AN EVALUATION OF CLASSIFICATION SYSTEMS FOR CONTAMINATED SITES WITH RECOMMENDATIONS FOR MANITOBA

by: Randy Arsenault

A Practicum Submitted to the Faculty of Graduate Studies
of the University of Manitoba in Partial Fulfilment of the Requirements
for the Degree of Master of Natural Resources Management

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Abstract

Industries, governments and organizations which are responsible for a number of contaminated sites are interested in initially assessing the risks of sites so effective and efficient decisions can be made about further investigation and remediation. Classification systems for contaminated sites are methods where by existing information is used to identify the possible risks of a site. Once systems are identified and classified, decisions can be made about further site or risk assessment leading to remediation.

Six classification systems were identified for evaluation: 1) the National Classification System for Contaminated Sites; 2) the U.S. Hazardous Ranking System (HRS); 3) Britain's Hazardous Assessment of Landfill Operations (HALO); 4) the Ontario Waste Disposal Site Classification System; 5) the New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning; and 6) the Quebec system for the Management of Contaminated Sites. These systems were evaluated using seven criteria desired for a Manitoba system: 1) uses existing information; 2) incorporates environmental concerns; 3) flexibility; 4) straightforward to use; 5) time and cost efficient; 6) ranks sites; and 7) provides for consistent interpretation of results.

It was found that the National Classification System fulfilled the criteria more fully than the other systems. The National Classification Systems is recommended to be used by government and industry to classify contaminated sites in Manitoba.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

> "A contaminated site is any area where a chemical substance or hazardous material has become located as a result of any spilling, leaking, pouring, abandoning, emptying, disposing, leaching or improper use of any kind. Such contamination may occur due to leaking landfills, transportation spills, leakage from underground storage tanks, residues of industrial activity, and remnants of improperly decommissioned industrial facilities". (CCME, 1992b)

There are likely thousands of contaminated sites across the country. The clean up of these sites or contaminated site remediation has become an important issue to government, industry and the public over the past years. The awareness that areas of land and water may be contaminated with hazardous chemicals has led to programs for clean up to protect human health and the environment.

While the majority of these contaminated sites likely pose a minimal threat to human health and the environment, the challenge is to effectively and efficiently manage the remediation of those sites where the nature and level of contamination may be cause for concern. This is important due to the large number of sites, the varied nature of contaminants, the many different technologies, and the potential high costs of remediation.

Before clean up can be initiated, identification of the type and extent of contamination must be determined so clean up plans can be successful. This may include the review of existing information such as site operation records, or the sampling and testing of soil and water for contamination. Systems are needed to identify and classify these sites, methods must be developed and adapted to physically assess the nature and extent of contamination, and technologies must be developed to remediate the contaminated soil.

A classification system is a tool which incorporates information about a site (usually information already on record), and designates the site in terms of the risk to humans and the environment.

Risk assessment and site assessment are procedures for reviewing the existing information of a site, and physically assessing the contamination through sampling and analysis. Risk assessment and site assessment are tools used to confirm whether remediation is required. For site assessments, the collection and review of existing information is generally referred to as Phase 1, whereas the physical assessment of the site is called Phase 2. Unlike classification systems, risk assessments and site assessments are designed to lead to a remediation plan. Classification systems are similar to a Phase 1 site assessment. Classification systems are an initial assessment of sites. Risk assessment and site assessment are reviewed in chapter 3, and various remediation technologies are reviewed in Appendix C.

The focus of this research is to review and evaluate existing classification systems for contaminated sites. The number of classification systems which assess the risk of contaminated sites to human health and the environment are limited. The reliability of these classification systems is also in question. Also, many systems available were designed for specific purposes, such as classifying landfill sites. Difficulties arise when systems designed for specific purposes (i.e. landfills only) are used to classify the many different types of contaminated sites.

1.2 Problem Statement

With increased levels of public expectation, political interest and more stringent environmental legislation, remediation of contaminated sites has become a higher priority for government and industry. Further, proper management and remediation of contaminated sites, is in the best interest of land owners, industry regulatory agencies and the public.

Identification and assessment of these sites are needed before effective remediation can be implemented. Once sites are identified, contaminated sites need to be classified on the basis of their risk to human health and the environment. Upon classification, assessment and remediation can be managed in the most cost efficient and effective manner.

The government of Manitoba, as well as many industries operating within the province, have a number of contaminated sites which may require assessment and cleanup. The cost of assessment of these sites can be quite high, and remediation costs can be millions of dollars. For example, the remediation of the Pukatawagan site cost Manitoba Hydro approximately $2.5 million dollars, and their budget for remediating decommissioned diesel sites over the next 7 years is over $30 million dollars (personal communication, D. Windsor, June 1995).

A system is needed which can identify and classify an large number and variety of contaminated sites, so efficient and effective decisions can be made for the further assessment and remediation of contaminated sites.

1.3 Goals and Objectives

The goal of this project is to evaluate contaminated site classification systems and make recommendations for a classification system to rank contaminated sites in Manitoba.

The specific objectives of the project are:

1. to review literature, legislation and policy relating to contaminated site identification, assessment and remediation;

2. to identify and obtain copies of classification systems for ranking contaminated sites;

3. to identify evaluation criteria for assessing classification systems for use in Manitoba;

4. to evaluate the identified classification systems;

5. to recommend a classification system to rank contaminated sites in Manitoba.

1.4 Definitions

A **contaminated site** is any area where a chemical substance or hazardous material has become located as a result of any spilling, leaking, pouring, abandoning, emptying, disposing, leaching or improper use of any kind. For example, sites may be contaminated because of leaking landfills, transportation spills, leaks from underground storage tanks and residues from industrial activity (CCME, 1992b).

A **hazardous material** is any material which because of its quantity, concentration, chemical composition, corrosive, flammable, reactive, toxic, infectious or radioactive characteristics, either separately or in combination with any substances, constitutes a present or potential threat to human health, safety, welfare, or to the environment, when improperly stored, treated, transported, disposed of, used or otherwise managed (CCME, 1992b).

Remediation is the removal of a chemical substance or hazardous material from the environment to prevent, minimize or mitigate damage to the public health, safety, welfare, or the environment (CCME, 1992b).

Site Assessment is the inspection and evaluation of a property by a qualified and experienced environmental consultant, to determine if activities on or near the site have resulted in contaminated conditions (CMHC, 1993).

CHAPTER 2: METHODS

The research methods consisted of three main elements: 1) review of literature; 2) interviews with professionals; and 3) review of classification systems.

2.1 Search and Review of Literature

Literature was obtained through the libraries of the University of Manitoba, Manitoba Environment, Hazardous Waste Corporation and the CCME office in Winnipeg, as well as through professional contacts, such as the practicum committee, consultants and the telephone interviews (section 2.2). Classification systems for contaminated sites were obtained through the library searches above, as well as telephone interviews and professional contacts.

The relevant literature was reviewed and is summarized in Chapter 3 - Contaminated Site Remediation.

2.2 Interviews

Informal telephone interviews were conducted over two periods, in June and July 1994, and April and May 1995. The first series of interviews were designed to ascertain what classification systems were being used by the various Canadian provinces, the United States, and the United Kingdom (Table 1). Once existing systems were identified, copies of the systems in use were obtained for review and analysis. Additional discussions were directed towards relevant literature, programs for site remediation, and criteria for evaluating classification systems.

Table 1 is a summary of the results of the telephone interviews. The contacts, their jurisdictions and what classification systems are being used are outlined. It was found that all provinces have adopted the CCME's National Classification System (section 5.2) to rank provincial contaminated sites, except Ontario. Ontario uses the National System to rank sites of joint federal/provincial concern but uses the Ontario Waste Disposal Site Classification

System (section 4.5) to rank provincial contaminated sites. The National System is accepted by P.E.I. but not used due to the small number of sites. The United States uses the U.S. Environmental Protection Agency's Hazard Ranking System (section 4.3), and the Hazard Assessment of Landfill Operations (HALO) system is used in the United Kingdom (section 4.4). It was found that Quebec and Ontario are the only provinces presently ranking and undertaking an inventory of provincial sites, and Quebec is the only province using the National system for this purpose. The provinces of Newfoundland, New Brunswick, Nova Scotia, Manitoba, Saskatchewan, Alberta and B.C., mainly use the National System for joint federal/provincial sites and sites of high risk potential. New Brunswick is using the "Assessment and Classification of Waste Disposal Sites for Closure Planning" for classifying waste disposal sites. Note: Systems selected are existing in Canada. Other systems are available, for example in various U.S. states. The HRS and HALO systems were evaluated as a comparison to the Canadian systems.

The second round of interviews were conducted with professionals from hydro electric utilities across Canada, Winnipeg consultants using the National Classification System, as well as agencies and individuals previously contacted. The objective was to identify the general opinions of the National System, the benefits and problems (if any).

Table 1: A list of jurisdictions, contacts, and the classification systems being used to rank contaminated sites.

Jurisdiction	Contact	System Status
Newfoundland	Carl Strong Director Newfoundland Department of Environment and Lands (709) 729-2574	-uses the CCME National Classification System. -not inventorying provincial sites.
Newfoundland	Dave Kiell Newfoundland Hydro Environment Division (709) 737-1409	-starting a program to deal with contaminated sites. -will be using CCME guidelines, and National System.
Nova Scotia	John Henderson Nova Scotia Department of Environment (902) 424-5300	-uses the CCME National Classification System. -not inventorying sites.
Nova Scotia	Alain Charpentier Nova Scotia Hydro Environmental Policy and Programs Division (902) 428-6236	-have used the National Classification System and CCME guidelines to classify one site. -not inventorying sites. -mostly site-specific, i.e regions submit a list of sites to be decommissioned, an initial site assessment is completed and clean-up is addressed.
New Brunswick	Louise Steward New Brunswick Department of Environment Hazardous Waste Branch (506) 453-4848	-uses the CCME National Classification System for high risk sites only. -not inventorying sites. -have a system to deal with waste disposal sites (see 6.4).

Prince Edward Island	Danny McGuinness Department of Environmental Resources Environmental Protection Division (902) 368-5000	-uses the CCME National Classification System for its factor numbers, but not to rank sites. -not inventorying -site by site basis: an environmental site assessment is required and a remediation plan is suggested.
Quebec	Annie Roy Contaminated Site Department MENVIQ (418) 643-2124	-uses the CCME National Classification System to inventory sites. -CCME (1992) replaced the previous provincial system. -intend to re-classify sites prior to 1992 with the National System.
Ontario	Don Bartkiw Manager Landfill Technology and Site Remediation Ontario Ministry of Environment (416) 323-5151	-uses the CCME National Classification System for Joint federal/provincial orphan sites only. -use the Ontario Waste Disposal Classification System to inventory provincial sites.
Manitoba	Edwin J. Yee Contaminated Site Specialist Manitoba Environment (204) 945-7069	-use the CCME National Classification System -not inventorying sites.
Manitoba	Dennis Windsor Manitoba Hydro (204) 474-3390	-uses the CCME National Classification System to rank and inventory all contaminated sites.
Manitoba	Dan Oleksiuk D. Oleksiuk Consulting Winnipeg, MB (204) 231-2637	-classifying contaminated sites for Manitoba Hydro using the National Classification System.
Manitoba	Dinko Tuhtar KGS Consulting Winnipeg, MB (204) 896-1209	-uses the National Classification to rank sites for clients.

Saskatchewan	Scott Robinson Manager Contaminated Sites Section Sask Environment and Resource Management (306) 787-6138	-uses the CCME National Classification System. -not inventorying sites.
Alberta	Helen Schiebel Site Remediation Branch Action on Waste Division Alberta Environmental Protection (403) 427-3946	-uses the CCME National Classification System -NCS replaced the previous provincial system. -at present, if a site is thought to be high risk, a risk assessment is completed.
British Columbia	Robert McClenahan Contaminated Site Remediation Unit Industrial Waste and Hazardous Contaminants Branch B.C. Ministry of Environment (604) 387-9948	-uses the CCME National Classification System when a site is suspected to be medium to high risk, or to use as a tool to gather background for high risk sites. -does not use it often. -not inventorying sites.
United States	Tim Gill U.S. Environmental Protection Agency Site Assessment Branch (703) 603-8856	-uses the U.S. EPA Hazard Ranking System to assess sites before placing sites on the National Priorities List (NPL).
United Kingdom	David George Dames and Moore England (044) 181 891-6161	-developed the Hazard Assessment of Landfill Operations (HALO) in 1985. -HALO is used in the U.K.

2.3 Evaluation Criteria

Criteria for the evaluation of the classification systems were obtained from the literature review, interviews with professionals, and discussion with the practicum committee.

In April and November of 1990, Contaminated Site Consultation Workshops were held where representatives from the Canadian government, industry, consultants and the public, concluded that a classification system was needed to classify contaminated sites in Canada. It was recommended that the following four criteria be incorporated in the system: 1) evaluation factors should be based on existing information; 2) environmental concerns should be addressed, as well as human health concerns; 3) the system should be flexible enough to rank many different sites; 4) the system should be straight forward to use (Trow et al., 1990).

It was agreed by professionals in Manitoba that the above are important and needed criteria for a classification system to rank sites in Manitoba. As well, three additional criteria were added after discussions with practitioners (personal communications, E. Yee, D. Windsor, D. Oleksiuk, D. Tuhtar, May 1995). The additional criteria are as follows: 1) the system should be time and cost efficient; 2) the system should rank sites relative to one another; and 3) the system should provide for consistent interpretation of results. The evaluation criteria which were used to assess classification systems to rank contaminated sites are listed in Table 2.

Table 2: Evaluation criteria for assessing classification systems to rank contaminated sites in Manitoba.

	EVALUATION CRITERIA
1.	▸ classification factors should be based on existing information
2.	▸ environmental concerns should be addressed, as well as human health concerns
3.	▸ the system should be flexible enough to rank many different sites
4.	▸ the system should be straight forward to use
5.	▸ the system should be time and cost efficient
6.	▸ the system should rank sites relative to one another
7.	▸ the system should provide for consistent interpretation of results

2.3.1 Description of Criteria

The following section is a description of the criteria used to evaluate the classification systems.

1) evaluation factors should be based on existing information

The factors within the classification system used to evaluate the risk of a site, such as the description of site, type of contaminants present, and proximity to surface water, should be available from existing information or information that is easy to obtain compared to a risk assessment. In general, existing information is any information found through literature or resource searches (e.g., operation records). For example, maps of the area provide information such as proximity to drinking water, and site historical records, planning studies and technical reports may indicate what contaminants were used or spilled at a site. Information which is gathered through sampling, test and analysis is not existing or easily obtainable information. Examples of information that is difficult and expensive to collect are, data documenting the chemical concentrations in the soil and the distance of migration of the chemical from the source.

2) environmental concerns are addressed, as well as human health concerns

Factors used to evaluated the risk of the site contamination should incorporate the risk to the environment and well as the risk to humans. For example, the system should be concerned with the impacts of the site on flora and fauna in the area, as well as the impacts to humans.

3) the system should be flexible enough to rank many different sites

There are many different types of contaminated sites, such as landfills, abandoned mines and gas stations, where each may have different contaminants, geography, and receptors. No two sites are the same. Thus, a classification system must be flexible enough to rank the various sites. The system should also be responsive to other factors, such as, changes to regulations, technical information and concentration limits. If there is an important characteristic of a site that is not incorporated within the system factors, then the system should be flexible enough to include it in the ranking. The system should also be flexible enough to deal with the continually changing base of knowledge, for example, contamination limits, and government regulations. The evaluation of a systems flexibility was based on whether factors not addressed by the system could be included and given value (i.e. scores) towards the ranking.

4) the system should be straightforward to use

A system should be easy to use and set up in a straightforward manner, with explicit directions on how to complete the factoring of systems. There should be clear rationale with explanations so that the assessor can develop an understanding of the ranking and hazard risk of the site. The assessor should not need expert knowledge of the classification system, the site or of contaminated site remediation.

5) the system should be time and cost efficient

A system was considered to be time and cost efficient if the ranking of system was based on existing information and could be completed faster and for less money than a risk and site assessment. If a system required in depth gathering of information through numerous questionnaires, and/or field sampling and testing, the system was seen as not time and cost efficient, and requiring special skills and expertise.

6) the system should rank sites

The system should rank the sites relative to one another according to the risk to human health and the environment. The classification and ranking of sites will generate an inventory so decisions can be made regarding further action (i.e. assessment leading to remediation) or no action on the sites. Note: it was found that none of the systems explicitly rank sites relative to one another, but some rank sites in groups of high, medium or low risk. Thus, criterion #6 was considered to be met if sites were ranked in at least groups relative to one another, using a defensible method (e.g. factor scoring, vector analysis).

7) the system should provide for consistent interpretation of results

A system was considered to provide a consistent interpretation for results, if the system had a strong defensible rationale for scoring factors (e.g. factor or vector analysis), and if the subjective judgements of the assessor were minimized. Thus, different assessors classifying the same sites should obtain similar results.

2.3.2 Limitations of Evaluation Criteria

There are some limitations to the evaluation of classification systems using the criteria in section 2.3. For example, determining whether the systems are straightforward or easy to use, are time and cost efficient or give reliable results, are somewhat subjective evaluations. Individual assessors may differ in what they perceive as a straightforward system, and since these systems have some measure of subjectivity, reliability is relative. Therefore, **the**

evaluations of the systems in accordance with the criteria established in this practicum, were determined at the discretion of this researcher, using the above rationale, and relating the systems to one another.

The interviews indicated, that evaluating systems with the criterion of being straight forward to use, implies that any one, professional or not, should be able to use the system. Of course, if this were the case, then the technical judgements allowed within the special consideration section of the National System would be potentially hazardous and extremely subjective, due to the lack of knowledge of the assessor (personal communication, D. Oleksiuk, May 1995). Thus some level of knowledge and understanding of the field is needed.

The overlap of the criteria should also be noted. If a system does not use existing or readily available information, then information from a quantitative site assessment may be required. Because this information requires sampling and laboratory testing, the criterion of being time and cost efficient will also not be met. Also, if a system does consistently rank sites, a system will meet the criteria of providing consistent interpretation of results. The reverse is true of flexibility and consistency. There is a direct trade off between these criteria. For example if a system is based on subjective judgements, then it is considered flexible, but not necessarily consistent. Conversely, if a system has a strict rationalized methodology, reliability and consistency is maximized by reducing the possibility of subjective judgments, but the system has a limited measure of flexibility. All systems will trade off one for the other, and ideally some systems will find a balance. Of course determining which system has balanced these criteria the best will be a subjective judgment, and can only be decided by users and stakeholders, as to what is more important, reliability or flexibility.

2.4 Review

The final stage of the methods was to assess the classification systems in terms of the evaluation criteria, to identify what system is best for Manitoba. Through the interviews, five existing systems were identified for review: 1) the U.S. Hazard Ranking System (HRS); 2) Britain's Hazard Assessment of Landfill Operations (HALO) system; 3) the Ontario Waste

Disposal Site Classification System (the Ontario System); 4) the New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning (the New Brunswick System); and 5) Canada's National Classification System for Contaminated Sites (the National System). The Quebec System, identified through the literature search, is presented as an example of systems used previously in Canada. The analysis of the systems are presented within Chapter 4.

CHAPTER 3: CONTAMINATED SITE REMEDIATION

Contaminated site remediation is a complex field. Practitioners are plagued by a less than perfect understanding of remediation processes, and inadequate procedures for the characterization of site conditions. This may lead to improper diagnosis of the problem regarding the extent and severity of contamination, and incorrect application of technologies.

In an attempt to meet these issues, the Canadian Council of Ministers of the Environment (CCME, 1989) initiated a five-year, $250 million National Contaminated Sites Remediation Program (NCSRP) to initiate the remediation of high risk contaminated sites (section 3.5). Under this program, the parties responsible for the contamination, when they can be identified, bear the cost of cleanup (the "Polluter Pays" principle); in the case where no owner can be traced or held responsible (i.e."orphan sites"), governments currently must absorb the costs (CCME, 1991-1992).

Further, in 1992, a National Classification System for contaminated sites was developed by the CCME (section 5.2). The main purpose of the system is to identify and classify the contaminated sites of high risk to human and environmental health in Canada, which may qualify for NCSRP funding (CCME, March 1992).

The purpose of this chapter is to outline the major issues related to contaminated site remediation, and to discuss site assessment, risk assessment and the National Contaminated Sites Remediation Program.

3.1 Policy Issues

In the past few years, incidents such as Love Canal and Chernobyl, have brought the issues of air, soil and water contamination to the forefront of public and political attention. There is a sense among many professionals that the process for dealing with contamination is far from effective. Many of the problems with remediation efforts can be attributed to the incompatibilities among the relevant science, policy and public perception (Walsh, 1990).

Thus, reducing these incompatibilities can improve the effectiveness, economy and speed of remediation.

The development of a process to manage contaminated site remediation presents a large challenge for science and policy makers. Improvements are needed in the development of sampling and monitoring methods, characterization of environmental and health effects, fate and transport modelling, and effective and reliable remediation technologies (Anderson, 1990).

In regards to the characterization of soil contamination, the available site assessment methods often cannot promote the accuracy and precision appropriate for the site remediation problem (Wallace et al., 1990). The available scientific and technical tools are not always able to gather adequate information, and there are incompatibilities in public perceptions and expectations, for example whether regulatory policy sets achievable remediation goals (Mackay, 1990).

The ultimate challenge for policy makers is the development of an institutional framework with procedures and guidance to make the most effective use of the science and to achieve the best attainable environmental results (Anderson, 1990).

The following sections are a brief discussion of some of the interrelated issues faced by practitioners and policy makers of contaminated site remediation.

3.2 Who pays?

Under the NCSRP, the CCME has affirmed the "polluter pays" principle under the program, and the federal, provincial and territorial governments have begun to put in place the legal structure to apply this principle (CCME, 1991-1992).

Thus, the determination of who is responsible for remediation of contaminated sites is a very important question affecting the remediation process. But, determining the responsible party is one thing, and making them pay is another. If the responsible party can not pay or cannot be determined, then the responsibility is bound to fall on the backs of the government and the tax payers. Because the cost of remediation can be high and public remediation funds are typically limited, mechanisms must be implemented by which responsible parties are compelled to pay for the cleanup efforts. This may also act to prevent contamination in the future.

Tough legislation and the power for federal and provincial agencies to enforce these laws, is one way to ensure responsible parties undertake environmental cleanup, and possibly reduce future contamination. For example, under the Manitoba Environmental Assessment Act, a corporation responsible for an offence can be fined up to one million dollars a day, for every day that a spill is not cleaned up once occurred (Government of Manitoba, 1988). If clean up is not undertaken, responsible parties can be forced to clean up the spill, and/or pay for the cost of clean up.

3.3 Remediation Decisions

Industry, government, and science must work together to ensure that remediation decisions can address cleanup effectively. This can be encouraged through the improvement of information transfer and communication between professionals, public, policy makers and scientists. Presently information sharing is not common due to the sensitive nature of these issues. Information sharing must improve to increase the effectiveness and speed of dealing with remediation problems.

One of the most important policy needs is realistic criteria for making remediation decisions. Special attention should be paid to decisions about whether remediation of a contaminated sites should be undertaken and when remediation should end.

3.3.1 Should we clean up the contaminated resource?

There may be situations where remediation is not desirable. Examples include: 1) the cost to society of the cleanup far exceeds the expected benefits of the cleanup in terms of human health and welfare, and ecological stability; 2) the contaminated site is not being used and it is perceived to have a low potential to be used in the future; 3) there are inexpensive substitutes for the contaminated resource; and 4) the contamination does not degrade water and/or soil quality to an unsafe or unhealthy level for humans and the environment (Anderson, 1990).

Should any site which is contaminated be remediated? Although this may be ideal, it may not be practical or possible, due to availability of effective technologies or remediation funds. If remediation is to be managed effectively, decisions must be made regarding the practicality, the priority of sites and allocation of funds. For example, sites of high risk to human health may be given priority for clean up, over isolated low risk sites.

Further decisions may involve the containment of a site rather than remediation, due to costs or availability of technologies. For example, the containment of an isolated low risk site (i.e. an old gas service stations) which will not be used in the future may cost far less than the analysis and remediation of that site. Thus, the money could be used more efficiently to remediate a high risk urban contaminated site.

3.3.2 How much remediation should be undertaken?

If a decision to remediate is made, three related decisions must follow: 1) a background analysis must be undertaken to determine the extent of the contamination and the remediation alternatives related to site conditions; 2) a remediation plan and technology must be selected on the basis of technical, environmental, and economic factors; and 3) a decision must be made when to stop remediation (Anderson, 1990).

One decision which is very important and often overlooked is the determination of a remediation endpoint and concentrations. The natural environment contains differing amount of chemicals, and also has a assimilative capacity for concentrations of chemicals. Therefore, 100% remediation is not necessary, and most likely not possible. Therefore, guidelines are needed to judge when a site is sufficiently remediated, or to determine when the concentration of chemical present does not present a risk to human and environmental health. Most times these guidelines are determined by regulatory agencies as environmental limits which must be followed. For example, the CCME released the "Interim Canadian Environmental Quality Criteria for Contaminated Sites", specifically for this reason. The document consists of numerical values which act as benchmarks to assess the degree of contamination at a site, as well as give chemical concentration limits for remediation plans to achieve through cleanup efforts (CCME, September 1991).

3.4 Risk Assessment

For a proper remediation plan to be initiated, information regarding the potential or known hazards and contamination of the site must be determined. This can be accomplished by a site assessment or risk assessment.

Estimates of the potential risk associated with contaminated sites can be used to determine when remediation is required, what type of remediation to use and when remediation will be complete. Risk assessment has become one of the principal techniques for formulating, assessing and managing the remediation efforts of contaminated sites.

The term risk assessment describes a broad range of methods used to estimate the probabilities of adverse or unwanted outcomes, for example associated with site contamination. Some organizations use the terms, "hazard assessment", or "risk analysis".

The following is a overview of risk assessment, and the techniques used to estimate and assess risks (Ibbotson, 1992).

Risk assessment typically focuses on the possibilities of adverse effects occurring to the environment or human health. The processes used to assess the potential risks at contaminated sites are divided into four basic components: 1) hazard identification; 2) dose-response assessment; 3) exposure assessment; and 4) risk characterization.

3.4.1 Hazard Identification - Site Assessment

Hazard identification involves describing the ability of a chemical to adversely affect the environment or human health. This entails understanding the physical extent and concentration of each chemical of concern present in the environment, and understanding the environmental fate of each chemical of concern (i.e. movement, behaviour, persistence) (Ibbotson, 1992).

The physical extent and distribution of a chemical released into the environment can be determined by conducting field samples and analyzing the collected samples. This is often referred to as site characterization or site assessment, and its main objective is to obtain sufficient information that represents the conditions that are occurring at the site. Site assessment of contaminated sites often involves gathering information on the locations, types, and numbers of people and biota that use the site and surrounding area (Ibbotson, 1992).

> "Site assessment is the inspection and evaluation of a property by a qualified and experienced environmental consultant, to determine if activities on or near the site have resulted in contaminated conditions." (CMHC, 1993)

Site assessment usually begins with gathering and evaluating existing information. The type of information gathered may be determined by a set of pre-determined guidelines, or may be determined initially when defining the objectives of the assessment. Although the amount and type of information may differ, the stage generally involving the gathering and evaluation of existing information is often called, a "Phase 1" site assessment.

Phase 1

A phase 1 site assessment is a review of existing and historical information about a site, which can help facilitate planning for a efficient, safe and thorough field investigation program (i.e. phase 2). This also helps to minimize the time, effort and cost of the overall site assessment. Phase 1 of the site assessment has three purposes: 1) to identify potential subsurface contaminants and environmental concerns at the site; 2) to identify, based on existing information, the subsurface conditions at and around the site; and 3) to establish a framework (i.e. work plan) for the subsequent site investigation. Table 3 outlines some potential sources and types of information used in a Phase 1 site assessment.

Much of the information may overlap and similar information may be identified through different sources. Only one source, such as owner files, may identify all the information needed. This will probably be the case for modern sites, which will have good data bases and information systems due to the recent strengthening in environmental regulations. An evaluation of many sources may be necessary for old or abandoned sites, which have a long and varied history.

Table 3: Sources and Types of Information for a Phase 1 Site Assessment

Sources of Information	Types of Information	Availability
owner and regulatory agency files	site operational and environmental history	site owner, government agencies
land use and ownership history	site activities and operations	municipal tax records and directories, title searches
aerial photographs	land use history, physical and drainage features	government agencies
archival records	historical photographs, operational history	national and local archives, corporate files
site plans and engineering drawings	site layout and features	corporate files, municipal files
historical maps and fire insurance plans	land use, industrial process areas	national and local archives
anecdotal reports	site history and practices	present and former employees, local residents, local histories
industrial activities and processes	manufacture, use, storage and disposal of chemicals	corporate archives, historical and contemporary trade, journal and texts

Phase 2

Phase 2 of the site assessment would involve physically gathering information regarding the contamination at a site. This may involve taking samples using boreholes of soil and water, and analyzing the samples for levels of concentrations, toxicology, solubility, etc. The last stage of Phase 2 would involve implementing a remediation program and cleaning the site.

Some of the areas of the site which may be observed are in a Phase 2 site assessment are: 1) the geophysics - the application of physical principles such as magnetism and gravity which can penetrate the subsurface; 2) the site hydrogeology - physical characteristics of the subsurface system that control contaminant migration as the site; 3) the chemical hydrogeology - chemical information regarding the sources, extent and movement of the subsurface contaminants; 4) the groundwater flow and contaminant transport models (may include mathematical transport modelling); 5) the surface soil and water contamination (including migration); and 6) assessment and remediation - sampling of the surface and subsurface to ensure that remedial goals have been achieved (Barker, et.al., December 1992).

3.4.2 Dose-Response Assessment

The objective of this step is to estimate the likelihood of adverse effects that can be caused by contact with known quantities of a chemical. The relationship between dose and response can be based upon the analysis of epidemiological, clinical, environmental, toxicological, biochemical, structure activity and exposure data. Most toxicological data for the effect of the chemical on humans are usually derived from laboratory studies of animals, whereas ecological risks are evaluated by establishing no-observable-adverse-effect-level (NOAEL) values for each chemical-organism of interest. NOAEL values are established by conducting studies in which specific organisms are exposed to known concentrations of chemicals in soil, air or water. Many types of organisms have been used to establish NOAEL levels including plants, seeds, soil and aquatic invertebrates, fish and mammals.

3.4.3 Exposure Assessment

For contaminated sites, exposure assessment consists of determining the environmental concentrations of a chemical at locations of interest, translating those concentrations into exposures, and finally translating the exposures into doses.

The objective of the first task is to determine the concentrations of a chemical at each location where a receptor is or could be located (usually a person, but can also refer to an animal or plant). The most common method is to take measurements from a few stationary locations, and use mathematical models to estimate environmental concentrations at many locations.

Once the concentrations of a chemical are known, the exposure (i.e. when a chemical comes into contact with the receptor) can be determined. The extent to which exposure occurs for humans in the context of a contaminated site, can be determined by examining the relevant exposure pathways, for example, ingestion of water, food items or soil, inhalation of vapours, and dermal contact.

Once exposures have been estimated or measured, the dose, or the amount of chemical taken up by the receptor via exposure pathways, can be determined.

3.4.4 Risk Characterization

The fourth and final step of the risk assessment process is to translate exposures and doses into risk estimates. This is accomplished by comparing the doses estimated in the exposure assessment, to the dose-response relationships of the dose-response assessment. For human health, risk characterization depends on whether individual chemicals of concern are considered to be carcinogens or non-carcinogens, as well as how many chemicals there are in each type.

For each receptor being studied, the doses associated with individual exposure pathways are summed to estimate total dose. The dose-response relationship for the chemical can then be consulted to determine the likelihood of an adverse effect occurring. Some chemicals can cause more than one type of adverse effect, such that each effect may need to be considered separately in the risk assessment. Similarly, some chemicals can cause different types of effects via different exposure pathways.

Ecological risks are determined by comparing measures or modelled concentrations at exposure locations to the toxicity on the environment defined through the NOAEL values. For example, when the concentrations of chemical are greater than the toxicity information, there is considered to be a potential for an adverse effect.

3.4.5 Risk Management

While the prime objective of risk assessment is to estimate the risks that a specific situation or site might pose, risk assessment does not address the "acceptability" of doses or to setting remediation goals or clean-up criteria. These complex issues are addressed in risk management. Once site assessment and risk assessment identify the risks of a contaminated site, risk management decides ways to minimize or eliminate the risk. For example, the management of the risks may include engineering barriers to prevent the migration of chemicals, or implementing remediation technologies to reduce the contamination to safe limits.

There is no single, comprehensive way of determining the "acceptability" of a dose or remediation goal. Any approach would need to account for several issues such as, environmental, technological, social, economic and political factors.

One method of deciding what are safe limits is to compare the levels with levels those set by government and regulations (e.g., CCME's Canadian Environmental Quality Criteria). Another approach is to compare the estimated risks to the risks of known similar situations. For example, the risks of using a contaminated site might be compared to the risks of crossing the street, or not wearing a seat belt while driving.

3.5 The National Contaminated Sites Remediation Program

In October 1989, the 5 year, $250 million National Contaminated Site Remediation Program (NCSRP) was initiated by the Canadian Council of Ministers of the Environment (CCME) (CCME, 1991-1992). The program was initiated to deal with the remediation of federal sites in Canada which have been polluted with hazardous materials, and to ensure the appropriate cleanup of sites where contamination is a serious threat to human health, and/or environmental quality.

The three main objectives of the NCSRP are 1) that the program be based on the effective application of the "polluter pays principle" for the identification, assessment and remediation of sites, 2) that program funds be provided to remediate those "orphan" high risk sites for which the owner is financially unable or the responsible party cannot be identified; and 3) that the program work with private industry to stimulate the development and demonstration of new and innovative contaminated site remediation technologies (Foote, 1992).

The $250 million budget for the program funds two principal components. The first $200 million is being directed towards orphan site remediation, and the remaining $50 million is allocated for technology development and demonstration. The funding for the program is provided on a cost shared basis between the federal government and provincial-territorial funding.

To reinforce the "polluter pays principle", federal, provincial and territorial governments are reviewing, and where necessary amending existing legislation in an effort to clearly define the liabilities of those responsible for contaminating a site. These legal initiatives will help serve as a preventative measure to reduce the contamination of sites in the future.

3.5.1 NCSRP-Framework

In April and November of 1990, the CCME held workshops to discuss the priorities and framework for the assessment and remediation of contaminated sites under the National Contaminated Site Remediation Program (NCSRP).

Figure 1 (Appendix B) outlines the process for remediation of contaminated sites under the program. The framework includes a series of screening and assessment tools, which when applied in a tiered approach, are intended to ensure effective decision making in the development of remediation objectives.

In March 1992, the CCME released a National Classification System for Contaminated Sites (see 2.3) to serve as a screening tool for the evaluation of contaminated sites (CCME, March 1992a). This system is used to synthesize information on contaminated sites to identify priority sites based on the threat they pose to human health and the environment.

In September 1991, the CCME released the Interim Canadian Environmental Quality Criteria. This document lists criteria expressed as concentrations of individual contaminants. The development of quality criteria will be ongoing as new information arises. Once sites are classified using the National Classification System, assessment of the sites can be carried out. The National Environmental Quality Criteria can be used as benchmarks for measuring the degree of soil and water contamination to indicate whether further action is required and when to stop remediation. The quality criteria can also help form a basis for determining the state to which the environment must be restored.

Once the assessment stage is reached there are two approaches to establish specific remediation objectives. A more general, "criteria-based" approach involves the direct application of the Canadian Environmental Quality Criteria, and the other more site-specific, "risk-assessment" approach, involves the characterization of potential hazards posed by the contaminants at a particular site (see Figure 1, Appendix B).

Further, in March 1992, an international workshop of experts was held to discuss a draft risk assessment framework that reflects one of the overall objectives of the program: to give equal consideration to human health and ecological risk when dealing with contaminated site remediation (Foote, 1992).

CHAPTER 4: DESCRIPTION AND EVALUATION OF CLASSIFICATION SYSTEMS

4.1 Overview

The systems being evaluated in this chapter are: Canada's National Classification System for Contaminated Sites (NCS); the U.S. Hazard Ranking System (HRS); Britain's Hazard Assessment of Landfill Operations (HALO); Ontario's Waste Disposal Classification Scheme (the Ontario System); the New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning (the New Brunswick System); and the Management of Contaminated Sites for Quebec (the Quebec System).

A classification system is a tool which incorporates information about a site (usually information already on record), and designates the site in terms of the risk to humans and the environment. Classification systems are similar to a Phase 1 site assessment.

Before the National Classification System was released in 1992, Environment Canada, and the provinces of Alberta, Saskatchewan, Manitoba, Quebec, Nova Scotia, P.E.I. and Newfoundland were using a system ("the Provincial System") based on one developed for New Brunswick in the early 1980's. The Provincial System was modified somewhat by Environment Canada and the provinces to account for physical and geographical differences. In the late 1980's, Alberta and Quebec modified the Provincial system further, by upgrading the additive factorial system for ranking. The Quebec System (section 4.7.1) is reviewed in this chapter and represents the last modification of the original Provincial system.

Ontario developed their own system in the early 1980's which uses an ordered check-list approach. British Columbia does not have a provincial system, but does provide site clean-up requirements based on contamination level criteria or a risk assessment matrix. Since the CCME released the National Classification System for Contaminated Sites, all provinces except Ontario have adopted the system within the provinces (see Table 1). Ontario uses the NCS for joint federal/provincial sites but uses their own system to inventory provincial sites (see Table 1). Although the NCS is accepted by most provinces, not all provinces are actively inventorying contaminated sites. Only the provinces of Ontario and Quebec are actively inventorying their provincial sites (see Table 1). The United States uses the Hazard Ranking System, and Britain uses the HALO system.

The following sections are descriptions and evaluations six classification systems. The evaluations of the systems are based on the evaluation criteria and methods discussed in Chapter 2 (section 2.3 - Table 2). Tables 5-10 outlines the evaluations for each system based on the evaluation criteria. Each table gives the evaluation outcome along with comments explaining how and why. Table 4 is a summary of the evaluations of the classification systems and the individual tables.

Table 4: Evaluation of Classification Systems for Contaminated Sites in Terms of Criteria for a Manitoba System.

Criteria\System	NCS	HRS	HALO	Ontario	N.B.	Quebec
1.uses existing information	√	O	X	√	√	√
2.incorporates environmental concerns, as well as human concerns	√	√	X	O	O	√
3.flexible to rank many different sites	√	X	X	√	√	X
4.straightforward to use	√	O	O	O	O	√
5.time and cost efficient	O	X	X	√	√	O
6.ranks sites	√	√	O	X	X	√
7.provides for consistent interpretation of results	√	√	O	X	X	√

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

4.2 The National Classification System for Contaminated Sites

In March 1992, the CCME released the National Classification System for Contaminated Sites (CCME, 1992a). The National system is a method of evaluating contaminated sites according to their potential adverse effects on human health and the environment, and is one of the tools developed for remediation of contaminated sites under the National Contaminated Sites Remediation Program (NCSRP).

The system uses existing or generally available information on the characteristics, contaminants (known or potential), and location of sites, to enable classification of the sites for remediation. The purpose of the system is to provide scientific and technical assistance in identifying sites, which may be considered high, medium or low risk to human health and the environment. The main goal of the system is to provide a scientifically defensible method to identify sites of high risk that may qualify for the NCSRP funding.

The National Classification System is not designed to provide a general quantitative risk assessment, but rather a tool for the classification and general prioritization of contaminated sites. The national system is a screening tool only to assess the need for further action of sites (i.e., characterization, risk assessment, remediation), and does not address specific factors such as those of a technological, socioeconomic, political or legal nature. The National Classification System does not make firm conclusions about the need for remediation, as this will still depend on a number of factors, including long-term use or redevelopment of the site, relevant site-specific objectives, local issues, availability of technology and cost of remediation.

4.2.1 Description of the National System

The National Classification System is designed to evaluate the general hazard or hazard potential of a site by scoring site characteristics that are grouped under three categories: 1) contaminant characteristics - the relative hazard of contaminants present at the site; 2) exposure pathways - the route the contamination may follow to a receptor (e.g., ground water, surface water, and/or air); and 3) receptors - living beings or resources that may be exposed to the contamination. These categories are based on the process for risk assessment (section 3.4), and this is why the National System is a risk-based system.

Within these three categories, a minimum of information is required to classify sites. The evaluation factors are as follows:

1. description of the site location,
2. types of contaminants likely to be present (and/or a description of historical activities),
3. approximate size of the site and quantity of contaminants on the site or in the soil,
4. approximate depth of water table,
5. geological map or survey information (soil, overburden and bedrock formation),
6. annual rainfall data,
7. surface cover information,
8. proximity to surface water,
9. topographic information,
10. flood potential of the site,
11. proximity to drinking water,
12. uses of adjacent water sources,
13. land use information (on-site and surrounding).

The National Classification System evaluates sites by giving them a total score on a scale from 0 to 100. A site scoring of 0 in the system is one for which all the evaluation factors are assigned the lowest possible score, and the site is not considered to be hazardous or contaminated. A score of 100 would represent a site for which all the factors received the highest possible score, and the site would be considered an extreme hazard to human health and the environment.

From the overall scores, sites are placed into classes (Class 1, 2, 3, N or I). Class 1 sites are those sites that received a score between 70 to 100. Sites in Class 1 are considered high risk sites and further action is required (e.g., further site assessment, risk assessment, remediation). Sites in Class 2 received a score between 50 and 69.9, indicating that there is a high potential for adverse effects and further action is likely required. Class 3 (scores from 37 to 49.9) sites are not considered a high concern, however further investigation may be carried out to determine whether action may be required. Sites in Class N (scores form 0 to 36.9) do not require further action (CCME 1992a).

Sites are not ranked relative to one another, but in four classes. Class 1 and Class 2 sites can be compared to each other in terms of the potential hazard to the environment. Sites within the same class cannot be compared to each other based on their individual numbered ranking.

The National Classification System also provides a method to deal with gaps in information required for ranking sites within the system. If sufficient information is not available, a score of one half the maximum allowable score is given with a question mark (?) placed beside. At the end of the system, the estimated (?) scores are added. If the estimated scores are in excess of 15, the site is placed in Class I (insufficient information).

When classifying sites, the National System provides a short evaluation form and detailed evaluation form. An assessor has the option of classifying a site using the short evaluation form if serious adverse impacts are known and have been well documented in site reports. If these adverse impacts are known, then the short evaluation form automatically classifies the site as Class 1.

The National Classification System uses an additive numerical method that assigns scores to the site characteristics and factors. The three categories (contaminant characteristics, exposure pathways, and receptors) are considered to be of equal importance and are weighted equally (33, 33, and 34 points, respectively).

Each of the evaluation factors (e.g., type of contaminant, rainfall, topography) are assigned a score ranging from 0 to 18. Those factors being assigned high maximum scores are considered to be of greater relevance than those with low maximum scores, in terms of contributing to the hazard or risk of the site. For example, Figure 2 (Appendix B) is an example of the scoring rationale which would be attached to the evaluation form. For factor C.1 (Direct Contact), if the off-site media (i.e. soil or air) is known to be contaminated, then it can receive a maximum score of 11. Whereas, a factor such as the potential for hazardous soil gas migration is not considered as great a hazard, and the maximum score is 1.5 (see Figure 2, Appendix B).

The detailed evaluation form, the main form used, presents the factors to be considered, and scoring guidelines (e.g. see Figure 2, Appendix B). The detailed evaluation form gives the assessor the option to classify the sites using known information (if any). If information regarding the known impacts is not available, the assessor classifies the sites based on the potential for adverse impacts. For example, within the system, an assessor would be advised to score Category II, C.1 (known impacts) or Category II, C. 2 (potential impacts) (see Figure 2, Appendix B). This option of classifying the site on known and/or potential impacts is given throughout the system.

The National Classification System also includes a method for including the special considerations of the assessor in the ranking of the site. For example, section C.3 in Figure 2 allows the assessor to score (+ or -) 4 points based on special considerations or technical knowledge about the site in regards to direct contact (see Figure 2, Appendix B). The special considerations may include pertinent knowledge which is not addressed by the system factors, and the assessor feels should be included in the ranking of the site.

4.2.2 Evaluation of the National System

Table 5: Evaluation of Canada's National Classification System (NCS) for Contaminated Sites in Terms of Criteria for a Manitoba System

Evaluation Criteria	NCS	Comments
1. uses existing information	√	- NCS uses existing or easily obtainable information only. - if data is unavailable there is a procedure to deal with information gaps. - in the absence of known concerns, potential concerns are addressed.
2. incorporates environmental concerns, as well as human health concerns	√	- environmental concerns, such as sensitive biological areas (e.g. sensitive aquatic environments, nature preserves, endangered species habitat, sensitive forests), are incorporated.
3. flexible enough to rank many different sites	√	- NCS provides a "special considerations" section where factors not be addressed in the system may receive a score.
4. straightforward to use	√	- NCS provides straight forward directions - the scoring rationale for each factor is outlined and justified Note: the d-base 3 program does not outline directions as well as the manual scoring procedure (personal communication, D.Tuhtar, May 1995).
5. time and cost efficient	O	- the criterion is met somewhat - NCS requires only existing information, but the amount of data is greater than the Ontario and New Brunswick systems (time and cost efficient), but less than HRS and HALO (not time and cost efficient). - no testing or analysis required.
6. ranks sites	√	- NCS uses an additive factorial system and ranks sites in classes of high, medium and low risk.
7. provides for consistent interpretation of results	√	- NCS was tested on 21 contaminated sites by five professionals, and statistical analysis found the NCS to provide consistent results (Trow et al.,1990).

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

As shown in Table 5, the National Classification System fulfilled the criteria of classifying sites using existing or generally available information. The NCS also allows for potential concerns to be addressed in the absence of known information, and provides a procedure to deal with information gaps. Although the NCS uses only existing information, more data is required than the Ontario and the New Brunswick systems, but less than the HRS or the HALO systems. For this reason the NCS was considered somewhat time and cost efficient relative to the other systems evaluated.

The NCS does fulfil the criterion of being straight forward to use. Directions are clearly given for identifying and imputing information, as well as how to score each of the factors. Scoring rationale is also given for each category.

The National Classification System does rank sites in classes of high, medium and low risk using an additive factorial method. Although the NCS does not rank sites relative to one another, it was considered to fulfil this criterion as compared to other systems. For example, ranking sites in classes of high, medium and low was the most evaluated systems have attained, and some systems do not rank sites at all. The NCS is also considered to give consistent results due to the factorial scoring method, and the minimization of subjectivity.

The NCS does fulfil the criterion of including environmental concerns. Factors such as contamination impacts on animals, plants, and sensitive environments (i.e. nature preserve, habitat for endangered species, etc.) are incorporated.

The National Classification System is considered flexible due to the option of including special considerations of the assessor. The "special considerations" section allows assessors to score factors of site that may not be covered by the system. The system is also considered to give reliable and valid classifications of sites, due to the well rationalized scoring method, and minimization of subjective scoring.

4.2.3 Conclusions and Comments

Most practitioners contacted through the interviews find the National system to be a good objective tool which gives reliable results on the ranking of contaminated sites (personal communications, A. Roy, D. Tuhtar, L. Steward, H. Schiebel, May 1995). Another benefit is that, the National System is a unified, standard system which provides guidelines and some measure of consistency to ranking contaminated sites in Canada, and is largely accepted by regulatory, industry and private agencies (personal communications, D. Oleksiuk, A. Roy, L. Steward, D. Tuhtar, May 1995).

Some problems with the National System identified through the interviews are: 1) sites classified using known or potential concerns can achieve the same ranking (personal communication, D. Oleksiuk, May 1995); 2) the "special considerations" section can be overused making the ranking of sites more subjective (personal communication, D. Oleksiuk, May 1995); 3) the National system and the other systems reviewed are trying to achieve the standard of a risk assessment with less information, time and resources (personal communication, D. Tuhtar, D. Oleksiuk, May 1995); 4) groundwater contamination is not addressed properly (personal communication, D. McGuinness, L. Steward, June 1994 and May 1995); and 5) the system is too long and intensive for classifying a small number of low risk sites (personal communication, L. Steward, June 1994 and May 1995).

The problem with a site based on known impacts achieving the same ranking as a site based on potential impacts is that the system is essentially equating known risk (i.e., measured) and potential risk (i.e., estimated). For example, the National System tends to generate fairly high scores in the absence of true contamination information (personal communication, D. Oleksiuk, May 1995). This may be related to problem #3 above, that these classification systems are trying to act as a quantitative risk or site assessment. These systems are only designed for initial information gathering and a general estimate of the potential hazard of a site. The classification and rankings achieved should only be used to decide which sites should have a risk or site assessment (i.e., phase 2). Only after a risk or site assessment is completed should remediation decisions be made. If this is misunderstood and a classification system is given the same consideration as a risk assessment, then crucial decisions regarding site management may be made upon estimated factors, in the absence of known information.

A suggested solution to this problem is the dividing of sites into two categories, sites based on all or some known concerns (i.e., giving them more credence because the information is known), and sites based on potential impacts. This could be achieved, for example, by either adding a "importance" score (e.g., 10 points), to sites classified with known information, or subtracting the weighted score (e.g., 10 points) from all sites classified on potential impacts. Another option is not to score the categories at all, but clearly outline whether potential or known information was used.

Although it was agreed that the "special considerations" section was beneficial in providing flexibility in the system, it was also recognized that if this section was over used, the reliability and validity of the scoring system would be in question (personal communication, D. Oleksiuk, May 1995). For example, the more technical judgement used to affect the ranking of the sites, the less likely the same ranking will be reproduced by different assessors. Thus, the classification of sites can become more subjective and less reliable. The "special considerations" section is important as the major factor allowing the National System to be flexible, but precautions should be taken against overuse.

Professionals from P.E.I. and New Brunswick feel that the National System does not deal with groundwater issues well enough to meet the needs of these provinces. Both P.E.I. and New Brunswick are very dependent on groundwater and well systems, and the National System is not sensitive enough to groundwater contamination (personal communication, D. McGuinness, L. Steward, June 1994 and May 1995). The National System was also found to be too long and intensive (personal communication, L. Steward, June 1994 and May 1995).

4.3 Hazard Ranking System (U.S. Environmental Protection Agency)

The Hazard Ranking System (HRS) is a risk-based classification system that has been applied to numerous contaminated sites in the United States, and serves as a screening tool to assess the relative threat from actual or potential releases of hazardous substances from a site (U.S. EPA, December 1988).

A HRS score is determined for a site by evaluating four pathways (surface water, ground water, air, and direct contact) by which hazardous substances can threaten health or the environment. The score for each pathway is obtained by evaluating a set of "factors" that characterize the potential that harm could be caused by the pathway.

Each factor is assigned a numerical value according to a defined protocol and this value is multiplied by a weighting factor to yield the factor score. The factor scores are then combined with factor categories. The total scores for the factor categories are multiplied together to develop a score for the relevant pathway. Finally the pathway scores are combined to produce the HRS score for the site. The HRS and HALO system are scored very similarly (see scoring description of HALO - section 5.4).

4.3.1 Evaluation of the HRS

Table 6: Evaluation of the U.S. Hazard Ranking System (HRS) in Terms of Criteria for a Manitoba System

Evaluation Criteria	HRS	Comments
1. uses existing information	O	- much of the information required is existing or easily obtainable, but the HRS requires some sampling and analysis, such as toxicity and mobility of chemicals present, ecosystem toxicity and bioaccumulation.
2. incorporates environmental concerns, as well as human health concerns	√	- factors deal with environmental threats such as ecosystem toxicity and bioaccumulation
3. flexible enough to rank many different sites	X	- HRS is very rigid making the system inflexible. - there is no method to address information not covered by the specific factors.
4. straightforward to use	O	- scoring is well rationalized with directions. - HRS is not as straight forward to use as other systems because it requires some use of complex tables and calculations.
5. time and cost efficient	X	- HRS is not time and cost efficient compared to the other systems, because of the amount analytical information required. - testing and analysis is required.
6. ranks sites	√	- HRS has a strong scoring methodology, and ranks sites in classes of high medium and low risk.
7. provides for consistent interpretation of results	√	- HRS has a strong scoring methodology which provides consistent results. - subjectivity is minimized.

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

The information required for the HRS is too extensive to be useful to assess sites based on available information (Trow et al., 1990). The HRS is a comprehensive system which classifies sites on a wide range of existing information, as well as physical, and chemical data. Although this makes the system reliable and consistent, some of the information required is not readily available making it time consuming, expensive, and difficult to collect. For this reason the HRS fulfilled the criterion of using existing information partially, but did not fulfil the criterion of being time and cost efficient. The HRS does require more in depth information than the other systems evaluated and does use a well rationalized additive factorial scoring method, ranking sites in classes of high, medium and low risk. The HRS is a reliable system, and fulfils the criterion of providing consistent results as well as ranking sites. Due to the rigidity of scoring and factors used, the HRS was not considered to be flexible.

The HRS is fairly simple to use. But, because of the amount of technical data required, as well as requiring the assessor to input formulas, and tables, only a partial fulfilment designation was given for the criterion of being straight forward to use.

The HRS, prior to 1990, incorporated only human health concerns but did not address environmental concerns. Revisions to the system since that time have included environmental factors, such as ecosystem toxicity and bioaccumulation.

4.4 British Hazard Assessment of Landfill Operations (HALO)

The HALO system is based on the identification of hazard potentials and the likelihood of occurrence, and is a modification of the U.S. Hazard Ranking System (Dames and Moore, 1985). Like the HRS, HALO is concerned with the pathways of groundwater, surface water and air pathways. HALO is not a complete risk assessment, since it does not fully estimate probable frequency of occurrence, consequences and acceptability of consequences.

HALO gathers information regarding a number of different types of hazards using three formal questionnaires and a fourth input document. From this information seven separate scores are produced for seven components: 1) Component A - material pollution potential; 2)

Component B - landfill operations audit; 3) Component C - groundwater pathway assessment; 4) Component D - surface water pathway assessment; 5) Component E - landfill gas evaluation; 6) Component F - direct contact assessment; and 7) Component LA - local amenity assessment.

Once the information is collected, like the HRS, a number of factors are scored based on a range of predetermined numbers (see Figure 3, Appendix B - "score"). Once the factor score is determined, it is normalized by dividing by the maximum allowable score (see Figure 3, Appendix B - "normalized score") and then multiplied by a factor weighting (see Figure 3, Appendix B - "factor weight"). The factor weights are predetermined to indicate the importance weighting factors. For example in Category D.1. Impact Assessment, D.1.b. Observed Release is considered three times more important than D.1.a. Degree of Containment (see Figure 3, Appendix B).

The factor scores are summed to give category scores which are multiplied by category weight scores (see Figure 3, Appendix B - "Total Impact Assessment Category Score"). The "weighted" category scores are summed to give a component score (see Figure 3, Appendix B - "Total Surface Water Form D Score").

HALO does not sum the component scores to give a "Total" score for the site. As the areas of hazards within the components are quite different, summation of the scores is meaningless. Although comparisons can be made between the component scores of different sites, overall comparative risk assessment (i.e. total score) is difficult. For example, the scoring system assigns weightings based on factors other than risk, such as site management training (see Figure 4, Appendix B - B.3.d), size of the site (Figure 4, Appendix B - A.3.e), and public complaints (Figure 4, Appendix B - LA.1.c). This may cause problems because a large site may score worse than a small site regardless of the amount of contaminants present (i.e. the risk). Therefore, HALO does not provide a ranking of sites in order of their hazard potential (Dames and Moore, 1985).

4.4.1 Evaluation of the HALO system

Table 7: Evaluation of Britain's Hazard Assessment of Landfill Operations (HALO) System in Terms of Criteria for a Manitoba System

Evaluation Criteria	HALO	Comments
1. uses existing information	X	- HALO uses existing information but some information may be difficult to collect (e.g., quantities of specific types of wastes, public complaints, depth to water table).
2. incorporates environmental concerns, as well as human health concerns	X	- HALO does not address environmental factors sufficiently.
3. flexible enough to rank many different sites	X	- HALO is not flexible - specific information is required and there is no flexible method to include information other than what is required. -HALO requires specific information such as public complaints, employee training and security.
4. straightforward to use	O	- the HALO system does provide directions for collecting and scoring information, although it is not outlined as well as other systems
5. time and cost efficient	X	- HALO is not time and cost efficient due to the time required to submit and collect the questionnaires, and the requirement of known information (i.e., chemical quantity and composition)
6. ranks sites	O	- HALO does not rank sites overall, although component (section) scores are ranked and can be compared.
7. provides for consistent interpretation of results	O	- the scoring uses the additive factorial method, and the directions are somewhat straight forward. - the system provides somewhat consistent results for the categories, but does not provide a consistent overall ranking.

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

Compared to the other systems, the HALO system fulfils the least of the criteria for a Manitoba system. HALO does not fulfil the criterion of using existing information, because specific information is required implying that sampling or physical measurement may be needed. The information may be existing for landfill sites, which the system is designed for, but data regarding the quantity of chemical present, public complaints and employee training programs are not generally existing information for contaminated sites. Also, there is no procedure to deal with information gaps, or a procedure for including estimated information.

Due to the use of multiple questionnaires and the possible need for physical measurement of the site, the HALO system is not considered to be time and cost efficient.

Compared to the other systems evaluated, the criterion for incorporating environmental concerns was poorly met. Of the numerous factors dealing with landfill operations and human health, only distance to critical habitat is a weighted factor (see Figure 4, Appendix B).

The HALO system provides very little flexibility. The HALO system also does not rank sites into overall classes, but does use an additive factorial system to give category scores. Although site category scores can be compared, an overall site score is not given. Thus, HALO only partially fulfils the criterion of ranking sites. Also, HALO is considered to partially fulfil the criterion of providing consistent results (i.e. results may be consistent for factor categories, but not overall site scores).

HALO is generally straightforward, but does not provide as detailed instructions for scoring as some of the other systems. Thus, HALO only somewhat fulfils the straight forward criterion (see Table 7).

4.5 Ontario Waste Disposal Site Classification Scheme

The Ontario system called, the "Waste Disposal Site Classification System" (June 1991) was designed for the Ontario Ministry of the Environment to establish an inventory of all known active and closed waste disposal sites in the province (Ontario MOE, June 1991). The purpose of the site inventory was to divide sites into broadly similar categories for further investigation and remediation. Data for the sites are obtained from the Ministry of the Environment's data files on individual sites, file archives, and site inspections. Assessors use technical information and judgement about a site and divide the sites into classes: Class A for sites with potential human health impacts, and Class B for sites with potential environmental impacts (see Figure 5, Appendix B). Sites are also classified as urban or rural, and the wastes within the sites are broadly categorized as industrial liquid hazardous wastes or municipal/domestic wastes. The technical assessment is based primarily on impacts of the site on groundwater. Beyond the classification listed above, no further categorization of the sites is provided by the system.

4.5.1 Evaluation of the Ontario System

Table 8: Evaluation of the Ontario Waste Disposal Site Classification System in Terms of Criteria for a Manitoba System

Evaluation Criteria	Ontario System	Comments
1. uses existing information	√	- uses information that is available only - requires a limited amount of information
2. incorporates environmental concerns, as well as human health concerns	O	- sites can be classified as a hazard to the environment, but further investigation is at the behest of the assessor.
3. flexible enough to rank many different sites	√	- the Ontario system is one of the most flexible systems - there are few classification factors to be addressed. - there is no set methodology for ranking.
4. straightforward to use	O	- methodology and directions are vague - technical judgements are required
5. time and cost efficient	√	- time and cost efficient. - only available information is used. - no testing and analysis required.
6. ranks sites	X	- does not rank sites relative to one another. - designates sites as no hazard, hazard to humans, or hazard to the environment. - sites in each category cannot be compared
7. provides for consistent interpretation of results	X	- results will likely be inconsistent. - there is no set methodology, and technical judgement may be required, thus there is a high potential for subjectivity.

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

The Ontario system uses only what information is available. A small amount of data is required compared to the other systems. For this reason the Ontario system satisfies the criteria of using existing information and being time and cost efficient as compared to a risk or site assessment.

The Ontario system has no set factors and rationale for assessing sites (see Figure 5, Appendix B). Assessments are based on the technical judgments of assessors, and can be based on different amounts of information available. Although this gives the system a great deal of flexibility (fulfils the criterion of being flexible), technical judgements mean a greater amount of subjectivity. Thus, there is a greater chance of inconsistent assessments between different assessors and for sites with varying amounts of information. The Ontario system does not meet the criterion of providing for consistent interpretation of results.

Although the Ontario system is straight forward to use, it requires technical knowledge. Thus, this system partially fulfilled the criterion of being straight forward to use.

The Ontario system does not rank sites in classes of high, medium and low risk (see Table 8). Also, a partial designation was given for meeting environmental concerns. The "hazard to the environment" is mentioned but the importance of this or whether it is measured further is not known due to the lack of protocol (see Figure 5, Appendix B).

4.6 The New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning

The New Brunswick system is named "Assessment and Classification of Waste Disposal Sites for Closure Planning" and was prepared for the New Brunswick Department of Environment in April 1992 (N.B. Department of Environment, April 1992). The system was developed to classify disposal sites that are about to be closed, as having a high or low priority, based on their overall potential to contaminate the environment. This classification system is based loosely on the National Classification System, but measures the potential for site contamination qualitatively, rather than quantitatively.

Classification of the sites is based on: 1) the potential for contamination; 2) whether or not off site contamination has been known to occur; and 3) the opinion of the inspector (see Figure 6, Appendix B). The inspector of the site is required to evaluate the potential for contamination by assessing the contaminants present, the pathways whereby such contaminants might leave the sight, and potentially affected receptors. Contaminants are assessed in terms of quantity and nature, pathways in terms of the potential for the contaminant to migrate off-site, and the receptors in terms of its sensitivity and location relative to the site. Once criteria are assessed and described in a site evaluation form, an evaluation is given which denotes the potential impact of the site, as minimal, moderate or severe. The site inspector may then voice knowledge or opinions regarding the site, and give the site an overall classification of high or low priority (see Figure 6, Appendix B).

4.6.1 Evaluation of the New Brunswick System

Table 9: Evaluation of the New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning in Terms of Criteria for a Manitoba System

Evaluation Criteria	New Brunswick System	Comments
1. uses existing information	√	- asks for known information on a number of general factors. - information required is existing or easily obtainable.
2. incorporates environmental concerns, as well as human health concerns	O	- factors such as aquatic resources and sensitive habitat are addressed. - only general information on these factors are required.
3. flexible enough to rank many different sites	√	- this is a very flexible system. - a limited amount of general information is required. - depends a great deal on the assessors judgement.
4. straightforward to use	O	- the system is simple to use. - the criterion was only met somewhat because technical judgement of the assessor is required.
5. time and cost efficient	√	- this system is time and cost efficient due to the small amount of general information required. - no testing and analysis required.
6. ranks sites	X	- there is no ranking methodology used. - sites are placed in categories of low and high priority. - sites cannot be compared to one another within the categories.
7. provides for consistent interpretation of results	X	- the system is very subjective due to its simplicity, the lack of set factors and ranking methodology, and the required judgement of the assessor.

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

This system, similar to the Ontario system, requires only a limited amount of existing information. This fulfils criterion #1 (uses existing information), and makes the system time and cost efficient. A partial fulfilment was given to the criterion of straight forward to use due to the requirement of technical knowledge and judgements.

Like the Ontario system, the qualitative nature and use of technical judgements make the New Brunswick system much more subjective than other systems. This is also due to the lack of ranking method used. Thus, the New Brunswick system does not rank sites, and does not provide for consistent interpretation of results, although the system is very flexible.

The New Brunswick system does incorporate environmental concerns, such as sensitive habitat, and aquatic resources.(see Table 9)

4.7 Management of Contaminated Sites for Quebec

Because of public concern about toxic sites in the mid-80's, the Quebec Ministry of the Environment (MENVIQ) initiated a program to classify, categorize and inventory their provincial contaminated sites (MENVIQ, October 1987). All sites were classified using this system until the National Classification System was released in 1992. Quebec intends to re-classify the sites from the previous inventory using the National System (see Table 1).

The previous site ranking system was based on a set of factors, such as the type of waste, the method of disposal or storage, the site and the surrounding land use. The information required for these factors was designed for existing information, so that sampling of the sites would not be necessary (see Figure 7, Appendix B).

Factors are rated based on their characteristics and predetermined scores from 0-10 (see Figure 8, Appendix B). When scoring, some factors are considered more important, and their score is multiplied by an importance weighting (see Figure 7, Appendix B - "weighting"). The factor scores are added and reduced to a percentage by dividing the total by the maximum allowable score and multiplying by 100 (Note: Figure 7, Appendix B - Total factor scores are divided by 4.4).

Categorized ranking is as follows:

Category I - 60 percent or more - the site is a potential risk for public health and/or a high potential risk for the environment.

Category II - 40 to 60 percent - the site is a medium potential risk for the environment and/or a small potential risk for public health.

Category III - 20 to 40 percent - the site may be a small potential risk to the environment but no risk against pubic health.

Note: any site with less than 20 percent was not classified.

If a categorized site were to have a remedial plan, then the following stages were taken: 1) site characterization; 2) choice of corrective measures; 3) implementation of the corrective measures; 4) control and evaluation; and 5) environmental follow up.

4.7.1 Evaluation of the Quebec System

Table 10: Evaluation of the Quebec Management of Contaminated Sites in Terms of Criteria for a Manitoba System

Evaluation Criteria	Quebec System	Comments
1. uses existing information	√	- information required is existing or easily obtained. - no sampling, testing or analysis required.
2. incorporates environmental concerns, as well as human health concerns	√	- environmental factors and concerns are addressed within the Quebec system. - the Quebec system requires information regarding the environmental potential and aesthetic considerations.
3. flexible enough to rank many different sites	X	- the Quebec system is not flexible. - a set of specific factors are addressed. - there is no method to address site factors not considered within the system.
4. straightforward to use	√	- the Quebec system is straight forward and simple to use. - directions are provided. - the methodology, an additive factorial system, is straight forward and easy to follow.
5. time and cost efficient	O	- the Quebec system is time and cost efficient compared to the HRS, but does require more information than the Ontario and New Brunswick systems.
6. ranks sites	√	- the Quebec system use an additive factorial system to rank sites is classes of high, medium and low risk.
7. provides for consistent interpretation of results	√	- results are consistent as subjectivity is minimized through set factors and scoring. - little judgement is required.

Key:
√ - The system fulfils the criterion
O - The system fulfils the criterion somewhat
X - The system does not fulfil the criterion

The National Classification System was modelled after the Quebec system. Both are straight forward to use and rank sites based on similar factors of existing information. The factorial ranking system is very similar. Sites are ranked in classes of high, medium and low risk, and the system provides consistent results. Also like the NCS, the Quebec system received a partial fulfilment for time and cost efficiency due to the relatively large amount of information required.

The systems differ in that the Quebec system incorporates unique environmental concerns, such as, environmental potential and aesthetic considerations, and the Quebec system is not flexible. Unlike the NCS, there is no "special considerations" section to make the Quebec system flexible to include factors not addressed by the system (see Table 10).

CHAPTER 5: DISCUSSION

Table 4 is a summary of the evaluations of the classification systems in terms of criteria for Manitoba. The National Classification System is the only system which fulfilled all the criteria for a Manitoba system. All other systems did not fulfil at least one of the desired criteria.

5.1 Existing Information and Time and Cost Efficiency

The difficulty with evaluating systems for the use of existing information is differentiating between what is existing information and what is not. For example, is data that must be found through in depth resource searches existing information? The general rule, as discussed in Chapter 2, is that existing site information is any data which is available without the need for sampling, testing and analysis. This is directly related to whether a system is time and cost efficient. If sampling and analysis must be completed (i.e., does not use existing information), the system is not considered time and cost efficient.

All systems fulfilled the criteria of using existing information, except HALO which requires information such as public complaints, employee population and site security. HRS was considered to fulfil this criterion only somewhat due to some of the technical data required. For these reasons HALO and the HRS were not considered time and cost efficient.

Although, the HRS and HALO partially fulfil the criterion of using existing information, the opposite is true for the Ontario system and the New Brunswick system. The Ontario and New Brunswick system do not require a great deal of information or information gathering, thus they have fulfilled the criterion very well. The same reasoning dictates that the Ontario and New Brunswick systems are the most time and cost efficient.

The NCS and the Quebec system fall somewhere in between. These systems require more existing information than the Ontario and New Brunswick systems but less than the HRS and HALO. Thus, these systems have fulfilled the criterion of using existing information but are somewhat time and cost efficient.

5.2 Incorporating Environmental Concerns

All systems except the HALO system fulfil the criterion of incorporating environmental concerns. Some systems incorporated environmental concerns uniquely, such as giving consideration to aspects rarely given value in hazardous materials management. For example, the Quebec system allows the assessor a score of 1 for whether the surrounding area is aestheticly pleasing. Aesthetics is not often considered when determining the "value" of an area.

The Ontario and New Brunswick system only partially fulfils this criterion due to their lack of detail and environmental factors. For instance the Ontario system states that further environmental concerns may need to be addressed. The system does not say that environmental concerns must be addressed, or designate what areas of concern should be investigated.

5.3 Flexibility and Providing Consistent Results

A system with rigid factoring and scoring is not considered flexible. Whereas, a system which has no set protocol is very flexible. A system with no set factoring and scoring allows greater subjectivity within its classification but increases the likelihood of inconsistent results. Conversely, a rigid system will provide for the consistent interpretation of results, but is not flexible enough to be applied to a varied number of sites.

Both the Ontario and New Brunswick systems are very flexible due to their lack of scoring methodology. The interpretation of information, and which information is used to classify sites is at the discretion of the assessor. This is beneficial when classifying many different types of contaminated sites. But, because the information may differ between sites and the classification is based on the judgment of the assessor, the chances are high that classifications of the same sites by different assessors will be different. Therefore, comparisons of site classifications should not be made using the Ontario and New Brunswick systems. Reliability could be improved with these systems if all sites were classified by the same person.

The HRS and HALO systems have very little flexibility (i.e. subjective judgements are minimised through a strong scoring rationale, factor scoring limits, and pre-determined factor weighting). These systems are very reliable and consistent, but cannot be applied to a number of different sites. Note: HALO provides consistent results within the scoring of categories, but is not designed to give an overall factor score.

The National System is both flexible and consistent. Technical judgment can be included through the special considerations section, and the strong scoring rationale gives a measure of consistency. But the increased flexibility probably means the NCS does not provide the same level of consistency as the HRS and HALO.

5.4 Risk Estimates not Risk Assessments

In general, all the systems evaluated are trying to accomplish what a site and risk assessment can do with less information, time and resources. This is not what these systems are designed for. Remediation decisions should not be made on the basis of the classification systems reviewed, because all these systems are *risk estimates* not risk assessments. These systems give an initial overview of the contamination at a site. Only decisions regarding the further site or risk assessment of the sites should be made. Once a site assessment or risk assessment is completed, remediation options can be determined.

5.5 Subjectivity

All the classification systems have a measure of subjectivity. A simple and understandable system can help to reduce the subjectivity. Even when a system has a strong scoring rationale assessors are required to make judgements. For example, within the Quebec system, assessors are asked to score factors between 1 and 10 based on a ten factor scoring rationale (see Figure 8, Appendix 5). Although suggestions for scoring may be given, a judgment is required.

Therefore, the greater the assessors understanding of the system and scoring rationale, the better the judgements of the assessor, and the less chance for subjective errors.

Most of the systems classify sites as high, medium and low priority. None of the systems give individual rankings for comparing sites relative to one another. This is not possible due is to the inherent subjectivity within the scoring of factors, and these systems.

The subjectivity in these systems does not allow the actual scores derived from the system, such as a score of 67 versus 69, to be compared to each other. The sites are placed in groups of high, medium or low based on the factor scores, and the sites within the groups are viewed as equal. For example, in the National System, all sites with scores between 70 and 100 are given a high priority designation. A site with a score of 85 is viewed the same as a site with a score of 95. The grouping of sites into classes makes up for the subjectivity in the system, making the results more reliable and consistent. Any subjectivity within the scoring (i.e. the Quebec system and the 1-10 factor scoring) would cause a plus or minus probability of the overall score being incorrect, unreliable and inconsistent. The placing of sites within groups, is in actuality allowing for the probability of mistakes. For this same reason, assessors should be aware that sites which are on the border between groups (i.e. medium to high, low to medium) have a probability of error.

5.6 The National Classification System - A Summary

The National Classification System is an expansion of the site classification systems previously used in Canada (i.e., the Quebec System). It uses a factor scoring system, assesses available information on site characteristics, and the majority of evaluation factors used in the National System (See 4.2.1) are also used in the Quebec System. The National System improved on the previous provincial systems and the other systems (e.g. the HRS), by including more environmental health concerns, by providing the option to assess the sites based on potential and known impacts, and by allowing "special considerations" of the assessor to be included within the classification (see 5.2.1).

The ranking of sites based on known and potential concerns was adopted from the U.S. HRS. This is not seen in the other systems. The National System is designed to allow sites to be classified completely on known concerns, or partially on known and potential concerns. This gives the system more flexibility depending on what information is available and gives the option of using known information leading to more consistent results. A problem with this function is that known and potential risks may tend to be equated. A site classified with potential information can attain the same score of a site classified with known information. This difficulty may be overcome by clearly separating the groups, so they cannot be compared to each other.

The National System is the only system evaluated which fulfils the criteria of providing consistent results as well as being flexible. Flexibility is incorporated into the system through the "special considerations" section (see 5.2.1), which allows technical judgements and special factors to be incorporated into the ranking. Assessors can give a plus or minus rating based on special factors which must be justified and documented. This is a beneficial characteristic as it allows the National System to be used on many different contaminated sites in various jurisdictions, and may be a reason why the system is being adopted by provinces and industries.

The majority of systems reviewed were designed to prioritize specific types of contaminated sites, whereas the NCS was designed specifically for classifying a number of different types of contaminated sites. For example, the HALO system was specifically designed for landfill operations and the New Brunswick system was designed for the closure of disposal sites. Problems arise when these systems are applied to sites other than landfills, because they are not designed to assess sites where the contamination and environmental risks are a result of unplanned activities or incidents.

The National Classification System is being used by all provinces in Canada, except Ontario, as well as being used by some hydro companies in Canada (see Table 1). The benefits of this are numerous. Firstly, if the National System is the standard system being used, then the results are more consistent across the country. This will allow comparisons of sites between jurisdictions and may be beneficial for regulatory, funding and research purposes. For example, it would be possible for Environment Canada to develop a comprehensive inventory of contaminated sites in Canada which might help create better awareness of the problems, aid in legislation and help fund cleanups.

A standardized system for classifying sites between industry, government and the public is also beneficial. If a standard system is accepted as a classification tool by regulatory, industry and private agencies, these sectors have a measure of confidence in the results of their site classifications. This may mean a greater level of agreement between government, industry and the public, as all sectors will be following the same guidelines and methods. This may also enhance greater communication and cooperation, which in turn will be useful for the development of classification systems, assessment methods and technologies.

CHAPTER 6: SUMMARY AND RECOMMENDATIONS

6.1 Summary

Through the analysis and evaluation, the National Classification System for Contaminated Sites was found to have met the criteria, established for this study, more completely than the other systems reviewed. The National Classification System uses existing information, includes environmental, as well as health concerns, is straight forward to use, is time and cost efficient, provides for the consistent interpretation of results and ranks sites in groups of high, medium and low risk. The National System is also an expansion of and has improved on many of the systems reviewed, by including beneficial factors, such as being designed to classify many different types of sites, being able to rank sites on known and potential impacts, and allowing for special considerations of the assessor within the ranking. A further benefit is that the National System is a generally accepted system by government, industry and private agencies, and is being used in most provinces in Canada.

6.2 Recommendations

> **1) The National Classification System for Contaminated Sites should be used by government and industry to classify contaminated sites in Manitoba.**

Although the National Classification System is the favoured system according to the evaluation criteria, no system is perfect. For example, the broad application of the National System may cause problems when applied to different jurisdictions, geographical areas, and the often site-specific issues of contaminated site remediation. For this reason the second recommendation is that:

> **2) industry and government should work to modify and improve the National System to make it more efficient and effective to meet site-specific needs in Manitoba.**

Manitoba Hydro is designing weighted sets of sub-factors to be incorporated into the "special considerations" scoring. This allows site-specific information not covered in the system to be incorporated and also reduces subjective judgments. Through open discussion with industry and government, modifications, such as the example of Manitoba Hydro, may lead to large improvements in the National System.

Another possible improvement may be to incorporate the National System with chemical data-bases and geographical information systems (GIS). For example, the general categorization of the hazardous substances within the system (i.e. high concern contaminants, medium concern contaminants, etc.) may not provide clear enough indication of the hazards present at a site and that more detailed chemical information may be needed within the rankings. This may be achieved by incorporating the National System with chemical information databases, such as CCInfo and Sigma-Aldrich. The data bases give descriptions of numerous chemicals, including the hazards of contact, inhalation and ingestion, as well as toxicological information. If it were possible to incorporate these systems, then once the chemical is identified, more in depth information from the chemical databases could be included in classifying the sites.

Further, much of the ranking information could be compiled on GIS saving much time and effort in classifying the sites. For example, information such as topography, annual rainfall data, proximity to surface, ground water, and population, could be compiled on GIS for later recall during classification of sites. This would potentially save time by eliminating the gathering of this information for each individual site. All physical geographical data could be compiled on GIS, and only the site specific data, such as, size of site, type of hazard and amount of hazardous substance would have to be compiled. Note: The National System has been incorporated with GIS on a limited basis, using selected data and a desk top GIS system (personal communication, E. Yee, August 1995).

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APPENDICES

APPENDIX A - INTERVIEWS

Appendix A - Interviews

The first set of interviews were conducted in June and July, 1994, and the second interviews were conducted in April and May, 1995. All contacts are listed in Table 1.

The purpose of the second interviews were to gather feedback on the National Classification System from professionals using the system. The following is a list of the questions that were discussed. Note the interviews were informal in style, and the following questions only served as a guideline.

1. Have you used CCME's National Classification System to rank contaminated sites? If yes, to what extent (i.e. general information gathering, ranking of a number of sites, for provincial of federal purposes, etc.)?

2. What is your overall opinion of the National Classification System for ranking contaminated sites in Canada or Manitoba (where applicable)? Discussing further any problems or criticisms.

3. If problems or criticisms, Do you have any suggestion how to improve or modify the National System to overcome the problems mentioned?

4. Do you feel it is possible to incorporate the National System with Geographical Information Systems (GIS) and chemical data-bases?

Note: The criteria for evaluating the classification systems for this research were also discussed in terms of being valid and comprehensive.

APPENDIX B - Classification System Figures

NATIONAL CONTAMINATED SITES REMEDIATION PROGRAM

ASSESSMENT/REMEDIATION FRAMEWORK

▼

National Classification System for Contaminated Sites

Classify risk relative to other sites

▼

National Environmental Quality Criteria (EQC)

Assess degree of soil and water contamination

▼ *Criteria-Based Approach* ▼ *Risk-Assessment Approach*

Establish site-specific remediation objectives

Figure 1: National Contaminated Sites Remediation Program Outline (CCME, 1991-1992).

Figure 2: Sample Scoring Rationale from the National Classification System for Contaminated Sites (CCME, March 1992a).

CATEGORY	EVALUATION FACTOR	SCORING GUIDELINE	RATIONALE	METHOD OF EVALUATION
II. Exposure Pathways (cont'd)	C. Direct Contact 1. Known contamination of media off-site • Known contamination of soil, sediment or air off-site due to contact with contaminated soil, dust, air, etc. (vector transported should also be considered). • Strongly suspected contamination of media off-site • No contamination of media off-site	11 6 0	Known or measured contamination off-site is an important consideration for determining impact of contaminants.	Record known or measured contamination of soil, se' or air on or off-site. Note any presence of soil gas, such as methane, ass' with site.
	2. Potential for direct human and/or animal contact a) Airborne Emissions (gases, vapours, dust, etc.) • Known or suspected airborne emissions impacting on neighbouring properties • Airborne emissions generally restricted to site • No airborne emissions	5 3 0	If air emissions are evident off-site, there is a great hazard for direct contamination of neighbouring biota and/or resources.	Review available site information to determine if the been complaints off-site (due to vapours, gas, dus Reports for these problems are not likely available f abandoned sites. Review regulatory site inspection If airborne emissions are known to be im neighbouring properties and possibly endanger public, some immediate action (including characte of emissions) should be initiated to curtail h emissions or otherwise reduce or eliminate exposure
	b) Accessibility of Site (ability to contact materials) • Limited or no barriers to prevent site access; contaminants not covered • Moderate accessibility or intervening barriers; contaminants are covered • Controlled access or remote location and contaminants are covered	4 3 0	The greater the accessibility to a site and to contaminants, the greater the chance for contamination of human and animal life by direct contact.	Review location and engineering of the site and dete there are intervening barriers between the site and h animals. A low rating should be assigned to a (cove surrounded by a locked chain link fence or in a location, whereas a high score should be assigned that has no cover, fence, natural barriers or buffer.
	c) Hazardous soil gas migration • Contaminants are putrescible and soil permeability is high • Soil contaminants are putrescible but soil permeability is low and/or groundwater is <2 m from surface • No putrescible contaminants at the site.	2 1 0	Methane gas migration has been known to cause explosions adjacent to abandoned landfills.	Consider presence of organic material on site, the water table, soil hydraulic conductivity, vegetati odours, etc.
	3. Special Considerations	-4 to +4	(See 3.7.3 in text)	Technical judgment.

RATING FACTOR	SCORING BASIS	SCORE (a) (CIRCLE ONE)	NORMALISED SCORE (c)	FACTOR WEIGHT (d)	FACTOR SCORE (e)
CATEGORY D.1 IMPACT ASSESSMENT					
D.1.a. DEGREE OF CONTAINMENT	....	0 1 2 3 4 5	5	1	0.6
D.1.b. OBSERVED RELEASE	....	0 1 2 3 4 5 6	6	3	2.0
TOTAL IMPACT ASSESSMENT CATEGORY SCORE, g = 2.6 x CATEGORY WEIGHT, h = 1 = 2.6					
CATEGORY D.2 ROUTE CHARACTERISTICS					
D.2.a. INTERVENING TERRAIN	....	0 1 2 3	3	2	2
D.2.b. LANDFILL SLOPE	....	0 1 2 3 4	4	1	.25
D.2.c. RAINFALL INTENSITY	....	0 1 2 3 4 5 6	6	2	1.67
TOTAL ROUTE CHARACTERISTICS CATEGORY SCORE, g = 3.92 x CATEGORY WEIGHT, h = 1 = 3.92					
CATEGORY D.3 TARGETS					
D.3.a. TYPE OF SURFACE WATER AND USE		0 1 2 3 4 5	5	2	0.8
D.3.b. DISTANCE TO NEAREST SURFACE WATER	....	0 1 2 3 4 5 6	6	1	0.0
D.3.c. TYPE OF DISCHARGE ENVIRONMENT	....	0 1 2 3 4	4	3	2.25
D.3.d. DILUTION POTENTIAL	....	0 1 2 3 4 5 6	6	2	0.67
TOTAL TARGETS CATEGORY SCORE, g = 3.72 x CATEGORY WEIGHT, h = 2 = 7,44					
TOTAL (SURFACE WATER) FORM D SCORE (i) = 13.96					

Figure 3: Sample Score Sheet from Britain's HALO system (Dames and Moore, 1985).

Chapter 3 Component A: Material Pollution Potential

3.1 INTRODUCTION
3.2 CATEGORY A.1 CONTROLLED WASTE QUANTITY
  3.2.1 Introduction
  3.2.2 Factor A.1.a Household Waste Quantity Up To 10 Years Old
  3.2.3 Factor A.1.b Household Waste Quantity Over 10 Years Old
  3.2.4 Factor A.1.c Commercial And Biodegradable Industrial Waste Up To 10 Years Old
  3.2.5 Factor A.1.d Commercial And Biodegradable Industrial Waste Over 10 Years Old
  3.2.6 Factor A.1.e Inert Industrial And Demolition Waste
  3.2.7 Factor A.1.f Difficult And Special Industrial Waste

3.3 CATEGORY A.2 CONTROLLED WASTE PHYSICAL STATE
  3.3.1 Introduction
  3.3.2 Factor A.2.a Liquid Waste: Quantity
  3.3.3 Factor A.2.b Sludge Waste: Quantity
  3.3.4 Factor A.2.c Containerised Waste: Quantity
  3.3.5 Factor A.2.d Difficult And Special Waste Disposal: Range Of Wastes

3.4 CATEGORY A.3 TOTAL CONTROLLED WASTE: LICENCE CONTROLS
  3.4.1 Introduction
  3.4.2 Factor A.3.a Potential Leachate Generation
  3.4.3 Factor A.3.b Leachate Management
  3.4.4 Factor A.3.c Liquid/Solid Input Ratio
  3.4.5 Factor A.3.d Attenuation Potential
  3.4.6 Factor A.3.e Site Area
  3.4.7 Factor A.3.f Total Airspace Filled
  3.4.8 Factor A.3.g Proportion Of Site Restored
  3.4.9 Factor A.3.h Proportion Of Site Area Active
  3.4.10 Factor A.3.i Standard Of Covering: Unrestored Non-Operational Areas Only

Chapter 4 Component B Landfill Operations Assessment

4.1 INTRODUCTION
4.2 CATEGORY B.1 WASTE INPUT/HANDLABILITY
  4.2.1 Introduction
  4.2.2 Factor B.1.a Difficult And Special Waste Quantity
  4.2.3 Factor B.1.b Household, Commercial And Biodegradable Industrial Waste Quantity

Figure 4: Factors and Components addressed in Britain's HALO system (Dames and Moore, 1985).

"CLASS A" CRITERIA - HAZARD TO HUMANS

THESE CRITERIA, SINGLY OR IN COMBINATION WITH OTHERS, INDICATE THE HIGHEST HAZARD TO HUMANS; FURTHER INVESTIGATIONS MAY BE WARRANTED TO DEFINE PRECISELY THE HAZARD(S) AND TO DETERMINE ACTIONS NECESSARY IN THE FUTURE.

- EXISTING DWELLING/STRUCTURE (WITH OR WITHOUT WELL) ON SITE
- PRIVATE WELL 1000 m FROM SITE
- MUNICIPAL WELL 1000 m FROM SITE
- PERENNIAL STREAM ON SITE OR WITHIN 1000 m FROM SITE AND THERE IS KNOWN DOMESTIC CONSUMPTIVE OR IN-STREAM USE OF STREAM WATER WITHIN 5 km DOWNSTREAM
- LIKELY FUTURE DEVELOPMENT OF LAND IN URBAN AREA OR IN DEVELOPED RURAL AREA
- SIGNIFICANT AQUIFER AT SURFACE OR WITHIN 10 m OF SURFACE AND GROUND WATER MOVEMENT IS DOWNWARD
- PAST PROBLEMS AT SITE

THE FOLLOWING SUPPLEMENT THE FOREGOING CRITERIA AND SHOULD BE NOTED FOR EACH SITE. THEY SHOULD NOT BE USED BY THEMSELVES TO CLASSIFY A SITE AS A "CLASS A" SITE.

- EASY PUBLIC ACCESS TO WASTE OR SITE
- EXISTING MONITORING FOR METHANE GAS, SURFACE OR GROUND WATER
- LANDFILL AREA 1 ha

"CLASS B" CRITERIA - HAZARD TO ENVIRONMENT

A SITE THAT DOES NOT SATISFY ANY OF THE "CLASS A" SITE CRITERIA IS AUTOMATICALLY A "CLASS B" SITE. THIS CLASSIFICATION INDICATES GENERALLY A LOW POTENTIAL FOR IMPACT ON HUMANS AND FURTHER INVESTIGATIONS REGARDING THESE IMPACTS ARE NOT AS URGENT AT THESE SITES AS AT THE "A" CATEGORY SITES. HOWEVER, THE HAZARD TO THE ENVIRNONMENT MAY STILL BE HIGH AND FURTHER INVESTIGATIONS MAY BE NECESSARY TO DEFINE THIS HAZARD.

Figure 5: Classification Rationale and Factors Addressed in the Ontario Waste Disposal Classification System (Ontario MOE, June 1991).

SITE CLASSIFICATION FORM

SITE NAME: ______________________ COUNTY: ______________

DATE OF INSPECTION: ______________________________

I. EVALUATION CRITERIA | **POTENTIAL FOR CONTAMINATION**

CONTAMINANT
- Nature of Materials ______________
- Quantity ______________

PATHWAY
- Run-off ______________
- Infiltration ______________

RECEPTOR
- Aquatic resources ______________
- Water supply ______________
- Sensitive habitat ______________
- Potential receptor ______________
- ("Nearest receptor)

SITE EVALUATION ______________ (MINIMAL, MODERATE, SEVERE)

II. OTHER CONSIDERATIONS

KNOWN OFF-SITE CONTAMINATION YES ______ NO ______

INSPECTOR'S ASSESSMENT ______________________________

____

____

____

____

____

____

____

____

III. SITE CLASSIFICATION
Overall "potential for contamination" based on I and II

LOW PRIORITY ______
HIGH PRIORITY ______

IV. RECOMMENDED CLOSURE METHOD

SIMPLE ______
OTHER ______

Figure 6: Sample Site Classification Form for the New Brunswick Assessment and Classification of Waste Disposal Sites for Closure Planning (New Brunswick Department of Environment, April 1992).

Contaminated Site Rating Method

FACTORS / SCORES	MARK (/10)	weighting PONDERATION (1-4)	TOTAL
1. Wastes characteristics			
1.1 Waste type(s)		3	
1.2 Physical state		2	
1.3 Quantity		2	
1.4 Compatibility between wastes		1	
2. Elimination/storage Method			
2.1 Age of the site		1	
2.2 Type of elimination/storage		4	
3. Site characteristics			
3.1 Topography		1	
3.2 Geology (permeability)		3	
3.3 Depth to underground water		3	
3.4 Potential of the aquifer(s)		2	
3.5 Inundation potential		2	
3.6 Surface water drainage		3	
3.7 Distance to surface water		2	
3.8 ~~Groundwater~~ stability		2	
3.9 Accessibility of the site		1	
4. Utilisation of the AREA			
4.1 Surrounding land use		3	
4.2 Surrounding aquifer use		2	
4.3 Aquifer type		1	
4.4 Surface water use		2	
4.5 Environment potential		3	
4.6 Aestetic considerations		1	
TOTAL ÷ 4.4 = %	----	----	440

CATEGORY	I	60%
	II	40 - 60 %
	III	20 - 40%
	REJECT	20 %

Figure 7: Sample Site Scoring Sheet and Rating Method for Quebec's Management of Contaminated Sites (MENVIQ, October 1987).

RATINGS

I- WASTE CHARACTERISTICS

1. Waste type(s) (annexe A)

10/10 = hazardous waste

8/10 = special waste (industrial waste such as described in annexe A but that can be almost considered as an hazardous waste on behalf of their characteristics)

7/10 = acidic mining residue

5/10 = special waste (industrial waste such as described in annexe A but that are fairly related to an hazardous waste)

4/10 = alkaline mining residue

2/10 = special waste (industrial waste such as described in annexe A but that can not be related to an hazardous waste)

2. Waste physical state

10/10 = liquid; gas[1]

7/10 = sludge (semi-liquid)

5/10 = solid, fine material

3/10 = solid, coarse material

Figure 8: Sample of Scoring Rationale and Rating of Factors for Quebec's Management of Contaminated Sites (MENVIQ, October 1987).

APPENDIX C - Remediation Technology

Appendix C - Remediation Technology

Once it has been decided to proceed with remediation and a background assessment is completed, a remediation technology must be selected on the basis of a number of criteria, including technical, environmental, and economic factors (Anderson, 1990).

Choosing the most appropriate technology is an important and difficult decision. Every contaminated site has its own characteristics upon which decisions should be made, including the type of contamination, type of soils, area of land, climatic differences and costs of technology. There are also a number of different remediation technologies now available from which to chose and many more currently being tested and developed to clean up soil from contaminated sites.

The diversity in the types of wastes and the variety of disposal scenarios necessitates a broad range of technologies for the cleanup of contaminated soils. Because each site possesses unique circumstances, each project should be evaluated on a case by case basis. Frequently, several remediation technologies may apply effectively to a site. At times, the most efficient approach is to employ a combination of techniques (Mamott, 1993).

Remediation technologies for contaminated soil are divided into three general categories: 1) physical control measures, such as excavation, capping and the use of liners; 2) *ex situ* treatment measures involving chemical and/or biological treatment; and 3) *in situ* treatment measures involving chemical and/or biological treatment (Canter, 1990).

Sections 4.1 - 4.5 give basic descriptions of some of the methods commonly available to remediate contaminated soil. The strengths and weaknesses, and the approximate costs are also discussed.

4.1 Vapour Extraction

Vapour extraction is an *in situ* process in which holes for extraction and sampling are bored and connected to a VE filter which extracts vapour with a fan (Mamott, 1993).

The strengths of this system are: 1) it is an in situ process (i.e. less chance of spreading contamination through transportation of contaminated soil); 2) it is ideal for small sites; 3) there is minimal site disruption; 4) it is non labour intensive; and 5) there is no need for excavation (Mamott, 1993).

Some of the weakness are: 1) it is not effective on non-volatile chemicals; 2) it is not effective on compacted soils; 3) requires a rather long time frame; and 4) requires frequent analysis (Mamott, 1993). The approximate cost for this treatment is $20-$50 (Canadian dollars) per ton of soil (Mamott, 1993).

4.2 Low Temperature Thermal Absorption

Low Temperature Thermal Absorption is the process where soil is removed from the site and heated in a rotary drier. While the soil is heated, exhaust gases are filtered out to a "baghouse" where residual hydrocarbons are polymerized (Mamott, 1993). This process is effective on a complete range of hydrocarbons, where virtually complete destruction is achieved (i.e., from 2 ppm to non-detectable). This system is also fast in comparison to other methods and also eliminates liability of differing soil types and conditions (Mamott, 1993).

Because of he required excavation (i.e. ex situ), it requires extensive permitting, and expensive heavy equipment. Also, this technology is cost sensitive to any excessive moisture, and soils containing chlorinated hydrocarbons may not be permitted (Mamott, 1993). The cost of this technology ranges from $50-$85 per ton of soil (Mamott, 1993).

4.3 Soil Washing

Soil Washing is a process where soils are removed from the site and washed with chemicals. The types of chemicals used for the washing depend on the type of contamination in the soil. Chemical washing is used to leach out hydrocarbons and heavy metals out of the soil, by creating chemical bonds with the soil contaminants and the washing solution. Once the chemicals are leached out, contaminated water and chemicals are treated by polymerized filtration, and hydrocarbons are polymerized as the heavy metals are removed from the water through chelating (Mamott, 1993).

Anhydrous liquid ammonia has been used to attempt extraction of metals from contaminated soils because it forms strong soluble ammonia complexes with many toxic metals. The feasibility of using anhydrous ammonia to extract common metal contaminants (i.e., lead, cadmium, mercury copper and zinc) from soil was studied. Sixty to seventy percent extraction of cadmium, copper, and zinc was obtained, but extraction rates of lead and mercury were low. The study found ammonia extraction of metals to be an ineffective method of site cleanup; it may be beneficial when combined with other remediation techniques (Clifford et al., 1993).

Soil washing has some benefits: 1) it is equally effective on heavy metals and hydrocarbons; 2) there is no limitations on chlorinated solvents; 3) the process can be mobile which means the possibility of washing the soil at the site; 4) the process is fast; 5) and it is effective under almost all soil conditions (Mamott, 1993).

The process has a number of weaknesses. The soil may have to be moved off the site, increasing the probability of spreading contamination. Further, even if soil washing is carried out at the site, excavation still must be performed requiring extensive and expensive equipment (Mamott, 1993).

Although this system can be very effective in the remediation of soil, contaminants are basically transferred from one media (i.e. the soil) to another; thus, some disposal to a landfill may still be required. This process also requires post treatment of the water raising the costs of the process. The cost of Soil Washing is approximately $55-$90 per ton of soil (Mamott, 1993).

4.4 Bioremediation

Bioremediation is the technology using microorganisms to detoxify and degrade hazardous wastes (usually organic compounds) and is a treatment technology that, depending on the site-specific conditions, can reduce the contamination to acceptable levels (Warith, 1992). A large number of bioremediation technologies exist; thus, one or more of the techniques may be chosen for at least part of a remediation scheme (Fiorenza et al., 1991).

Bioremediation can be conducted *in situ* or *ex situ*. *In situ* bioremediation is beneficial because the biodegradation can occur without transferring the contamination from one part of the environment to the other. The *in situ* process involves inoculation corridors being placed for the optimal contamination contact. The microbes and nutrients are then fed into the contaminated area. Then, a bioreactor is used to treat the inoculant and ground water (Mamott, 1993).

Ex situ bioremediation involves removal and transportation of soil to a pre-made collection cell. The inoculant is then pumped into the corridors of the cell and fed to the bioreactor for treatment (Mamott, 1993).

Bioremediation is beneficial because it can be performed in situ and ex situ. It is effective on most hydrocarbons, it can be used for BOD reduction and it can be utilized in very wet soil conditions. It is also relatively simple to receive permits for the use of this technology (Mamott, 1993).

Bioremediation requires extensive analysis and is very environmentally sensitive, requiring the proper temperature, pH, and nutrients. For example, most remediation bacteria cannot survive in cold climates of northern Manitoba. For this reason, *ex situ* bioremediation is usually more effective because of its controlled setting. It is also not effective on compacted soils and soils contaminated with chlorinated hydrocarbons. A weakness is that bioremediation is a relatively slow process usually taking from 60 to 250 days to complete (Mamott, 1993). Bioremediation costs from 40 to 75 dollars per ton of soil (Mamott, 1993).

4.5 Excavation and Disposal

Excavation and disposal is the process of digging up the contaminated soil and dumping it at a permitted hazardous waste landfill site. Although this process is fast, relatively inexpensive and equally effective for all contaminants and soil conditions, the soil is not de-contaminated and the problem is just transferred to another location. There is also the chance of spreading the contamination through excavation and transportation to the landfill. This is becoming less of an option as more and more landfills become reluctant to accept contaminated soil (Mamott, 1993).

The cost of this method is dependant on the prices of excavation equipment and distance to transport. An approximate price is $35-$90 per ton of soil (Mamott, 1993).