, the technology has limited application to inorganic contaminants and therefore has generally limited application to the decommissioning of power plants.

4.4.2 Soils

Contaminated soils underlying waste impoundments could be similar to sludge but have a much lower water content. Consequently, the remedial techniques suggested for sludge are also appropriate for contaminated soils.

The only significant concern with some soils may be the pH level. For acidic soil, reclamation could be undertaken by mixing it with an appropriate amender such as lime. To correct the pH level to a depth of approximately 30 cm, the amender can be mixed with conventional discing equipment. To correct deeper contamination, however, would require material excavation, treatment, and replacement.

4.4.3 Groundwater

There are essentially two ways of dealing with contaminated groundwater: collection and treatment, and containment. Either option can be carried out as outlined in Subsection 4.2 for ash disposal sites.

4.5 Fuel Storage Areas

The remedial techniques that can be applied to contaminated soils and groundwater underlying and surrounding fuel storage areas are similar to those outlined in Subsection 4.4. One additional approach that may be applicable to oil-contaminated soils is biodegradation.

Biodegradation is a process whereby microbes convert the hydrocarbons in oily wastes to carbon dioxide and water. This is generally accomplished by promoting the growth of indigenous microbes or by mixing specially cultured microbes, peroxide, and nutrients with the waste. Lime may also be added to minimize the solubility of any metals that may be present.

The suitability of biodegradation as a reclamation technique could be limited by the type and amount of contamination and the future land use. It must also be undertaken in accordance with the requirements of the regulatory authority and be capable of achieving specific, defined residual contaminant levels.

Given the potential cost savings and environmental benefits of avoiding excavation, this technology is worth considering.

4.6 *Landfills*

Once all site landfills have been located and their contents identified, waste disposal and site remediation can proceed in much the same manner as that described in Subsection 4.4 for waste impoundments. The main difference between landfills and impoundments is the non-compressive nature of many landfill wastes, such as old process equipment and piping. In addition, many materials not amenable to sludge treatment techniques would have to be segregated from the other landfill wastes, if some sort of waste fixation is required. On the other hand, it may be possible to recover, reuse, or recycle some material, e.g., scrap metal.

4.7 *Cooling Ponds*

For those sites where the cooling pond is to be permanently drained, the remedial measures described in Subsection 4.4 are, in most cases, directly applicable to pond sludge, soils, and groundwater. An advantage of this approach is that detailed sampling can be postponed until the pond base is dry, thereby facilitating the development of a more straightforward and less costly sampling program than would be possible for an undrained pond.

As mentioned earlier, however, it may be desirable to maintain the pond at more or less the same elevation and water volume as when the plant was operating. An important consideration in this regard is the impact that draining can have on the habitat established in and around the reservoir or cooling pond during the operating life of the facility. The fish habitat, fishery, and any wildfowl or wildlife activities dependent on these waterbodies could be severely affected by draining.

If the pond is drained, geotechnical investigations should be conducted on the pond embankments to confirm their integrity under drawdown conditions. The quality of the pond water should also be assessed to determine whether treatment is required before the water is released.

If a pond cannot be drained, some of the remedial techniques described earlier are not appropriate without modification. For example, submerged and saturated solids at the bottom of the pond are probably not amenable to *in-situ* treatment. In most cases, it would be more practical to remove the wastes with a suction dredge or crane-operated scraper and dewater them, before applying any other remedial technique(s). More definitive approaches to the remediation of undrained ponds would have to be developed on a site-specific basis.

4.8 *Buildings and Structures*

4.8.1 *Residual Chemicals*

Unused process chemicals and reagents can be returned to suppliers, relocated for use at another plant, offered for use through a waste materials exchange, or directed to approved facilities for disposal. The development of appropriate handling procedures for these materials is greatly expedited if chemical storage areas were well inventoried and documented during the latter stages of the plant's operating life. This is especially true of the plant laboratory which probably contains many hazardous and toxic chemicals, although in relatively small quantities.

4.8.2 *Gutters and Sumps*

The methods selected to remove contaminated sludge from gutters and sumps depend heavily on the physical consistency of the material. For example, fluid sludges could be removed with a vacuum truck and discharged to a treatment facility, whereas dry sludges would normally be removed manually. Some sludges could be too dry for efficient removal by suction alone or too wet for manual excavation in which case it might be necessary to use high-pressure wash water to create a slurry which can then be handled like a wet sludge.

Wash water, wet sludges, and slurries probably require dewatering to minimize the subsequent cost of treatment or disposal, and the centrate, supernatant, or seepage generated by the drying process normally require treatment before discharge.

The treatment and disposal alternatives suitable for dry or dewatered gutter and sump solids are similar to those described for waste impoundment sludges.

4.8.3 Asbestos

The following four basic remedial options can be used to control exposure to asbestos:

- **removal**, in accordance with strict occupational health and safety requirements, for ultimate disposal in an approved landfill;
- **encapsulation** of the material by coating it with a sealant;
- **enclosure** of the material by separating it with physical barriers from other building environments;
- **implementation of an administrative program** - no remedial techniques are applied but the area(s) is (are) inspected regularly for changes in exposure potential, and staff are trained in handling asbestos.

The most appropriate option for a given plant site is a function of the type and form of asbestos involved (this will generally require sampling and analysis), the extent of its use, its location, and perhaps most importantly, whether the future land use requires that the building be demolished. If the building and asbestos are both to remain, steps have to be taken to ensure that the indoor air quality is not compromised at any time after completion of the decommissioning process.

4.8.4 Buried Services

One of the major difficulties likely to be encountered when decommissioning buried services in general and drain lines in particular is to determine the nature and location of accumulated sludges.

Possible problem areas can often be identified by observing conditions in the gutter or sump serviced by a line. If solid volumes in the gutter or sump are significant, then sludge could very well be in the drain line. The chemistry of the sludge can be inferred from that of the related gutter or sump. Closed-circuit television can be used to inspect lines of relatively large diameter, and fibre-optic/boroscopic techniques can be used to inspect lines less than 150 mm in diameter.

If it has been determined that the accumulated solids in a buried line pose a threat to soil or groundwater, one of three remedial techniques can be applied: cleaning, sealing, or removal.

Cleaning could be undertaken hydraulically with high-pressure wash water or mechanically with “snakes” or “pigs”. A “snake” is a power rodding machine that pulls or pushes scrapers, augers, or brushes through the line. A “pig” is a bullet-shaped projectile that is hydraulically propelled through the line to scrape the interior pipe surface. Mechanical cleaning is generally followed by hydraulic scouring to clear loosened debris and sediments. Solids and wastewater collected during the cleaning process can both be handled in the manner already described for sludge from the gutter and sump.

Sealing (generally with concrete) is the simplest and least costly method of dealing with buried services but should only be undertaken on relatively small and clean lines whose presence will not interfere with the proposed future land use.

Removal of buried service lines may be dictated by the future land uses; but if required, it would normally be undertaken only where sealing is not deemed an appropriate alternative and cleaning is not feasible.

4.8.5 Foundations

The extent of foundation removal required depends on the proposed future land use and the degree to which contaminants have migrated away from and below the building floor elevation. If contaminants have affected the granular backfill underlying the structure as well as the surrounding soils, portions of the floor slab, grade beams, and some or all of the main supporting elements may have to be removed to provide access to contaminated material.

4.8.6 Cooling Water Structures

The removal or sealing of cooling water structures, particularly those located offshore, almost always involves some in-water construction or demolition. Dredging and in-water construction and demolition techniques must be carefully selected to minimize the disturbance of bottom sediments and the potential impact on fish and their habitat.

Further details on recommended practices are presented in Recommendations R407 (Dredging and In-water Construction) and R424 (Aquatic Life) of the Construction Phase of the Environmental Codes of Practice (Environment Canada, 1989).

Section 5

Development of Remediation Criteria

5.1 Introduction

The decommissioning of SEPSs in Canada is currently hampered by still-developing policy and procedures, and lack of precedent. A significant missing component of the decommissioning process is regulatory guidelines that identify "acceptable" levels of contamination. Most regulatory agencies have at least interim criteria in place, but validation of these criteria is ongoing. These guidelines will be used to assess on-site measures by serving as indicators of whether site remediation may be necessary and, if so, to what extent. They will also provide direction in the development and implementation of monitoring programs. Therefore, the proponent of a decommissioning project should contact the provincial regulatory authority early in the decommissioning process.

Numerous factors, some of them site-specific, must be considered when remediation criteria are being developed. In principle, the preferred approach is to use remediation guidelines that will permit the site to be returned to an unrestricted land use. However, while unrestricted land use may be an attainable goal for major portions of the site, it may not be a practical or feasible objective for some areas, most notably those which have been used for purposes of disposal. In all cases, regulatory authorities will seek assurance that the remediation to be undertaken will minimize the risks to human health and the environment during the future land use, and on that basis require that:

- site-specific criteria be risk-based; and
- the proponent justify any proposed departure from the target of unrestricted land use.

The major factors that should be considered in developing site-specific remediation criteria are:

- background chemistry of soil;
- concentration of on-site contaminants;
- environmental and human health toxicity of the contaminants;
- the amount and type of contaminated material;
- mobility of the contaminants and the migration pathways to points of human or environmental impact;
- synergistic effects of contaminants at the site;
- sensitivity of the surrounding environment;
- existing municipal and provincial land use requirements for the site and surrounding lands;
- adjacent land use and planned future use of the site;
- contaminant migration control mechanisms;

- aesthetics;
- public perception;
- potential contaminant treatment technologies; and
- cost.

5.2 *Preferred Approach*

The "National Guidelines for the Decommissioning of Industrial Sites" (CCME, 1991) recommends a 2-tier approach to the development of remediation criteria.

Tier-1 remediation criteria are generic values that are promulgated by the regulatory authority with jurisdiction. They are not site-specific. Rather, they approximate the acceptable concentrations of soil contaminants for all site conditions and land uses without defining actual risk.

Tier-2 remediation criteria are developed through a detailed assessment of the site-specific factors noted in Subsection 5.1. Tier-2 criteria would generally be applicable where contaminants are identified for which regulatory guidelines have not been developed, where background levels exceed Tier-1 guidelines, or where the attainment of Tier-1 criteria is either unnecessary or impractical. Tier-2 remediation criteria may include an evaluation of exposures through natural or engineered pathways.

At some sites, Supplementary Conditions may be required by the regulatory authority to complement remediation criteria when:

- factors such as available technology restrict the level of remediation;
- contaminants must be isolated on site; or
- long-term remedial action is required, e.g., cleanup of contaminated groundwater in fractured bedrock.

Tier-1 criteria would normally be applied during the planning and site assessment phases of the decommissioning process, whereas the development of Tier-2 criteria would normally be undertaken as part of a more detailed assessment of site-specific data.

5.2.1 *Tier-1 Criteria Development*

Tier-1 criteria are relatively conservative. They are not necessarily indicative of the final site-specific guidelines, i.e., they are generic and must be protective of all sites, including sensitive ones, therefore site-specific variables are not considered for them. However, they do provide a potential means of streamlining the decommissioning process by rationalizing the screen-out of any contaminants below the "acceptable" concentration. On the other hand, contaminants at higher than "acceptable" concentrations would require further evaluation, such as that described for Tier 2.

The comparison of the Tier-1 criteria with site data will indicate whether the site is contaminated, and if so, to what extent.

5.2.2 *Tier-2 Criteria Development*

The development of Tier-2 criteria is a relatively complex task in that it should take into account numerous site-specific factors related to environmental pathways, regulatory requirements concerning future land use, and the potential for and significance of human exposure. Important aspects of the Tier-2 process can be divided into five components:

(i) characterization of the environmental nature of the site in terms of soil, groundwater, meteorology, etc.;

(ii) characterization of the contaminants of potential concern in terms of quantity, environmental behaviour and mobility and the level of toxicological concern they pose to both human health and the environment;

(iii) prediction of the ultimate fate of contaminants by expanding upon measured data with calculations or predictive computer models;

(iv) identification of the future land use, municipal and provincial land use requirements of the site and surrounding lands, and the major features associated with that use, e.g., type of building; and

(v) characterization of the type of people who will use the site (e.g. adult staff or children) and their anticipated activities while on site, e.g., working indoors or playing outdoors.

This information would subsequently be used to determine the potential routes of exposure, the doses from each route, and the cumulative dose from all routes. "Acceptable" concentrations could then be established by determining the maximum concentration that would not exceed the "acceptable" dose. For the assessment of "acceptable" concentrations, a series of manual worksheets or a computer model, which effectively does the same sort of calculations, can be used.

One example of a predictive model is AERIS (An Aid for Evaluating the Redevelopment of Industrial Sites), which was developed under the auspices of the Decommissioning Steering Committee established by the CCME (CCME, 1990). The AERIS model consists of four basic elements: an "intelligent" preprocessor, component modules, a postprocessor, and supporting databases. The preprocessor takes the form of a series of questions that AERIS asks the user about the redevelopment scenario to be evaluated and is termed "intelligent" because of its use of "expert systems" technology.

The health-based concentrations generated by the Tier-2 process should be compared with Tier-1 criteria and adjusted as necessary to ensure that the "acceptable" concentrations are less than those associated with adverse environmental effects.

Contaminants that are subsequently detected in concentrations greater than these "acceptable" levels are then subject to either:

- remedial action to reduce their concentrations to the "acceptable" level; or
- further investigation to determine what control actions are required, e.g., development of a secure on-site landfill.

5.3 Supplementary Conditions

Many plant sites contain contaminated material that must remain *in situ*, because of its mode of occurrence, e.g., volume of disposed ash. At some sites, some remediation activity, e.g., stripping of hydrocarbons from groundwater, may be required for a period of time that extends well beyond the completion of all other decommissioning activities. In most of these situations, site use is restricted to some degree. Ongoing monitoring is required throughout the period of restricted use, and the utility company generally retains liability for whatever contaminants remain on the site.

The following are other factors to be considered during the process of developing remediation criteria:

- the desire of interested parties to provide input to the decision-making process;
- the need to develop a process that is viewed as being fair, adequate, and defensible;
- the need to produce results that are scientifically defensible and consistent with the intended objectives;
- the need to produce results that can be approved by the regulatory agency without undue difficulty, e.g., the process could be perceived as flawed if "acceptable" concentrations were identified that far exceeded background levels; and
- the need to address questions from the public about the potential long-term impact of site contaminants.

Such factors may have an impact on the establishment of final remediation criteria. It is important, therefore, that utility companies remain responsive to the different sensitivities, priorities, and perspectives that interested outside parties bring to the process.

Section 6

Recommended Environmental Protection Practices

6.1 Introduction

The decommissioning of SEPSs is likely to occur in the same basic sequence of stages as occurred during the construction and commissioning of individual units. Although some measures related to site remediation may be initiated when the first unit is permanently shut down, the implementation of many elements of the decommissioning program will not occur until all units at the station have been retired.

This Section is organized in the format of a decommissioning manual and outlines recommended mitigative measures for all decommissioning activities of significant environmental concern. As noted in Subsection 1.3, these recommendations have been formulated to allow for the implementation of remediation technologies and practices that may not be specifically mentioned in this Code but that achieve an equivalent, or better, level of environmental protection. Also, more stringent municipal, provincial, or legal requirements must be taken into account and satisfied where they exist.

The "Design Phase" of the Environmental Codes of Practice contains three series of recommendations numbered 100, 200, and 300. The recommendations in the "Construction Phase" of the Code comprise Series 400, and those in the "Operations Phase", Series 500 (Environment Canada, 1985b; 1989). The recommendations in this report comprise Series 600.

6.2 Decommissioning Planning

6.2.1 Scheduling of Decommissioning Activities

RECOMMENDATION R601. Planning for decommissioning should start in the design stage of the project life cycle for new stations and as early as possible in the operating stage for existing stations.

Rationale. Planning for decommissioning at the facility development stage highlights potential (decommissioning) problem areas and helps to identify system designs and operating procedures and practices that can prevent or reduce site contamination. It also enables the operator to demonstrate that a life-cycle approach is being taken to the development and long-term management of the facility.

6.2.2 Mothballing

RECOMMENDATION R602. Mothballing should not in any circumstance be used to avoid the implementation of decommissioning and remediation activities.

Rationale. The indefinite postponement of remediation and decommissioning activities results in the continued migration of contaminants, if and where they exist, and increases both the environmental impact and cleanup cost associated with the contaminant.

6.2.3 Minimum Requirements of the Decommissioning Plan

RECOMMENDATION R603. The following points should be identified as the minimum requirements of the site decommissioning plan:

(i) that implementation of the plan be undertaken in consultation with the appropriate regulatory agencies and the public;

(ii) that the plan assess or identify the measures required to protect potentially affected ecosystems throughout the decommissioning process;

(iii) that the long-term protection of potentially affected ecosystems be assessed within the context of future land use requirements;

(iv) that all structures that are not used during future land use will be removed or rendered stable;

(v) that all chemicals, raw materials, and contaminated material will be removed, treated, recycled, reused, disposed of, or secured, whether on- or off-site, to the extent necessary to ensure the attainment and maintenance of remediation criteria;

(vi) that access controls will be provided for all structures which will remain on-site that may be unsafe or hazardous to humans or animals;

(vii) that monitoring will be provided for all contaminant control, containment, or treatment systems remaining on-site;

(viii) that remediation of aesthetically unacceptable portions of the site will be undertaken;

(ix) that site remediation will be undertaken to a level and in a manner that will provide long-term environmental protection and ensure safe future use;

(x) that all contaminants, wastes, and structures left on-site that restrict future land use or require periodic monitoring will be registered on the property title in a manner that meets with the approval of the appropriate provincial and municipal regulatory authorities;

(xi) that implementation and execution of the plan will require the submission of written reports to the appropriate regulatory authorities;

(xii) that all work will proceed under appropriate legal authority and in accordance with all applicable legislation; and

(xiii) that every reasonable effort will be made to employ the principles of 3R management to reduce waste disposal quantities.

Rationale. Involvement of the regulatory agencies is essential since regulatory compliance and land use are controlled by these bodies. The removal of structures and provision of access controls for those structures that remain are required to ensure safety during future use. The removal, containment, treatment, and monitoring of contaminants are required to ensure the long-term environmental integrity and safety of the site. Aesthetic remediation ensures that the facility does not become an "eyesore" to the public. The formal recording of restrictions on the property title helps to ensure that the site or portions thereof are not used in an inappropriate manner. Submission of regular reports on the decommissioning process and, where applicable, on monitoring after completion, forms the basis of regulatory approvals and public information exchange.

6.3 Site Information Assessment

6.3.1 Project Management

RECOMMENDATION R604. A manager should be assigned to the decommissioning project at the site information assessment stage.

Rationale. The conduct of a decommissioning project requires the same basic approach as that used in the design, construction, and commissioning of a new facility. The early assignment of a project manager will facilitate the coordination of project activities and the provision of required resources in a timely manner in the event that unforeseen contamination problems are encountered on the site.

6.3.2 Maintenance of Operations Facilities

RECOMMENDATION R605. An assessment of the operating station's infrastructure and facilities should be undertaken in advance of implementing the decommissioning plan to determine what facilities should remain in place once "normal" operations have ceased.

Rationale. The premature termination of plant operations such as site security and wastewater treatment could jeopardize the continuation of processes and procedures necessary to minimize the impact of the station on the environment.

6.3.3 Information Required for the Conduct of the Site Assessment

RECOMMENDATION R6O6. The following information, where available, should be examined by utility companies as they prepare documentation for the site assessment:

(i) all previous environmental assessments completed for the property, including well drilling and geotechnical reports;

(ii) aerial photographs;

(iii) topographic maps and site drainage plans including areas of fill or watercourse alteration;

(iv) water quality records for both surface water and groundwater;

(v) site climatological data (e.g., wind rose);

(vi) interviews with employees;

(vii) plant construction specifications, plans, and drawings;

(viii) piping schematics and plans;

(ix) drawings, specifications, and inventories of fuel and chemical storage areas;

(x) drawings, specifications, and monitoring data for all waste storage, treatment, and disposal areas;

(xi) all waste manifests and reports of environmental incidents and spills of hazardous material;

(xii) drawings or diagrams of all underground utilities, structures, storage tanks, and wells, as well as their operational history;

(xiii) laboratory operating practices;

(xiv) information on all electrical equipment that may contain a liquid dielectric;

(xv) pest and weed control practices utilized on-site including types of chemicals used, application areas, and disposal practices;

(xvi) a physical inspection or audit of the site by trained specialists;

(xvii) pertinent regulations promulgated by agencies responsible for environment, health, labour, and natural resources, as well as municipal bylaws that may be applicable to the site;

(xviii) previous decommissioning experience at other facilities;

(xix) information available from long-term residents in the area;

(xx) local newspaper articles and other archived material on the facility; and

(xxi) environmental audit reports.

Rationale. Any or all of these sources could assist in defining the pre-operational environmental background of the site and identifying potential areas of contamination that should be evaluated during the reconnaissance testing program.

6.3.4 Preparation of a Site Assessment Report

RECOMMENDATION R607. A site assessment report containing the following elements should be prepared for submission to the appropriate regulatory authority:

(i) a description of:

- the site and its surroundings,
- its facilities,
- its operating history, and
- its waste disposal practices;

(ii) potential problem areas and contaminants of concern;

(iii) health and safety considerations that are important to the conduct of decommissioning;

(iv) areas, if any, requiring immediate action and the proposed interim actions, e.g., for a leaking underground storage tank;

(v) proposed site assessment investigations;

(vi) proposed land use options for the site if unrestricted land use cannot be achieved;

(vii) plans for a public consultation program;

(viii) an assessment of the environmental impact of the decommissioning process itself; and

(ix) a preliminary decommissioning schedule.

Rationale. The submission of this information should provide the regulatory authority with sufficient information to formulate a position on the utility company's proposed decommissioning plan or identify additional areas and concerns it would like to see addressed during the conduct of site investigations.

6.4 The Reconnaissance Testing Program

6.4.1 Initial Planning

RECOMMENDATION R608. The reconnaissance testing program should be developed so as to target:

(i) suspected areas of contamination identified during the site information assessment;

(ii) site boundaries in proximity to areas where the potential exists for contamination to move off site (e.g., groundwater, soil carried off site by wind or runoff);

(iii) structures and wastes whose removal appears to be impractical or difficult; and

(iv) areas that may be physically unstable.

Rationale. Targeting of these areas will help to characterize the nature of site contamination and probable cleanup problems and priorities at an early stage of the decommissioning project.

6.4.2 *Program Design and Review*

RECOMMENDATION R609. The proposed reconnaissance testing program should be reviewed with the appropriate regulatory authority before its implementation.

Rationale. The regulatory agency will want to ensure that all relevant codes, regulations, guidelines, etc. are addressed by the program.

6.4.3 *Program Implementation*

RECOMMENDATION R610. Implementation of the reconnaissance testing program should include:

(i) the development of a well designed and organized sample collection, preservation, storage, transportation, and chain-of-custody system;

(ii) the distribution of written sampling and analysis protocols to all appropriate staff and external consultants involved in the program; and

(iii) a procedure for expanding upon the sampling program if or as potential problem areas are identified by field personnel.

Rationale. Management of the significant number of samples generated at a typical plant site could be problematic without the implementation of a pre-determined system, particularly when follow-up is required. The application of sound sampling and analysis protocols is crucial to ensuring the consistency of data. It is also more cost-efficient to undertake additional sampling while the initial field team is on site.

6.4.4 *Compilation and Presentation of Data*

RECOMMENDATION R611. The results of the reconnaissance testing program should be presented to the appropriate regulatory authority in a report that:

(i) identifies the types and concentrations of contaminants in soils, sediments, surface water, and groundwater on and adjacent to the site;

(ii) identifies possible pathways of contaminant movement as well as potential receptors and exposure points;

(iii) compares contaminant data with Tier-1 criteria;

(iv) identifies areas and structures that require remediation for the future land use, e.g., problems regarding physical stability;

(v) identifies and quantifies the potential for waste recycling; and

(vi) recommends additional work, where and as necessary, to better quantify site cleanup, reclamation or long-term monitoring requirements.

Rationale. This information is required to enable both the proponent and the regulatory authority to determine the appropriate level of follow-up action required for specific areas of the site, or more specifically to determine whether:

(i) contaminant levels are below Tier-1 criteria, there is no risk to the environment or public health and safety, and sufficient information is available to proceed with the development of a detailed decommissioning plan;

(ii) contamination is present at concentrations exceeding Tier-1 criteria, but not at levels considered to pose an immediate threat to the environment or public health and safety; further assessment is required to quantify risks before preparing the decommissioning plan; and

(iii) contamination, facilities, or structures are present on the site that pose an immediate threat to the environment or human health and safety - immediate action and further assessment are required.

In summary, this report would form the basis for proceeding with the development and approval of the detailed testing program.

6.5 Detailed Testing Program

As noted in Subsection 2.5, the general approach to the detailed testing program should be like that of its predecessor, in other words, the principles described in Subsection 6.4 for the reconnaissance testing program also apply to this phase of the decommissioning program. Additional considerations are presented in Subsections 6.5.1 and 6.5.2.

6.5.1 Program Planning

RECOMMENDATION R612. The detailed testing program should be developed in a manner which ensures that:

(i) all media, i.e., soil, water, concrete, etc., identified as being contaminated in excess of the Tier-1 criteria are resampled in sufficient detail to accurately define the extent and level of contamination;

(ii) all structures, deposits, and facilities identified as having the potential for physical instability are examined in sufficient detail to define the level of remediation required to ensure long-term stability; and

(iii) the program team follows the sampling and analysis procedures and protocols which were used in the reconnaissance testing program.

Rationale. Contamination has to be quantified before the utility company can proceed with the development of specifications for the site remediation plan and associated tender documents. Using the same procedures and protocols helps to ensure that representative samples are collected and that scientifically defensible comparisons can be made among data sets.

6.5.2 Preparation and Presentation of the Program Report

RECOMMENDATION R613. The results of the detailed sampling program should be presented to the appropriate regulatory authority in a report that:

(i) delineates those areas of the site where contaminant levels exceed the Tier-1 criteria;

(ii) determines the volume of contaminated material by media and type;

(iii) determines whether contamination is underneath structures that will remain on-site;

(iv) identifies the extent of surface and groundwater contamination (if any) and projects its future migration;

(v) identifies any off-site contamination concerns;

(vi) characterizes the physical and chemical properties of all liquid and solid wastes that will have to be removed, handled, stabilized, treated, or disposed of;

(vii) assesses the environmental impact of leaving or remediating contaminants on-site;

(viii) determines, to the extent practical, the current and predicted exposure point concentrations of contaminants of potential concern; and

(ix) identifies the technological options for and feasibility of remediating the site to meet Tier-1 criteria.

Rationale. The objective of the detailed testing program is to define site remediation criteria, and these criteria could have a major impact on the final decommissioning cost. Social and environmental impacts have to be put into the perspective of the technical and economic feasibility of site-specific remedial options. The result may be either the imposition of relatively expensive remediation technology or the identified need to modify the remediation criteria or the initially proposed end land use. Regulatory involvement in this process helps to ensure that the expectations of all concerned parties reflect both the complexity of the problem and the feasibility of the various remediation actions.

6.6 *Preparation of the Decommissioning and Cleanup Plan*

6.6.1 *The Role of Future Land Use*

RECOMMENDATION R614. The ideal goal of the decommissioning and remediation plan should be unrestricted future land use but in every case site remediation activity should ensure the long-term protection of human health, safety, and welfare, as well as the environment, to the degree required by the planned future land use.

Rationale. Unrestricted future land use requires the imposition of the most stringent remediation criteria to arrive at the "cleanest" site. As noted previously, however, unrestricted land use may not be required or may not be feasible, in which case, efforts must be focussed on the effective containment, treatment, and monitoring of on-site contaminants.

6.6.2 *Presentation of a Report on the Plan*

The decommissioning and remediation plan provides an assessment of the technological options that can remediate contaminated areas of the site to the criteria defined as a result of the detailed test program. Environmental effectiveness, technical feasibility in light of site-specific constraints, and cost are included in this evaluation.

RECOMMENDATION R615. A draft decommissioning and remediation plan should be provided to the appropriate regulatory authority. This plan should:

(i) summarize data on contaminants present in concentrations in excess of the Tier-1 criteria;

(ii) identify, delineate, characterize, and quantify materials to be removed for recycling, reuse, treatment, or disposal;

(iii) identify, delineate, characterize, and quantify materials to be remediated on-site as well as summarize the possible remediation alternatives and their implications;

(iv) describe and rationalize the methods proposed for site remediation, e.g., technical feasibility and cost;

(v) propose a schedule of work;

(vi) discuss how the remediation plan is to be integrated into the overall site decommissioning process;

(vii) summarize the worker occupational health and safety plan;

(viii) discuss how any residual contaminants affect future use of the site (if at all); and

(ix) identify any long-term monitoring provisions or restrictions on future land use that may apply to the site.

Consultation regarding this draft report should be followed by the submission of a final report to the appropriate regulatory authority that provides a detailed design of all waste management, cleanup, containment, reclamation, and monitoring plans.

Rationale. The consultation process and the submission of a report on the plan are the basis on which regulatory approval for decommissioning is granted.

6.7 Implementation of Decommissioning and Remediation Plans

6.7.1 Handling of Contaminated Material by Contractors

RECOMMENDATION R616. All external contractors involved in the removal, treatment, or final disposition of contaminated material should be licensed or otherwise approved for such work by the appropriate regulatory authority.

Rationale. The contracting of services involving the handling of contaminated material to approved contractors helps to ensure that all remediation and disposal activities are undertaken in accordance with applicable regulatory requirements.

6.7.2 Construction and Inspection of On-site Containment Facilities

RECOMMENDATION R617. Before removing any contaminated material that is to be contained or otherwise treated on-site, the proponent should:

(i) construct and inspect the containment or treatment facilities to ensure that the requirements of approved plans and specifications are met;

(ii) install all monitoring devices associated with the containment or treatment facility.

Rationale. Removal of contaminated material before the development of appropriate remediation facilities can result in the unnecessary contamination of other site areas. Monitoring of the facility should start immediately upon the placement of material.

6.7.3 Consistency with Environmental Codes of Practice

RECOMMENDATION R618. The siting, design, construction, and operation of all on-site facilities developed in association with decommissioning projects should be undertaken in a manner that is consistent with the intent of Environment Canada's "Environmental Codes of Practice for Steam Electric Power Generation".

Rationale. The Codes are not regulations (see Subsection 1.1). However, their application will minimize or eliminate the potentially adverse environmental effects associated with the development of new facilities and they could provide useful guidance in the development of long-term monitoring programs.

6.7.4 Removal and Disposition of Material and Equipment

RECOMMENDATION R619. To the extent practicable, proponents or their contractors should:

(i) dewater sludge and similar residues and undertake final disposal in accordance with all applicable codes, guidelines, regulations, and legislation;

(ii) treat wastewaters derived from sludge-dewatering and the cleaning of plant sumps and gutters in an on-site facility;

(iii) drain all free-flowing liquid from equipment before its removal for sale, scrapping, or disposal;

(iv) drain, vent, and purge all tanks and piping before its removal; and

(v) sample and analyze all unlabelled, liquid-filled electrical equipment for PCB content before removal.

Rationale. Sludge-dewatering increases physical strength and reduces bulk and treatment cost. All wastewaters should be directed to a treatment facility before release. Draining of equipment, vessels, and piping minimizes the potential for leakage during removal and transport. Unlabelled electrical equipment may be PCB-contaminated and, if so, must be handled in accordance with federal and provincial regulations.

6.7.5 Removal of Buried Equipment and Services

RECOMMENDATION R620. To the extent practicable, proponents or their contractors should:

(i) drain, purge, excavate, and dispose of all underground storage tanks;

(ii) excavate and remove buried drums for treatment, destruction, or disposal, unless drum contents can be verified and it can be demonstrated that leaving the material *in situ* does not pose an unacceptable environmental risk;

(iii) drain, purge, and excavate all buried services that will not be required in the future land use unless it can be demonstrated that leaving the lines *in situ* is no more detrimental environmentally (the latter approach will normally apply only to relatively small, clean lines);

(iv) treat all drains, purges, etc. in accordance with the requirements of all applicable codes, guidelines, regulations, and legislation.

Rationale. Most underground services and drums will very likely be subject to long-term structural failure.

6.7.6 Excavation of Contaminated Soil and Sediment

RECOMMENDATION R621. Before commencing any site excavation activity, the proponent should implement a site materials and traffic movement plan that ensures, to the extent practicable, that:

(i) contaminated soil is excavated in lifts with periodic sampling and analysis to monitor the progress of contaminant removal;

(ii) contaminated soil is segregated from uncontaminated material;

(iii) excavations are not backfilled until sampling and analysis have been completed; and

(iv) material used for backfilling is verified to conform with the established cleanup criteria before its placement.

Rationale. Excavation in lifts in conjunction with regular monitoring minimizes the amount of material that must be removed. Items (ii), (iii), and (iv) are intended to minimize the potential for cross-contamination of clean material.

6.8 Confirmatory Sampling and Completion Reporting

6.8.1 Sampling and Analysis

RECOMMENDATION R622.
A confirmatory sampling and analysis program should be developed and implemented in accordance with the following general principles:

(i) testing of "cleaned" or treated materials as distinct phases of the remediation plan are completed;

(ii) sampling and analysis of soil from contaminated zones and adjacent areas;

(iii) installation and sampling of piezometers in all areas where the depth of contaminated soil exceeded that of the water table or where the water table was previously found to be contaminated;

(iv) analysis of adjacent bodies of surface water;

(v) examination of groundwater quality in immediate proximity to containment cells and secure landfills; and

(vi) monitoring of all air quality parameters identified as potential concerns during the course of the detailed testing program.

Rationale. The conduct of this test work determines the areas where decontamination has been effective, i.e., required remediation criteria have been achieved, as well as those areas requiring further remediation or long-term monitoring. It is also the sole basis on which proponents can proceed with the development of a project completion report.

6.8.2 Recommended Elements of the Project Completion Report

RECOMMENDATION R623. A project completion report should be prepared for submission to the appropriate regulatory authority and should include, but not necessarily be limited to:

(i) a physical description of the site and its operational history;

(ii) a description of areas of contamination and contaminated materials on-site;

(iii) a summary of the approved remediation criteria for the site;

(iv) a description of all on-site structures that had to be decontaminated, isolated, stabilized, or demolished;

(v) a description of all demolition, remedial action, and cleanup work carried out;

(vi) as-built drawings of the decommissioned site;

(vii) the identification of all disposal and controlled access areas remaining on-site;

(viii) a description of all ongoing treatment programs at the site;

(ix) a description of the proposed future land use for the site;

(x) the identification of conditions on-site that restrict land use and an indication that these restrictions will be registered on the title to the property;

(xi) a description of any ongoing or long-term monitoring program at the site; and

(xii) certified copies of all confirmatory sample analyses.

Rationale. This information will be required to demonstrate that the specified remediation criteria have been achieved and that the site has been remediated in accordance with the decommissioning and remediation plan.

6.9 Miscellaneous Considerations Relevant to the Management of Site Decommissioning

6.9.1 Long-term Monitoring Programs

RECOMMENDATION R624. Long-term monitoring programs should be developed and implemented for all on-site containment and treatment facilities as well as for areas of restricted access.

Rationale. Monitoring is the only way in which proponents can ensure the continued integrity of on-site environmental control measures and systems.

6.9.2 Restrictions on Future Land Use

RECOMMENDATION R625. Where restrictions on future land use are unavoidable, land use controls should be imposed by registering the existence of land use limitations on the property title in a manner that meets with the approval of the appropriate municipal and provincial authorities.

Rationale. Formal registration of land use restrictions will ensure that future owners do not inadvertently disturb on-site containment facilities or otherwise develop the property inappropriately.

6.9.3 Arrangements for Coverage of Decommissioning Costs

RECOMMENDATION R626. Utility companies should develop an estimated decommissioning cost for all steam electric generating stations as early as is practical in the operating life of the facility and thereafter make appropriate arrangements to meet these costs.

Rationale. This recommendation is intended to clearly identify the need to have funds available to cover the costs associated with the development and implementation of the decommissioning plan **at the time of decommissioning**. An approach followed by some utility companies in addressing this need is to incorporate an allowance for decommissioning costs directly into the rate base. However, it is recognized that this may not be the preferred approach for all utility companies and that the inclusion of any such costs in utility rates would be subject to the approval of the rate-setting authorities with jurisdiction.

Section 7

Summary of Recommendations

A summary of the Decommissioning Phase Code is presented in Table 1 to provide an overview for the reader. The Recommendations as presented in Section 6 should be consulted for more details.

TABLE 1 Summary of Recommendations

Number	Subject	Summary of Recommendation	Section
R601	**Decommissioning Planning** - Scheduling of Decommissioning Activities	Planning for decommissioning should start in the design stage for new plants and as early as possible in the operating stage for existing stations.	6.2.1
R602	**Decommissioning Planning** - Mothballing	Mothballing should not be used to postpone the implementation of decommissioning activities.	6.2.2
R603	**Decommissioning Planning** - Minimum Requirements of the Decommissioning Plan	The minimum requirements of the decommissioning plan are: i) plan implemented in consultation with regulatory agencies and the public; ii) assessment of the measures required to protect on-site ecosystems throughout decommissioning; iii) assessment of the long-term protection of potentially affected ecosystems in the context of future land use; iv) removal of all structures not used or their being rendered stable; v) treatment of all contaminated material to the extent necessary to attain the defined site remediation criteria; vi) provision of access controls for all potentially dangerous structures that remain on-site;	6.2.3

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R603	**Decommissioning Planning** - Minimum Requirements of the Decommissioning Plan (cont.)	vii) monitoring for all containment/treatment systems that remain on-site; viii) remediation of aesthetically unacceptable portions of the site; ix) site remediation to a level that provides long-term environmental protection and ensures safe future land use; x) registration of all contaminants remaining on-site on the property title in accordance with regulatory requirements; xi) submission of written reports to regulatory authorities; xii) all work proceeds under appropriate legal authority and in accordance with applicable legislation; xiii) reasonable employment of 3R management principles.	
R604	**Decommissioning Planning** - Project Manager	A manager should be assigned to the project at the site information assessment stage.	6.3.1
R605	**Site Information Assessment** - Maintenance of Operations Facilities	The station infrastructure and facilities are assessed to determine what facilities should remain in place once "normal" operations have ceased.	6.3.2
R606	**Site Information Assessment** - Information Required for the Site Assessment	Sources of information that should be examined by utility companies include: i) previous environmental assessments; ii) aerial photographs; iii) topographic maps and drainage plans; iv) water quality records; v) climatological data for the site; vi) employee interviews;	6.3.3

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R606	**Site Information Assessment** - Information Required for the Site Assessment (Cont.)	vii) plant construction plans and drawings; viii) pipe schematics and plans; ix) drawings and inventories of fuel and chemical storage areas; x) data on waste storage, treatment, and disposal areas; xi) reports on environmental incidents and spills of hazardous material; xii) drawings of underground services; xiii) laboratory operational practices; xiv) information about oil-filled electrical equipment; xv) pest and weed control practices; xvi) on-site audit; xvii) pertinent regulations; xviii) decommissioning experience at other facilities; xix) long-term area residents; xx) local newspapers and other archived material; xxi) environmental audit reports.	
R607	**Site Information Assessment** - Preparation of a Site Assessment Report	A report should be submitted to the appropriate regulatory authority that contains: i) a description of the site and surroundings; ii) potential problem areas; iii) health and safety considerations; iv) areas requiring immediate action; v) proposed site investigation; vi) proposed land use options; vii) plans for a public consultation program; viii) an assessment of the environmental impact of the decommissioning process; ix) a preliminary decommissioning schedule.	6.3.4
R608	**Reconnaissance Testing Program** - Initial Planning	The reconnaissance program should target: i) suspected areas of contamination;	6.4.1

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R608	**Reconnaissance Testing Program** - Initial Planning (Cont.)	ii) site boundaries; iii) structures and wastes that will remain on site; iv) areas that may be physically unstable.	
R609	**Reconnaissance Testing Program** - Program Design and Review	The proposed program should be reviewed with the appropriate regulatory authority before implementation.	6.4.2
R610	**Reconnaissance Testing Program** - Program Implementation	Implementation of the program should include: i) the development of a sample management system; ii) written sampling/analysis protocols; iii) a procedure for expanding upon the defined program.	6.4.3
R611	**Reconnaissance Testing Program** - Compilation and Presentation of Data	Program results should be presented to the regulatory authority in a report that: i) identifies the types and concentrations of site contaminants; ii) identifies possible contaminant pathways; iii) compares contaminant data with Tier-1 criteria; iv) identifies areas and structures that require remediation; v) identifies and quantifies the potential for waste recycling; vi) recommends areas requiring further field work.	6.4.4
R612	**Detailed Testing Program** - Program Planning	The detailed program should be developed so as to ensure that: i) all contaminated media are resampled in sufficient detail to define the extent and level of contamination;	6.5.1

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R612	**Detailed Testing Program** - Program Planning (Cont.)	ii) all structures, deposits, and facilities with the potential for physical instability are examined in sufficient detail to define the level of remediation required; iii) the same sampling and analysis protocols are used as were followed in the reconnaissance testing program.	
R613	**Detailed Testing Program** - Preparation and Presentation of the Program Report	Results of the detailed program should be presented to the regulatory authority in a report that: i) delineates areas of contamination; ii) determines the volume of contaminated material by media and type; iii) determines if contamination is beneath structures that are to remain on-site; iv) identifies the extent of surface and groundwater contamination; v) identifies any off-site concerns; vi) characterizes the physical and chemical properties of all wastes; vii) assesses the impact of leaving or remediating contaminants on-site; viii) determines the current and predicted exposure point concentrations; ix) identifies the technological options for and feasibility of remediating the site to meet Tier-1 criteria.	6.5.2

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R614	**Preparation of the Decommissioning and Remediation Plan** - The Role of Future Land Use	The ideal goal of the decommissioning and remediation plan should be unrestricted land use but in every case remediation should ensure long-term protection of human health, safety, and welfare, and the environment, to the degree required by the future land use.	6.6.1
R615	**Preparation of the Decommissioning and Remediation Plan** - Presentation of a Report	A draft report should be given to the appropriate regulatory authority that: i) summarizes contaminant data; ii) identifies and describes materials that are to be removed for recycling, reuse, treatment, or disposal; iii) describes site remediation alternatives and their implications; iv) describes the proposed remediation methods; v) proposes a schedule of work; vi) identifies how the plan will be integrated into the overall decommissioning process; vii) summarizes the worker occupational health and safety plan; viii) discusses how residual contaminants affect future land use; ix) identifies long-term monitoring provisions or restrictions on future land use.	6.6.2
R616	**Implementation of Decommissioning and Remediation Plan** - Handling of Contaminated Material by Contractors	All external contractors involved in the handling of contaminated material should be licensed or otherwise approved for such work by the appropriate regulatory authority.	6.7.1

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R617	**Implementation of Decommissioning and Remediation Plan** - Construction and Inspection of On-site Containment Facilities	Before removing any contaminated material that is to be handled on site, the project proponent should: i) construct and inspect the required containment and treatment facilities; ii) install all monitoring devices associated with the facilities.	6.7.2
R618	**Implementation of Decommissioning and Remediation Plan** - Consistency with Codes of Practice	The siting, design, construction, and operation of all facilities associated with the decommissioning project should be undertaken in a manner consistent with the intent of Environment Canada's Codes of Practice for SEPGs.	6.7.3
R619	**Implementation of Decommissioning and Remediation Plan** - Removal and Disposition of Material and Equipment	To the extent practicable, the proponent should: i) dewater sludge and similar residues; ii) treat all wastewater associated with decommissioning activities; iii) drain free-flowing liquid from equipment; iv) drain, vent, and purge all tanks and piping; v) sample unlabelled electrical equipment for PCB content.	6.7.4
R620	**Implementation of Decommissioning and Remediation Plan** - Removal of Buried Equipment and Services	To the extent practicable, the proponent should: i) drain, purge, excavate, and dispose of all underground storage tanks; ii) excavate and remove buried drums for treatment; iii) drain, purge, and excavate all buried services not required in future land use; iv) treat all drainings, purges, etc. in accordance with regulatory requirements.	6.7.5

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R621	**Implementation of Decommissioning and Remediation Plan** - Excavation of Contaminated Soil and Sediment	A site materials and traffic movement plan should be implemented before commencing excavation to ensure that: i) contaminated soil is excavated in lifts with periodic sampling and analysis; ii) contaminated material is segregated from uncontaminated material; iii) excavations are not backfilled until sampling and analysis have been completed; iv) material used for backfilling is verified to be 'clean'.	6.7.6
R622	**Confirmatory Sampling and Completion Reporting** - Sampling and Analysis	Confirmatory sampling and analysis should include: i) testing of treated materials as distinct phases of the remediation plan; ii) testing of soils from zones that were contaminated; iii) installation of piezometers in areas where the depth of contamination extended below the water table; iv) testing of adjacent bodies of surface water; v) examination of groundwater in immediate proximity to containments; vi) air quality monitoring.	6.8.1
R623	**Confirmatory Sampling and Completion Reporting** - Recommended Elements of the Report	A project completion report should be submitted to the regulatory authority; it should include: i) a description of the site and its operational history;	6.8.2

TABLE 1 Summary of Recommendations (Cont.)

Number	Subject	Summary of Recommendation	Section
R623	**Confirmatory Sampling and Completion Reporting** - Recommended Elements of the Report (Cont.)	ii) a description of on-site contamination; iii) the approved site remediation criteria; iv) a description of all on-site structures that had to be remediated; v) a description of all demolition, remedial action, and cleanup work; vi) as-built drawings of the decommissioned site; vii) the identification of disposal and controlled access areas remaining on-site; viii) a description of ongoing treatment programs; ix) a description of the proposed land use; x) the identification of conditions that restrict land use; xi) a description of ongoing monitoring programs; xii) certified copies of all confirmatory sample analyses.	
R624	**Miscellaneous Considerations Relevant to the Management of Site Decommissioning** - Long-term Monitoring Programs	Long-term monitoring programs should be implemented for all on-site containment and treatment facilities as well as areas of restricted access.	6.9.1
R625	**Miscellaneous Considerations Relevant to the Management of Site Decommissioning** - Restrictions on Future Land Use	All restrictions on future land use should be recorded on the property title.	6.9.2
R626	**Miscellaneous Considerations Relevant to the Management of Site Decommissioning** - Inclusion of Decommissioning Cost in the Utility Rate Base	Utility companies should develop a decommissioning cost estimate as early as is practically possible in the life cycle of the facility and thereafter make appropriate arrangements to meet these costs.	6.9.3

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Appendix A

Working Group 15
Decommissioning Phase
Environmental Codes of Practice for Steam Electric Power Generation

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Appendix B

Canadian Steam Electric Power Generating Stations (as of 1991)

Table B-1 Canadian Oil-fired Thermal Generating Units (1991)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
Holyrood 1	Nfld. & Lab. Hydro	175	1970
Holyrood 2	Nfld. & Lab. Hydro	175	1971
Holyrood 3	Nfld. & Lab. Hydro	150	1979
St. John's 1	Nfld. Light & Power	10	1957
St. John's 2	Nfld. Light & Power	20	1959
Charlottetown 5	Maritime Electric	5	1948
Charlottetown 6	Maritime Electric	7	1955
Charlottetown 7	Maritime Electric	7	1960
Charlottetown 8	Maritime Electric	10	1963
Charlottetown 9	Maritime Electric	20	1968
Point Tupper 1	Nova Scotia Power	80	1969
Tufts Cove 1	Nova Scotia Power	100	1965
Tufts Cove 2	Nova Scotia Power	100	1972
Tufts Cove 3	Nova Scotia Power	150	1976
Coleson Cove 1	New Brunswick Power	350	1976
Coleson Cove 2	New Brunswick Power	350	1976
Coleson Cove 3	New Brunswick Power	350	1977
Courtenay Bay 1	New Brunswick Power	45	1961
Courtenay Bay 2	New Brunswick Power	13	1964
Courtenay Bay 3	New Brunswick Power	100	1966
Courtenay Bay 4	New Brunswick Power	100	1967
Dalhousie 1	New Brunswick Power	100	1969
Tracy 1	Hydro Quebec	150	1964
Tracy 2	Hydro Quebec	150	1965
Tracy 3	Hydro Quebec	150	1967
Tracy 4	Hydro Quebec	150	1968
Lennox 1	Ontario Hydro	550	1976
Lennox 2	Ontario Hydro	550	1976
Lennox 3	Ontario Hydro	550	1976
Lennox 4	Ontario Hydro	550	1977
Total Units: 30	Total Utilities: 7	Total Capacity: 5 217 MW	

Table B-2 Canadian Gas-fired Thermal Generating Units (1991)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
R.L. Hearn 1	Ontario Hydro	96	1951
R.L. Hearn 2	Ontario Hydro	96	1952
R.L. Hearn 3	Ontario Hydro	96	1952
R.L. Hearn 4	Ontario Hydro	96	1953
R.L. Hearn 5*	Ontario Hydro	191	1961
R.L. Hearn 6*	Ontario Hydro	191	1960
R.L. Hearn 7*	Ontario Hydro	191	1961
R.L. Hearn 8*	Ontario Hydro	191	1961
Queen Elizabeth 1**	SaskPower	62	1959
Queen Elizabeth 2**	SaskPower	62	1959
Queen Elizabeth 3	SaskPower	92	1971
Medicine Hat 3	City of Medicine Hat	15	1974
Medicine Hat 4	City of Medicine Hat	3	1929
Medicine Hat 6	City of Medicine Hat	5	1947
Medicine Hat 7	City of Medicine Hat	32	1953
Clover Bar 1	Edmonton Power	162	1970
Clover Bar 2	Edmonton Power	162	1973
Clover Bar 3	Edmonton Power	167	1976
Clover Bar 4	Edmonton Power	167	1979
Rossdale 2	Edmonton Power	10	1944
Rossdale 3	Edmonton Power	26	1949
Rossdale 4	Edmonton Power	27	1953
Rossdale 5	Edmonton Power	28	1955
Rossdale 8	Edmonton Power	67	1960
Rossdale 9	Edmonton Power	71	1963
Rossdale 10	Edmonton Power	71	1966
Burrard 1	BC Hydro	150	1966
Burrard 2	BC Hydro	150	1963
Burrard 3	BC Hydro	150	1962
Burrard 4	BC Hydro	150	1967
Burrard 5	BC Hydro	150	1968
Burrard 6	BC Hydro	162	1975
Total units: 32	Total Utilities: 5	Total Capacity: 3 289 MW	

* These units are also capable of coal-fired operation.
** These units are also capable of oil- and coal-fired operation.

Table B-3 Canadian Coal-fired Thermal Generating Units (1991)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
Glace Bay 3	Nova Scotia Power	15	1951
Glace Bay 4	Nova Scotia Power	15	1954
Glace Bay 5	Nova Scotia Power	15	1955
Glace Bay 6	Nova Scotia Power	15	1959
Glace Bay 7	Nova Scotia Power	36	1967
Lingan 1	Nova Scotia Power	150	1979
Lingan 2	Nova Scotia Power	150	1980
Lingan 3	Nova Scotia Power	150	1983
Lingan 4	Nova Scotia Power	150	1984
Maccan	Nova Scotia Power	15	1949
Point Aconi 1	Nova Scotia Power	180	1993
Point Tupper 2	Nova Scotia Power	150	1973
Trenton 3	Nova Scotia Power	20	1953
Trenton 4	Nova Scotia Power	20	1959
Trenton 5	Nova Scotia Power	150	1969
Trenton 6	Nova Scotia Power	150	1991
Belledune 2	New Brunswick Power	450	1993
Chatham 1	New Brunswick Power	10	1948
Chatham 2	New Brunswick Power	22	1956
Chatham 3	New Brunswick Power	22	1987
Dalhousie 2	New Brunswick Power	200	1979
Grand Lake 5	New Brunswick Power	5	1951
Grand Lake 6	New Brunswick Power	5	1952
Grand Lake 7	New Brunswick Power	13	1953
Grand Lake 8	New Brunswick Power	60	1963
Atikokan 1	Ontario Hydro	215	1985
J. Clark Keith 1	Ontario Hydro	64	1952
J. Clark Keith 2	Ontario Hydro	64	1952
J. Clark Keith 3	Ontario Hydro	64	1953
J. Clark Keith 4	Ontario Hydro	64	1953
Lakeview 1	Ontario Hydro	262	1962
Lakeview 2	Ontario Hydro	262	1963
Lakeview 3	Ontario Hydro	284	1965
Lakeview 4	Ontario Hydro	284	1965
Lakeview 5	Ontario Hydro	266	1967
Lakeview 6	Ontario Hydro	266	1969
Lakeview 7	Ontario Hydro	285	1969
Lakeview 8	Ontario Hydro	285	1969
Lambton 1	Ontario Hydro	495	1970
Lambton 2	Ontario Hydro	495	1970
Lambton 3	Ontario Hydro	495	1970
Lambton 4	Ontario Hydro	495	1970
Nanticoke 1	Ontario Hydro	497	1973
Nanticoke 2	Ontario Hydro	497	1973

Table B-3 Canadian Coal-fired Thermal Generating Units (1991) (Cont.)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
Nanticoke 3	Ontario Hydro	497	1973
Nanticoke 4	Ontario Hydro	497	1974
Nanticoke 5	Ontario Hydro	497	1975
Nanticoke 6	Ontario Hydro	497	1977
Nanticoke 7	Ontario Hydro	497	1978
Nanticoke 8	Ontario Hydro	497	1978
Thunder Bay 1	Ontario Hydro	88	1963
Thunder Bay 2	Ontario Hydro	155	1981
Thunder Bay 3	Ontario Hydro	155	1982
Brandon 1	Manitoba Hydro	33	1958
Brandon 2	Manitoba Hydro	33	1959
Brandon 3	Manitoba Hydro	33	1959
Brandon 4	Manitoba Hydro	33	1959
Brandon 5	Manitoba Hydro	105	1969
Selkirk 1	Manitoba Hydro	66	1960
Selkirk 2	Manitoba Hydro	66	1960
Boundary Dam 1	SaskPower	62	1959
Boundary Dam 2	SaskPower	60	1960
Boundary Dam 3	SaskPower	142	1969
Boundary Dam 4	SaskPower	142	1970
Boundary Dam 5	SaskPower	142	1973
Boundary Dam 6	SaskPower	280	1977
Poplar River 1	Saskpower	278	1980
Poplar River 2	Saskpower	280	1982
Estevan 2	Saskpower	15	1950
Estevan 3	Saskpower	19	1953
Estevan 4	Saskpower	29	1957
Battle River 1	Alberta Power Limited	28	1956
Battle River 2	Alberta Power Limited	28	1964
Battle River 3	Alberta Power Limited	148	1969
Battle River 4	Alberta Power Limited	148	1975
Battle River 5	Alberta Power Limited	370	1981
H.R. Milner 1	Alberta Power Limited	145	1972
Sheerness 1	Alberta Power/TransAlta	380	1986
Sheerness 2	Alberta Power/TransAlta	380	1990
Genesee 1	Edmonton Power	386	1989
Genesee 2	Edmonton Power	386	1994
Keephills 1	TransAlta Utilities	383	1983
Keephills 2	TransAlta Utilities	383	1984
Sundance 1	TransAlta Utilities	280	1970
Sundance 2	TransAlta Utilities	280	1973

Table B-3 Canadian Coal-fired Thermal Generating Units (1991) (Cont.)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
Sundance 3	TransAlta Utilities	355	1976
Sundance 4	TransAlta Utilities	355	1977
Sundance 5	TransAlta Utilities	355	1978
Sundance 6	TransAlta Utilities	365	1980
Wabamun 1	TransAlta Utilities	64	1958
Wabamun 2	TransAlta Utilities	64	1956
Wabamun 3	TransAlta Utilities	140	1962
Wabamun 4	TransAlta Utilities	280	1968
Total Units: 93	Total Utilities: 8	Total Capacity: 18 204 MW	

Table B-4 Canadian Nuclear Generating Units (1991)

Station & Unit No.	Operating Utility	Capacity (MW)	Start Date
Point Lepreau 1	New Brunswick Power	635	1983
Gentilly 2	Hydro Quebec	638	1983
Bruce A-1	Ontario Hydro	904	1977
Bruce A-2	Ontario Hydro	904	1977
Bruce A-3	Ontario Hydro	904	1978
Bruce A-4	Ontario Hydro	904	1979
Bruce B-5	Ontario Hydro	915	1985
Bruce B-6	Ontario Hydro	915	1984
Bruce B-7	Ontario Hydro	915	1986
Bruce B-8	Ontario Hydro	915	1987
Darlington 1	Ontario Hydro	935	1988
Darlington 2	Ontario Hydro	935	1990
Darlington 3	Ontario Hydro	935	1991
Pickering A-1	Ontario Hydro	542	1971
Pickering A-2	Ontario Hydro	542	1971
Pickering A-3	Ontario Hydro	542	1972
Pickering A-4	Ontario Hydro	542	1973
Pickering B-5	Ontario Hydro	540	1983
Pickering B-6	Ontario Hydro	540	1984
Pickering B-7	Ontario Hydro	540	1985
Pickering B-8	Ontario Hydro	540	1986
Total Units: 21	Total Utilities: 3	Total Capacity: 16 617 MW	