METHODS FOR INVENTORIES OF

Contaminated Sites

ENVIRONMENTAL

QUALITY CRITERIA

GUIDANCE *for*

DATA COLLECTION

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MET

SWEDISH ENVIRONMENTAL PROTECTION AGENCY

Contents

Foreword

In 1990, the Swedish Environmental Protection Agency was assigned the task of planning for the remediation of the nation's contaminated sites. A nation-wide inventory of industrial branches was carried out during 1992–1994 for the purpose of identifying the sites and branches most urgently in need of attention. The inventory was based on existing information, which indicated that field investigations had not yet been undertaken at the majority of the sites.

The industrial inventory is now being complemented, and for that purpose a method has been developed for the assessment of risks on a uniform basis and with a reasonable degree of reliability. By applying a uniform method, sites can be compared in order to set priorities for further investigation and remediation, and to make decisions about hazardous and suspected hazardous sites.

The method consists of three parts. The first part deals with environmental quality criteria for contaminated areas, including a method for risk classification. The second part provides guidance for the collection of data required for risk classification. The third part, presented in a separate report, describes analytical procedures which are included in the method.

The first part is included in a series published by the Swedish Environmental Protection Agency under the general heading of Environmental Quality Criteria. The other reports in the series are entitled *The Forest Landscape, The Agricultural Landscape, Groundwater, Lakes and Watercourses* and *Coasts and Seas.*

This report, *Contaminated Sites,* is based on our current understanding of environmental effects and their causes. As our understanding is being improved continuously, a revision will be needed eventually. Developments in the work of the Swedish Environmental Protection Agency can be followed on our Internet web site: **www.environ.se**. Concise versions of the reports are available there as well.

The project leaders for this report are Per Gullbring and Fredrika Östlund of the Swedish Environmental Protection Agency. The work has been carried out in co-operation with the following individuals and institutions: Ingvar Björklund, Hans Borg, Thomas Alsberg, Cecilia Andrén and Erik Gravenfors of the Institute for Applied Environmental Research at Stockholm University; Ingemar Cato, Dag Fredriksson and Ulf Qvarfort of the Swedish Geological Survey; and Lennart Dock of the Institute of Environmental Medicine at Karolinska Institute.

The method has been tested with trial inventories of contaminated sites in eight Swedish counties. It has also been submitted for review and comment by government agencies, universities and other interested parties.

The Swedish Environmental Protection Agency is grateful for the assistance of all who participated in the project.

Swedish Environmental Protection Agency
Stockholm, 2002

Summary

Part 1 of this report on contaminated sites is one of six in a series of reports issued by the Swedish Environmental Protection Agency under the general heading of ENVIRONMENTAL QUALITY CRITERIA. The others are entitled *The Forest Landscape, The Agricultural Landscape, Groundwater, Lakes and Watercourses* and *Coasts and Seas.*

The purpose of the series is to enable local and regional authorities and others to make accurate assessments of environmental quality on the basis of available data, thus providing a more solid foundation for environmental planning and the establishment of environmental objectives. Each of the reports includes assessment criteria for a selection of parameters relating to objectives and threats that are associated with the main subject of the report.

A contaminated site is a landfill site or area of soil, groundwater or sediment which is so contaminated by a point source that concentrations significantly exceed local or regional background levels. The environmental quality criteria described in this report may be used to assess individual contaminated sites. They are a tool for assessing the risk associated with a contaminated site on the basis of limited information. The area is assigned to one of four risk classes as a result of the assessment.

The risk classification is an overall assessment of the degree of hazard posed by the contaminants, the level of contamination, the potential for migration of the contaminants as well as the degree to which protection of human health and the environment is required in the area. Criteria, questionnaires and tables have been provided to assist in various aspects of the assessment. Only a small part of the information required for risk classification is derived from environmental monitoring programmes. Most of the data is generated by special studies and investigations conducted at each site.

Part 2 of this report provides guidance regarding the requirements that must be met by the input data used in order to classify the risks associated with contaminated sites with an adequate degree of reliability. The guidance also explains how to collect the necessary data, plan and carry out the required sampling and analysis. Together, parts 1 and 2 comprise a complete guide for all the steps involved in conducting inventories of contaminated sites.

The model thus described is entitled MIFO, which, in Swedish, stands for Methods for Inventories of Contaminated Sites, and consists of two phases. The first phase is a preliminary survey, which begins with the identification of relevant objects for assessment and industries, followed by data-collection from maps and archives, together with on-site inspection and interviews. The preliminary inventory concludes with descriptions, evaluations and a final report.

The second phase is a preliminary site investigation that begins with an on-site inspection and the drawing up of a geological profile and sampling plan. Samples are then taken at strategically selected locations and analysed to quantify the relevant parameters. The preliminary site investigation concludes with descriptions, evaluations and a final report.

This report also contains information on quality assurance and safety issues.

PART 1

Environmental

Quality Criteria for

Contaminated Sites

Environmental Quality Criteria

The vision of an ecologically sustainable society includes protection of human health, preservation of biodiversity, conservation of valuable natural and historical settings, an ecologically sustainable supply and efficient use of energy and other natural resources. In order to determine how well basic environmental quality objectives and more precise objectives are being met, it is necessary to continuously monitor and evaluate the state of the environment.

Environmental monitoring has been conducted for many years at both the national and regional levels. But, particularly at the regional level, assessments and evaluations of current conditions have been hindered by a lack of uniform and easily accessible data on baseline values, environmental effects, etc.

This report is one of six in a series which purpose is to fill that information gap, by enabling counties and municipalities to make comparatively reliable assessments of environmental quality. The reports can thus be used to provide a basis for environmental planning, and for the setting of local and regional environmental objectives.

The series bears the general heading of "Environmental Quality Criteria", and includes the following titles: *The Forest Landscape, The Agricultural Landscape, Groundwater, Lakes and Watercourses, Coasts and Seas,* and *Contaminated Sites.* Taken together, the six reports cover most of the natural ecosystems and other types of environment found in Sweden. It should be noted, however, that coverage of wetlands, mountains and urban environments is incomplete.

Each of the reports includes assessment criteria for a selection of parameters relating to objectives and threats that are associated with the main subject of the report. The selected parameters are, for the most part, the same as those used in connection with national and regional environmental monitoring programmes; but there are also some "new" parameters that are regarded as important in the assessment of environmental quality.

Most of the parameters included in the series describe current conditions in natural environments, e.g. levels of pollution, while direct measures of human impacts, such as the magnitude of emissions, are generally not

included. In addition to a large number of chemical parameters, there are several that provide direct or indirect measures of biodiversity.

In all of the reports, assessments of environmental quality are handled in the same way for all of the parameters, and usually consist of two separate parts (see also page 13). One part focuses on the effects that observed conditions can be expected to have on environment and human health. Since knowledge of such effects is often limited, the solution in many cases has been to present a preliminary classification scale based on general knowledge about the high and low values that are known to occur in Sweden.

The second focuses on the extent to which measured values deviate from established reference values. In most cases, the reference value represents an approximation of a "natural" state, i.e. one that has been affected very little or not at all by human activities. Of course, "natural" is a concept that is not relevant to the preservation of cultural environments; in such contexts, reference values have a somewhat different meaning.

The results of both parts are expressed on a scale of 1-5, where Class 1 indicates slight deviations from reference values or no environmental effects, and Class 5 indicates very large deviations or very significant effects. The report on Contaminated Sites with its discussion of pollutants in heavily affected areas complements the other five reports. In those cases where the parameters are dealt with in several of the reports, which is particularly the cases for metals, the report on Contaminated Sites corresponds (see further pages 13-14). However, the various parameters cannot be compared with each other in terms of risks. The following paragraphs review the extent of agreement with corresponding or similar systems used by other countries and international organizations.

INTERNATIONAL SYSTEMS FOR ENVIRONMENTAL QUALITY ASSESSMENT

Among other countries, the assessment system that most resembles Sweden's is that of Norway. The Norwegian system includes "Classification of Environmental Quality in Fjords and Coastal Waters" and "Environmental Quality Classification of Fresh Water". A five-level scale is used to classify current conditions and usability. Classifications are in some cases based on levels of pollution, in other cases on environmental effects.

The European Union's proposal for a framework directive on water quality includes an assessment system that in many ways is similar to the Swedish Environmental Quality Criteria.

If the parameters used in the latter are regarded as forms of environmental indicators, there are many such systems in use or under development. However, the concept of environmental indicators is much broader than the parameters of Environmental Quality Criteria.

Acidification

Eutrophication

Organic pollutants

Use of land and water

The forest landscape

Acidification

Leaching of nutrients

Metals

Proportion of ancient forest and deciduous forest in the landscape.
Presence of dead wood and large trees

Groundwater

Acidification

Nutrients

Metals
Pesticides

Water table

Chloride

Redox

Lakes and watercourses

Acidification

Nutrients

Metals

Presence of aquatic organisms

Light conditions

Oxygen
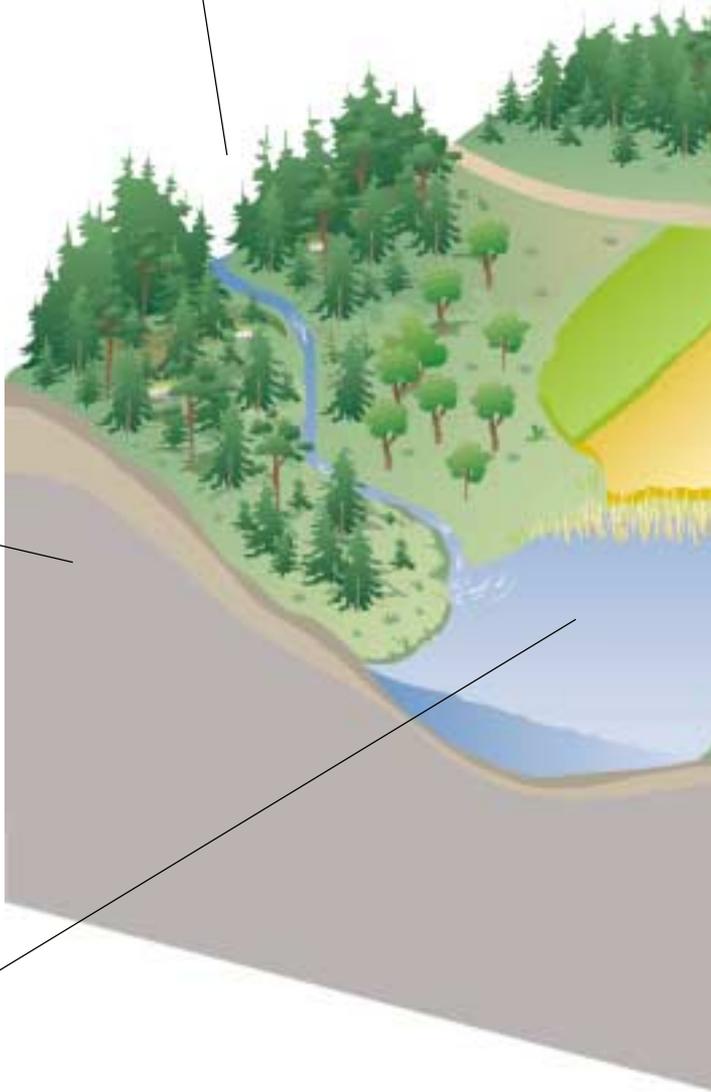
The agricultural landscape

Acidification

Leaching of nutrients

Metals

Content and extent of the agricultural
landscape
Customary land use
Quality of arable land
Number of species

Contaminated sites

Metals
Organic pollutants
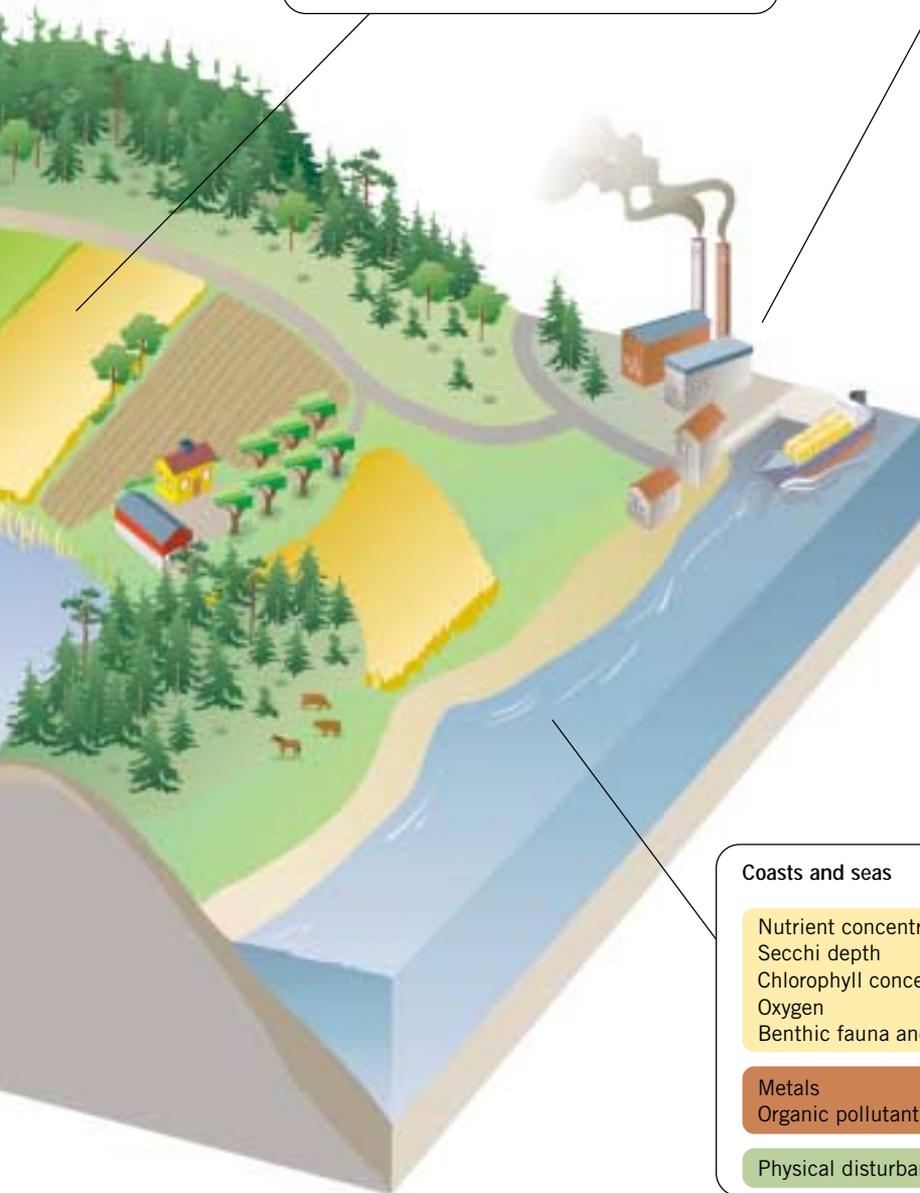
Coasts and seas

Nutrient concentrations
Secchi depth
Chlorophyll concentration
Oxygen
Benthic fauna and macrovegetation

Metals
Organic pollutants

Physical disturbance along the coast

Internationally, the most widely accepted framework for environmental indicators is based on PSR-chains (Pressure-State-Response). Indicators are chosen which reflect the relationship between environmental effects, and/or there causes and measures taken. There is also a more sophisticated version, called DPSIR (Driving forces-Pressure-State-Impact-Response). Variants of the PSR/DPSIR systems are used by, among others, the OECD, the Nordic Council of Ministers, the United Nations, the World Bank, the European Union's Environmental Agency.

ASSESSMENT PROCEDURE

Measurements/data

→ Assessment of current conditions — indicates environmental effects associated with current conditions

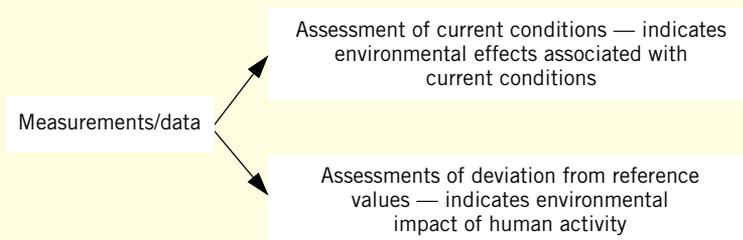→ Assessments of deviation from reference values — indicates environmental impact of human activity

Assessment of current conditions

Wherever possible, the scale used in assessments of current conditions is correlated with effects on different parts of the ecosystems and their biodiversity, or on human health ("effect-related classification"). In some cases, the assessment is based only on a statistical distribution of national data ("statistical classification").

The scale is usually divided into five classes. Where the assessment is based on effects, Class 1 indicates conditions at which there are no known negative effects on the environment and/or human health. The remaining classes indicate effects of increasing magnitude. Class 5 includes conditions leading to the most serious negative effects on the environment and/or human health. Due to wide natural variations, especially with regard to biological phenomena, the indicated effects are not always the result of human activities, in which case they can not be labelled as "negative"(see below).

Where the assessment is based only on a statistical distribution, there is no well-defined relationship between effects and class limits. It should be noted that parameters that are evaluated on the basis of different criteria cannot be compared with each other.

Reference values

Ideally, the reference value for a given parameter represents a natural state that has not been affected by any human activity. In practice, however, reference values are usually based on observations made in areas that have experienced some slight human impact. In some cases, historical data or model-

based estimates are used. Given that there are wide natural variations of several of the parameters, reference values in many cases vary by region or type of ecoystem.

Deviations from reference values

The extent of human impact can be estimated by calculating deviations from reference values, which are usually stated as the quotient between a measured value and the corresponding reference value:

$$\text{Deviation} = \frac{\text{Measured value}}{\text{Reference value}}$$

The extent of deviation is usually classified on a five-level scale. Class 1 includes conditions with little or no deviation from the reference value, which means that effects of human activity are negligible. The remaining classes indicate increasing levels of deviation (increasing degree of impact). Class 5 usually indicates very significant impact from local sources.

Organic pollutants and metals in heavily polluted areas are dealt with in greater detail in a separate report, Contaminated Sites, which includes a further sub-division of Class 5, as follows:

Contaminated Sites				
Impact from point sources:				
	None/ slight	Moderate	Substantial	Very great
Class 1	Class 2	Class 3	Class 4	Class 5
Other reports				

Environmental Quality Criteria for Contaminated Sites

State of the environment and problems

A contaminated site is a well-defined area for which the level of contamination from one or more point sources significantly exceeds the relevant background level. A site may consist of a landfill or an area of contaminated soil, groundwater or sediment.

The pollution of land and water by industrial activities has occurred over a period of several hundred years, resulting in a large number of landfills and other contaminated sites. The Swedish Environmental Protection Agency estimates that there are about 22,000 contaminated sites through-out the country.

Contaminated sites have only recently been considered from the planning and environmental protection viewpoints. Many of these sites are already releasing large quantities of contaminants that have unacceptable effects on the environment. In many cases, the pollutants comprise serious future threats to human health and the environment.

Environmental quality assessments

Environmental quality criteria are used to assess individual contaminated sites, which may range in size from a petrol station to a large industrial complex or part of a groundwater system that has been polluted by a point source. The criteria have been developed primarily for the investigation of contaminants that have been in the ground for a long period of time, but they may also be applied to more recent, acute problems.

The purpose of the criteria is to permit a comprehensive assessment of the risks associated with specific contaminated sites, even in cases for which available data are limited. The results are intended to provide a basis for the setting of priorities and for decisions concerning additional investigations, remediation, the declaration of a hazardous site or other measures. The area is assigned to one of four risk classes as a result of the assessment.

Class 1: Very high risk
Class 2: High risk
Class 3: Moderate risk
Class 4: Low risk.

There is no limit to the number of parameters that may be used in connection with environmental quality criteria for contaminated sites. It should be possible to assess all kinds of contaminants that may be present in a contaminated site. Therefore guidance on how to carry out assessments for a number of parameters is given in Appendices 4 and 5.

Environmental quality criteria are used to classify contaminated sites according to level of risk. In the following pages, the term "risk classification" is used in place of "environmental quality criteria for contaminated sites".

TABLE 1.

Questions concerning risk classification of contaminated sites

Questions about the site	Questions concerning risk to man and the environment and scale on which answers are placed
Hazard assessment	
Which contaminants are present?	Level of hazard? Low <————————> Very high
Contamination level	
Level of contaminants in each of the media in which they occur?	What is the current conditions? (How serious are the effects?) Slight <————> Very serious Deviation from reference value, i.e. degree of influence from point source? None <————————> Very large
Total amount of each pollutant?	Small <————————> Very large
Total volume of contaminated material?	Small <————————> Very large
Migration potential	
How rapidly does the pollutant spread through various media?	Slow <————————> Very rapid
Sensitivity/Protective value	
Potential exposure of humans, present and future?	Sensitivity of exposed groups? Low <————————> Very high
Potential risk to the environment, present and future?	Level of protection required for exposed environment? Low <————————> Very high
Comprehensive risk assessment	
	Overall risk of the site to humans and to the environment? Low <————————> Very high

Procedures for data-collection are described in Part 2 of this report. The data collected from a contaminated site provide answers to a number of questions relating to present conditions at and around the site, and to the associated risks to man and the environment (see Table 1). Many

different aspects are considered, within the context of the following four general issues:
• hazard assessment
• contamination level
• migration potential
• sensitivity/protection value

The risk associated with each of these aspects is assigned one to four levels. The boundaries between the levels are set so that conditions at all contaminated sites in Sweden – from those which present only a slight risk, to the most severely contaminated – are taken into account.

Finally the four aspects are weighed together in a comprehensive assessment on the basis of which the site is assigned to one of the four risk classes.

Assessments of current conditions and deviations from the reference values are conducted according to the same principles as those applied to the other five major categories of environmental quality criteria, with two exceptions: Firstly, only those contaminated sites which have been polluted by a point source are considered and the reference value is represented by the contaminant concentration that would occur if the site were not affected by a point source. This concentration, or reference value, can often be measured in a nearby area. The reference value reflects the natural concentration of the relevant substance, possibly with a slight addition from the effects of human activity. Secondly, in comparison with the other major categories of environmental quality criteria, classes 4 and 5 have been further subdivided.

The human health risk is evaluated at the individual level, which means that the risk is the same whether one or several persons are exposed. Risk to the environment is evaluated in relation to species and ecosystems.

Risk is evaluated with regard to both current and future situations, i.e. for the area that is already contaminated and areas that may experience negative effects in the future due to the spread of contaminants. The magnitude of the risk is dependent on factors such as type of land use.

The time frame considered in the assessment is hundreds to thousands of years. The point of departure for assessments of the exposure of humans and the environment is the type of land use, which may already have been decided in a detailed plan or merely been proposed in a general planning document.

Risk assessments apply to contaminated buildings and other constructions, land, groundwater, surface water and sediments. Landfills and filled-in areas are regarded as land.

In order to make assessments of the various aspects readily comprehensible, three forms are completed for each site – two for underlying assessments, and one for the comprehensive risk evaluation (see Appendices 3, 6 and 7). As much information as possible is compiled; even uncertain data are noted, and indicated with a question mark ("?"). This is because valuable information may be lost if only that which is absolutely certain is noted.

The conclusions derived from the two underlying assessments are noted on the form for comprehensive risk assessment, contributing to an overview of the entire situation. All parameters are first evaluated separately, and then weighed together in the final assessment for risk classification.

Data requirements and method

Very little of the data used in assessing environmental quality criteria for contaminated sites comes from environmental monitoring programmes. Most of the data comes from the preliminary surveys and the preliminary site investigation that is carried out in connection with the inventories of contaminated sites. The relevant procedures for data collection are described in Part 2 of this report.

The method presented here for risk classification can be applied to sites for which the volume of data varies widely. It can also be applied to sites for which data have been acquired by means other than inventories, for example in cases where field studies have previously been conducted.

Risk classification may be repeated several times for the same site if new data are acquired. Underestimation of the risks must be avoided when carrying out the assessments. Assessments must be based on a "reasonably conservative" scenario. To base them on a "worst case" scenario may result in a significant overestimate of the actual risk. The greater the degree of uncertainty in the data, the greater the need for strict evaluations.

Area typology

For assessments of contaminated sites, there is no area typology. Contaminated sites often have levels of contamination that greatly exceed natural variations in the country. Therefore, the method described here is considered to be more appropriate than the use of an area typology based on natural or background levels which are then related to reference values.

References

Swedish Environmental Protection Agency, "Branschkartläggningen – en översiktlig kartläggning av efterbehandlingsbehovet i Sverige"; report nr. 4293, 1995

Swedish Environmental Protection Agency, "Handlingsprogram för efterbehandling"; report nr. 4454, 1995

Swedish Environmental Protection Agency (1996), Generic guideline levels for contaminated sites (In Swedish: Generella riktlinjer för förorenade områden – beräkningsprinciper och vägledning för tillämpning) Report No. 4638

Swedish Environmental Protection Agency (1998), Proposed guideline levels for contaminated petrol stations (In Swedish: Förslag till branschspecifika riktvärden för förorenade bensinstationer). Report No. 4889
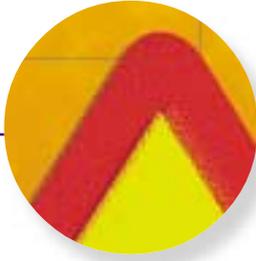
Hazard Assessment

This section is concerned with assessment of the risks associated with the hazardous properties of the contaminants present at the site.

Background

It is necessary to know what contaminants are present at the site.

When there are no analytical results, which usually is the case during the preliminary survey (phase 1), the hazard assessment will have to be based on knowledge of the activities previously located at the site and the industrial processes and chemicals involved. Such information will indicate which chemicals are likely to be found at the site. Additional useful information can be obtained from previous site investigations, verbal reports and impressions from on-site observations.

When the preliminary site investigation (phase 2) has been performed, the analytical data obtained should reveal which contaminants are actually present. However, such information may also be available as a result of previous investigations of the site.

Hazard assessment

The hazard depends on the intrinsic properties of the contaminants.

In the present context, *hazard* is defined as the inherent potential of a substance or a group of substances to harm human beings or the environment. This potential is also referred to as the *toxicity* of the substance. The hazard depends entirely on the chemical properties of the substance.

A contaminated site often contains a mixture of contaminants. How and to what extent these interact is usually unknown. In the part of an assessment of a contaminated site which is based on the intrinsic chemical properties of the contaminants present, each contaminant is treated as a separate entity. This generally means that a site contaminated with multiple contaminants will be classified as representing a greater hazard than a site containing only one type of contaminant.

The regulations and recommendations of the Swedish National Chemicals Inspectorate (KemI), which cover a broad range of chemicals, are suitable tools for use for the hazard assessment of a contaminated site.

The first step is to check if the contaminants present at the site are banned from use or if their use is restricted. Such chemicals are listed in

the KemI limitation list. If a contaminated site is suspected to contain chemical compounds that are banned from commercial use or are being phased out, the site has to be considered a serious hazard.

The next step is to check if the contaminants belong to the 200 substances listed in the KemI Observation list or included in the "Sunset project". If so, the site also has to be considered a serious hazard.

The KemI Regulations on the Classification and Labelling of Chemical Products, which cover more than 2200 substances, describe how chemicals can be classified according to their hazardous properties with respect to health and environmental effects. If a particular property of a chemical is not classified it may be because an assessment has not been carried out. The KemI procedure of substance classification includes an assignment of each substance to one or several "hazard classes" with associated risk phrases describing the nature of the health or environmental hazard. The assignment follows strictly defined criteria. The hazard classes for chemical compounds used by the KemI include: Highly toxic (T+), Toxic (T), Corrosive (C), Harmful to the environment (N), Harmful to health (Xn), Irritating (Xi), Harmful to the environment without symbol (-), Moderately harmful to health (V). The environmental hazard assessment is subdivided into aquatic environments and all other environments. The aquatic hazard assessment is based on information on acute toxicity, persistence in the environment, and potential for bioaccumulation. All these properties indicate a possibility for harmful environmental effects.

TABLE 2.

Criteria for the classification of hazard assessment

Slightly hazardous	Moderately hazardous	Very hazardous	Extremely hazardous
"moderately harmful to health" (V)	"harmful to health" (Xn), "irritating" (Xi) "harmful to the environment without symbol" (-)	"toxic" (T), "corrosive" (C) "harmful to the environment" (N)	"very toxic" (T+), substances that are not allowed to be handled commercially or are being phased out

The KemI hazard classification system can be used for the hazard classification of contaminants at polluted sites as listed in Table 2.

Metals are generally considered to be present in their most toxic form. Exceptions can be made under certain circumstances, for example if the actual chemical species is known. The reason for any exception should always be clearly stated in the evaluation report.

The KemI classifications and regulations generally consider pure individual chemical substances and may therefore be difficult to apply to

TABLE 3.

Hazard classification of certain chemical substances, products and mixtures

Slightly hazardous	Moderately hazardous	Very hazardous	Extremely hazardous
Iron	Aluminium	Cobalt*	Arsenic*
Calcium	Scrap metal	Copper*	Lead*
Magnesium	Acetone	Chromium* (if Cr VI is	Cadmium*
Manganese	Aliphatic hydrocarbons	not present)	Mercury*
Paper	Wood fibre	Nickel*	Chromium (VI)*
Wood	Tree bark	Vanadium*	Sodium (metal)
	Zinc*	Ammonia	Benzene*
		Aromatic hydrocarbons*	Cyanide*
		Phenol*	Creosote*,**
		Formaldehyde	Coal tar
		Glycol	PAH*
		Concentrated acid	Dioxins*
		Concentrated bases	Chlorobenzenes*
		Solvents	Chlorophenols*
		Styrene	Chlorinated solvents
		Petroleum ash	Organochlorine
		Petroleum products	compounds
		Aviation fuel	PCB*
		Heating oil	Tetrachloroethylene*
		Waste oil	Trichloroethane*
		Lubrication oil	Trichloroethylene*
		Hydrogen peroxide	Pesticides
		Paints and dyes	
		Cutting oil	
		Petrol	
		Diesel oil	
		Wood tar	

* Swedish EPA generic guideline levels available

**aged creosote with high content of polycyclic aromatic hydrocarbons

contaminated sites where contamination by several contaminants is likely. In order to facilitate the assessment of chemical hazards at contaminated sites a number of substances and groups of substances frequently present at such sites have been evaluated and listed in Table 3, basically according to the KemI criteria. The Swedish Environmental Protection Agency (Swedish EPA) has issued guideline values for several of the substances and this is indicated in the table.

The contaminants present at the site being assessed are noted in the appropriate box under the heading "chemical hazard assessment" in the

comprehensive risk assessment protocol (Appendix 7), an example can be seen on page 50. Incomplete information, i.e. suspected, but not verified, contaminants, is noted with a question mark ("?"). Naturally occurring substances are only included if their levels exceed the guideline level or the natural background level. Substances that are not normally present in the environment are always included.

References

Swedish Environmental Protection Agency (1996), Generic guideline levels for contaminated sites (In Swedish: Generella riktlinjer för förorenade områden – beräkningsprinciper och vägledning för tillämpning) Report No. 4638

Swedish Environmental Protection Agency (1998), Proposed guideline levels for contaminated petrol stations (In Swedish: Förslag till branschspecifika riktvärden för förorenade bensinstationer). Report No. 4889

National Chemicals Inspectorate (1996), Limitation List (In Swedish: Begränsningslistan – förteckning över ämnen som är förbjudna eller vars användning är inskränkt)

National Chemicals Inspectorate (1997), Regulations on the Classification and Labelling of Chemical Products, KIFS 1997:5 (English translation of KIFS 1994:12, available at www.kemi.se)

National Chemicals Inspectorate (1998), Observation List – Example list of chemicals requiring particular attention. (available at www.kemi.se)

National Chemicals Inspectorate (1994), The Sunset Project (In Swedish: Solnedgångsprojeket), KEMI Report 13/94
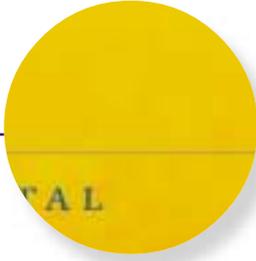
Contamination Level

This section is concerned with assessment of the risks associated with the amounts and concentrations of the contaminants, and with the volume of contaminated material.

Background

It is necessary to determine the level of every contaminant in each of the media where it is present, as well as the total amount of every contaminant at the site and the total volume of contaminated material.

Phase 2 of the inventories, the preliminary site investigation, includes sampling and analysis. The results are used in the assessment of the level of contamination. In some cases, an estimate of the level of contamination can be made already in the first phase, based on olfactory and visual impressions at the site, or on data from previous studies. The reliability of the sampling procedures and analytical methods used in previous studies must be evaluated, in order to ensure that the quality of the results is adequate. If the quality is adequate, the results from previous studies may be used in the same way as fresh data acquired in phase 2 of the inventory.

If only 1–5 samples have been taken at the site, the highest observed value is used in the comparisons. If more than five samples have been taken it may be more appropriate to use either the next-highest value or the 90th percentile.

An estimate of the amounts of the contaminants and the volume of contaminated material in buildings and other constructions, in the ground and in sediments is required. For this purpose, it may be possible to use information about or estimates of the amounts used at the site of chemicals which are now regarded as contaminants due to spillage, etc. General knowledge about branch or industry practices in the handling of chemicals, visual and olfactory impressions during visits to the site, and the results of sample analysis may also be useful in making such estimates.

Assessment of the contamination level

Risks are related to:
• the severity of the effects which can be caused by the observed contaminant concentrations; the extent to which the site is affected by point sources; the amounts of the contaminants; the volume of contaminated material.

The current conditions is assessed by measuring the concentrations of contaminants at the site. Those levels are then compared with reference values to determine the extent of deviation from those values.

The contamination level is a combination of the current conditions, deviation from reference values, the amounts of contaminants, and the volume of contaminated material. The current conditions and deviation from reference values are assessed for all media, with the exception of buildings and other constructions. The amount of each contaminant and the volume of contaminated material are assessed for buildings and other constructions, land and sediments.

To assist in the assessment of the contamination level, an assessment form is provided (see Appendix 3). The number of samples taken at the site, and which of them are used for comparison should be noted on the form. Information on all contaminants, both observed and suspected, is noted. Assessments based on uncertain data are indicated with a question mark ("?"). Analysis results that cannot be used due to lack of comparative data are noted in a special area. Also noted are references to the data with which the measured values are compared. If comparisons with different references yield different results, this should be noted in the areas provided, if the connection between specific references and results is clear. An example of a completed form is provided at the end of this chapter.

Conclusions regarding contamination levels are entered on the form for comprehensive risk evaluation (see Appendix 7).

Assessment of current conditions

The state of the environment is related to the severity of the effects that may be caused by contaminants at the measured concentrations. The concentrations measured at the site are compared with effects-related values, which can be used to make an effects-related assessment. Several types of effects-related values can be used.

For *soil,* the Swedish guideline values for contaminated soil are preferred. As of spring 2000, there are general guideline values for 36 substances in soil, and sector specific guideline values for contaminated petrol stations. The guideline values for contaminated sites may be regarded as levels of contamination below which there is no short- or long-term risk for negative effects on humans or the environment. Guideline values for soil have been developed for several different types of land use. To assess current conditions, comparisons are made with the guideline values for the most sensitive type of land use. If there are no Swedish guideline values available, corresponding values from other countries may be used instead.

Guideline values are also preferred for *groundwater.* Guideline values for a number of substances at petrol stations have been proposed. For other substances, Swedish drinking water quality standards are used, where these are based on health criteria. If no Swedish value for drinking water quality

is available, corresponding values from the World Health Organization, the European Union and other countries may be used, on condition that they are based on health criteria.

There are no guideline values for contaminated *surface water* in Sweden. However, use can be made of values developed in connection with the Swedish *Environmental Quality Criteria for Lakes and Watercourses* or the Canadian water quality criteria for the protection of aquatic life.

At present, there are no adequately documented effect-related values for *sediment* upon which to base a classification of current conditions. For certain substances, guideline values from other countries can be used. Selected effect limits are noted in Table 6, Appendix 4. For sediment, the deviation from reference values is assigned greater weight when assessing the contamination level.

TABLE 4.

Criteria for the classification of current conditions

Moderate	Slightly serious	Moderately serious	Serious	Very serious
Land, sediment and groundwater, if guideline values are available	< guideline values	1–3 x guideline values	3–10 x guideline values	>10 x guideline values
Groundwater, if guideline values are not available	< drinking water quality standard*	1–3 x drinking water quality standard*	3–10 x drinking water quality standard*	> 10 x drinking water quality standard*
Surface water	< Cwq < L/W	1–3 x Cwq 1–3 x L/W	3–10 x Cwq 3–10 x L/W	> 10 x Cwq >10 x L/W
Tox data	< LC50/1000	LC50/1000–LC50/300	LC50/300–LC50/100	>LC50/100

* = threshold of risk to human health
Cwq = Canadian water quality criteria
L/W = material from *Environmental Quality Criteria for Lakes and Watercourse*s; see Table 4, Appendix 4

If effects-related data of the type noted above are lacking for specific substances, assessments may be made with the help of toxicological and ecotoxicological data taken from reference books and data bases such as IUCLO. In the absence of more suitable information, it can be assumed that the LOEC (lowest observed effect concentration) is approximately the LC50 level divided by 1000, where the LC50 is the concentration at which fifty percent of the test organisms die. In certain tests, an EC (effects concentration) is used instead of the LC to describe acute effects.

The criteria used in assessing current conditions at contaminated sites are summarised in Table 4.

The classification of various substances in different media (except sediment) is presented in Appendix 4.

Deviation from the reference value

Reference value

Reference values represent the concentrations of substances which would be found at a site if it were not contaminated by one or more point sources. They can be used to determine the extent of contamination from such sources.

Reference values can often be obtained in the immediate vicinity of a given site, as long as the point source has not affected the area where they are measured. A contaminated site may, itself, function as an intermediate source of contamination that can affect its surroundings. The reference values given in Appendix 5 indicate the concentrations above which a site may be regarded as being affected by a point source. Sites where concentrations are below those reference values may also be affected by a point source, though the observed levels may also be the result of natural causes or the diffuse spread of contaminants.

Thus, reference values reflect natural concentrations, possibly with some minor addition of contaminants from human activity. Urban areas usually have higher reference values than rural areas. Reference values may also be available for substances that do not occur naturally in the environment. Reference values reflect current environmental conditions, and have nothing to do with levels that are regarded as desirable or levels that have negative effects.

Reference values can be established in a number of ways. The best reference values are based on data from areas that are unaffected by point sources in the immediate vicinity. Investigations based on the analysis of less than five samples are not valid in this context. Where 5–20 samples have been taken, either the highest or next-highest value is used as the reference value. Where more than twenty samples have been analysed, the 90th or 95th percentile may be used.

When there are no studies of nearby areas that are unaffected by point sources, regional or national data may be used. These often have the advantage of being based on a very large number of samples. If possible, reference values from several different studies are used. Appendix 5 includes reference values for various media, based primarily on national inventories.

For *soil,* the reference values presented correspond to the 90th percentile of the Swedish Geological Survey's geochemical mapping, involving the analysis of 12,000 samples of the fraction smaller than 0.063 mm, i.e. fine sand, silt and clay. Particle size affects metal concentrations:

In general, the smaller the particles, the higher the concentration of metals. Samples analysed in connection with inventories are the coarser, less homogenous fraction of particles smaller than 2 mm, which makes comparisons more difficult. Pollutant concentrations measured for particles smaller than 0.063 mm are roughly 1.4 times greater than those measured for larger particles.

For *soil,* reference values for metals and certain organic substances in urban soils are available. The values are based on the sampling, analysis and statistical treatment of the data from 50–170 samples from each of nine urban areas. The 90th percentile of these samples is used as the reference value.

For *groundwater,* the reference values presented have been developed in connection with *Environmental Quality Criteria for Groundwater.* For both *sediment* and *surface water,* national reference values have been developed in connection with *Environmental Quality Criteria for Lakes and Watercourses.*

For *marine sediments,* national reference values have been developed in connection with *Environmental Quality Criteria for Coasts and Seas.*

For all four categories – soil, groundwater, surface water and sediment – there are also reference values available for certain group parameters and toxicity tests, based on a trial inventory conducted during 1994–1995. Some naturally occurring substances may register on tests for EGOM (extractable gas-chromatographic organic material), PBS (potential bioaccumulating substance) and AOX (adsorbable organic halogen). Elevated analysis results indicate either that organic contaminants may be present, or that background concentrations may be high. The organic group parameters are intended to serve a screening function that is sufficiently specific to determine whether or not a site is contaminated. The results of such analyses should be interpreted with caution, given that they provide no information on, for example, which chlorinated substances or PAHs (polycyclic aromatic hydrocarbons) may have affected the outcome.

Classification of the deviation from reference values

The criteria used to classify deviation from reference values for contaminated sites are summarised in Table 5. Examples of such classifications for

TABLE 5.

Criteria for classifying the deviation from reference values

Effect of point sources

Little or none	Moderate	Large	Very large
< Reference value	1–5 x Ref. value	5–25 x Ref. value	> 25 x Ref. value

a number of parameters in various media are provided in Appendix 5. The tables in which the sample characteristics best match the conditions at the site being assessed is the most appropriate for use in the assessment.

Amount & volume

The risk to health and the environment is also related to the amount of a contaminant at the site and the volume of contaminated material. There is no general method for determining whether an amount is considered to be large or small. The assessment of the amount of a contaminant is dependent upon its toxicity.

One possible set of classification criteria is proposed in Table 6; but this is not valid for contaminants of very high toxicity, such as dioxins. Such substances must be regarded as presenting an "extremely great hazard", and their mere presence indicates that the amounts should be regarded as "very large".

TABLE 6.

Criteria for classification of the amount of contaminants and the volume of contaminated material (in kilograms)

Amount/volume:	Slight	Moderate	Large	Very large
Amount of extremely hazardous contaminant	—	—	Few kg	Tens of kg
Amount of very hazardous contaminant	—	Few kg	Tens of kg	100s of kg
Amount of moderately hazardous contaminant	Few kg	Tens of kg	100s of kg	Tons
Volume of contaminated material	<1000 m^3	1000–10 000	10 000–100 000	>100 000 m^3

The volume of contaminated material (soil or sediment) is assessed without regard to type and concentration of the contaminant. In general, the greater the volume of contaminated material, the greater the risk. Assessing total volume is difficult and, at some sites, impossible, due to lack of information.

Comprehensive assessment of the contamination level

The level of contamination is assessed for each contaminant separately, in each of the media where it is present, by weighing all four major factors – current conditions, deviation from the reference value, amount of pollutant and volume of contaminated material.

Large amounts of contaminants occurring in high concentrations and in a large volume of material imply a high general contamination level. The reverse is true for sites with small amounts of a contaminant in low concentrations and small volumes of material. A site with a few "hot spots", but with small total amounts of contaminants, has a lower general contamination level than a site with the larger amounts of the same contaminants.

Conclusions from the assessment of the contamination level are entered on the form for comprehensive risk assessment. The substances that should go forward to the comprehensive risk assessment are those for which the contamination level is high or very high and those that are very or extremely hazardous.

References

Canadian Council of Resource and Environment Ministers for the Environment, *CCME Canadian Water Quality Guidelines*, 1996

Swedish Environmental Protection Agency, The chemistry of groundwater in Sweden (In Swedish: Grundvattnets kemi i Sverige); report nr. 4415, 1995

Swedish Environmental Protection Agency (1996), Generic guideline levels for contaminated sites (In Swedish: Generella riktlinjer för förorenade områden – beräkningsprinciper och vägledning för tillämpning) Report No. 4638

Swedish Environmental Protection Agency, *Bakgrundshalter i mark - halter av vissa metaller och organiska ämnen i jord i tätort och på landsbygd*, report nr. 4640, 1997

Swedish Environmental Protection Agency (1998), Proposed guideline levels for contaminated petrol stations (In Swedish: Förslag till branschspecifika riktvärden för förorenade bensinstationer). Report No. 4889

Swedish Environmental Protection Agency, *Metallerna och miljön*, report nr. 4135, 1993

Swedish Environmental Protection Agency, *Långlivade organiska ämnen och miljön*, report nr. 4136, 1993

Swedish National Food Administration, "Livsmedelsverkets kungörelse om dricksvatten"; SLVFS 1993:35, 1993

World Health Organization (WHO), *Guidelines for Drinking Water Quality: Volume 1, Recommendations*, 1993

Object: Valdemarsvik (formerly Lundberg's Leather)	Recorded by (name, date):	Fredrika Norman, 1998-07-10
ID no.: BKL 123	Revised by (name, date):	

Indicate uncertain items with question mark ("?")

Soil

Note substances, with reference numbers in parentheses

No. samples	7	

Comparisons made with (tick): ❏ …percentile, ❏ next-highest value, ☒ highest value, ❏ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious
	As, Co, Pb, V	Cu, Ni, Cr	Cd, Zn	Hg
Substances for which assessment of status is not possible due to lack of comparative data	Mn, Mo, Ti			

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
		As, Cd, Co, Pb, V, Ni, SPOT	Cu, Ni, Cr	Zn, Ha, EGOM, EOX
Substances for which assessment of deviation is not possible due to lack of comparative data	Mn, Mo, Ti			

	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				

References used	Appendix 4, Table 1: General guideline values for contaminated soil Appendix 5, Tables 1-3: Background levels in soil

Groundwater

Note substances, with reference numbers in parentheses

No. samples	3	

Comparisons made with (tick): ❏ …percentile, ❏ next-highest value, ☒ highest value, ❏ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious
	As, Cu	Ni, Cd	Cu	Cr, Pb
Substances for which assessment of status is not possible due to lack of comparative data	V, Co, Zn, Mo			

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
	Cu, EGOM	As, EOX	Al, Zn, Cd, SPOT, algae test	Pb, Microtox
Substances for which assessment of deviation is not possible due to lack of comparative data				

References used	Appendix 4, Table 3: Norms for drinking water. Appendix 5, Table 6: Environmental quality criteria for groundwater. Note: This **does not refer to** observed mercury in groundwater.

Example of completed form

Surface water

Note substances, with reference numbers in parentheses

No. samples	5		

Comparisons made with (check): ☐ ...percentile, ☐ next-highest value, ☒ highest value, ☐ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious
	Cr, Ni, Zn, As, Pb, Cu	Cd		
Substances for which assessment of status is not possible due to lack of comparative data	Al, V, Mn, Co, Mo			

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
	As, Cd, Microtox	V, Cr, Ni, Cu, Zn, Pb, EOX, AOX	Co	
Substances for which assessment of deviation is not possible due to lack of comparative data	Al, Mn, Mo			

References used:	Appendix 4, Table 4: Environ. quality criteria for lakes and watercourses Appendix 4, Table 4: Environmental quality criteria for lakes and watercourses Note: This **does not refer to** observed mercury in groundwater

Sediments

Note substances, with reference numbers in parentheses

No. samples	4		

Comparisons made with (check): ☐ ...percentile, ☐ next-highest value, ☒ highest value, ☐ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious
	Omitted due to lack of effects-related data			
Substances for which assessment of status is not possible due to lack of comparative data				

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
	Zn, Cd, Ni, As, Pb, Co	Cu, Hg, SPOT, EOX		Cr
Substances for which assessment of deviation is not possible due to lack of comparative data				

	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				
References used				

Buildings and other constructions

Note substances, with reference numbers in parentheses

No. samples	0		

	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				
References used				

Potential for Migration

This section deals with the factors that determine how rapidly contaminants can be dispersed within and between various media, in concentrations and amounts that imply a risk for harmful effects.

Background

It is necessary to know how quickly contaminants (in concentrations and amounts that imply a risk for harmful effects) spread within and between different media.

It is not necessary to determine the exact rate of migration, since that would require significant resources and a large database. It is sufficient to carefully determine whether or not the spread of contaminants is currently in progress or likely to occur in the future, and in either case to estimate the order of magnitude of the migration rate.

In order to make such an assessment, the following information is required:
• the geology and hydrology of the site
• the chemical attributes of the soil
• the current distribution of contaminants
• the characteristics of buildings and other constructions
• the behaviour of the contaminants in the environment.

For most sites, the first phase of the inventory is based on information collected from a variety of sources, including on-site inspection, a description of the site and its surroundings, maps and a preliminary analysis of the speed and direction of groundwater flows. For some sites, data may be available from previous studies of sufficiently high quality to be suitable for use. Descriptions and estimates of migration rates during the first phase should be completed during the on-site inspection, not afterwards, in order to ensure that all the necessary information is collected.

The information used in the second phase is more extensive. In addition to that collected during the first phase, it includes the results of fieldwork such as borehole samples, geological charts and analyses. The information thus obtained is still limited in scope, but nevertheless yields improved hydrogeological data on the slope of the groundwater surface, the characteristics of individual soil strata, the distribution of impermeable and porous layers, fracture zones in the bedrock, and other phenomena which provide favourable conditions for the spread of contaminants.

Information concerning the behaviour of contaminants in the environment is available from the scientific literature and from persons with expertise in the area.

The most common mode of transport for environmental contaminants is via water. However, some contaminants, e.g. viscous oil, move in a separate phase through the environment. Others are transported via the atmosphere, either as gases or as particles. Apart from the means of transportation, the migration rate is influenced by such factors as degradation processes, dilution and sorption.
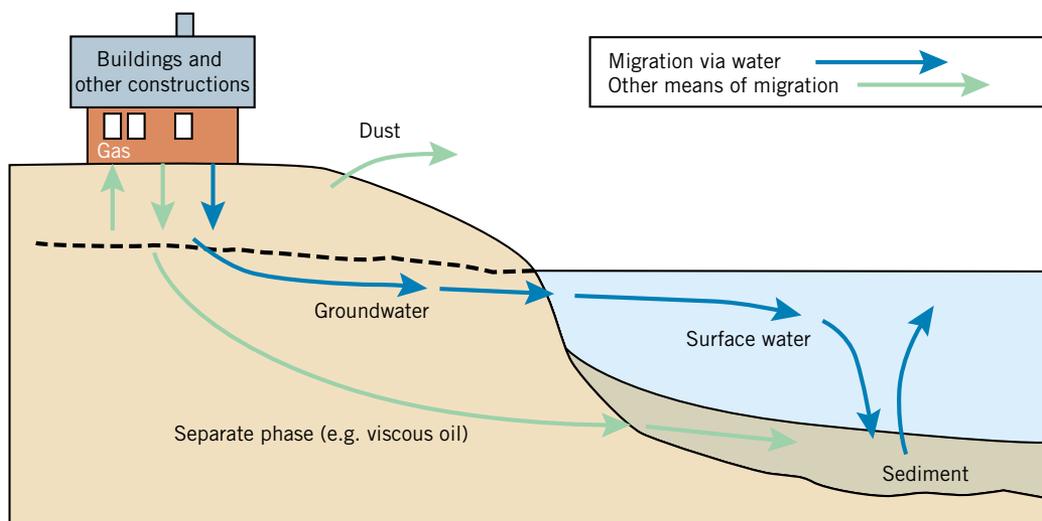
FIGURE 1: Migration pathways of contaminants in the environment. Each arrow indicates a pathway considered in risk classification.

The transport of contaminants in various media is described for the area that is already contaminated, as well as for the surrounding area which may be affected in the future by levels of contamination that imply a risk of harmful effects. Together, they comprise the "affected area" which includes all associated media – soil, buildings and other constructions, groundwater, surface water and sediments.

The migration rate is described on the basis of a "reasonably conservative" scenario. The greater the uncertainty of the data, the more conservative the assessment. Special attention must be paid to phenomena and conditions which, in themselves, can increase or decrease the rate of contaminant migration, for example: impermeable layers, utility trenches, piles, below-ground constructions, layers of sand and gravel, and fracture zones.

It is difficult to calculate the migration rate when the available information is limited, which is often the case. The assessment form shown in Appendix 6 is intended to assist in this regard. It serves as a checklist to ensure that all conceivable transport paths have been considered, thus helping to systematise the data from which the migration rate is estimated. A map of the "affected area" and a diagram of boreholes are drawn directly

on the form. An example of a completed form is provided at the end of this chapter.

The migration of every contaminant is described separately for each medium in which it is present. Historically documented migration patterns are often helpful in estimating current and future distribution.

The following sections explain how to draw a borehole diagram, systematise the data, and calculate or estimate the rate of contaminant migration.

Borehole diagram and map of "affected area"

A borehole diagram, including any lakes or watercourses in the area, is drawn on Form D, "Migration Factors". The diagram should include the soil types and their distribution, the elevation of the ground surface, the height of the groundwater table, the level of the upper edge and tip of the borehole casing, and other standard borehole data. The data should always be presented according to the reporting standards of the Swedish Geotechnical Association.

A map of the affected area should also be drawn on the form and include the contaminated site and the surrounding area within which there is a risk of future contamination. A rough sketch of the map is made at the beginning of the assessment of migration potential, and is completed after all the migration pathways have been considered. It may sometimes be necessary to divide the area into sub-sections, each with different conditions.

The boundaries of the affected area are comprised of lakes, drainage channels (i.e. watercourses), surface depressions, and any other feature that may arrest the flow of groundwater and thereby limit the expansion of a contamination "plume". If there are no natural or artificial barriers to this expansion, the approximate distance of contaminant migration over one thousand years is used to denote the outer limit of expansion. This applies only to contamination concentrations and/or amounts that imply a potential risk to human health and the environment. The completed map should be drawn on a scale of 1:10,000, and indicate the area boundaries, grid intersections, the direction of groundwater flows, the geographical north, and the locations at which contamination has been verified.

Migration to and from buildings and other constructions

Contaminants may disperse from buildings and other constructions to be transported via soil, groundwater, surface water or sediments. This migration should be estimated as the percentage leached per year. The movement of gases and fluids from the ground and into the buildings should also be described. The permeabilities of both the ground and the building are key factors with respect to the penetration of volatile substances into buildings.

Migration in soil and groundwater

The distance over which contaminants can migrate each year in the ground and in groundwater should be noted. The migration of both water-soluble

substances and substances that move in a free phase or in the form of dust particles should be included.

The rate of migration for water-soluble contaminants is described or calculated first. The initial assumption is that they move at the same speed as the groundwater.

It is appropriate to make a preliminary calculation of the groundwater flow in the soil. This can be done by reference to Figure 2. The flow rates indicated are those that apply when the slope of the groundwater surface is one percent. If instead the slope is, for example, five percent, the rate of flow increases by a factor of five.
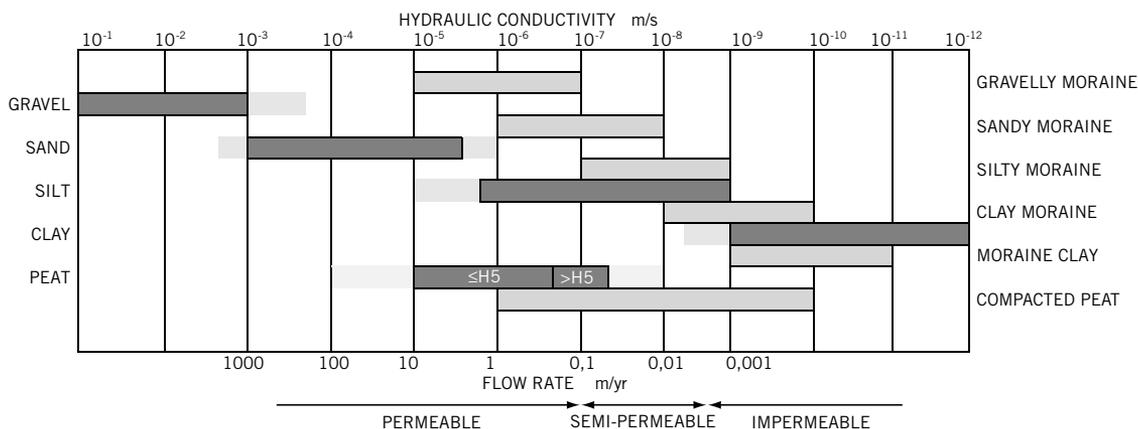
FIGURE 2: Groundwater flow rate and hydraulic conductivity in various soils, where the slope of the groundwater surface is one percent (ref. Carlsson & Gustavsson, 1984). (Light-grey indicates area of uncertainty).

A contaminant that infiltrates through the ground surface is transported via the unsaturated zone down to the groundwater. The rate at which this occurs depends on the permeability of the soil above the water table. It is assumed that any contaminant located above the water table will eventually filter down into the groundwater.

Groundwater tends to flow through those sections of the soil where the resistance is least. Contaminants are often spread out in a branching pattern. It may be assumed that groundwater flows at right angles to the contours of the ground surface, from higher to lower ground.

Theoretically, a so-called "migration plume" extends from the source of contamination in the direction of the groundwater flow – if the soil has a uniform composition. However, such a pattern seldom occurs in reality. Because of diffusion and differences in density, migration may even occur at right angles to or in the opposite direction of the groundwater flow.

After first equating the rate of contaminant migration with the groundwater flow rate, the following factors must also be considered:

- degradation of contaminants
- sorption of contaminants in the ground
- increases in the rate of contaminant migration due to:
  a) presence of natural transport paths such as cracks in dry clay, layers of sand, gravel and clay, peaty soils, fracture zones in rock, etc.
  b) man-made transport paths such as technical installations, including drainage ditches in industrial areas, utility trenches, piles, tanks, old and new sewers, sewage and water discharges into lakes and ditches, below-ground constructions, paved surfaces, etc.
- Past migration. Information about present migration pathways can be deduced by observations of settling in the ground or landfills, changes in the odour and colour of soil layers, and changes in vegetation, as well as by sampling and analysis.

Each of these factors can give cause for modification of the migration rate initially assumed.

Separate migration rates must be calculated or estimated for contaminants that move in a free phase. Their speed depends primarily on the ground's permeability and on the composition of the fluid, i.e. whether or not it is viscous.

Separate rates are also calculated for contaminants that can be spread in the form of dust. The rate depends primarily on the extent of vegetation cover, exposure to wind, and the moisture content of the ground surface.

Migration from soil and groundwater to surface water

Contaminants can spread from soil and groundwater to nearby lakes and watercourses. An assessment can be made both for watercourses and for the lakes they discharge into. If the surface water is already contaminated, that fact is noted on Form D. If it is not contaminated, an estimate is made of how many years it takes for contaminants in soil and groundwater to migrate to it.

The direction of the groundwater flow determines which surface water body is threatened with contamination. The length of time to contamination is related to the distance from the contaminant's starting point to the surface water, the migration rate in soil and groundwater, and the volume of run-off via the ground surface, ditches and sewage lines.

Contaminants are spread to watercourses via groundwater or run-off from the land. It is not unusual for older sewers to empty directly into a lake or watercourse. Even if these are no longer being used for their original purpose, contaminated water may drain through them. Ditches and drainage systems that have been, or are still being, used to transport surface water and/or shallow groundwater may also transport contaminated water. Maps and diagrams are the most suitable references for locating such channels, but changes in vegetation and visible chemical deposits may also provide clues.

It may be difficult to observe deep groundwater inflows to lakes and watercourses, but springs on lake-bottoms are not unusual. These are often located in deep holes where the water is colder than the surrounding water during summer.

Contaminant migration to surface water occurs more rapidly from soils located in a groundwater outflow zone than from those in an inflow zone. Calculations should be made both for substances dispersed via water and for those that move independently.

Initially contaminants should be assumed to migrate at the same speed as the soil- and groundwater. The next step is to determine whether there is any reason to modify that assumption on the basis of the following factors:

- spreading of contaminants into lakes and other destinations via run-off from land, ditches and sewers
- increased migration rates due to high and varying water tables, high surface-water levels and flooding.

Migration in surface water

The distance travelled by the contaminants is expressed in terms of kilometres per year. The factors determining contaminant transport are the flow rate and the water turnover in surface water bodies. A rapid turnover can lead to such dilution of the contaminants in surface water that they do not reach harmful levels.

Initially it should be assumed that contaminants migrate at the same rate as the water flow. The next step is to determine whether there is any reason to modify that assumption because of uneven migration.

In general, the rate of migration is related to water flow conditions and the type of surface water involved. A complete blending of contaminants with flowing water does not usually occur until they have been transported over a fairly long distance. The rate and extent of mixing may vary with bottom conditions, the volume of the water flow and other factors.

Migration in lakes and along shorelines is often related to the water turnover, the water depth, the size of the lake, wind conditions and other factors. Turnover times for small Swedish lakes are often a year or longer. Contaminated water from land areas can settle at various depths in the water column due to differences in water density resulting from variations in temperature and salinity.

Migration in sediments

The rate of migration for contaminants in sediments, at levels that imply potentially harmful effects, should be given in metres per year. There are two types of migration processes:

1. The migration of contaminants in a separate, sinking phase or contaminants bound to a rapidly sinking solid phase, e.g., lead shotgun pellets, red lead oxide in sand-blasting waste, and heavy oils. The migration rates for such substances are slight to moderate.

2. The migration of contaminants which are initially transported with surface water, either in dissolved form or attached to particles. Under certain conditions, these contaminants may settle out and contaminate sediments. Contamination may be evenly distributed from the contaminant source in the direction of the water flow, or it may have an uneven pattern. Contaminants in the sediment may re-enter the water by different processes and be transported some distance before once again settling out as sediment at a new location.

For sedimentation to take place, the water flow rate must be fairly slow, and there must be particles to which the contaminants can attach themselves. On sandy and rocky bottoms, which are often erosion and transport bottoms, there is usually little accumulation of sediments. Various degrees of sedimentation occur on bottoms of clay, mud or fibre-banks.

Contaminants bound to particles may be further transported after being resuspended in the water by disturbances from dredging operations, boat traffic, powerful waves, gas formation, etc. Biological activity may also disturb sediments to the extent that they are resuspended and redeposited. Sedimentary contaminants may re-enter the water due to chemical changes that are related, for example, to oxygen levels and the transformation of contaminants in sediments. However, these two factors have only minor effects on migration.

Assessment of risk related to migration
The magnitude of the risk is related to the size of the calculated or estimated migration potential.

Given that contamination concentrations are large enough to lead to harmful effects, rapid migration is judged to imply a greater risk than slower migration. Classification of the estimated migration rates is shown in Table 7.

Assessments of migration rates for individual sites are noted on Form D, the assessment form for migration potential, and the assessment of risk related to migration potential is noted on the form for comprehensive risk assessment.

The following examples are given as guidance to the assessment of the risk related to migration potential in soil and groundwater.

Land with impermeable soils has a low migration potential, as long as there are no backfilled areas or drainage systems, the slope of the groundwater surface is insignificant and groundwater flow is downwards. This could be land with clay soil up to several metres thick, which does not crack on drying and does not include porous layers. Examples of soils in this category are clay moraines and well humified and compacted peat soils.

Land with evenly distributed, semi-permeable soils has moderate migration potential, as long as there are no drainage systems and the groundwater slope is moderate. Among the soil types in this category are

TABLE 7.

Principles for the classification of migration potential

Paths and rates of migration
Migration potential for

Path/medium	Slight	Moderate	Large	Very large
From buildings, constructions	None	<5 %/yr	5-50 %/yr	>50 %/yr
In soil & groundwater	None	<0.1 m/yr	0.1–10 m/yr	>10 m/yr
From soil & groundwater to surface water	>1000 yrs	1000–100 yrs	100–10 yrs	<10 yrs
In surface water*	None	<0.1 km/yr	0.1–10 km/yr	>10 km/yr
In sediments	None	<0.1 m/yr	0.1–10 m/yr	>10 m/yr

*So diluted that concentrations never reach toxic level

fine sand, sandy-silty moraines, sandy moraines, mixed and fine-grained moraines and silty moraines.

Land with porous soils has a large migration potential, as long as the ground water surface is relatively steep or the topography is uneven. Soils in this category include coarse silt, sand, gravel, gravelly moraines and most coarse-grained moraines. Even land with impermeable soils can have a large migration potential if there are drainage systems or the water table is high. The same applies to clay soils with layers of sand or drying fissures, and to exposed rock with fissure zones.

Land with porous soils, a distinctly sloping groundwater surface and/or uneven topography has a very large potential for migration. This is also true of rock fracture zones, and of land with a high and varied water table, a high water table in backfill-, layers of coarse silt, sand or gravel.

References

Carlsson & Gustavsson, "Provpumpning som geohydrologisk undersökningsmetodik"; Swedish National Council for Building Research, report nr. 41, 1984

Grip, H. & Rodhe, A ., *Vattnets väg från regn till bäck*; Forskningsrådets Förlagstjänst, 1985

Swedish Environmental Protection Agency, "Föroreningar i deponier och mark – ämnens spridning och omvandling"; report nr. 4473, 1995

Object	Recorded by (name, date):	Fredrika Norman, 1998-07-10
Valdemarsvik (formerly Lundberg's Leather)		
ID no.	Revised by (name, date):	

Dispersion factors are assessed for pollutants that are present in concentrations or amounts which pose a risk of negative effects. Indicate uncertain items with question mark ("?").

Borehole diagram and map of affected area

Borehole diagram

Map of affected area

The only groundwater flow is in a southeasterly direction to the bay, Valdemarsviken. Accordingly, the area of affected ground and groundwater is limited to the factory site, and to the area between the factory and Valdemarsviken.
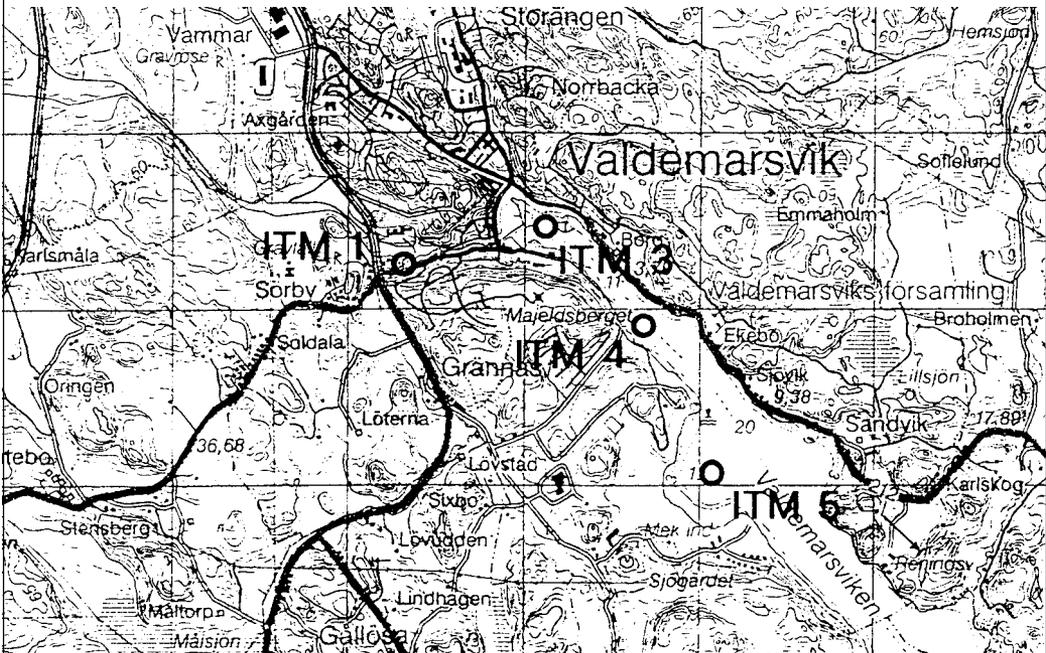
Pollutants in buildings and other constructions	—
Migration pathways (describe)	—
Known previous migration (describe)	Pollutants have moved periodically under the factory's concrete base, and then spread very rapidly
Other	—
Estimated leaching (% per year)	—

From ground to buildings

Volatile pollutants in ground	—
Ground's porosity (m/yr)	—
Buildings' porosity (m/yr)	—
Known previous migration	—
Other	—
Estimated rate of gas penetration into buildings	—

Ground and groundwater

Current location of pollutants in ground, describe and indicate on map	In aquifer located in backfill above predominant clay/mud-clay

Rate of migration for substances transported via water through ground

Pollutants transported by water	Hg, Zn, Cd, Cu, Ni, Cr
Ground's porosity in most porous stratum (m/s)	Hydraulic conductivity in backfill estimated to be >10^{-6} m/s within factory area, less in more consolidated backfill near the bay
Slope of groundwater surface (%):	Northwest-southeast direction. Between SGU 3 and lake surface is 0.5%
Groundwater flow (approx. m/yr)	0.5 m/yr
Biodegradable pollutants	—
Rate of decay (half-life)	—
Pollutants retained in soil	—
Organic carbon content in soil (%)	—
Other favourable conditions for retention in soil, e.g. clay content (describe)	—
Natural transport channels, e.g. drying-cracks in clay (describe)	—
Man-made transport channels, e.g. buried utility lines (describe)	Old pipes that function as drainage channels from factory to river
Known previous migration (m/yr)	To Fifallaå River, ca. 100 m
Other	It can be assumed that there is another aquifer beneath the impermeable clay/mud-clay. The water pressure in that aquifer is probably high, and the pressure surface can be at the ground surface or higher. The clay/mud-clay stratum and the high groundwater pressure prevent polluted water from reaching the assumed underlying aquifer. This also poses the risk that water from the underlying aquifer could be forced up through any hole drilled in the impermeable stratum, with resulting uncontrolled migration of the pollutants and with very serious consequences.
Estimated migration rate in ground and groundwater (m/yr)	0.5 m/yr

Pollutants dispersed via dust	—
Ground surface dryness (normal, drier than normal, much drier than normal)	—
Vegetation cover (% and type)	—
Exposure to wind (sheltered, exposed, very exposed)	—
Known previous migration (m/yr)	—
Other —	
Estimated migration rate via dust (m/yr)	—

Rate of migration for substances that move independently through the ground

Pollutants migrating in a separate phase	—
Ground's porosity (m/s)	—
Pollutants' viscosity (slow-moving, highly fluid)	—
Known previous migration (m/yr)	—
Other —	
Estimated migration rate of pollutants in a separate phase (m/yr)	—

Ground/groundwater to surface water

Surface water already contaminated by known previous migration (name)	Fifallaå River and Valdemarsvik
Endangered surface water (name)	Valdemarsvik's currently unpolluted water
Pollutants' migration rate in ground/groundwater (m/yr)	—
Distance from pollution to endangered surface water (m)	100 m
Surface run-off via ground, ditches, sewage pipes (yes/no)	Old pipes function as direct drainage channels from factory to river
Water table variations, flooding, high water (yes/no)	Yes, risk of flooding. At high water, risk that pollutants enter the waters of the river and Valdemarsvik
Other —	
Estimated years for migration to surface water	Surface water is already polluted

Surface water

Pollutants dispersed in surface water	Cr, Cu, Hg (?)
Surface water flow-rate (km/yr)/turnover (yrs)	Water turnover is estimated to be rapid, leading to widespread migration
Dilution leads to harmless levels in surface water (yes/no)	Yes (?)
Uneven distribution in surface water (yes/no)	Yes, due to saltwater stratification
Known previous migration (m/yr)	—
Other —	
Estimated migration rate in surface water (km/yr)	Probably very little migration in harmful concentrations

Contaminated sediments, known previous migration, (describe and indicate on map)	—
Pollutants transported via water to sediments	Cr, Cu, Hg (?)
Sedimentary conditions in various sections of water system (describe)	—
Boat traffic that stirs up sediments (yes/no)	Yes, shipping
Dredging (yes/no)	—
Powerful waves (yes/no)	—
Gas-formation (yes/no)	—
Pollutants in separate phase in sediments (describe)	—
Other	Distribution affected by wind and saltwater stratification
Even distribution (m/yr)	—
Uneven distribution, note also on map (describe)	—
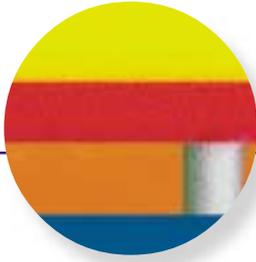
Sensitivity
and Protection Value

This section deals with the severity of the consequences of contamination with respect to exposure of man and the environment.

Background

In order to assess the severity of contamination at contaminated sites, it is necessary to determine and describe the degree of exposure to which humans and the environment are currently subjected and likely to be subjected in the future. This requires knowledge of contaminants' specific locations, and the direction in which they may migrate in concentrations and amounts that imply a risk of harmful effects. For example, whether contaminants are located at the ground surface or at deeper layers is of decisive importance. Knowledge of the land use is also required, both at present and in the future (e.g. specified in a detailed plan, or suggested in a general planning document). Land use determines which groups of people and which ecosystems are exposed, as well as the extent of exposure. For example:

- If contaminants are located in surface soil in residential areas, people can be exposed by direct ingestion of contaminated soil (primarily small children), skin contact, inhalation of fumes and dust, consumption of home-grown vegetables that have taken up contaminants, and by drinking contaminated groundwater. Soil-dwelling organisms, plants growing in the soil and larger animals can all be affected. Aquatic organisms can be exposed when groundwater mixes with surface water, which also affects sediments.

- If contaminants lie in the soil in residential areas, at depths below one metre direct exposure can only occur as the result of excavation. Only those plants with relatively deep roots are directly affected. However, harmful fumes can penetrate buildings, and contaminants may spread via groundwater to local wells from which drinking water is taken. Even at this depth, contaminants may spread via groundwater to surface water and thus affect organisms in surface water and sediments.

- Exposure via skin contact may occur if contaminated sediments are located, for example, where bathing takes place. Organisms that live in the sediment can be exposed and resuspension to surface water results in the exposure of aquatic organisms.

Assessment of risk related to human sensitivity and the protection value

The level of risk is related to the sensitivity of exposed humans, and to the protection value for the exposed environment.

A separate assessment is made for each of the two aspects, and the results are noted on the form for comprehensive risk assessment (see Appendix 7 and the example at the end of the following chapter).

Sensitivity and protection value are indicated with their initial letters S and P respectively. The type of land use upon which the assessment is based and a brief description of the exposure conditions should also be noted on the form. Sensitivity is assessed at the individual level, i.e. regardless of how many humans are exposed. Table 8 provides guidance for classifying levels of sensitivity.

TABLE 8.

Criteria for classifying levels of human sensitivity to contaminants (S)

Slight	Moderate	High	Very high
- No human exposure, e.g. small enclosed unused area	– Slight occupational exposure – Groundwater not used for drinking, e.g. enclosed industrial area	– Significant occupational exposure during work hours, e.g. office area – Slight exposure of children – Ground- and/or surface water used for drinking – Land used for crops or animal husbandry – Outdoor recreation area, e.g. greenbelt	– Permanent residential area – Extensive exposure of children – Ground- and/or surface water used for drinking, e.g. house lot, day-care centre, housing area

---

The protection value is assessed in connection with the species and/or ecosystems that are exposed to contaminants at the site. Relevant information can often be found in plans for nature conservation and various kinds of biological inventories. Table 9 provides guidance for classifying the required protection value.

TABLE 9.

Criteria for classifying the protection value

Slight	Moderate	High	Very high
– Heavily contaminated site – Ecosystem heavily damaged by various uses and activities, e.g. landfills, spoil heap or asphalted area	– Somewhat disturbed ecosystem – Common ecosystem within region, e.g. typical forest or farmland	– Relatively unusual ecosystem within region – Exposure of individual species or ecosystems identified in local or regional conservation plans as of great value, e.g. shorelines, sensitive watercourses, recreation areas and urban parks	– Site with individual species or ecosystems identified in local, regional or national conservation plans as being of especially great value, e.g. national parks, nature reserves, nature conservation areas, marine sanctuaries, animal refuges, and other areas in which the protection of endangered species and their habitats is considered to be of national interest
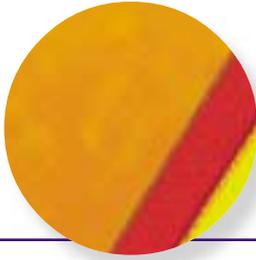
Comprehensive Assessment and Risk Classification

This section describes the comprehensive assessment and classification of the current and future risks posed by the contaminated area to human health and the environment. This is achieved by weighing together the hazard assessment, the contamination level, the potential for migration and the sensitivity and the protection value.

As a result of the assessment, the site can be assigned to one of the following risk classes:

Class 1 – Very high
Class 2 – High
Class 3 – Moderate
Class 4 – Low

COMPREHENSIVE ASSESSMENT - RISK CLASSIFICATION

MIGRATION POTENTIAL

VERY LARGE

LARGE

MODERATE

SLIGHT

RISK CLASS 1

RISK CLASS 2

RISK CLASS 3

RISK CLASS 4

LOW   MODERATE   HIGH   VERY HIGH
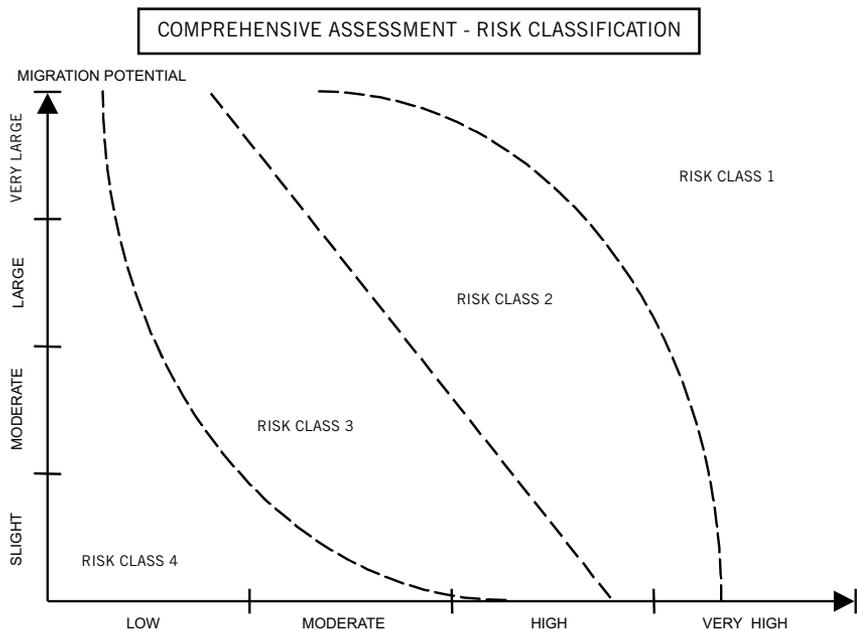
FIGURE 3: Schematic diagram of comprehensive risk classification, including hazard assessment, the contamination level, the potential for migration and the sensitivity and the protection value.

Form E, Comprehensive Risk Assessment (see Table 7), is intended to assist in the evaluation process. Among the items of information to be noted are conclusions from the separate forms for contamination level and potential for migration (Appendices 3 and 6). Assessments of hazard and of sensitivity/protection value are entered directly. The following information should also to be included: administrative details that may help in setting priorities; previous risk classifications; impressions from the on-site inspection.

Separate assessments are made for each contaminant and each of the media in which they occur. Comprehensive risk assessments are made on the basis of a "reasonably conservative" scenario.

Included with Form E is a diagram that provides an overview of the four different aspects for all the contaminants and media at the site. The purpose of the diagram is to assist in weighing all the information on which the comprehensive risk assessment is based.

Risk is a weighting of both probability and consequence. For contaminated sites, probable risk is a function of the migration potential, as represented by the vertical axis of the diagram. Consequences are related to the hazards of contaminants, the level of contamination, human sensitivity and the protection value, which are distributed along the horizontal axis.

On the following two pages is an example of a completed form, including the diagram. The horizontal lines from the vertical axis of the diagram indicate the potential for migration for all media at the site: soil and groundwater (S/gw), surface water (sw), sediments (sed), and buildings and other constructions (b/c). Represented by points along the horizontal axis are the hazards assessment (H), contamination level (C), sensitivity (S) and protection value (P).

The completed diagram thus includes one to four horizontal lines. The placement of the various points on the lines determines the risk class to which the site is assigned. If all points on all lines fall within the same class range, the site is assigned to that class. If, however, the points are distributed among two or more classes, it is necessary to decide which class best describes the site. Important factors in this regard are the impressions of the assessor, the size of the site and the number of different contaminants involved. The greater the number of contaminants, the greater the risk is assumed to be.

Object Valdemarsvik (formerly Lundberg's Leather)	Recorded by (name, date) Fredrika Norman, 1998-07-10
ID no BKL 123	Revised by (name, date)
Industrial branch Tannery	

Indicate uncertain items with question mark ("?")

Hazard assessment (H)

Note substances in appropriate squares

Slightly hazardous	Moderately hazardous	Very hazardous	Extremely hazardous
	Zn, bark extract, colour dyes, preserving salts	Cu, Ni, chromium salts, phenol	Cd, Cr, Hg, Pb, DDT

Contamination level (C)

Shows current polluted media. Data from Form C, Contamination level. Note substances in appropriate squares

Media	Slight	Moderate	High	Very high
Buildings/construction				
Soil		As, Pb, V, SPOT	Cu, Cd, Ni, Cr	Hg, Zn, EGOM, EOX
Groundwater		Ni, As, EOX	Cu, Zn, Zd, SPOT algae test	Cr, Pb, HEGOM, micro-tox (Hg not measured)
Surface water			Co	(Hg not measured)
Sediment		Cu, Hg, SPOT, EOX		Cr

Potential for migration

Data from Form D, Potential for migration. Put cross (x) or note substances in appropriate squares

Direction	Small	Moderate	Large	Very large
From buildings/ constructions		X (?)		
To buildings	X (?)			
In soil and groundwater				X (?)
To surface water				Already polluted
In surface water	X (?)			
In sediments			X (?)	

Sensitivy (S) protection value (P)

Write S for sensitivity and V for protection value

	Slight	Moderate	Great	Very great
From buildings/ constructions		S		
Soil & groundwater	S, P (groundwater)			S (soil)
Surface water & sediments		S		P

Evaluation of S and P based on land use. ....Industrial land, urban area, built up area................ which is
(check) ☒ current land use, ❑ future land use as per detailed plan, ❑ future land use as per general guidelines.

Brief description of exposure conditions: The ground area and water are heavily used for active forms of outdoor

recreation, and is located near permanent buildings. The site is centrally located in an urban area, near a housing area.

There is currently no natural flora or fauna within the site. No extraction of groundwater, now or in the future.
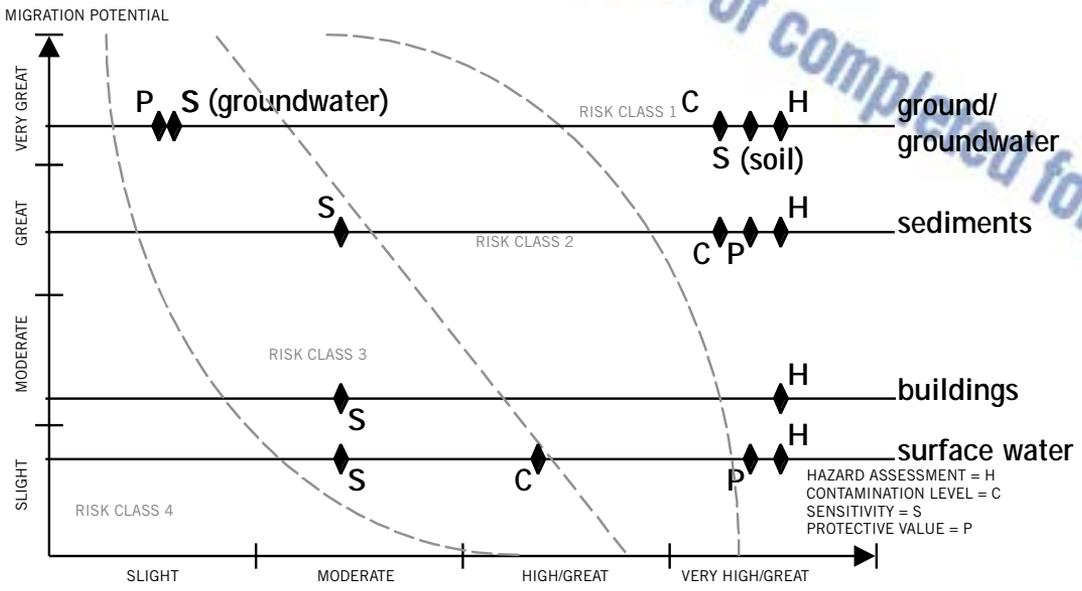
COMBINED ASSESSMENT & RISK CLASSIFICATION

MIGRATION POTENTIAL

P S (groundwater)

RISK CLASS 1

C   H   ground/
                       groundwater
S (soil)

VERY GREAT

S

RISK CLASS 2

H   sediments
C P

GREAT

RISK CLASS 3

MODERATE

H   buildings

S

H   surface water

SLIGHT

S

C

P

RISK CLASS 4

HAZARD ASSESSMENT = H
CONTAMINATION LEVEL = C
SENSITIVITY = S
PROTECTIVE VALUE = P

SLIGHT   MODERATE   HIGH/GREAT   VERY HIGH/GREAT

Investigator's general impressions:. . . . .

. . . .

. . . .

. . . .

. . . .

Site assigned to   ☒ 1 "Very high risk"
risk class   ❏ 2 "High risk"
(check)   ❏ 3 "Moderate risk"
                         ❏ 4 "Low risk"

Explanation:. . *Great potential for dispersion in soil, sediments and surface water. For soil, sensitivity is judged to be great; for other media, slight or moderate. The degree of environmental protection required is greatest for surface water and sediments, slight for soil and groundwater. Pollutants are mercury, cadmium, chromium and lead, which are very hazardous. Contamination level is high or very high.*

Other grounds for setting priorities
❏ exposure to pollutants occurs at present in following ways . . . .

. . . .

Links
❏ There are other contaminated sites which endanger the same body of water, namely:. *the local community, other* . . . .
. . . . *buildings and industries, household dumps and an older copper works north of Lövstad that pollutes Valdemarsvik. Pollution in groundwater comes primarily from the leather works.*

❏ There are other contaminated sites associated with the same activity, namely: *a waste dump that was located outside the industrial area, beneath the present-day ICA supermarket. Outside the site are at least two dumps that are treated as separate objects.*

PART 2

Guidance for

Data Collection

Introduction

Historical background

The history of Sweden's industrial development can be divided into three periods. The first extended from the mid-1700s to World War I, and was dominated by the development of the steam engine and railway systems. During the second period, from the beginning of World War I to the end of World War II, oil replaced coal as the predominant energy source, and electricity played an increasingly important role in technological development. The third period, from 1945 to the present, has been dominated by the development of electronics, rapid communications and efficient transport systems.

Apart from mining and its associated refining industries, there was no significant industrialisation in Sweden until the mid-1800s. It was then that the first mechanical industries were established and industrial methods began to be applied on a broader scale, especially within the wood products industry. However, it was not until the 1890s that industrialism achieved a major breakthrough in Sweden.

A distinctive feature of early industrialisation in Sweden is that a relatively large proportion of the manufacturing plants was located in rural areas. Railways, pulp mills, sugar plants, etc. were many and small. Factories were often located on small rivers that were often severely polluted as a result. In urban areas, industries were often concentrated the outskirts of cities. Due to urban expansion, those areas are now located near city centres.

During recent years, industry has altered its methods of handling chemicals in response to technological developments and changes in legislation. Within a given branch and for a given product, the chemicals used and methods of handling them may have varied over the years. One example is provided by the tanning industry, which prior to 1900 used a process based on extracts from the bark of oak and pine. A chromium-based process developed toward the end of the 19th century then became widely adopted. The older process remained in use, but in a modified version which in most cases replaced bark extracts with synthetic organic chemicals. Other examples are DDT and mercury, the use of which in agriculture is now prohibited or restricted by laws.

In selecting analytical methods for the investigation of contaminated sites, it is necessary to take both currently and previously used chemicals

into consideration. Among other things, chemicals that have recently come into use will not be expected to be found at industrial sites that ceased to operate prior to the introduction of those chemicals.

In general, there are three stages in the use and handling of chemicals at an industrial site:
- use of raw materials and chemicals necessary to an industrial process
- interim storage of wastes for possible recycling
- final storage of wastes.

In many industries, there is extensive use of a range of chemicals. The type of industry determines which chemicals are used and which waste products are produced. Most chemicals are stored for a period of time prior to use. Organic solvents, oils etc. are usually stored in tanks or barrels, while solid chemicals are stored in sacks or barrels. If the quantities are very large, dry chemicals may be stored in stockpiles located on site or nearby, which may give rise to diffuse or concentrated migration. Usually, contamination is heaviest wherever chemicals have been stored or loaded. Contamination is often the result of spillage or of damage to tanks, pipes, etc. Chemicals may also have been deposited directly on the ground, which was not uncommon before the enactment of environmental laws.

Industrial processes often lead to waste products in the form of solids, liquids or a mixture of both. These wastes may be stored in landfills, ponds, etc. while awaiting treatment, recycling or final storage.

Prior to the 1970s, the water used in industrial processes was hardly ever treated before being returned to the environment. When water treatment facilities were established, the sludge they accumulated was often handled in a less than satisfactory manner, for example by tipping it in landfills or old mine shafts.

The landfills at industrial sites are often quite old, and protective measures that may have been taken are of varying efficiency. Often, large quantities of waste products have been used as backfill in the area.

The contaminants characteristic of various industrial branches are reviewed in Appendix 8. Summary descriptions of the branches are provided in the so-called *Branschkartläggningen* (see section sub-titled "Industrial inventory", below).

Industrial inventory

In co-operation with Sweden's county administrations, the Environmental Protection Agency conducted an inventory of industrial branches during 1992-1994. The purpose of this *Branschkartläggning* ("BKL") was to investigate those branches of industries and operations the sites of which were assumed to be in greatest need of remediation.

One component of BKL was a risk classification of individual sites, based on assessments of the potential severity of negative effects on human

health and the environment, and on the probability that such effects would occur. Branches and sites were distributed among four risk categories on a scale from "slight" to "very great". The inventory was based on available information, and reliable data was lacking for many sites. Thus the risk classifications of BKL are unreliable for many sites.

In addition, each industrial branch was assigned a general risk class according to such factors as production processes, raw materials used, products/wastes and routines for handling them, health and environmental effects of contaminants associated with each branch, and the amounts of contaminants involved. Among the branches placed in the highest risk category were paper-and-pulp, wood preservation, mining, metal works, surface coating, repair shops and the entire chemical industry.

The inventory resulted in a rough estimate of 7000 sites that may require remediation, and were therefore assigned to risk classes 1–3. Of •
identify and quantify the major risks to health and the environment to which a contaminated site may give rise

- provide a basis for priorities and decisions regarding continued investigation and remediation
- provide an overview of the extent of the problem within regions, industries and the country as a whole
- provide information for inclusion in regional remediation data bases
- provide a basis for assessments of the need for restrictions on land use, in accordance with Swedish regulations and laws relating to areas of environmental risk.

Risk classification models

Efforts are underway in several countries to identify contaminated sites and, based on preliminary site investigations and knowledge about the industrial branches, to determine how many of them are in need of remediation. There have been few attempts to develop a uniform national classification system for contaminated sites. However, Canada has done so, and the method is in some ways similar to that suggested in this guidance for data collection.

General models for risk classification of land and water have long been available. The best known are named LeGrand and DRASTIC. The former is relevant to point sources of contamination, and the latter to larger areas. Both of them are used primarily to evaluate the vulnerability to contamination of groundwater, or to classify the risks posed by various types of landfills. Both are mathematical models for evaluating and integrating a variety of parameters, which are usually weighted in relation to each other. The weighting may vary, depending on whether the evaluation was made in relation to a general category of contaminants or to a specific pollutant. The final results are often presented in the form of a map.

Risk classification of land and water has not been applied in Sweden

until recent years. Within the framework of its hydro-geological survey on the scale of 1:50,000, Sweden's Geological Survey has prepared maps of the sensitivity to the infiltration of contaminants. At the Institute of Geology, Chalmers University of Technology in Gothenburg, efforts have been made to adapt the LeGrand and DRASTIC models to Swedish conditions.

In the context of remediation, the Växjö and BKL models were developed in connection with inventories of municipal landfills during the 1980s. Other models which have been developed are the Örebro model, which was designed especially for mining wastes, and the Swedish Defence Ministry's model, which is based on BKL, with the addition of preliminary site investigation for certain sites.

Most of the models mentioned above lack established criteria for the assessment of contaminated sites. Some of the models can be helpful in forming an impression of a site's sensitivity for the transport of contaminants (see Table 11). None of the models noted above meets all of the requirements for inventories or classifications of contaminated sites in Sweden.

TABLE 11.

Alternative classification models for land and groundwater, with relevant parameters

Model	Geology	Hydro-geology	Migration profile	Effects on surroundings	Sensitivity of surroundings	Chemical profile	Contamination profile	Risk classification
LeGrand	x	x	x	x	x			x
DRASTIC	x	x	x	x	x			x
Växjö	x	x		x	x	x	x*	x
Östgöta	x	x	x			x	x*	
Örebro	x	x	x	x	x	x	x**	x
BKL						x	x	x
Canada		x			x	x	x	x

*Refers only to landfills

**Refers only to mining wastes

The model that has been developed for conducting inventories in Sweden is known as the Method for Inventories of Contaminated Sites (Swedish acronym, "MIFO"). It consists of two phases, both of which can be completed at relatively low cost (see Figure 4). Following completion of the first phase, the most critical sites are selected for further investigation in the second phase. Given that the cost of investigating contaminated sites is very high, this is a cost-effective way to select the sites of highest priority.
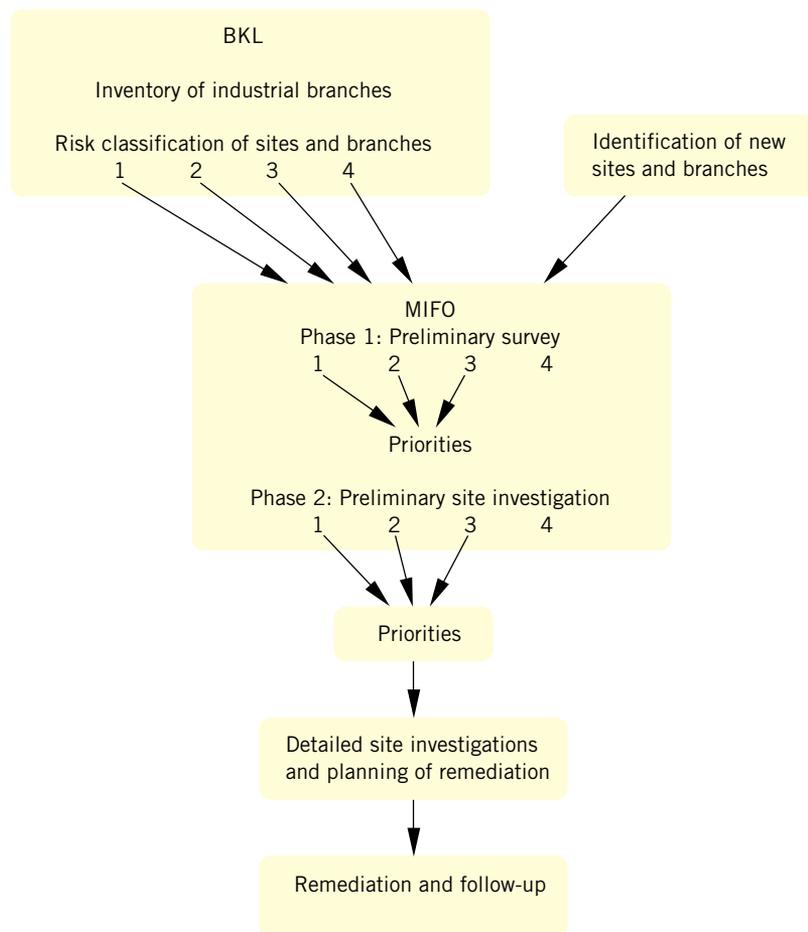
FIGURE 4 MIFO model in relation to the industry inventory (BKL) and subsequent activities. The figures reflect the distribution of contaminated sites between four risk classes.

References

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Swedish Environmental Protection Agency, "Branschkartläggningen"; report no. 4393, 1995

Swedish Environmental Protection Agency, "Inventering och riskklassificering av äldre gruvavfallsupplag"; report no. 4396, 1995

MIFO Inventories

The model

MIFO, which, in Swedish, stands for Method for Inventories of Contaminated Sites, is a model based on thorough studies of maps and archive materials, and on preliminary site investigations which include the analysis of samples from various media at strategically selected locations.

MIFO inventories consist of two phases, the first of which includes a *preliminary survey* and *risk classification.* The second phase involves a *preliminary site investigation* and a *new risk classification.*

PHASE 1: PRELIMINARY SURVEY

Identification of sites and industrial branches

↓

Site visit and data collection, completion of Forms A and B

↓

Compilation and evaluation of:
– hazards assessment
– contamination level (Form C)
– potential for migration (Form D)
– sensitivity/protection value

↓

Risk classifications (Form E)

↓

Selection of sites for Phase 2

↓

Reporting
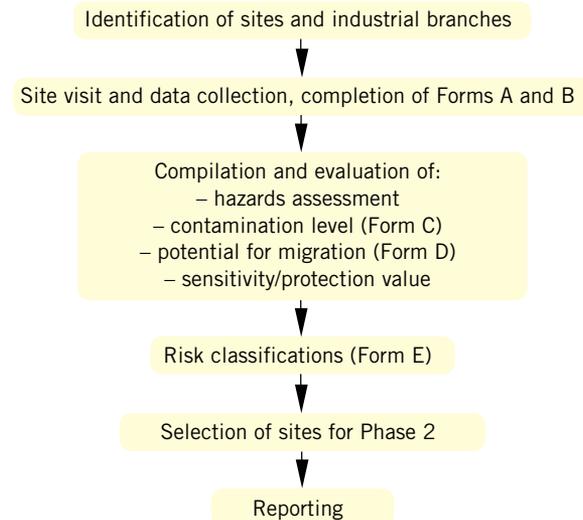
Identification of sites and branches

The preliminary survey of sites and industries is based on information available from the Swedish Environmental Protection Agency's inventory of industrial branches, known as "BKL". Since that information is not complete, an attempt must be made to identify additional sites and branches that may be of interest. Identified sites are then investigated individually.

Site visits and data collection

The next step during Phase 1 is to collect available data about the site by such means as carrying out a site inspection, studying maps and archive

materials, and conducting interviews. Information of an administrative nature is entered on Form A, while descriptions of the site, the activities conducted there, and the surrounding area are entered on Form B.

Description and evaluation
The data thus gathered is evaluated with respect to the hazards of the contaminants, the contamination level, migration potential, and sensitivity/required protection value. The relevant information is entered on Forms C, D and E.

Risk classifications
The preliminary survey concludes with an overall evaluation of risk, after which the sites are distributed among four risk classes. The evaluation carried out at this stage is such that some sites are placed in risk classes without the benefit of field studies, sampling or analysis.

Selection
After the risk classifications, the sites to be included in Phase 2 are selected.

Reporting
The results are reported and then stored in digital format.

PHASE 2: PRELIMINARY SITE INVESTIGATION

Site inspection

↓

Geological profile

↓

Sampling plan

↓

Sampling

↓

Analysis

↓

Compilation and evaluation of:
– hazards of contaminants
– contamination level (Form C)
– Migration potential (Form D)
– sensitivity/required protection value

↓

Risk classifications (Form E)

↓

Reporting
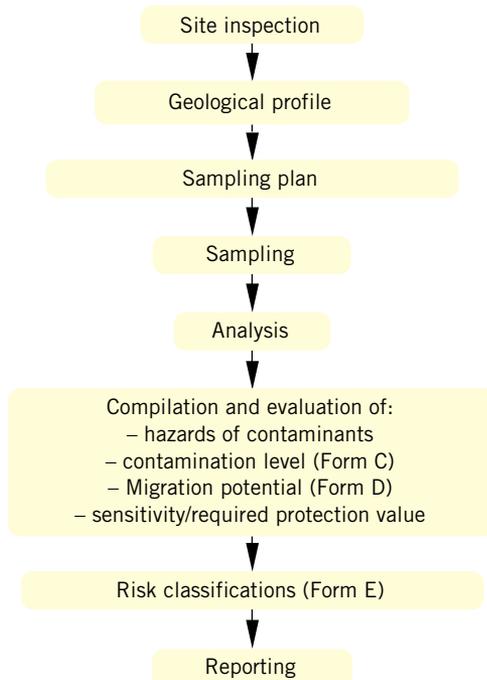
On-site inspection and geological profile

A preliminary site investigation begins with an on-site inspection in order to get a general impression of the migration potential. The on-site inspection is conducted with the help of available maps. In the absence of geological maps at a suitable scale, a diagram of the main geological features is constructed.

Sampling plan

A sampling plan is designed on the basis of the on-site inspection and available information concerning the site's geology and history of contamination. Included in the plan are details about the media to be sampled, the sampling locations, and the types of analysis to be carried out.

Sampling

The next step is to carry out the sampling plan with established methods.

Analysis

The MIFO-model includes a number of selected chemical analyses and toxicological tests for screening purposes. Specific analyses should be carried out if it is known that specific substances have been handled or released at the site. The model also includes tests relating to acute toxicity, genotoxicity and reproductive effects.

Compilation and evaluation

The evaluation from the preliminary survey of Phase 1 is complemented with the data generated during Phase 2.

Risk classifications

As with the first phase, the second phase concludes with the sites being assigned to one of four risk classes. The risk classification of Phase 2 is usually much more reliable than that of BKL or Phase 1, and adjustments of those classifications may therefore be necessary.

Reporting

The results are reported and then stored in digital format.

Working procedures

Organisation

Inventories of contaminated sites will be carried out primarily with state financing in the form of regional inventories under the direction of municipal governments and county administrative boards. Other public authorities, the armed forces and business organisations, may also conduct inventories. In order to produce uniform results, the method presented in this guidance should be applied, regardless of the initiating organisation.

Uniformity is especially important if the results are to form the basis of decisions about areas of environmental risk, as defined by Swedish law.

Planning and implementation

The primary responsibility for official national inventories rests with the Swedish Environmental Protection Agency. Its tasks in this regard include overall planning, supervision, distribution of resources and follow-up. Resources are distributed in relation to government allocations to the Agency, and the highest priority is given to those industries and sites which are judged to comprise the greatest threats to health and the environment. In setting priorities, consideration is also given to practical and cost aspects, partly to avoid duplicating efforts in the same region.

Responsibility for implementing the inventories rests with municipalities and county administrative boards. The latter are responsible for overall planning, support and quality control. The county boards are also responsible for ensuring that general information concerning the inventories reaches public agencies and other interested parties. In principle the responsibility for implementation should be assigned to those responsible for supervision as stipulated by Swedish environmental law. For sites at which no environmentally harmful activity has been conducted, the responsibility rests with municipalities. Special agreements can be made between municipalities and county administrative boards concerning the responsibility for carrying out an inventory.

The recommended procedure for conducting an inventory is described below; but for limited inventories, a simpler procedure may suffice.

- The extent and main focus of the inventory are described in a several-year plan, which serves as the basis for decisions by the Swedish Environmental Protection Agency (SEPA).
- When the necessary resources have been allocated and the terms of their use approved, the county administrative board should appoint a *project leader* whose first task is to develop a detailed inventory plan. The project leader should be assisted by a *steering committee* with decision-making authority. The committee should include representatives of county planning and environmental protection agencies. Cultural heritage agencies should also be represented, if any site included in the inventory is of historical interest. Any interested party that may be affected by the inventory should be contacted and, where necessary, appropriate negotiations should be conducted. A similar detailed plan should be developed for any inventory which is to be carried out by a municipality.
- If a county administrative board is responsible for implementation, copies of the plans for the proposed inventory should be distributed to the affected municipalities, among others. A public information meeting should be held within the review period, during which the affected municipalities and branch organisations should be entitled to appoint representatives to a *reference group.* The agency responsible for the inventory should explain who will carry out the work – agency personnel (possibly engaged

temporarily for this purpose), personnel from other agencies, or consultants.

- After the plan of the proposed inventory has been presented, decisions regarding its final shape should be taken by the steering committee.

The next stage of the process depends on whether the work is to be carried out by agency personnel (Alternative A) or by consultants (Alternative B). A combination of the two may be appropriate in order to utilise the greatest available competence for various aspects of the inventory.

- Alternative A: agency personnel carry out most of the inventory work. Sub-contracting of drilling, sampling and analysis may be appropriate. In calls for tenders, it should be clearly noted that supervision will be exercised.
- Alternative B: If consultants are engaged, calls for tenders shall be issued. If a county administrative board makes use of other public agencies, colleges, universities or national institutes, no tenders are required, but if a municipality makes use of such public agencies, formal tenders are required.

In cases where a municipality is responsible for an inventory, an agreement with the relevant county administrative board should also be established. This could well be in the form of a grant, tied to a number of conditions; one of which should be that supervision will be exercised. Another condition is that any purchases of goods and services should be subject to competitive bidding.

With both Alternatives A and B, the personnel working directly with the inventory should participate in any special training that is offered.

- In many cases, the work will be carried out by a number of individuals who form a working group under the direction of a project leader appointed by a municipality or county administrative board. With Alternative B, it may be appropriate to assign a co-ordinating function to someone connected with the hired agency or consultancy firm. The project leader should act as the working group's chairperson.
- The inventory's ongoing results, finances and conformity to its time-schedule should be regularly reported at meetings of the steering committee. In addition to the above-noted approval of the inventory plan, the most important decisions that the steering committee has to make are those regarding classification, publication and which objects are to be investigated on-site. The reference group should meet at least once during the inventory period, and should also be kept reasonably informed of work in progress.
- Recommendations regarding the classification of sites are the responsibility of the project leader, alternatively of the inventory-maker or the consultancy"s co-ordinator. Results and proposed classifications should be presented to the steering committee, which must then decide if there are sufficient grounds to pass the recommendations on to interested parties for review.

- The results of the inventory and the recommended risk classifications should be submitted to the same interested parties that were invited to review the inventory plan.
- Decisions concerning the risk classification, as well as other decisions concerning the direction of the study and publication are made by the steering committee. For sites that are difficult to assess, the committee may need to enlist the help of outside expertise, e.g. SEPA, academic researchers, or, in cases where a municipality is responsible for implementation, a county administrative board.

County administrative boards are responsible for ensuring that inventory results are made available for use in physical planning, etc. Municipalities are responsible for the application of inventory results in municipal planning.

The organisation that is built up during the inventory period may, if the occasion arises, also be used to carry out more detailed investigations or remediation.

Inventories conducted under supervision other than that of the state and municipalities can be organised in the same way as described above. It is desirable that inventories be conducted openly, and that all interested parties be given an opportunity to participate in the process, to be kept informed, and to receive a final report of the results.

Competence requirements

Accredited field technicians and laboratories should conduct the sampling and analysis of water specimens. Experienced personnel must carry out the sampling of land, groundwater and sediments, as well as the geological inventories. As there is no formal accreditation of such skills in Sweden, county administrative boards may need the assistance of SEPA in evaluating the competence of individuals.

Individuals with higher academic degrees or equivalent competence should be engaged to evaluate geological, hydro-geological, limnological, chemical and ecotoxicological data. The same requirements apply to those who process and evaluate the results of analyses and tests relating to health risks and environmental effects.

Since the conditions that exist at contaminated sites are usually complex, it is necessary that the personnel who make the final evaluations have a broad experience of risk assessment, as well as adequate knowledge of the transformation and circulation of chemicals in the environment. A solid background is also a requirement for the ability to weigh all the factors and make a comprehensive assessment of the risks that a contaminated site may pose to humans and the environment.

Two ways to ensure that the investigations are of high quality are to always demand documented references, and to negotiate the services of especially qualified individuals within the organisations engaged. In this context, the training programmes offered by SEPA can be very useful.
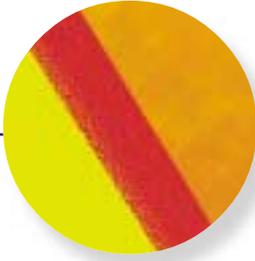
PHASE 1: Preliminary Survey

The preliminary survey, Phase 1, establishes hypotheses concerning the contaminants that can be expected to occur at a site, their distribution, and the way humans and the environment can be exposed. Those hypotheses are then verified or rejected in Phase 2.

Identification of sites and industries

Using information from the Swedish Environmental Protection Agency's inventory of industrial branches, (Branschkartläggningen) as basis, a new inventory of sites and industrial branches is carried out.

FIGURE 5 An old abandoned industrial site.

Sources that may be helpful in locating new objects for investigation are the Swedish Patent and Registration Office (business registry), fire department records, branch organisations, business associations and municipal archives. Membership records of trade unions and business organisations (e.g. Swedish Employers' Confederation) may also be helpful, despite the fact that they only date from the 1920s. One difficulty here is that during the early stages of industrialisation labour was organised only at larger workplaces.

The National Heritage Board is currently building up a database of historical industrial sites; its experience and knowledge of historical research, in general, may also be helpful. Local folklore societies may have documented older industrial activities in the area. For larger communities, telephone directories may yield useful information, even if the addresses are no longer current. Important information can also be obtained from photographs, postcards, aerial photos, television archives, etc. The National Land Survey has an archive of so-called vertical and diagonal photographs which can be useful even for more detailed inventories.

Other useful materials include maps, drawings and industry publications. Older factories and larger industries usually compiled extensive documentation of their histories, information that is often available from libraries and second-hand bookstores. In addition, larger industries usually maintain their own archives. Older reference works often contain useful information concerning early industrial processes and the industrial structures of various localities. Two other sources on early industries are the reference works, *Geografiskt Handlexikon öfver Sverige* and *Svenska Orter*, which provide detailed information about Swedish and local geography.

Information concerning more recent industrial activity can often be found in the archives of municipal environmental health departments and county administrative boards. These materials consist of reports from routine inspections, companies' annual environmental reports, and accident investigation reports.

It is difficult to locate more or less undocumented industrial activities of which no visible traces remain. Often, the only way to obtain information about them is through interviews with individuals familiar with the local area, including members of pensioners' societies and community associations. If no such sources are available, the only alternative in most cases is to take a large number of samples for the detection of contaminants. The Swedish Geological Survey's biogeochemical maps can be useful in this regard.

Data collection and site inspection

On-site inspection is an important part of the preliminary survey and requires careful planning. The purpose of the visit is to interview operational personnel, and to inspect the facility and its surroundings. Those

to be interviewed should be informed in advance, and the interviews should cover the points included on forms A, B and D. Background studies should be conducted prior to the inspection, and an effort should be made to acquire copies of old maps and photographs, which should be labelled and dated. Photographic documentation of the site as it appears today is often of great value.

When inspecting the site, economic maps on the scale of 1:10,000 should be used, along with architectural drawings and planning maps. Nearby neighbours and older maps of the area are of great potential value. Notes on maps and drawings should be made with a soft lead pencil.

Checking the data
The data thus collected are often unclear or contradictory, in which case they should be double-checked with the information source. To the fullest extent possible, all data should be verified according to one or more of the following criteria:

- documentation is available
- at least two verbal reports are in agreement
- field observations have been made.

Uncertain or unverified data should be indicated on the forms with a question mark ("?"). Examples of completed Forms A and B are provided at the end of this chapter. Geographical co-ordinates of properties, contaminated sites and landfills should be noted and can be derived from the economic map.

Administrative data – Form A
Administrative data are noted on Form A (see Appendix 1).

Comments:
- The site's ID number should consist entirely of numerals. In some case, these may correspond to those used in "BKL", the inventory of industrial branches noted above (figures available from Swedish Environmental Protection Agency). The other figures follow the sequence: county code/municipality code/site number, for example 05/63/111.
- The site's industrial branch is given according to the categories of BKL (see Appendix 8).
- The title of the inventory refers to the entire project.
- Previous studies and investigations that are relevant to the assessment include consultants' reports, follow-up programmes, inventories, etc. Examples include soil inventories, bore-samples, soundings, etc. that have been carried out on site and can be used in the construction of a three-dimensional model of the area. Data concerning the soil's stability and subsidence may also be useful. Hydro-geological inventories

provide information on groundwater flows, in- and outflow zones, migration potential, water quality, etc.

- In addition to topographical and economic maps, other maps may be useful. Information about maps can be obtained from industry, municipal property-supervision offices, local consultants, the National Land Survey and the Swedish Geological Survey (geology, hydro-geology and geochemistry).

  Construction geology maps. Usually on the scale of 1:2,000–20,000. They provide information about the geotechnical conditions, especially in urban areas.

  Soil maps of the Swedish Geological Survey (SGU). Series Ae on the scale of 1:50,000 and Series Ak, usually at 1:100,000. Information on distribution of soil types at depth of 0.5 metres, along with some soil-probe data. Working copies on the scale of 1:10,000 can be ordered from SGU, which can also supply the accompanying geological descriptions and analysis results (not chemical analyses). Soil maps can be ordered in digital format.

  SGU bedrock maps. Series Af on the scale of 1:50,000 show the distribution of bedrock types, fractures and tectonic conditions.

  SGU groundwater maps. Series Ah on the scale of 1:250,000 show the potential yield of different types of aquifer, the position of larger groundwater supplies, groundwater divides, fracture zones, areas with risk of saltwater intrusion or elevated fluoride levels, etc.

  SGU geochemical maps. Soil geochemical and bio-geochemical maps on the scale of 1:1 million or 1:250,000 provided summary information on metals in moraine deposits and metal concentrations in shallow groundwater. These maps can be useful to locate areas of diffuse contamination or larger contaminated sites.

  SGU marine geological maps. Show the distribution of various types of sediment down to the underlying bedrock, both horizontally and vertically. They also provide information on dynamic bottom processes, i.e. erosion and deposition. Special maps of sediment chemistry give the concentrations of heavy metals and organic environmental toxins.

- Information on benchmarks is available from the National Land Survey, municipalities and economic maps.

- *Wells and boreholes.* Wells on the site or within the affected area are important to the future land use of the area and potential conflicts with area residents. Existing wells and boreholes are also used for taking samples and measuring groundwater levels in connection with the groundwater component of the preliminary site investigation. Relevant information can be obtained from previous inventories, SGU's register of wells, and interviews. Some industries may have older wells of their own within the area. Data from wells can provide information on soil depth, stratification sequence and water flows.

Industry, site and surroundings – Form B

Information regarding the industrial activity, the contaminated site and its surroundings are entered on Form B (see Appendix 2).

Comments on description of industrial activity

- Summary description of current processes. Information can be obtained primarily from interviews with operational personnel, though some information may also be available from the supervising authorities.
- Summary description of earlier processes. Information can be obtained primarily from interviews with current or former employees, archives and the relevant literature, all of which is usually very time-consuming. Larger industries have often maintained their own documentation. Alternative sources are local libraries or, for example, the Institute of Industrial History at the Royal Institute of Technology in Stockholm. The principal focus should be on locating and interviewing older key personnel. This is especially important in the case of abandoned industries; otherwise, crucial sources of information, sometimes the only ones remaining, will be lost forever.
- Chemicals used in industrial processes. The data should be as comprehensive as possible. It should be collected in connection with, and in the same way as, the descriptions noted in the two preceding paragraphs. If possible, amounts and storage locations should also be noted. Guidance is given in Appendix 1.

Comments on contaminated site and its surroundings

- Types of soil. Should be given as one of the following alternatives: *Impermeable:* clay, clay moraines, silt with clay layers, muds and most compacted peat deposits. *Semi-permeable:* mixed-grained and fine-grained sandy and sandy-silty moraines, silty and fine sands. *Porous:* coarse gravelly moraines, sandy and gravelly soils. *Backfill,* which may comprise many different kinds of material with diverse characteristics. *Rock:* Industrial facilities sited partly or entirely on exposed bedrock are comparatively rare.
- Topography. The degree of slope (expressed as percent) is primarily of interest for assessing groundwater flow and surface water run-off. Data can be obtained from topographical maps. The relevant slope is that which affects the flow of groundwater, which means that it may be necessary to consider areas outside the limits of the site in question. If an open body of water (sea, lake, river, etc.) borders the site, the slope can be assumed to end at the water line.
- Principal drainage area, as delineated by the Swedish Meteorological and Hydrological Institute in its basic reference, *Avrinningsområden i Sverige (Watersheds in Sweden), Svenskt Vattenarkiv.*
- Age and condition of buildings. This information is primarily useful for

locating sites where chemicals have been handled. In some cases, the buildings themselves may contain environmentally harmful substances, e.g. mercury used in the manufacture of chloralkali or asbestos from insulating material. Waste materials from demolished buildings may also have been used as backfill. If there are no buildings, or those formerly present have been demolished, this is noted on the appropriate form.

- Drainage of leachate/run-off: Of primary interest in this regard are sites where the larger portion of contaminants infiltrates soil and groundwater.
- Run-off. This refers to the water that runs off from roofs and ground surfaces. In a closed system, run-off water is channelled into drainage pipes, which usually lead to a surface water body, but sometimes to a treatment facility. In an open system, open ditches drain the run-off to a surface water body. Many industrial areas with closed systems have previously had some sort of open system. In such cases, both types are recorded.
- Landfills. Defined as a final storage area for waste products. A landfill situated outside the principal site is often regarded as a separate site and is to be dealt with as such.

Risk classification

See Part 1.

Setting priorities for Phase 2

The costs of Phase 2, the preliminary site investigation, are so great that it is usually not possible to include every site that is suspected of being contaminated on the basis of the Phase 1 assessment. It is necessary to select sites for further investigation based on the following considerations:

Highest priority is given to those sites for which there is a clear risk of severe negative effects on human health and/or the environment, and those for which such effects are already in evidence. Sites with significant concentrations and amounts of contamination are also given highest priority.

The next-highest priority is given to sites that pose a threat to nearby areas with especially sensitive ecosystems or of exceptionally great conservation value, and to sites from which large amounts of contaminants may migrate over a long period of time. Other high-priority sites include those for which inventory co-ordination is cost-effective, and those for which it is important to establish responsibility for the site.

Reporting

See separate chapter starting on page.

References

Generalstabens litografiska anstalt, *Svenska Orter*, Stockholm, 1932

Generalstabens litografiska anstalt, *Geografiskt Handlexikon öfver Sverige*, Stockholm, 1982

Form A. ADMINISTRATIVE INFORMATION

Indicate uncertain items with question mark ("?")

Name of survey: *Sw. Env. Protection Agency Preliminary survey, 1994-95*	Phase (1 or 2, per MIFO): **2**
Object: *Valdemarsvik (formerly Lundberg's Leather)*	First recorded by (name, date) : **Ulf Qvarfort, 1996-05-25**
Id no: **BKL 123**	Revised by (name, date): **Dag Fredrikson, 1996-10-22**
Preliminary risk-classification, per BKL **2**	Revised by (name, date):

Industrial branch	**Tannery**		
SNI branch code. Automatically filled in when data recorded			
County (name, code)	**Östergötland**		
Municipality (name, code)	**Valdemarsvik (0563)**		
Topographic map. Automatically filled in when data recorded	**8G Norrköping SO**		
Economic-Yellow map. Automatically filled in when data recorded	**Oj Valdemarsvik**		
Geographical co-ordinates. Object's, property's or main building's centre point. National grid, six figure grid reference	X= North	Y= East	Z= Elevation
Type of property, per CFD			
Buildings and other constructions present and previous (outline)	**Tanning vats, storage facilities, preparation area, central heating unit, oil cistern, machine shop, carpenter shop**		
Object address			
Facility's owner or equivalent, including address	**Municipality of Valdemarsvik, 615 80 Valdemarsvik**		
Current property owner, if other than facility owner, incl. address			
Contact person at monitoring agency or the like, incl. address	**Karin Karlsson, Maintenance Dept.; Knut Knutsson, Property Management**		
Property size (m^2)	**10,000**		
Previous studies and surveys	**Eva Siljeholm, 1992: Metals in Valdemarsvik's bottom sediments; Valdemarsvik Maintenance Dept. ELK Co., 1995: Analysis of metals from Valdemarsvik, J&W. SGU survey related to clean-up of Lundberg's Leather.**		
Other sources (maps, aerial photos, etc.), and their present locations	**SGU, Aa 158, Ae 167 plus reports and notice no. 48, Area map; Valdemarsvik Maintenance Dept. Old photos in city archive and museum**		
Bench mark locations			
Wells/boreholes within industrial or affected area: location, condition and type (groundwater tubes of metal and plastic, dug and drilled wells, none)	**(None)**		

Form B. DESCRIPTION OF ACTIVITY, SITE AND SURROUNDINGS

Indicate uncertain items with question mark ("?")

Object: Valdemarsvik (formerly Lundberg's Leather)	Recorded by (name, date): Dag Fredriksson, 1996-08-30
Id No: BKL 123	Field inspection (name, date): Dag Fredriksson, 1996-08-30
	Field inspection (name, date):

Description of activity

Facility status (in operation, discontinued before 1969, discontinued after 1969, no known previous activity)	Shut down before 1969
Accessibility (fenced, open)	Open
Industrial activity, approximate number of years	100
Start and stop of operations (year)	1860-1960/70
Environmental disturbance from operation, approximate number of years	100
Production (product & quantity including, if possible, years for various products)	Unknown
Process description, current (outline)	None
Process description, previous (outline)	Tannery, and carpentry shop
Process waste water, current disposal (connected to own or municipal treatment facility, untreated to named body of water)	–
Process waste water, previous disposal (same alternatives as foregoing)	To nearby body of water
Chemicals used in industrial processes	Chromium, phenols, DDT, colour dyes, salts, mercury
Process waste products, temporary storage (amount and type)	None
Remediation carried out (type of measure, e.g. covering, enclosing)	Clean-up near oil cistern, emptying of tanning vats under central building, asphalting of ground surface for road and parking area
Planned remediation (same alternatives as foregoing)	None
Conflicting uses (water supply, local residents, farming, forestry, water use, recreation, imminent change of ownership, other— specify). Note all known conflicts.	Water use, change of ownership

Site and surroundings

Land use at site (industrial, agricultural, dense settlement, forestry, park, other)	Industrial land, urban area, buildings
Land use within affected area (same alternatives as foregoing)	Urban area, buildings, park
Distance from object to *nearest* housing area 0-50 m, 50-200 m, 200-500 m, 500-1000 m, >1000 m)	0-50 m
Visible damage to vegetation within site (yes, no)	
Visible damage to vegetation within affected area (yes, no)	None
Predominant soil conditions within site (impermeable, semi-permeable or porous, backfill material, rock, other)	Impermeable soil strata, backfill
Topography, slope (%)	0.5%
Type of nearby recipient (groundwater, ditch, brook, river, lake, sea)	Groundwater, sea
Name of nearby recipient and distance from pollution (per topographic, economic map)	Valdemarsvik, Baltic Sea
Principal drainage basin, per SMHI	68/69

Buildings and other constructions

Buildings, including demolished (age and condition)	Old industrial buildings and an oil cistern. Majority of remaining buildings from 1920s and 1949

Contaminated ground

Location	Under central building and central heating unit		
Volume of contaminated material (m^3)			
Surface area (m^2)			
Geographical co-ordinates, national grid, six figure reference	X= North 645370	Y= East 154690	Z= Elevation
Contaminants	Oil, Cr, Hg		

Contaminated groundwater

Location			
Volume of contaminated material (m^3)			
Surface area (m^2)			
Geographical co-ordinates, national grid, six figure reference	X= North 645370	Y= East 154690	Z= Elevation
Contaminants	Oil, Cr, Hg		

Contaminated sediments

Location	See separate site, "Valdemarsviken"		
Volume (m^3)			
Surface area (m^2)			
Geographical co-ordinates national grid, six figure reference		North	East Elevation
Contaminants			

Drainage water and dumps

Type of water drainage system (closed, open, unknown). Destination (groundwater, ditch, brook, river, lake, sea, peat bog, other)	Unknown		
Dump (within object, outside object, none, other)	Outside the object are two dumps that are treated as separate objects		
Type of dump (in use, open, under construction, discontinued, used as backfill)	Used as backfill		
Contents			
Leaching from dump (to surface water, groundwater, none)	To surface water; to groundwater		
Geographical co-ordinates national grid, six figure reference	X= North 645370	Y= East 154690	Z= Elevation

Other (e.g. settling, contents of filled areas, covered piles of earth, loading areas, tanks, burned areas, filled-in water

accumulations): . . . .

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PHASE 2: Preliminiary Site Investigation

Site inspection, geological map & sampling plan

Site inspection

The site is first inspected during Phase 1. If a supplementary inspection is required, it can be performed in connection with the construction of a geological map.

Geological map

The geological map describes surface features. It should both form the basis of a sampling plan, and should be used in the assessment of migration potential. Suitable working maps on the scale of 1:10,000 are available from the Swedish Geological Survey for sites located in southern and south central Sweden. Construction geology maps can be used instead of urban ones.

Where no such maps are available, a geological map can be constructed as follows:

The surface to be described includes the affected area of the site, plus an additional area large enough to display principal geological features.

Topographical maps, stereoscopic black-and-white or infrared aerial photos, and other sources providing information about elevations, can serve as appropriate bases. The geological map is completed in the field, partly with the help of spade and auger. Sections of soil of more or less uniform composition (clay, sand, rock, etc.) are delineated and charted. Each section is categorised according to the system of the Swedish Geotechnical Society, and any symbols used are explained in a map legend.

The types of soil thus categorised are those found at the sub-surface level of 0.5 metre. When delineating a section, it is necessary to use approximate boundary zones, usually within a range of 30 metres (equivalent to three millimetres on the map). Phenomena that are especially important for the hydrogeology of the area should be noted on the map, even if they are too small to be charted as separate entities. This includes smaller areas of exposed rock, small patches of clay, and small areas of thin peat. Small springs and groundwater outflow zones are also important to note. Definite observations regarding the type of soil in roadside embankments, ditches, etc. are noted separately in red ink. Thin layers of soil, i.e. less than 0.5 metre deep, are indicated with diagonal striped lines on the map. Very small areas of exposed rock are indicated with a red cross. Backfilled areas are noted with vertical striped lines, and the underlying soil type is specified where possible.

Backfill is any material that covers the original ground surface. When it consists of natural soil, it is described in the same way as natural soils. Backfill may also consist of many other types of material, including tree bark, wood, ashes, ore tailings, oil-shale residues, crushed blasted stone, demolition wastes, coal and coke residues, etc. All such materials may be mixed together with natural soil in various combinations and amounts, in which case the backfill is classified as "industrial waste deposits".

Loose layers of soil are described and delineated by means of drilling and sampling, according to the standards of the Swedish Geotechnical Society, as illustrated in Figure 6.

Even if a contaminated site has often been greatly altered by factories and other constructions, roads and backfilling, the surrounding area may provide a clear indication of the original geological conditions. In order to produce a good map, it is necessary to understand the relationships between surface formations, topography, vegetation and geological features. Some examples of how such relationships can be interpreted are: Areas of level moraine-topography containing birch, alder and pools of water indicate that a layer of clay covers the moraine. A dominance of spruce on level areas is indicative of silt or clay. In the same way, the land use may also be instructive: Rye and potatoes are usually grown on porous soils, wheat on hard clay; muddy areas are often used for grazing, etc.

Legend

Symbol	Description
G	Gravel
L	Clay
△	Sandy moraine
⊞	Backfill over clay
●	Rock

FIGURE 6 Example of finished geological map.

Planning of sampling programme

A sampling programme is planned in order to ensure the quality and orderly execution of the fieldwork.

The sampling plan includes descriptions of:
- which media are to be sampled, and why. (This defines the sampling area, which may be subdivided.)
- the exact locations of samples and boreholes, including reasons for choosing those locations, which are to be noted on the map
- the sampling methods to be used, and reasons for selecting them
- how samples are to be prepared, which analyses are to be carried out on each of them, and why.

The media and sampling locations are to be indicated on a site map drawn on the same scale as the available background materials (drawings and planning maps), but not less than 1:2000. The site map should include information on:
- point sources of contamination, plus known contaminants and landfills at the site
- existing wells and boreholes
- benchmarks
- exact sampling locations for soil, groundwater, surface water and sediments.

Some of this information may be included on a map on a different scale, as in Figure 7.
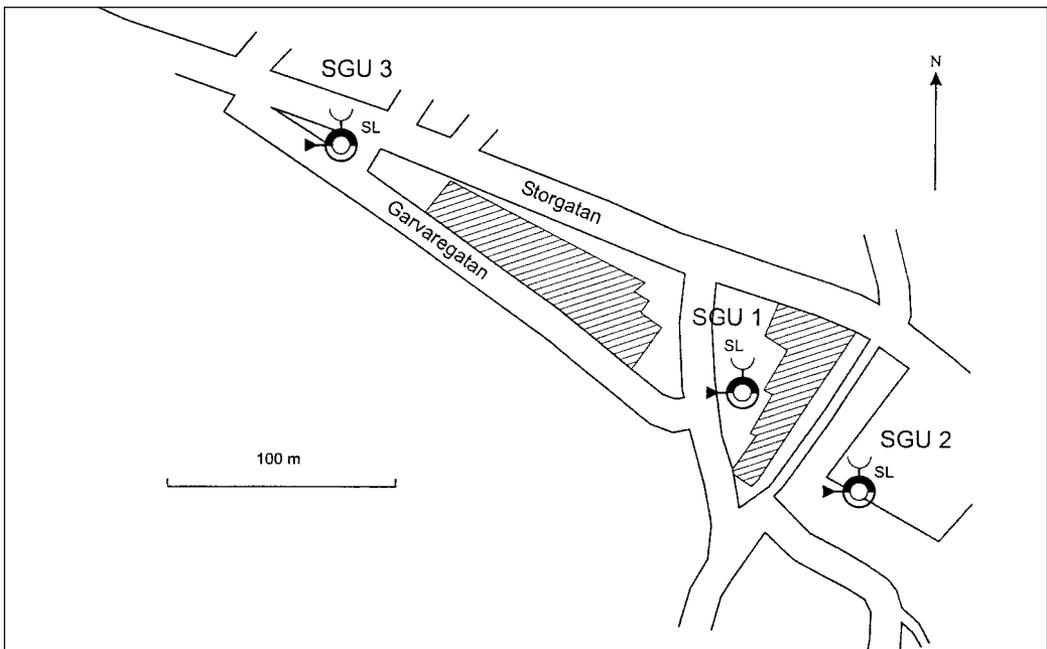
FIGURE 7 Example of completed site map.

Selection of sampling media

The selection of sample locations and media to be sampled should be made so that the minimum number of samples is required, in order to accurately describe the conditions at the site. Samples are to be taken in media that are suspected, or known to be contaminated. Samples can be taken from buildings and other constructions, land, soil air, groundwater, surface water and sediments.

Soil samples may be taken from loose natural layers of soil, backfill or other deposited waste, natural layers of organic and inorganic material, including gravel, sand, silt, clay, moraine, mud, peat and even topsoil.

Groundwater is the water within the saturated soil zone, and may be found in soils, backfill and the pores/fissures in rock. Landfills do not usually contain groundwater that is in contact with the surrounding area. However, there is often an internal groundwater table, especially in landfills with an impermeable base.

Surface water is the water in brooks, rivers, lakes and seas. Groundwater becomes surface water whenever it rises above the surface of the land.

Sediments are deposits in lakes, mires, pools, and some parts of rivers and coasts. In sediments, it is possible to detect contaminants which have been transported via ground- and surface water, even in low concentrations. Sediments usually consist of mud, clay, sludge, sulphidic clays, and even fibre-banks.

Selection of the location of boreholes and sampling stations

Boreholes and sampling stations are selected with the object of:
- verifying the presence of contaminants
- verifying the potential for migration
- measuring local background levels.

The number of boreholes may vary between sites depending on the type, size and extent of the industrial activity in question, and on economic considerations.

The reliability of the investigation should not depend on the size of the area studied. A reasonable guideline for sites with a variety of contaminants is about five sampling points per hectare.

Soil and groundwater should be sampled together at the same sampling points, as should sediment and surface water. Existing wells and boreholes within the probable area of contaminant migration should also be sampled. The general rule is to collect more samples than the number to be analysed. It is important to retain any samples not analysed for eventual supplementary tests and analyses.

It may be useful to localise volatile contaminants with soil-air measurements in order to derive maximum information from soil and groundwater

samples. Geophysical measurements and other scanning methods may also help to localise contaminants.

It is most important to take samples at those locations that are believed to contain the highest concentrations of contaminants. In locating these so-called "hot spots", information concerning previous activities, processes and unusual occurrences at the site may be helpful. For example, hot spots are usually found near petrol station storage tanks, tar separators and filterng cisterns at gasworks, filling stations for liquid chemicals, sewers, etc. If the locations of the highest concentrations are not known, the number of samples should be increased in order to increase the probability of finding areas of heavy contamination. Landfills often have inhomogeneous contents, which complicates the sampling process. In some cases, it is better to rely on existing data than to take new samples.

Samples for the verification of pollutant migration are taken in soil, groundwater and sediments. Soil samples are taken just above the groundwater surface. Samples must be taken at locations sufficiently distant from the original source of contamination to ensure that migration can be verified with adequate reliability. Longer distances can be chosen when it is known that the transport has been rapid, e.g. at the boundary between loose soil and solid rock, or in porous sediment layers.

The distribution of contaminants can be estimated on the basis of information concerning how long they have been present in soil or groundwater, as well as the speed and direction of their transport via groundwater. In order to determine the slope and direction of the groundwater surface, at least three observation points are needed, of which one can be on the surface of a lake.

For surface water and sediments, sampling stations are located in the nearest lake or sedimentary zone of a river that is downstream from and in contact with the contaminated site. Downstream surface water samples should be taken as close to the source of contamination as possible. There is no point in taking surface water samples if the receiving body of water has a very rapid turnover. Instead, samples are taken from sediments on accumulation bottoms.

If a pollutant spreads in a free phase, i.e. without being transported by a medium, samples should be taken either just above the groundwater surface or at the lowest level of the aquifer, depending on the nature of the substance involved.

To measure local background levels, samples can be taken near the site being investigated. Sampling locations should not be contaminated by the site or by any other point source. The habitats must be similar to those within the contaminated site, samples should be taken from the same type of soil, and surface water bodies should be similar in size and degree of eutrophication. The nearest upstream lake can serve as a suitable location for surface water and sediment samples. In some cases, background

samples can be taken from deeper sediment layers. At least five samples must be taken if the results are to be useful in an assessment.

Selection of sampling methods
The selection of sampling methods is explained in the following chapter.

Selection of analytical procedures
Analytical procedures should be selected with the objective of a general picture of contamination of the site. A proper assessment requires knowledge of which contaminants are present, the concentrations at which they occur and their toxicities. Analytical procedures are described in *Analysmetoder*, (Analytical Methods) report nr. 4947 of the Swedish Environmental Protection Agency.

In describing the characteristics of a contaminated site, it is desirable to obtain information on levels and amounts of individual contaminants. Some of them may be regarded as specific to certain industrial branches, e.g. metals and cyanides used in connection with surface finishing, creosote, copper and arsenic used at wood-impregnating facilities, and have a given place in an analytical programme.

Contaminants at many sites are complex and their composition is more or less unknown. Landfills and polluted industrial land have often been used for a variety of purposes. Chemical synthesising and manufacturing processes may have generated wastes with unknown characteristics. Degradation processes in ground and water may lead to the formation of new chemical substances. The uncontrolled disposal of unknown substances in landfills is another factor that significantly increases the uncertainty surrounding the contents of landfills.

A complete or fairly comprehensive chemical description of the contents of a contaminated site is, in most cases, both theoretically and practically impossible, not only due to economic considerations. An economical and practical alternative is to use a combination of branch-specific and group parameters to describe the presence and concentrations of certain groups of substances that are interesting from the point of view of the environment and human health. Where there is uncertainty regarding the total contaminant load, group parameters are to be used.

A system of group parameters, in combination with simple biological tests, has long been in use by authorities responsible for supervising industrial activities that affect the environment. That system currently serves as the basis for decisions on whether or not to restrict contamination discharges. Such a system may also be helpful in connection with preliminary site investigations of contaminated sites.

The MIFO model presented in a previous chapter includes a basic and a supplementary programme for analyses that can be used in descriptions of physical and chemical characteristics. The basic programme covers

common contamination-indicating parameters; nutrients, metals, EGOM, dry matter, ash content and supporting parameters. The EGOM analysis should be complemented with a mass spectrometry screening analysis (GC-MS) in order to obtain more detailed information about the substances detected. Different parameters are recommended for different media (see Table 12). One way to reduce the costs of analysing several group parameters is to carry out a single sample extraction, and then use portions of the extract for the various summary parameters.

The basic programme represents a minimum standard from which deviations are permitted only in exceptional cases, for example if it is evident that certain metals cannot possibly be present. If specific analyses

TABLE 12.

Basic and supplementary programmes for chemical and physical analyses in inventories of contaminated sites. Parameters in the supplementary programme are chosen on the basis of knowledge about the site.

Element/Medium	Land	Groundwater	Surface water	Sediments
Basic programme				
pH		x	x	
Temperature		x	x	
Conductivity		x	x	
Colour		x	x	
Turbidity		x	x	
Oxygen level & saturation		x		
Total nitrogen		x	x	
Total phosphorous		x	x	
Chloride		x	x	
Metals: Ag, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Pb, Hg	x	x	x	x
EGOM	x	x		x
Dry matter	x			x
lAsh content	x			x
Supplementary programme				
AOX		x	x	
EOX	x	x		x
Volatile hydrocarbons (SPME)	x	x	x	x
Polar/non-polar hydrocarbons		x		
PAH screening	x	x		x
PBS	x	x		x
TOC		x	x	
Other specific analyses	x	x	x	x

are conducted as part of the supplementary programme, certain parameters may be excluded from the basic programme.

The following parameters must always be included in the basic programme for sediments and soil: chrome, nickel, copper, cadmium, lead, mercury, ash content, EGOM and GC-MS screening.

The following parameters should always be included in the basic programme for ground- and surface water, chrome, nickel, cadmium, copper, lead, pH, conductivity, EGOM and GC-MS screening.

The supplementary programme includes AOX, EOX, volatile hydrocarbons (SPME), polar/non-polar hydrocarbons, PAH screening, PBS, TOC and other specific analyses. For studies of surface water and sediments in coastal and marine areas, should the parameters conductivity and AOX be omitted because of the salinity.

For sites with high levels of EGOM or suspected bioaccumulating contaminants, PBS should be tested. When petroleum products or PAH are suspected, PAH or oil and fat analyses should be carried out. The selection of analyses for specific substances should be based on conclusions about potential contaminants at the site drawn from the available information about the chemicals and products that have been involved. Appendix 8 reviews the contaminants associated with various industrial branches.

Biological tests are carried out in order to evaluate the comprehensive effects of contaminants on test organisms in various media. Such tests provide no information on which groups of chemicals or individual substances cause the effects. Biological tests are used to describe the characteristics of industrial wastewater, but the same methods can also be used to analyse soil, ground- and surface water, and sediments. Descriptive biological analysis is carried out in combination with chemical and

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TABLE 13.

Basic programme and supplementary programme of biological tests for inventories of contaminated land and water sites.

Tests from the supplementary programme should be selected on the basis of available information about the site.

Element/Medium	Land	Groundwater	Surface water	Sediments
Basic programme				
Microtox	x	x	x	x
Supplementary programme				
Algae test		x	x	x
Mussel test		x	x	x
Cell test (EROD)	x			x
Umu-C test	x	x		x

physical analyses, in a series of steps. Applications and procedures are reviewed in a SEPA general guideline: *Biologisk - kemisk karakterisering av industriellt avloppsvatten (Biological and chemical characterisation of industrial wastewater)*,

The MIFO model recommends use of the first step in the wastewater characterisation process, which includes simple and inexpensive screening tests. Since the reactions of test organisms vary according to the type of pollutant and species, the tests must be conducted with several different organisms, preferably from different trophic levels. A smaller number of tests may be acceptable in certain cases for reasons of cost. Biological tests often require greater effort than chemical analyses.

The MIFO model includes a basic and a supplementary programme for biological tests (see Table 13). The basic programme consists only of the Microtox test. The supplementary programme includes EROD, UMU-C, and tests for algae, mussels and cells. For ground- and surface water, the Microtox test should be complemented with algae and mussel tests if the site is suspected of containing significant amounts of environmentally harmful substances. The mussel test should be applied at sites located in close proximity to bodies of brackish or salt water. Cell tests should be carried out for sites that are believed to contain dioxin, dioxin-like substances, etc. The Umu-C test applies if genotoxic substances are suspected.

References

National Institute for Construction Research, "Beteckningar vid geotekniska undersökningar"; pages 1–5

Swedish Environmental Protection Agency, "Biologisk-kemisk karakterisering av industriellt avloppsvatten"; *Allmänna råd* 89:5, 1989

Swedish Geotechnical Society, *Geoteknisk fälthandbok*; report nr. 1:96, 1996

Swedish Geological Inventory, "Metodik och jordartsindelning tillämpad vid geologisk kartering i skala 1:50 000"; reprint from series Ae, 1994

Sampling and field investigation

Sampling and field investigations are carried out to provide information for use in the assessment of migration potential and contamination concentrations. Groundwater flows comprise one of the most important factors affecting the migration potential.

The number of samples can vary, but it is always better to take too many rather than too few. Selection of the samples for analysis is done afterwards, and the unanalysed samples are saved until the investigation is complete.

All equipment used to take samples must be clean. The taking, sealing and storage of samples must be done in such a way that the sample properties remain unchanged until analysis is complete. It is advisable to consult the analytical laboratories in advance, as they often provide sample containers.

Where it is suspected that on-site contaminants are potentially harmful to human health, special protective measures must be taken during the sampling process.

Soil samples

The following protocol may be used for recording the details of soil samples.

Suggested protocol for soil samples

Site ID number		Location no	Date	Page
Assignment name or number		Method	Ref. area	Sampler's ID
Diagram of sampling location		X co-ordinate	Y co-ordinate	Z co-ordinate
		Groundwater observations		
		Date	Time	Depth
Depth below surface of reference area	Soil type— preliminary classification	Sample no.	Observations: Colour, odour, etc.	

Comments:

- The site ID number is the same as that used on Form A.
- A suitable format for the sampling location number is: organisation number/sampling year/sequential location number; for example, IBM9908.
- The preliminary classification of soil type is noted in the field without further analysis, according to SGF 87. It should also be noted whether or not the borehole reaches the bedrock.
- Each of the samples is identified with a sequential number, which may be printed on tear-off tabs that are enclosed with sample pouches.
- Observations of deviating or evidently contaminated layers of soil are described in terms of type, colour, odour, moisture, etc. Deviations from the site's normal stratification sequence are noted, if they appear to have significance for the potential for migration – for example, a centimetre-thin layer of peat, clay or sand. The water table is also noted in this section of the protocol.

The following section describes how to take samples with a helical auger and how to dig a soil pit. These methods are the most commonly used for preliminary site investigations. Additional sampling methods are described in the handbooks, *Vägledning för miljötekniska markundersökningar* (Guidelines for environmental-technical soil investigations) and *Geoteknisk fälthandbok* (Geotechnical field handbook).

Helical auger

When sampling with a helical auger, mixed samples are continually taken at successive depths. The quality of the samples depends on how they are handled, the type of soil, and groundwater conditions. Auger samples are best suited to cohesive soils and silt, but can also be taken in coarser soils above the water table.

The boreholes are located in accordance with the sampling plan. Routine safety measures should be taken. The exact locations often need to be adjusted. Location of cables should be carried out on-site in connection with sampling.

The auger is usually one metre in length with a maximum diameter of 6-10 centimetres, and slightly tapered toward the tip. It should always be cleaned before the start of drilling. Attention should be paid to drilling resistance and the sound produced, as these may provide clues to the type of soil. When the auger is drawn out of the ground, soil remains fastened between the spiral ridges. Any contaminants from layers through which the auger passed while being drawn out must be removed from the outer surface of the soil sample; this can be done with a knife or trowel.

The distribution of soil layers, the stratigraphy, is determined and the types of soil are classified according to the geotechnical standard, SGF 81.

To the fullest extent possible, this should be done in the field. While the material is still fresh, contaminants which can be observed should be described in terms of colour, odour, moisture, etc. Those observations are noted in a separate drilling protocol.

Samples are taken directly from the soil between the auger's spiral ridges; this can be done by hand. Plastic bags can be used to protect samples and hands from contamination. The auger must be cleaned between samples taken at various depths. The basic procedure is to sample the auger material in half-metre lengths. In cases where successive layers of soil have a uniform composition, a bulked sample may sometimes be used; but there is a risk that any contaminants present will be diluted. Layers that deviate from the local norm or are suspected of containing contaminants should be sampled separately. The samples are placed in double plastic bags and sealed as tightly as possible. A suitable method for labelling the samples is to place a tab with a printed ID number facing out between the two layers of plastic. Soil samples with liquid contaminants are placed in special glass jars with tightly sealed lids, then placed in a plastic bag together with a number tab. The sample bags are immediately put in a cooling bag for transport to the laboratory.

Sampling locations should be measured from surveying control points or established references (buildings or other permanent structures). Adequate precision is often given with a compass, visual alignment, a measuring tape and simple levelling instruments. The coordinate system used and measurement accuracy should conform to the general guidance in the 1996 field manual of the Swedish Geotechnical Society. In most cases, this involves the use of the national grid known as RT90 and measurement class B (± 1 metre on the horizontal and $\pm 0,1$ metre in height). Extra accuracy is required with inventories of groundwater, and whenever the sampling locations are situated near pipes or buried structures of any sort.

The helical auger method has the advantage of being simple and quick. It also requires little space and causes minimal damage. Since it is frequently used, there is good access to equipment and competent operators. Among the disadvantages is the fact that it is difficult to obtain samples that have not been contaminated by other layers through which the auger passes. Also, coarser types of soil do not always remain in place within the spiral ridges, and the borehole tends to cave in fairly quickly below the water table. In moraine, use of the method is limited to loosely compacted and fine-grained material. A hard metal tip on the auger can facilitate penetration of moraines and dense strata.

Soil pits

An excavating machine can be used to dig soil pits above the water table, down to a depth of about six metres. A tractor equipped with a power shovel can reach down to about four metres. When digging by hand,

depths beyond half a metre are not realistic.

The stratification sequence is observed and noted in the same manner as with the helical auger method. Information regarding phenomena such as water seepage, cavities, etc. is also noted. The stratification profiles are photographed are described with a simple diagram. The scale in photographs must be established with some kind of size-reference object (e.g. shovel, coin).

Before taking samples, the walls of the excavation are cleaned. Samples may be taken with a shovel, or with a sampling cylinder pressed into the vertical walls. To ensure a representative sample, several samples are taken from the same stratum at various points in the test hole and then mixed together to produce a bulked sample. There may be occupational health risks associated with sampling in test holes. After the sampling is completed, the holes are filled in.

The same procedures are used for recording the location of the soil-pit and handling the samples as those discussed for the helical auger method.

The advantages of sampling with soil pits are that it provides a good overview of the stratification sequence, and large samples can be taken without the risk of cross contamination between layers. Also, holes may be dug even in very coarse material and the method is relatively inexpensive. Compared with boreholes, it provides a larger scale on which to study the soil and its appearance, and it is easier to take representative samples.

The disadvantages are that the method takes up a lot of space, and any contaminated soil that is dug up must be properly disposed of. In addition, the holes must be filled in again, and any penetration of impermeable layers may lead to the undesirable spread of contaminants. Sampling with deeper machine-excavated holes is most suitable for mixed materials above the water table, at locations where no serious contamination is suspected.

Equipment

The equipment used for soil sampling consists of: maps, compass, measuring tape, notebook, pens/pencils, sample bags, containers, telephone, shovel, trowel, plumb line for measuring water table, protective clothing, helmet, gloves, boots, spray-bottle with sterilising soap, spray-bottle with water, and the addresses and phone numbers of underground cable information centres, landowners, etc.

Groundwater sampling

In many cases, the first step in sampling groundwater is to insert into boreholes special tubes in which samples can be taken and groundwater levels can be observed. It is important that the materials used in tubes and hoses do not contribute any contaminants to the water being sampled.

No casing is used with groundwater tubes. They are inserted by hand into the boreholes drilled in connection with the taking of soil samples.

This can only be done in fine-grained soils, and only if the walls of the boreholes do not collapse. The tube has a filter at the level of the water table. Sometimes the tube can be inserted directly by hand; otherwise, it is necessary to use a drilling machine and a sounding rod inside the tube.

In backfill and coarse soil, the tube may be hammered into the ground with a drilling machine sledgehammer. In that case, a steel tube must be used, which excludes the possibility of metal analyses. There are other methods for inserting tubes without first drilling a hole, for example the use of Joel-tubes.

After the tube is inserted, it should be sealed around the perimeter at the ground surface so that no extraneous contamination finds its way into the groundwater. Clay, bentonite, or a mixture of bentonite and sand can be used for that purpose.

In some case it may be possible to use an external casing, which enables a sandfilter to be used at the tip of the groundwater tube. This is appropriate for groundwater tubes that are permanently installed, but it is of only marginal interest with MIFO inventories due to cost. With coarse soil and deep-penetrating tubes, however, it is the only practical way to carry out a complete programme of analyses.

The preferred material for groundwater tubes is connectable plastic pipe equipped with vents at the lower end. Tubes made of steel, PVC and other materials are less appropriate, since their use limits the range of possible parameters that can be analysed.

The filter is placed either at the level of the water table or in the groundwater reservoir, depending on the behaviour of the contaminants and their miscibility with water. For substances that mix completely, the filter is placed at the upper level of the saturated zone. For liquids that do not mix with water (LNAPL), the filter is placed at the boundary between the saturated and unsaturated zones. For dense liquids that do not mix with water (DNAPL), the filter is placed at the lower level of the saturated zone, usually 1-2 metres beneath the water table. The size of the tube should be in proportion to the sampling equipment; a suitable minimum diameter is 50 mm (two inches).

When groundwater tubes are installed, they are cleaned with water or compressed air in order to ensure good contact and a natural filter around the tube's filter tip. Samples are usually not taken until about one week later, in order to minimise any disturbance to groundwater flows occasioned by the installation process. If the soil is porous, a few hours may suffice; in other cases several weeks may be needed.

In comparison with other schemes, the suggested programme of analyses requires large quantities of water. In some cases, this may be arranged by the installation of a sand filter, or by spreading the sampling over a longer period of time.

Suggested protocol for groundwater samples

Site ID No.		Location no.	Date	Page
Assignment name or number		Method	Ref. area Upper edge of tube	Sampler's ID
Construction		X co-ordinate	Y co-ordinate	Z co-ordinate (soil surface)
		Groundwater observations		
		Date	Time	Depth below upper edge of tube
Depth below surface of reference area	Temperature (C)	Freezer Bottle no.	Refrigerator Bottle no.	Observations: Colour, odour, etc.

Levelling

The upper edge of the groundwater tube or well must be levelled, preferably in accordance with the national system.

Taking samples

The following protocol can be used to record groundwater samples.

Before any samples are taken, specific details about the boreholes should be noted. This information is obligatory, and is included on the form for groundwater sampling.

Prior to draining the tube and/or sampling, the water table is measured with a sounding device. The distance from the water table to the tube's upper edge is measured with a precision of at least ten millimetres. Since the groundwater in the tube is seldom representative of that in the surrounding area, it is removed prior to sampling. This is repeated until a quantity of water equal to three times the volume of the tube has been removed. Samples are taken from the water which enters the tube following this process.

Samples are taken with a hydrometer, water sampler, or a submersible electric pump made of plastic. At the same time, the groundwater's temperature is taken. Before filling the containers, the entire water sample should be well mixed. If the sample contains suspended particles, all of the water must be decanted and homogenized before the containers are filled. This is done by transferring the entire sample to a collection–trough, where it is allowed to settle for ten minutes; after which, the upper

"particle-free" layer is decanted and mixed. Samples intended for metal analysis must be almost completely free of particles.

Sample containers should be made of polyethylene or polypropylene. Those containing samples intended for metals analysis must be cleaned according to SS O2 81 94. Samples believed to contain volatile substances should be poured into glass bottles closed with a polished glass stopper or Teflon film.

Tidying up

After the sampling is completed, the groundwater tubes should be sealed or removed. Sealing is accomplished by cutting off the tube about one metre below ground level, and filling the hole with a material such as bentonite. If a tube is to be left in place for future sampling, the opening must be covered with a lockable cap.

Equipment

The equipment required includes a detailed map with sampling locations indicated, compass, sounding device for measuring water table, tool box, torch, tape and everything needed for removing and sampling water, including hoses and hose clamps. Also: a calibrated temperature meter or equivalent, sampling forms, pens/pencils, labelled sample containers, and a cooling bag for storage and transport of samples.

Surface water samples

The following protocol can be used to record samples of surface water.

It is recommended that samples taken from lakes and flowing water e collected directly into sample-containers without the use of a water sampler. In lakes, a boat is driven slowly into the wind and the container is held beneath the water surface ahead of the bow. In moving water, the

Suggested protocol for surface water samples

Site ID No.			Location no.	Date		Page
Assignment name or number			Sampling method	Weather Conditions		Sampler's ID
Water depth			X co-ordinate	Y co-ordinate		
Sampling depth	Temp. (C)	Oxygen (mg/l)	Freezer Bottle no.	Refrigarator Bottle no.	Observations: Colour, odour, and appearance	

container is held beneath the surface against the stream. In both cases, the container should be grasped from underneath and pushed against the stream, in order to prevent the water from passing over the hand.

When samples are taken at deeper levels, a Ruthner water sampler should be used. When the water is to be analysed for metals, a sampler with shielded metal surfaces is used. Water samplers are to be sealed in clean plastic bags during transport, and rinsed several times before samples are taken.

Readings of oxygen level and temperature are taken in the field. Both are measured with a test probe, at the surface and at one-metre intervals down to the bottom. Sample preservation is carried out at the laboratory.

Suggested protocol for sediment samples

Site ID No.		Location no.	Date	Page
Assignment name or number		Sampler's ID	Weather & flow conditions	
Water depth		X co-ordinate	Y co-ordinate	
Sediment layer: range in cm	Refrigerator Bottle no.		Colour, odour, and appearance	

Equipment

The equipment used for sampling surface water includes a detailed map on which sampling locations are indicated, compass, a plumb line or echo-sounder, water sampler for deep samples, instruments for field measurements of temperature and oxygen, sampling protocols, pens/pencils, labelled sample containers and cooling bags.

Sediment samples

The following protocol can be used to record sediment samples.

If conditions permit, a core-sampler is used to take sediment samples. The sampler should be so constructed that all sediment layers, from unstable surface materials down to hard clay or mineralised sediments are included in the profile. The water column above the area being sampled should not be turbid. The sampler should be equipped to allow sampling of different layers of the sediment profile. If necessary, the sediment profile should be subdivided according to the stratification sequence.

When taking samples from mineral transport bottoms in flowing water, a modified Ekman or Ponar sampler may be used. It may be possi-

ble to push the sampler down to the bottom with the help of a metal outer tube. For transport bottoms, only a surface layer of 0–2 cm, or perhaps even a thinner layer of 0-1 cm, is usually of interest. Bulked samples should be taken from a large area. Taken together, the samples should represent all sediment layers formed during the time that contaminants were settling out.

The rate of sedimentation in lakes may vary. Under more or less natural conditions, the annual rate of accumulation is between 0.5–1.0 mm. But on bottoms located near e.g. cellulose factories, annual accumulation can range from one millimetre to several centimetres. For contaminated layers formed in recent years, the sample should include only the "fluffy" top organic sediment. For older contaminated sediments, samples can be taken at depths of 0-10 cm, or down to the mineralised sediment layer.

Near large sources of organic contamination, such as fibre-banks, a bulked sample comprised of samples taken at one-metre intervals can be taken. In such cases, it is necessary to use a longer core-sampler. Detailed instructions on the sampling of sediments are provided in two publications of the Swedish Environmental Protection Agency, *Recipientkontroll, Del 1 (Recipient monitoring, part 1)* and *Metodhandbok Vatten (Handbook of methods, Water)* (see References, below).

If sediment samples are not taken at the same locations as those for surface water, the water's temperature and oxygen level must be read at the surface and at one-metre intervals down to the bottom. If possible, the readings should be taken with a test probe. Four profiles should be taken at each location. Both the basic and the supplementary programme each require two-litre samples of resettled sediments.

Equipment
The equipment used for sampling sediments includes a detailed map on which sampling locations are indicated, compass, plumb line or echo-sounder, sediment sampler, equipment for sectioning the sediment core, plastic tweezers, glass spoons, labelled sample containers and cooling bags. Also: containers for possible physical samples, instruments for field measurements of temperature and oxygen, sampling protocols, pens/pencils, repair kit, and plastic buckets, etc. for cleaning and storing equipment.

Other field procedures
There are field procedures that may be helpful in the preparing of a sampling plan. However, they do not yield sufficiently good results to replace laboratory methods.

There are geophysical procedures that detect foreign substances in soil, groundwater and sediments, as well as chemical procedures that determine substance concentrations. The following procedures may be of interest in connection with MIFO inventories. (More detailed descriptions of the

alternatives are provided in the two 1994 publications of the Swedish Environmental Protection Agency noted in the References, below.)

Geophysical procedures

The electrical, magnetic and radioactive properties of soil samples are among those measured by geophysical procedures. However, methods that rely on the electrical conductivity of contaminants are not very suitable for the detection of non-conducting liquids such as oil. Geophysical procedures are effective where the geology is fairly simple and uniform, and where the contrast between the media and its contaminants is great.

Most of these procedures are sensitive to electrical and magnetic disturbances, which may make interpretation and evaluation in urban and industrial areas difficult. Examples include:

- Georadar, which can be used to determine the water table in coarse soil, and to detect buried wastes, cisterns, pipes, etc. The radar produces a continuous record that can be read directly on site. The result is a stratification profile that requires no excavation. Georadar cannot usually be used in clay areas .

- Resistance measurements, which can be used to determine the water table under relatively simple geological conditions, and to identify both the stratification sequence and areas of contaminated groundwater. The procedure yields accurate results, but requires much work.

- Electro-magnetic mapping (slingram), which can be used to detect buried wastes, cisterns, etc. The measurements yield stratification profiles and require no excavation or contact with the ground. Maximum measuring depth is usually 5–6 metres. The procedure is usually not suitable in clay .

- Magnetometer, which measures alterations in the soil's magnetic field, and can thus be used to locate magnetised iron objects. The measurements yield stratification profiles and require no contact with the ground. Measuring depth is limited to 5–10 metres, depending on background disturbances.

Chemical field analyses

Chemical field analyses which can be used at contaminated sites are reviewed in the 1996 Swedish Environmental Protection Agency publication, *Fältanalyser av förorenad mark* (Field analysis of contaminated soil), (see References, below). They involve the use of laboratory instruments adapted to field conditions, specially designed field instruments, and calorimetric techniques. Apart from problems of precision, the disadvantages of these instruments include sensitivity to factors that are almost always relevant in field situations; humidity, dust and temperature changes. The chief advantage is that many analyses can be performed quickly and directly in the field.

Among the adapted laboratory instruments are: a portable fluorescent X-ray spectrometer (XRF) for the analysis of metals; an infrared spectrophotometer (IR) for the analysis of gases, including such volatile substances as benzene, toluene, xylene and chlorinated hydrocarbons; and a gas chromatograph (GC) for the analysis of both volatile and non-volatile organic substances. Depending on the type of calibration, these instruments can produce quantitative or semi-quantitative results.

Included among the specially designed instruments are PID and FID (see Analysis of soil air, below). For the identification of organic compounds in soil air and groundwater, it is sometimes possible to use the Gore-Sorber system. This uses a sorbent that is placed in soil or groundwater, then analysed after being exposed for a certain length of time. The method provides an overview of contamination conditions, and is used primarily for screening.

The third category of instrument makes use of colorimetric reactions, including reagent columns, various liquid chemical field tests, and immunological reactions. The methods vary greatly in terms of specificity, but they all yield semi-quantitative results.

The immunology-based method differs somewhat from the others, in that it is based on the special affinity of monoclonal anti-bodies for certain contaminants. This method has been developed for use with, among other substances, benzene, toluene, petroleum hydrocarbons, PAH and PCB.

For those with suitable laboratory experience, these methods are simple to apply and the results are easy to interpret. Many immunological tests yield good correlation between field and laboratory results. However, there may be less correlation in cases where there are complex contaminants or inhomogeneous soil.

Analysis of soil air

Photo-ionisation detectors (PID) and flame ionisation detectors (FID) can be used to qualitatively analyse solvents and other ionisable fluid compounds at sites contaminated by petroleum products. PID measurements are quick and easy, and are used to describe the properties of large quantities of sample material. The method is limited in that it does not permit either quantitative or qualitative assessments of contaminants that are not specifically tested for. Measurements are usually taken from soil samples in plastic bags or other containers.

For volatile organic compounds such as benzene, toluene, xylene and chlorinated hydrocarbons, gas chromatography measurements can be taken in the field. This provides rapid on-site information regarding which substances are present and their approximate concentrations. Air and water samples can be analysed at the same time without any additional preparations.

Biogeochemical tests

Biogeochemical tests measure the uptake of metals and other substances by living material, including plant roots and/or aquatic mosses. Plant samples are taken along small streams and analysed for their metal content, among other variables. If suitable vegetation is lacking, aquatic mosses can be planted out for subsequent analysis.

Plant roots and aquatic mosses absorb metals. The substances detected in the samples reflect the presence of those same substances in water. The results provide a comprehensive picture of the flow of metals to watercourses by such processes as leaching from rocks and soil, seepage from contaminated sites, and discharges from industry.

Samples are taken both upstream and downstream from contaminated sites. The results can be compared with a body of reference data derived from ca. 28,500 sampling locations included in the Swedish Geological Survey's (SGU) biogeochemical map which covers roughly half of the country's surface area. The methods used in biogeochemical mapping are described in the SGU series, *Rapporter och Meddelanden (Reports and Notices)*, and a 1991 publication of the Swedish Environmental Protection Agency, *Metodhandboken (Handbook of methods)*.

References

Lindmark, "Miljögeotekniska fältundersökningsmetoder"; SGI, Varia 416, 1993

Swedish Environmental Protection Agency, *Fältanalyser av förorenad mark: Översikt och jämförelse av konventionella metoder*; report nr. 4566, 1996

Swedish Environmental Protection Agency, *Recipientkontroll, Del 1: Undersökningsmetoder för basprogram, metoderna*, BIN SR 01 och BIN SR 11, 1986

Swedish Environmental Protection Agency, *Metodhandbok: Vatten*, 1991

Swedish Environmental Protection Agency, *Vägledning för miljöstrategiska markundersökningar. Del I, Strategi;* report nr. 4310, 1994

Swedish Environmental Protection Agency, *Vägledning för miljötekniska markundersökningar, Del II: Fältarbete*, report nr. 4311, 1994

Swedish Geotechnical Society, *Geoteknisk fälthandbok*; report nr. 1:96, 1996

Preparing samples

The handling of samples in the field and the laboratory must be appropriate and of corresponding quality to the analyses and tests that follow. If there are no suitable means of preserving samples, or if it is not known how they are affected by storage, they must be analysed immediately. Samples must be stored at a temperature of $4 \pm 2°\,C$ in the dark. Soil and sediment samples intended for biological testing should not be kept in a refrigerator longer than one month. Corresponding samples of ground- and surface water should be kept frozen at a temperature below $-18°\,C$. Preparation must have as little effect as possible on the samples, and should be carried out in such a way as to prevent occupational health problems.

Soil samples

Soil analyses should be carried out on the fraction with a particle size less than two millimetres. Preparation of samples of organic matter and those containing volatile substances should follow the procedures of ISO/CD/SC3 N 261. If possible, large particles may be sifted out in the field. Normally, samples are sieved in the laboratory with nylon sieves. It may be difficult to sieve heavily polluted soil, due to such factors as the clumping together of particles. If it is not possible to sift the sample, particles larger than two millimetres can be removed with tweezers.

If a bulked sample is to be analysed, samples are homogenised and mixed prior to analysis. Detailed instructions on how to subdivide samples can be found in a 1972 publication of Byggforskningen (Building Research).

Some samples need to be pulverised, in which case suitable precautions must be taken against the risk of highly volatile substances being emitted as a result of the heating which occurs during the pulverisation process. Pulverisation and the subdivision of the sample into smaller portions for analysis are usually done by the laboratory, which thus becomes responsible for maintaining quality.

Sediment samples

Preparation of sediment samples is always done in the laboratory, although very large particles may be sorted out in the field. After at least one whole

day in cold storage at the laboratory, most of the water covering the sediment is decanted or pumped out, until only about one centimetre remains.

Half of that water is then removed and set aside. The sediment is stirred carefully, after which the sample is strained through a nylon mesh with a two-millimetre grid. The water previously set aside may be added to the sample as required and used to wash any remaining loose sediment from the nylon mesh. Adding more water may make it difficult to divide the sample into smaller portions for analysis.

The strained sample is divided into smaller samples under vigorous stirring. Polyethylene or polypropylene containers should be used for metal analyses and biological tests. For analyses of organic substances glass vessels that have been cleaned with acid or acetone are preferred.

Ground- and surface water

As a rule, ground- and surface water samples are not subject to any special preparations.

Chemical and physical analyses

The analyses recommended for use with the MIFO model are briefly described below. For more detailed descriptions, see the Swedish Environmental Protection Agency's report no. 4947.

Basic programme

pH values are determined with a potentiometer, using a combination electrode. A medium's pH value is an index of how acid or alkaline it is. Among other things, pH influences the solubility of various substances, and the forms in which they occur.

Conductivity refers to the water's capacity to transmit an electric current, and is expressed in terms of inverse resistance. Conductivity indicates the concentration of dissolved salts in the water.

Colour is determined visually with a comparator and colour reference samples. The colour of water depends on its content of coloured components; humus is the most common of these, but metals such as iron can also produce strong colours. Among other things, a water's colour indicates its origins, e.g. whether it comes from marshland or has been mixed with groundwater. Colour is also used to assess the potential for metals to bind with humus particles.

Turbidity is determined with a nephelometer that, under standardised conditions, compares the spreading of light in the sample with its spread in standard samples. Turbidity indicates the extent to which suspended particles of various substances decrease transparency and increase the spreading of light. In some cases, high turbidity may contribute to increased adsorption of contaminants.

Oxygen level and oxygen saturation are determined with an electrode directly in the water. The oxygen level is of great importance for aquatic living conditions. Low oxygen levels confirm the presence of reducing onditions.

Total nitrogen is measured with a colorimeter after digestion with peroxide disulphate. Nitrogen, together with phosphorus is one of the principal nutrients in water, and the total amount of nitrogen present in all forms provides a measure of aquatic nutrient levels.

Total phosphorus is measured with a colorimeter after digestion with peroxide disulphate. Together with nitrogen, phosphorus is one of the two main nutrients in water, and its total quantity in all forms provides a measure of aquatic nutrient levels. There is often a close relationship between total phosphorus and algae concentrations/chlorophyll levels. In some cases, high concentrations of nutrient salts may reduce the effects of contaminants: The increased plant growth in surface waters that results from a larger supply of growth-stimulating nutrient salts leads to a dilution of contaminants.

Chloride levels are determined by titration or an equivalent method, such as ion chromatography. The chloride level indicates the salinity of water, which is influenced by proximity to the sea. This test is also used to trace contaminants in groundwater. Chloride levels greater than one gram per litre may produce distortions in the analysis of TOC, AOX, etc.

Together with dry matter content and ash content, the parameters listed above are intended to provide physical and chemical background information to be used in assessments of other parameters.

Metal concentrations can be determined by means of atomic absorption with the use of a flame, a graphite oven, cold vapourisation of mercury, or any other equivalent method such as ICP-AES or ICP-MS. Metal concentrations in solid samples are determined after digestion with nitric acid in accordance with SS 028150-2. If an accurate analysis of mercury in water is required, other methods may be used, including amalgamation in a gold trap and subsequent detection with fluorescence or atomic absorption.

EGOM, extractable gas-chromatographable organic matter, measures the total quantity of organic matter that can be extracted with cyclohexane (for groundwater) and acetone (for soil and sediments). The determination is made with a gas chromatograph equipped with a flame-ionisation detector (GC/FID). The method is suitable for estimates of oils and fats.

Dry substance and ash content: The sample is weighed, dried at 105° C, weighed again, then fired at 550° C and weighed yet again. The analysis yields the dry matter content of the sample and the proportions of organic and inorganic matter. The results are used to convert wet weight to dry weight.

Supplementary programme

AOX, absorbable organic halogen. The organic substances in water samples are absorbed by activated carbon and burned in oxygen, after which the level of halogens is measured by titrating microcoulometrically.

EOX, indicates the quantity of halogenated substances that are capable of being extracted, which is nearly always less than the absorbable quantity. The technique used to analyse the extract is the same as for AOX.

SPME, solid phase micro extraction, is a quick method for screening and specific analysis of volatile compounds such as BTEX. The method enables direct sampling of organic contaminants in air and water samples, using a very thin glass fibre coated with a stationary adsorbent phase, which is then injected directly into a GC or HPLC.

Oils and fats are extracted with CFC 113 and determined by means of infrared spectrophotometry. The extracts can be analysed for the total amount of extractable aliphatic substances, non-polar aliphatic hydrocarbons and non-polar aromatic hydrocarbons.

PAH screening, extractable polycyclic aromatic hydrocarbons. The process is the same as for EGOM and EOX, but the final determination is made with thin-film chromatography and a fluorescence detector. The results are given in milligrams of PAH equivalent per litre. The process does not yield any information about individual PAHs, but it is comparatively inexpensive.

PBS, potentially bioaccumulating substances. After application and elution of the extract derived from EGOM on a disc of thin film, a semi quantitative analysis of organic substances is carried out on various sections of the disc. By applying substances with known octanol-water partition coefficients, the partition coefficients for the tested extract can be determined. When the EGOM value is low, it is usually not necessary to test for PBS.

TOC, detects the total amount of organic carbon that is oxidised to carbon dioxide. Under certain conditions, high levels of organic carbon can limit the effects of toxins.

Biological tests

Brief descriptions of biological testing methods are provided below. Additional details can be found in the Swedish Environmental Protection Agency's report no. 5054.

Basic programme

Microtox. The standard method or the alternative so called 100%-method can be used for tests of ground- and surface water, as well as sediment porewater. The method is based on use of the luminescent bacterium, *Vibrio fisheri (*also called *Photobacterium phosphoreum),* whose production of light is measured before and after exposure to a test substance or environmental sample. Toxicity is expressed as EC50 and EC20 values. Additional details can be found in ITM-report 49, page 39.

Supplementary programme

Algae test is used for ground- and surface water, and for moderately turbid water from sediment pores. The growth rate, i.e. the increase in number of cells, is measured indirectly with a fluorometer after 72 hours. Growth retardation is expressed as the growth rate relative to that of a control sample. The results are expressed in terms of EC50, EC10, LOEC and NOEC values.

Mussel test is used for ground- and surface water, and for water from sediment pores. The test is performed with the help of common mussel larvae, which can be exposed to a dilution series in order to establish EC50, LOEC and NOEC values. The test is conducted during spring and early summer, in connection with the release of gametes. It is also possible to keep common mussels in cold storage for testing at future dates.

EROD cell test. Enzyme activation is used to test soil and sediment samples. Dioxins, dioxin-like substances, PCB, PAH, etc., increase the ability of cells to metabolise 7-ethoxy-resorufin to resorufin, which occurs through the production of the enzyme CYP1A1 in the cell. The resorufin produced is fluorescent, a property which can be used to quantify the enzyme. The results are stated in terms of TCDD equivalents (TEQ).

Umu-C test is based on the effects of toxic substances on a certain gene segment. By switching on the Umu-C gene, production of the enzyme ß-galactosidase is stimulated. The enzyme is quantified with the help of an added substrate; the presence of the product thus formed is detected with reagent colour and a spectrophotometer. When the presence of genotoxic substances is suspected, the test includes use of the bacterium, *Salmonella tuphimurium.*

Quality Control

Quality control is a collective term for all activities associated with the systematic planning which is necessary to ensure that a product or service fulfils stated quality requirements. It applies to measures taken before, during and after the work is carried out. High standards must be maintained at every stage of an inventory in order to achieve comparable results of sufficient quality.

Accredited laboratories using internal quality control procedures must perform the analyses connected with an inventory. Information on laboratories accredited for various analyses in Sweden can be obtained from SWEDAC.

Unless otherwise provided by this guidance, the quality control of field investigations must conform to the requirements specified in the 1996 reference work, *Geoteknisk Fälthandbok (Geotechnical Field Handbook)*.

The Swedish Environmental Protection Agency has provided general guidance on the quality control of environmental monitoring in the 1992 reference work, *Handbok i Kvalitetssäkring (Handbook for Quality Control)*. In 1996 the Agency also published guidance on the data quality standards required by remediation activities. The guidance includes instructions on the planning, implementation and follow-up of site investigations.

The basic requirements of quality control are that the work be carried out by qualified personnel, that recommended techniques be used, and that sources of error and other difficulties be carefully documented.

A system of quality control should be established, including for example:

- a description of the organisational structure of the project
- designation of the person with overall responsibility and, where appropriate, those with delegated authority
- a plan for data-collection and field work
- methods to be used in the field, e.g. EN/ISO standard, Swedish standard, SGF recommended standard, ENV standard or other appropriate methods
- analytical procedures, as noted in this guidance
- documentation and archiving of results
- budget, including personnel expenses
- time schedule, including deadline for final analysis and report.

References

Swedish Environmental Protection Agency, *Rätt datakvalitet: Vägledning i kvalitetssäkring vid miljötekniska undersökningar*, report no. 4667, 1996

Swedish Environmental Protection Agency, *Kvalitetssäkrad miljökontroll: Handbok i kvalitetssäkring*, Allmänna råd 92:1, 1992
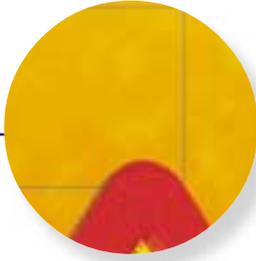
Safety Issues

When conducting inventories of contaminated sites, it is essential to take precautions against the special risks associated with contaminated soil, gas, water and waste material. Drilling personnel must be informed of the risks that their work may entail, and a clear chain of responsibility must be established before any work is begun. An emergency plan should also be in place in case of accident.

A detailed discussion of safety issues is included in the guidance issued in 1994 by the Swedish Environmental Protection Agency, entitled *Vägledning för miljötekniska markundersökningar (Guidance on technical environmental soil investigation)*, and in the ISO's standard *Guidance on Safety*. Particular emphasis should be placed on personal injuries, and accidents involving the spread of contaminants in the environment.

Working with contaminated sites involves the following special risks:

Chemicals. Under normal circumstances, exposure to toxic chemicals during the carrying out of an inventory is limited. But attention should be paid to the possible risks of corrosive acids, alkaline substances, cyanides, dioxins, PCB, DDT and creosote. Information on chemicals that are harmful to human health is available from the Swedish National Board of Occupational Safety and Health (*Arbetarskyddsstyrelsens författnings-samling,* 1993).

Fires and explosions. There is always a risk of fire when working with flammable substances. Extra caution is required with methane gas, petrol, diesel and other oils, paraffin, solvents, and powerful oxidants in combination with organic substances. Wherever there is the slightest risk of remaining explosives, no drilling should be attempted without the approval of qualified experts.

Uncontrolled gas or water discharges. Pockets of gas or groundwater can be kept under high pressure by impermeable geological layers. Such conditions may be difficult to detect, and must always be kept in mind when drilling through such layers. If there is a risk of contaminated water discharges, precautions must be taken in advance so that the borehole can be sealed after drilling.

Ground conditions. In old industrial areas, and wherever old building materials are used as backfill, there is a risk of concealed hollows in the ground that can result in poor stability, cave-ins, etc.

Utility cables. All sites must be checked for possible buried cables, even where none are suspected. It is also important to keep an eye on above ground wires and cables.

Water and sewage pipes. The precise location of water and sewage pipes must be established, especially if they are still in use.

Safety equipment. The type and use of safety equipment must be adapted to circumstances, and always allow a sizeable margin against anticipated risks. The minimum requirements consist of a telephone, overalls, rain gear, helmet, gloves, work boots, rubber boots, and a spray-bottle with clean water. Other items that are usually on hand are a face-protecting visor, safety glasses, hearing protection, chemical-resistant overall and particle-filter mask.

References:

Swedish National Board of Occupational Safety and Health, *Gräv säkrare: Tips om hur jord fungerar*, publication H7, 1981

Swedish National Board of Occupational Safety and Health, *Schaktning i jord*, publication H13, 1987

Swedish National Board of Occupational Safety and Health, *Hygieniska gränsvärden*, AFS 1993:9, 1993

ISO/TC 190/SC2 N78 VS8 Guidance on safety 10 381 Soil Quality-Sampling
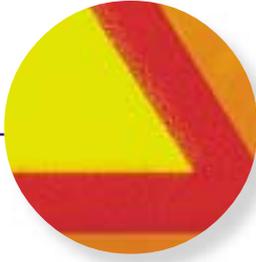
Reporting

Reporting

The basis of the final report is the information included on the completed forms, maps, analysis results and other data. Most of the information is kept in folders and/or simple databases, with the ultimate aim of storing it all in an integrated national data base. If the inventory covers a large number of objects, several industrial branches or a large area, it should be broken down into several separate reports.

Forms and notes

The completed Forms A, B, C, D and E are to be treated as working papers, a fair copy made and archived.

Maps, drawings, photos, etc.

A fair copy of the geological map should be drawn, and a legend explaining any symbols should be added. The locations of boreholes for soil and groundwater samples are to be indicated on the area map. Where appropriate, copies of the borehole diagrams can be included on the area map. In most cases, the sampling locations for surface water and sediments can also be noted on the area map, otherwise they should be noted on the geological map. Point sources of contamination should also be indicated on either the area map or the geological map, likewise any drainage facilities or landfills. Distance scales and north-arrows should be added to copies of the maps and to sections of the maps and drawings used to show details. New maps and drawings should include a legend and be signed by the originator and a quality-controller. Photographs should be labelled and dated.

Levelling protocol

The levels of the ground surface should be shown together with the levels of the upper edges of groundwater tubes and of well rings. Lake surfaces, dams and water surfaces that are of significance to the groundwater flow pattern should also be noted.

Drilling and sampling protocols

Drilling and sampling protocols are to be treated as working papers, a fair copy made and archived. The drilling and sampling methods used should

be noted. The drilling locations are indicated on Form D, Migration potential.

Analysis and test results
Protocols of all the analysis results should be included.

Quality control plan
Quality management and the quality control measures taken are to be described.

Report format
Reports of Phase 1 begin with a summary of risk-classification results and suggestions for the setting of priorities. This is followed by a discussion of the aims of the study and the problems addressed. The project is described. The current state of knowledge is reviewed, i.e. previous studies, along with the methods and materials used to identify the objects assessed.

If the report covers many objects, the different objects should be reported in tabular form. There should be a short summary description of sites in Classes 1 and 2 (about one-half page per site). If there are very many sites in those classes, the explanatory text on Form E can suffice as a description.

The results of Phase 2 are presented in a separate report that begins with a summary including the risk classification. The report also includes descriptions of the project, the overall and specific problems addressed, objectives, and the state of knowledge prior to the inventory. For each object, the following items are included: completed forms; maps; analysis results; and the considerations that form the basis of the risk classification, primarily as indicated on Form E.

Example of report format

Foreword
Contents
Summary
Problems addressed
General and specific problems associated with the inventory site or industrial branch
Boundaries of the area to be assessed and working procedures
Branch descriptions (where relevant)
General map
State of knowledge, i.e. previous inventories
Methods
Quality management and control
Conclusions

To be included in Phase 2 report for each object:
- Brief summary description of the object (ca. one-half page)
- Forms A, B, C, D and E
- Area map
- Geological map
- Drawings, photos, etc.
- Drilling and sampling procedures
- Analysis and test methods
- Analysis results
- Quality control protocol

Content – Appendices

Form A. ADMINISTRATIVE INFORMATION

Indicate uncertain items with question mark ("?")

Name of survey:	Phase (1 or 2, per MIFO):
Object:	First recorded by (name, date) :
Id no:	Revised by (name, date):
Preliminary risk-classification, per BKL	Revised by (name, date):

	X=	Y=	Z=
Industrial branch			
SNI branch code Automatically filled in when data recorded			
County (name, code)			
Municipality (name, code)			
Topographic map Automatically filled in when data recorded			
Economic-Yellow map Automatically filled in when data recorded			
Geographical co-ordinates. Object's, property's or main building's centre point National grid, six figure grid reference	X= North	Y= East	Z= Elevation
Type of property, per CFD			
Buildings and other constructions present and previous (outline)			
Object address			
Facility's owner or equivalent, including address			
Current property owner, if other than facility owner, incl. address			
Contact person at monitoring agency or the like, Incl. address			
Property size (m^2)			
Previous studies and surveys			
Other sources (maps, aerial photos, etc.), and their present locations			
Bench mark locations			
Wells/boreholes within industrial or affected area: location, condition and type (groundwater tubes of metal and plastic, dug and drilled wells, none)			

Form B. DESCRIPTION OF ACTIVITY, SITE AND SURROUNDINGS

Page 1 of 2

Indicate uncertain items with question mark ("?")

Object:	Recorded by (name, date):
Id No:	Field inspection (name, date):
	Field inspection (name, date):

Description of activity

Facility status (in operation, discontinued before 1969, discontinued after 1969, no known previous activity)	
Accessibility (fenced, open)	
Industrial activity, approximate number of years	
Start and stop of operations (year)	
Environmental disturbance from operation, approximate number of years	
Production (product & quantity including, if possible, years for various products)	
Process description, current (outline)	
Process description, previous (outline)	
Process waste water, current disposal (connected to own or municipal treatment facility, untreated to named body of water)	
Process waste water, previous disposal (same alternatives as foregoing)	
Chemicals used in industrial processes	
Process waste products, temporary storage (amount and type)	
Remediation carried out (type of measure, e.g. covering, enclosing)	
Planned remediation (same alternatives as foregoing)	
Conflicting uses (water supply, local residents, farming, forestry, water use, recreation, imminent change of ownership, other— specify). Note all known conflicts.	

Site and surroundings

Land use at site (industrial, agricultural, dense settlement, forestry, park, other)	
Land use within affected area (same alternatives as foregoing)	
Distance from object to *nearest* housing area 0-50 m, 50-200 m, 200-500 m, 500-1000 m, >1000 m)	
Visible damage to vegetation within site (yes, no)	
Visible damage to vegetation within affected area (yes, no)	
Predominant soil conditions within site (impermeable, semi-permeable or porous, backfill material, rock, other)	
Topography, slope (%)	
Type of nearby recipient (groundwater, ditch, brook, river, lake, sea)	
Name of nearby recipient and distance from pollution (per topographic, economic map)	
Principal drainage basin, per SMHI	

Buildings and other constructions

Buildings, including demolished (age and condition)	

Contaminated ground

Location			
Volume of contaminated material (m^3)			
Surface area (m^2)			
Geographical co-ordinates, national grid, six figure reference	X= North	Y= East	Z= Elevation
Contaminants			

Contaminated groundwater

Location			
Volume of contaminated material (m^3)			
Surface area (m^2)			
Geographical co-ordinates, national grid, six figure reference	X= North	Y= East	Z= Elevation
Contaminants			

Contaminated sediments

Location			
Volume (m^3)			
Surface area (m^2)			
Geographical co-ordinates national grid, six figure reference		North	East Elevation
Contaminants			

Drainage water and dumps

Type of water drainage system (closed, open, unknown). Destination (groundwater, ditch, brook, river, lake, sea, peat bog, other)			
Dump (within object, outside object, none, other)			
Type of dump (in use, open, under construction, discontinued, used as backfill)			
Contents			
Leaching from dump (to surface water, groundwater, none)			
Geographical co-ordinates national grid, six figure reference	X= North	Y= East	Z= Elevation

Other (e.g. settling, contents of filled areas, covered piles of earth, loading areas, tanks, burned areas, filled-in water accumulations): . . . .
. . . .
. . . .
. . . .
. . . .

Form C. CONTAMINATION LEVEL

Object:	Recorded by (name, date):
ID no.:	Revised by (name, date):

Indicate uncertain items with question mark ("?")

Soil

Note substances, with reference numbers in parentheses

No. samples		

Comparisons made with (tick): ❏ …percentile, ❏ next-highest value, ❏ highest value, ❏ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious

Substances for which assessment of status is not possible due to lack of comparative data	

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source

Substances for which assessment of deviation is not possible due to lack of comparative data	

	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				

References used

Groundwater

Note substances, with reference numbers in parentheses

No. samples		

Comparisons made with (tick): ❏ …percentile, ❏ next-highest value, ❏ highest value, ❏ sensory impression

Current conditions	Slightly serious	Moderately serious	Serious	Very serious

Substances for which assessment of status is not possible due to lack of comparative data	

Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source

Substances for which assessment of deviation is not possible due to lack of comparative data	

References used

Surface water

Note substances, with reference numbers in parentheses

No. samples		

Comparisons made with (check): ❑ …percentile, ❑ next-highest value, ❑ highest value, ❑ sensory impression				
Current conditions	Slighty serious	Moderately serious	Serious	Very serious
Substances for which assessment of status is not possible due to lack of comparative data				
Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
Substances for which assessment of deviation is not possible due to lack of comparative data				
References used:				

Sediments

Note substances, with reference numbers in parentheses

No. samples		

Comparisons made with (check): ❑ …percentile, ❑ next-highest value, ❑ highest value, ❑ sensory impression				
Current conditions	Slighty serious	Moderately serious	Serious	Very serious
Substances for which assessment of status is not possible due to lack of comparative data				
Deviation from reference value	Little or no effect from point source	Moderate effect from point source	Large effect from point source	Very large effect from point source
Substances for which assessment of deviation is not possible due to lack of comparative data				
	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				
References used				

Buildings and other constructions

Note substances, with reference numbers in parentheses

No. samples				
	Slight	Moderate	Large	Very large
Amount of pollutant				
Volume of contaminated material				
References used				

Classification of current conditions

Figures in tables are rounded

Contaminated soil

TABLE 1.

Classification of current conditions for contaminated soil in terms of mg/kg _dw_ based on guide-line values for contaminated soil. The boundary between "Slightly serious" and "Moderately serious" tis used as the guideline value for sensitive land use (KM).

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Metals				
Arsenic	< 15	15–45	45–150	>150
Lead	<80	80–240	240–800	>800
Cadmium	<0.4	0.4–1.2	1.2–4	>4
Cobalt	<30	30–90	90–300	>300
Copper	<100	100–300	300–1000	>1000
Chromium (applies only if CrVI is absent)	<120	120–360	360–1200	>1200
Chromium VI	<5	5–15	15–50	>50
Mercury	<1	1–3	3–10	>10
Nickel	<35	35–105	105–350	>350
Vanadium	<120	120–360	360–1200	>1200
Zinc	<350	350–1050	1050–3500	>3500
Other inorganic substances				
Total cyanide (applies only if easily available cyanide is absent)	<30	30–90	90–300	>300
Easily available cyanide	<1	1–3	3–10	>10
Organic substances				
Phenol + cresol	<4	4–12	12–40	>40
Total chlorophenol, (excluding pentachlorophenol)	<2	2–6	6–20	>20
Pentachlorophenol	<0.1	0.1–0.3	0.3–1	>1
Total mono- and dichlorobenzenes	<15	15–45	45–150	>150
Total tri-, tetra- och penta-chlorobenzenes	<1	1–3	3-10	>10
Hexachlorobenzene	<0.05	0.05–0.15	0.15–0.5	>0.5
Total PCB	<0.02	0.02–0.06	0.06–0.2	>0.2
Dioxins, furans planar PCBs (TCDD equivalents)	<10 ng/kg dw	10–30 ng/kg dw	30–100 ng/kg dw	>100 ng/kg dw
Dibromochloromethane	<2	2–6	6–20	>20
Bromodichloromethane	<0.5	0.5–1.5	1.5–5	>5
Carbon tetrachloride	<0.1	0.1–0.3	0.3–1	>1
Trichloromethane	<2	2–6	6–20	>20
Trichloroethylene	<5	5–15	15–50	>50

Table 1, continued.

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Tetrachloroethylene	<3	3–9	9–30	>30
1,1,1-trichloroethane	<40	40–120	120–400	>400
Dichloromethane	<0.1	0.1–0.3	0.3–1	>1
2,4 dinitrotoluene	<0.5	0.5–1.5	1.5–5	>5
Benzene	<0.06	0.06–0.18	0.18–0.6	>0,6
Toluene	<10	10–30	30–100	>100
Ethylbenzene	<12	12–36	36–120	>120
Xylene	<15	15–45	45–150	>150
Carcinogenic PAH	<0.3	0.3–0.9	0.9–3	>3
Other PAH	<20	20–60	60–200	>200
Aliphatics				
>C5–C16	<100	100–300	300–1000	>1000
>C16–C35	<100	100–300	300–1000	>1000
Aromatics				
Total toluene, ethylbenzene and xylene	<10	10–30	30–100	>100
>C8–C10	<40	40–120	120–400	>400
>C10–C35	<20	20–60	60–200	>200
Other				
MTBE	<6	6–18	18–60	>60
1,2 dichloroethane	<0.05	0.05–0.15	0.15–0.5	>0.5
1,2 dibromomethane	-	-	-	>0.004
Tetraethyl lead	-	-	-	>0.001

Contaminated groundwater

TABLE 2.

Classification of current conditions for contaminated groundwater in terms of µg/l, based on guidelines for contaminated petrol stations. The boundary between "Slightly serious" and "Moderately serious" is used as the guideline.

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Non-polar aliphatic hydrocarbons	<100	100–300	300–1000	>1000
Total extractable aromatics	<100	100–300	300–1000	>1000
Benzene	<10	10–30	30–100	>100
Toluene	<60	60–180	180–600	>600
Ethyl benzene	<20	20–60	60–200	>200
Xylene	<200	200–600	600–2000	>2000
Carcinogenic PAH	<0,2	0.2–0.6	0.6–2	>2
Other PAH	<10	10–30	30–100	>100
MTBE	<50	50–150	150–500	>500
Lead	<10	10–30	30–100	>100
1,2 dichloroethane	<30	30–90	90–300	>300
1,2 dibromomethane	<1	1–3	3–10	>10

Classification of current conditions for contaminated groundwater in terms of µg/l, based on health-related threshold values for drinking water. The value for "suitable" is chosen if available, otherwise the value for "suitable with reservations" is used. The boundary between "Slightly serious " and "Moderately serious" tis used as the threshold value.

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Copper	<2000	2000–6000	6000–20000	>20000
Antimony	<10	10–30	30–100	>100
Arsenic	<50	50–150	150–500	>500
Lead	<10	10–30	30–100	>100
Easily available cyanide	<50	50–150	150–500	>500
Cadmium	<5	5–15	15–50	>50
Chromium	<50	50–150	150–500	>500
Mercury	<1	1–3	3–10	>10
Nickel	<50	50–150	150–500	>500
Selenium	<10	10–30	30–100	>100
Silver	<10	10–30	30–100	>100

Contaminated surface water

Classification of current conditions for contaminated surface water in terms of µg/l, based on data developed in connection with the project, "Environmental Quality Criteria for Lakes and Watercourses". The boundary between "Slightly serious" and "Moderately serious" is the level that poses increased risk of biological effects.

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Copper	<9	9–30	30–90	>90
Zinc	<60	60–180	180–600	>600
Cadmium	<0.3	0.3–1	1–3	>3
Lead	<3	3–10	10–30	>30
Chromium	<15	15–45	45–150	>150
Nickel	<45	45–140	140–450	>450
Arsenic	<15	15–45	45–150	>150

TABLE 5.

Classification of current conditions for contaminated surface water in terms of μg/l, based on Canadian water quality criteria for protection of aquatic life. The boundary between "Slightly serious" and "Moderately serious" is the relevant Canadian water quality criterion.

Substance	Slightly serious	Moderately serious	Very serious	Extremely serious
Arsenic	<50	50–150	150–500	>500
Lead	<1	1–3	3–10	>10
Cadmium	<0.01	0.01–0.03	0.03–0.1	>0.1
Copper	<4	4–12	12–40	>40
Chromium III	<20	20–60	60–200	>200
Mercury	<0.1	0.1–0.3	0.3–1	>1
Nickel	<150	150–450	450–1500	>1500
Zinc	<30	30–90	90–300	>300
Easily available cyanide	<5	5–15	15–50	>50
Phenol	<1	1–3	3–10	>10
Monochlorophenol	<7	7–21	21–70	>70
Dichlorophenol	<0.2	0.2–0.6	0.6–2	>2
Pentachlorophenol	<0.5	0.5–1.5	1.5–5	>5
Cresol	<1	1–3	3–10	>10
Monochlorobenzene	<15	15–45	45–150	>150
Dichlorobenzene (1,2)	<2.5	2.5–7.5	7.5–25	>25
Dichlorobenzene (1,4)	<4	4–12	12–40	>40
Trichlorobenzene	<0.5	0.5–1.5	1.5–5	>5
Tetrachlorobenzene	<0.15	0.15–0.45	0.45–1.5	>1.5
Pentachlorobenzene	<0.03	0.03–0.09	0.09–0.3	>0.3
Hexachlorobenzene	<0.0065	0.0065–0.0195	0.0195–0.065	>0.065
PCB	<0.001	0.001–0.003	0.003–0.01	>0.01
Carbon tetrachloride	<13	13–39	39–130	>130
Trichloromethane	<2	2–6	6–20	>20
Trichloroethylene	<20	20–60	60–200	>200
Tetrachloroethylene	<110	110-330	330–1100	>1100
Benzene	<300	300–900	900–3000	>3000
Toluene	<2	2–6	6–20	>20
Ethyl benzene	<90	90–270	270–900	>900
Non-polar aliphatic hydrocarbons	<100	100–300	300–1000	>1000
1,2 dichloroethane	<100	100–300	300–1000	>1000
MTBE	<700	700–2100	2100-–7000	>7000

Contaminated sediments

No classification of current conditions. Certain effects thresholds are given in Table 6.

TABLE 6.

Examples of effects thresholds for metals and organic substances in marine sediments. Data taken from "Environmental Quality Criteria for Coasts and Seas". Values are stated in mg/kg dw, 1% organic carbon; the values for metals were derived with total analysis. All values indicate the concentrations in sediments at or above which biological effects on the most sensitive species may be anticipated. Differences are due to the application of different methods and definitions.

Contaminants	Effects threshold (ER-L) NOAA	Effects threshold TEL Canada 1996	Safety threshold OSPAR	Safety threshold WRC, UK
Arsenic	35	5.9	7.2*	8
Cadmium	5	0.6	0.7	2
Chromium	80	37	52*	100
Copper	70	36	19*	40
Mercury	0.15	0.17	0.13*	0.4
Nickel	30	18	16*	100
Lead	35	35	30*	40
Zinc	120	123	12*	200
Chlordane	0.5			
P,p´, DDE	2.0		0.002*	
Total DDT	3.0			
Dieldrin	0.02		0.0007*	0.005
Naphthalene	340		0.04	
Phenanthrene	225		0.09	
Anthracene	150		0.05	
Fluoranthene	600		0.1*	
Pyrene	350		0.15*	
Benzo(a)anthracene	230		0.075*	
Chrysene	400		0.1*	
Benzo(a)pyrene	400		0.09*	
PCBs (sum of 7)			0.001*	
TBT			0.00002*	

*Values regarded as preliminary

References, Appendix 4

Canadian Council of Resource and Environment Ministers for the Environment (CCME), *Canadian Water Quality Guidelines*, 1996

Swedish Environmental Protection Agency, *Generella riktvärden för förorenad mark – beräkningsprinciper och vägledning för tillämpning*, report no. 4638, 1993

Swedish Environmental Protection Agency, *Förslag till riktvärden för förorenade bensinstationer*, report no. 4889, 1998

Swedish National Food Administration, *Livsmedelsverkets kungörelse om dricksvatten*, SVLFS 1993:35, 1993

Deviation from reference values

In the following tables, the appropriate dividing line between **"little or none"** and "moderate" effects from a point source of pollution is used as the reference value. The figures have been rounded.

Contaminated land

TABLE 1.

Classification of deviation from reference value for contaminated land. The reference value used is the 90th percentile of the Swedish Geological Survey's geochemical survey of metals in undisturbed moraines analysed with ICP (mg/kg dw for ca. 16 000 samples).

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Arsenic	<10	10–45	45–230	>230
Cobalt	<10	10–45	45–230	>230
Copper	<25	25–130	130–650	>650
Nickel	<20	20–110	110–550	>550
Lead	<20	20–90	90–450	>450
Zinc	<60	60–300	300–1500	>1500

TABLE 2.

Classification of deviation from reference value for contaminated land. The reference value used is the 90th percentile of samples taken in urban areas by the Swedish Environmental Protection Agency, for metals in deep moraines analysed with ICP (mg/kg dw for 60–110 samples).

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Arsenic	<10	10–50	50–250	>250
Cadmium	<0.3	0.3–1.6	1.6–8	>8
Chromium	<30	30–150	150–800	>800
Cobalt	<10	10–45	45–230	>230
Copper	<25	25–120	120–600	>600
Nickel	<25	25–130	130–650	>650
Lead	<25	20–120	120–600	>600
Zinc	<70	70–350	350–1800	>1800
Mercury*	<0.1	0.1–0.5	0.5–2.5	>2.5
Vanadium	<40	40–200	200–1000	>1000

*Reference value for mercury is maximum value of 60 samples

TABLE 3.

Classification of deviation from reference value for contaminated land. The reference value used is the 90th percentile of samples taken in urban areas by the Swedish Environmental Protection Agency, for metals in deep sedimentary soil layers, analysed with ICP (mg/kg dw for 60–110 samples).

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Arsenic	<7	7–35	35–175	>175
Cadmium	<0.15	0.15–0.8	0.8–4	>4
Chromium	<45	45–230	230–1200	>1200
Cobalt	<15	14–70	70–350	>350
Copper	<30	30–140	140–700	>700
Nickel	<30	30–160	160–800	>800
Lead	<25	20–125	125–625	>625
Zinc	<100	100–500	500–2500	>2500
Mercury*	<0.2	0.2–0.85	0.85–4.25	>4.25
Vanadium	<60	60–300	300–1500	>1500

*Reference value for mercury is maximum value of 56 samples

TABLE 4.

Classification of deviation from reference value for contaminated land. The reference value used is the 90th percentile of samples taken in urban areas by the Swedish Environmental Protection Agency, for organic substances (mg/kg dw for 30–40 samples, values rounded).

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Total extractable aliphatics	<80	80–400	400–2100	>2100
Total extractable aromatics	<30	30–160	160–800	>800
Non-polar aliphatic hydrocarbons	<13	13–65	65–330	>330
Toluene	<0.5	0.5–2.3	2.3–12	>12
1,1,1-trichloroethane	<0.3	0.3–1.6	1.6–8	>8
Trichloromethane	<0.9	0.9–4.5	4.5–22	>22
Total chloroaliphatic hydrocarbons	<1	1–5	5–26	>26
Phenanthrene	<0.5	0.5–2.4	2.4–12	>12
Benzo(a)anthracene	<0.4	0.4–2	2–10	>10
Benzo(a)pyrene	<0.4	0.4–2	2–11	>11
Benzo(g,i,h)perylene	<0.4	0.4–2	2–9	>9
Indeno(1,2,3-c,d)pyrene	<0.4	0.4–2	2–9	>9
Pyrene	<0.6	0.6–3	3–16	>16
Chrysene	<0.5	0.5–2.5	2.5–13	>13
Fluoranthene	<1	1–5	5–24	>24

Table 4, continued.

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Benzo(k)fluoranthene	<0.4	0.4–2	2–9	>9
Benzo(b)fluoranthene	<0.7	0.7–3.5	3.5–18	>18
Total PAH	<5	5–26	26–130	>130
Total carcinogenic PAH	<2.5	2.5–13	13–65	>65
Total other PAH	<2.7	2.7–13	13–70	>70

TABLE 5.

Classification of deviation from reference value for contaminated land. Reference value based on survey results. The number of samples taken per survey is indicated.

Effects from point source

Substance	No. samples	Little or none	Moderate	Large	Very large
EGOM, mg org C/kg dw	10	<1	1–5	5–25	>25
PAH screening, mg PAH equivalent/kg dw	10	<10	10-50	50–250	>250
EOX mg Cl/kg dw	10	<0.2	0.2–1	1–5	>5
HEGOM mg Cl/kg dw	10	<0.2	0.2–1	1–5	>5
Cell test EROD ng TEQ/g dw	10	<5	5–25	25–125	>125

Contaminated groundwater

TABLE 6.

Classification of deviation from reference value for contaminated groundwater. Data in μg/l from "Environmental Quality Criteria for Groundwater".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Cadmium	<5	5–25	25–125	>125
Arsenic	<10	10–50	50–300	>300
Lead	<5	5–25	25–125	>125
Copper	<4000	4000–20000	20000–100000	>100000
Zinc	<700	700–3500	3500–17500	>17500
Aluminium	<300	300–1500	1500–7500	>7500

TABLE 7.

Classification of deviation from reference value for contaminated ground water. Reference value based on survey results, with EGOM as an exeption.

Effects from point source

Substance	No. samples	Little or none	Moderate	Large	Very large
EGOM, μg org C/l		<20	20–100	100–500	>500
PAH screening, μg PAH equ/l	9	<10	10–50	50–250	>250
EOX, μg Cl/l	6	<1	1–5	5–10	>10
Microtox, EC50, 15 min. vol. %	24	>95	95–70	70–50	<50
Microtox, EC20 15 min. vol. %	25	>90	90–50	50–15	<15
Algae test, 72 h EC50 vol. %	9	>80	80–70	70–50	<50
Algae test, 72 h EC10 vol. %	9	>80	80–25	25–15	<15
Umu-C test, without S9, dilution factor 1	10	0.9–1.55			
Umu-C test, without S9, dilution factor 3	10	0.9–1.36			
Umu-C test, with S9 dilution factor 1	10	0.79–1.36			
Umu-C test with S9 dilution factor 3	10	0.85–1.23			
LOEC vol. %		80–40	40–20	20–10	<10

TABLE 8.

Classification of deviation from reference value for large contaminated watercourses in northern Sweden. Data in μg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<6	6–30	30–160	>160
Zinc	<40	40–200	200–1000	>1000
Cadmium	<0.15	0.15–0.75	0.75–4	>4
Lead	<3.5	3.5–18	18–90	>90
Chromium	<2.2	2.2–11	11–55	>55
Nickel	<4	4–20	20–100	>100
Cobalt	<1.5	1.5–8	8–40	>40
Arsenic	<1.8	1.8–9	9–45	>45
Vanadium	<1.3	1.3–7	7–35	>35

TABLE 9.

Classification of deviation from reference value for large contaminated watercourses in southern Sweden. Data in μg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<9	9–45	45–230	>230
Zinc	<55	55–280	280–1400	>1400
Cadmium	<0.4	0.4–2	2–10	>10
Lead	<9.5	9.5–50	50–240	>240
Chromium	<4.5	4.5–22	22–110	>110
Nickel	<8	8–40	40–200	>200
Cobalt	<4	4–20	20–100	>100
Arsenic	<3.5	3.5–18	18–90	>90
Vanadium	<5	5–25	25–125	>125

TABLE 10.

Classification of deviation from reference value for small contaminated watercourses in northern Sweden. Data in µg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<2	2–10	10–50	>50
Zinc	<12	12–60	60–300	>300
Cadmium	<0.1	0.1–0.5	0.5–2.5	>2.5
Lead	<1.2	1.2–6	6–30	>30
Chromium	<1.1	1.1–6	6–30	>30
Nickel	<2.5	2.5–12	12–60	>60
Cobalt	<0.9	0.9–4.5	4.5–23	>23
Arsenic	<0.5	0.5–3	3–14	>14
Vanadium	<0.8	0.8–4	4–20	>20

TABLE 11.

Classification of deviation from reference value for small contaminated watercourses in southern Sweden. Data in µg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<3.5	3.5–18	18–90	>90
Zinc	<25	25–130	130–650	>650
Cadmium	<0.5	0.5–2.5	2.5–12	>12
Lead	<7.2	7.2–35	35–180	>180
Chromium	<2.2	2.2–11	11–55	>55
Nickel	<3.2	3.2–16	16–80	>80
Cobalt	<1.8	1.8–9	9–45	>45
Arsenic	<2.7	2.7–14	14–70	>70
Vanadium	<2.5	2.5–13	13–65	>65

TABLE 12.

Classification of deviation from reference value for contaminated lakes in northern Sweden. Data in μg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<2	2–10	10–50	>50
Zinc	<12	12–60	60–300	>300
Cadmium	<0.3	0.3–1.4	1.4–7	>7
Lead	<3.3	3.3–16	16–80	>80
Chromium	<0.5	0.5–3	3–14	>14
Nickel	<1.5	1.5–8	8–40	>40
Cobalt	<0.9	0.9–4.5	4.5–23	>23
Arsenic	<1.8	1.8–9	9–45	>45
Vanadium	<1.3	1.3–7	7–35	>35

TABLE 13.

Classification of deviation from reference value for contaminated lakes in southern Sweden. Data in μg/l from "Environmental Quality Criteria for Lakes and Watercourses".

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<3.5	3.5–18	18–90	>90
Zinc	<26	26–130	130–650	>650
Cadmium	<0.5	0.5–2.5	2.5–12	>12
Lead	<7	7–35	35–180	>180
Chromium	<2.2	2.2–11	11–55	>55
Nickel	<3.2	3.2–16	16–80	>80
Cobalt	<1.8	1.8–9	9–45	>45
Arsenic	<2.7	2.7–14	14–70	>70
Vanadium	<2.6	2.6–13	13–65	>65

TABLE 14.

Classification of deviation from reference value for contaminated surface water. Reference values based on survey results.

Effects from point source

Substance	No. samples	Little or none	Moderate	Large	Very large
AOX, µg Cl/l	19	<30	30–150	150–750	>750
EOX, µg Cl/l	27	<1	1–5	5–25	>25
Microtox, EC20	31	>80	80–70	70–50	<50
15 min. vol. %					

Contaminated sediments

TABLE 15.

Classification of deviation from reference value for contaminated lake sediments in Sweden. Data in mg/kg dw from natural values from "Environmental Quality Criteria for Lakes and Watercourses". A factor ten is used when nothing else is said in the report.

Effects from point source

Substance	Little or none	Moderate	Large	Very large
Copper	<100	100–500	500–2600	>2600
Zinc	<1000	1000–5000	5000–10000	>10000
Cadmium	<7	7–35	35–170	>170
Lead	<400	400–2000	2000–10000	>10000
Chromium	<160	160–800	800–4100	>4100
Nickel	<80	80–400	400–2000	>2000
Cobalt	<150	150–750	750–3700	>3700
Arsenic	<32	32–160	160–800	>800
Vanadium	<200	200–1000	1000-5000	>5000
Mercury	<1	1-5	5–26	>26

TABLE 16.

Classification of deviation from reference value for contaminated marine sediments. Data in mg/kg dw from "Environmental Quality Criteria for Coasts and Seas". Metals analysed with Swedish standard method.

Effects from point source

Substance	Little or none	Probable	Large	Very large
Copper	<80	80–400	400–2000	>2000
Zinc	<360	360–1800	1800–9000	>9000
Cadmium	<3	3–15	15–75	>75
Lead	<110	110–550	550–3000	>3000
Chromium	<70	70–350	350–2000	>2000
Nickel	<100	100–500	500–2500	>2500
Cobalt	<60	60–300	300–1500	>1500
Arsenic	<45	45–230	230–1200	>1200
Vanadium	<180	180–900	900–4500	>4500
Mercury	<1	1–5	5–25	>25
Barium	<700	700–3500	3500–18000	>18000
Beryllium	<4.2	4.2–20	20–100	>100
Germanium	<28	28–140	140–700	>700
Lithium	<70	70–350	350–1800	>1800
Molybdenum	<40	40–200	200–1000	>1000
Antimony	<4.7	4.7–25	25–120	>120
Tin	<14	14–70	70–350	>350
Thallium	<1.5	1.5–8	8–40	>40
Wolfram	>70	70–350	350–1800	>1800
PAHs (sum of 11)[1]	<2.5	2.5–12	12–60	>60
HCB	<0.001	0.001–0.005	0.005–0.025	>0.025
PCBs (sum of 7)[2]	<0.015	0.015–0.08	0.08–0.4	>0.4
Total PCB	<0.08	0.08–0.4	0.4–1.9	>1.9
Total HCH	<0.003	0.003–0.015	0.015–0.08	>0.08
Total chlordane	<0.0003	0.0003–0.0015	0.0015–0.008	>0.008
Total DDT	<0.006	0.006–0.03	0.03–0.15	>0.15
EOCl	<30	30–150	150–750	>750
EOBr	<3	3–15	15–75	>75
EPOCl	<3	3–15	15–75	>75
EPOBr	<0.8	0.8-4	4–20	>20

[1] Sum of phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(g,i,h)perylene, indeno(c,d)pyrene
[2] Sum of PCB 28, 52, 101, 118, 153, 138, 180

TABLE 17.

Classification of deviation from reference value for contaminated sediments. Reference values based on survey results.

Effects from point source

Substance	No. samples	Little or none	Moderate	Large	Very large
EGOM, mg org C/kg dw	21	<25	25–125	125–625	>625
PAH screening, mg PAH equ./kg dw	17	<10	10–50	50–250	>250
EOX, mg Cl/kg dw	21	<2	2–10	10–50	>50
Microtox, whole sample, vol. % 30 min. EC50		>10	10–3	3–1	<1
Microtox, whole sample, vol. % 30 min. EC20		>3	3–1	1–0.3	<0.3
Microtox pore water15 min., vol. % EC50	24	>90	90–70	70–50	<50
Microtox pore water15 min., vol. % EC20		90–50	50–25	25–15	<15
Cell test, EROD ng TEQ/g dw	9	<2	2–10	10–50	>50
Mussel test, mortality %			<3	3–10	>10
Mussel test, Development factor			<45	40–45	>45
Algae test, 72 h EC50 vol. %	18	>95	95–70	70–25	<25
Algtae est, 72 h EC10 vol. %	18	>95	95–50	50–10	<10

Auxiliary parameters

TABLE 18.

Auxiliary parameters are not used in making assessments. They are used to assist in the evaluation of analysis results relating to the other parameters. The natural ranges of variation for the designated auxiliary parameters are shown in the table.

Aux. parameter	Soil	Groundwater	Surface water	Sediments
pH	-	6–8	6.5–7.5	-
Temperature, °C	-	5–15	0–25	-
Conductivity, mS/m	-	<50	<10	-
Colour mg Pt/l	-	<100	<100	-
Turbidity, FNU	-	<100	<0.5	-
Oxygen level	-	-		-
Oxygen saturation, %	-	-	>90	-
Total N, mg/l	-	<0.5	0.3	-
Total P, mg/l	-	<2	<2	-
Chloride, mg/l	-	<100	<100	-
TOC, mg/l	-	<5	>5	-
Dry matter		-	-	
Ash content %	>95	-	-	

References, Appendix 5

Swedish Environmental Protection Agency, *Grundvattnets kemi i Sverige,* report no. 4415, 1995

Swedish Environmental Protection Agency, *Resultat från försöksinventeringen utförd 1994–1995*, 1996 (unpublished)

Swedish Environmental Protection Agency, *Bakgrundshalter i mark – halter av vissa ämnen i jord i tätort och på landsbygd,* report no. 4640, 1997

Form D: POTENTIAL FOR MIGRATION

Object	Recorded by (name, date):
ID no:	Revised by (name, date):

Dispersion factors are assessed for pollutants that are present in concentrations or amounts which pose a risk of negative effects. Indicate uncertain items with question mark ("?").

Borehole diagram and map of affected area

Borehole diagram

Map of affected area

From buildings and other constructions

Pollutants in buildings and other constructions	
Migration pathways (describe)	
Known previous migration (describe)	
Other	
Estimated leaching (% per year)	

From ground to buildings

Volatile pollutants in ground	
Ground's porosity (m/yr)	
Buildings' porosity (m/yr)	
Known previous migration	
Other	
Estimated rate of gas penetration into buildings	

Ground and groundwater

Current location of pollutants in ground, describe and indicate on map	

Rate of migration for substances transported via water through ground

Pollutants transported by water	
Ground's porosity in most porous stratum (m/s)	
Slope of groundwater surface (%):	
Groundwater flow (approx. m/yr)	
Biodegradable pollutants	
Rate of decay (half-life)	
Pollutants retained in soil	
Organic carbon content in soil (%)	
Other favourable conditions for retention in soil, e.g. clay content (describe)	
Natural transport channels, e.g. drying-cracks in clay (describe)	
Man-made transport channels, e.g. buried utility lines (describe)	
Known previous migration (m/yr)	
Other	
Estimated migration rate in ground and groundwater (m/yr)	

Migration rate for substances transported from ground via dust

Pollutants dispersed via dust	
Ground surface dryness (normal, drier than normal, much drier than normal)	
Vegetation cover (% and type)	
Exposure to wind (sheltered, exposed, very exposed)	
Known previous migration (m/yr)	
Other	
Estimated migration rate via dust (m/yr)	

Rate of migration for substances that move independently through the ground

Pollutants migrating in a separate phase	
Ground's porosity (m/s)	
Pollutants' viscosity (slow-moving, highly fluid)	
Known previous migration (m/yr)	
Other	
Estimated migration rate of pollutants in a separate phase (m/yr)	

Ground/groundwater to surface water

Surface water already contaminated by known previous migration (name)	
Endangered surface water (name)	
Pollutants' migration rate in ground/groundwater (m/yr)	
Distance from pollution to endangered surface water (m)	
Surface run-off via ground, ditches, sewage pipes (yes/no)	
Water table variations, flooding, high water (yes/no)	
Other	
Estimated years for migration to surface water	

Surface water

Pollutants dispersed in surface water	
Surface water flow-rate (km/yr)/turnover (yrs)	
Dilution leads to harmless levels in surface water (yes/no)	
Uneven distribution in surface water (yes/no)	
Known previous migration (m/yr)	
Other	
Estimated migration rate in surface water (km/yr)	

Sediments

Contaminated sediments, known previous migration, (describe and indicate on map)	
Pollutants transported via water to sediments	
Sedimentary conditions in various sections of water system (describe)	
Boat traffic that stirs up sediments (yes/no)	
Dredging (yes/no)	
Powerful waves (yes/no)	
Gas-formation (yes/no)	
Pollutants in separate phase in sediments (describe)	
Other	
Even distribution (m/yr)	
Uneven distribution, note also on map (describe)	

Form E COMPREHENSIVE RISK ASSESSMENT

Object	Recorded by (name, date)
ID no	Revised by (name, date)
Industrial branch	

Indicate uncertain items with question mark ("?")

Hazard assessment (H)

Note substances in appropriate squares

Slightly hazardous	Moderately hazardous	Very hazardous	Extremely hazardous

Contamination level (C)

Shows current polluted media. Data from Form C, Contamination level. Note substances in appropriate squares.

Media	Slight	Moderate	High	Very high
Buildings/construction				
Soil				
Groundwater				
Surface water				
Sediment				

Migration potential

Data from Form D, Migration potential. Put cross (x) or note substances in appropriate squares.

Direction	Small	Moderate	Large	Very large
From buildings/ constructions				
To buildings				
In soil and groundwater				
To surface water				
In surface water				
In sediments				

Sensitivy (S) protection value (P)

Write S for sensitivity and V for protection value.

	Slight	Moderate	Great	Very great
From buildings/ constructions				
Soil & groundwater				
Surface water & sediments				

Evaluation of S and V based on land use. .... which is (check) ❏ current land use, ❏ future land use as per detailed plan, ❏ future land use as per general guidelines. Brief description of exposure conditions: ....

....

....

COMBINED ASSESSMENT & RISK CLASSIFICATION

MIGRATION POTENTIAL

VERY LARGE

LARGE

MODERATE

SLIGHT

RISK CLASS 1

RISK CLASS 2

RISK CLASS 3

RISK CLASS 4

LOW   MODERATE   HIGH   VERY HIGH
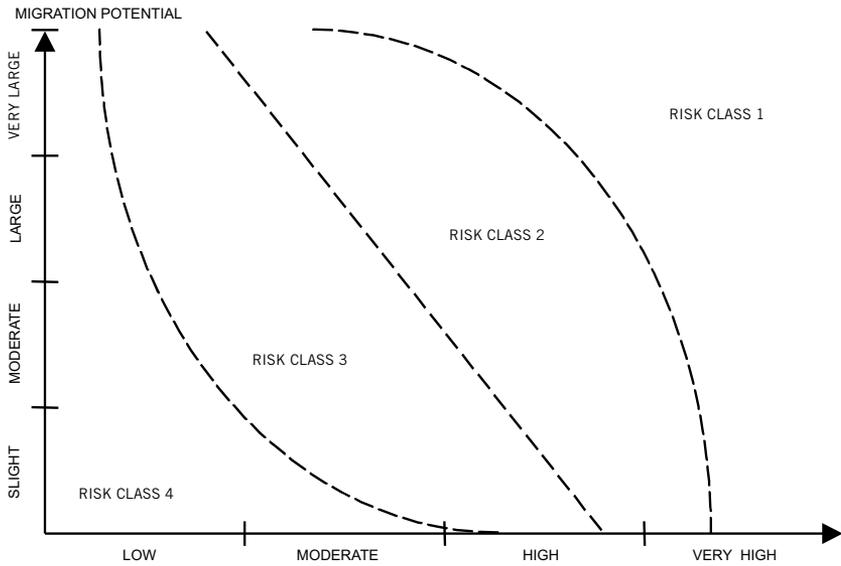
Investigator's general impressions:. . . . .
. . . .
. . . .
. . . .
. . . .

Site assigned to risk class (check)	❏ 1 "Very high risk" ❏ 2 "High risk" ❏ 3 "Moderate risk" ❏ 4 "Low risk"

Explanation:. . . . .
. . . .
. . . .
. . . .

Other grounds for setting priorities
❏ exposure to pollutants occurs at present in following ways . . . .
. . . .

Links
❏ There are other contaminated sites which endanger the same body of water, namely:. . . . .
. . . .
. . . .
. . . .

❏ There are other contaminated sites associated with the same activity, namely: . . . .
. . . .
. . . .

Industrial branches and associated pollutants

Mines and mine wastes	Metals, cyanides, aromatic hydrocarbons and oil
Primary metal works, secondary metal works, iron and steel manufacture	Metals, fluorides, cyanides, chlorinated and non-chlorinated solvents, phenols, PAH and PCB
Ferro-alloys	Metals (Cr, Mo, V)
Accumulators	Metals (Pb, Cd, Ni)
Graphite electrodes	Metals, PAH, tars
Surface finishing of metals	Metals, fluorides, cyanides, aromatic hydrocarbons, chlorinated solvents, phenols, PAH, PCB and oils
Foundries	Metals, phenols
Glass-making	Metals (Pb, As)
Manufacturing industry	Metals, oils, pigment residues
Asphalt works	Oils, bitumen, solvents
Mineral wool	Phenols, nitrogen
Graphic production	Metals (Ag), solvents
Printing	Metals, aromatic hydrocarbons, chlorinated and non-chlorinated solvents, phenols, cyanides, PAH and oil
Electro-technology	Metals, aromatic hydrocarbons, chlorinated and non-chlorinated solvents and PCB.
Chloralkali	Mercury, dioxin
Chlorates	Graphite wastes, Cr 6+, dioxins/furans
Other inorganic chemistry	Metals, cyanides, gypsum waste, etc.
Gas works (discontinued)	PAH, aromatic hydrocarbons, phenols and cyanides
Oil refining	Metals, oils, acidifying and oxidant-forming substances
Oil storage	Metals, organic compounds, vinyl chloride, oils
Other organic chemistry	Common organic chemicals
Paint & pigment	Metals, organometallic compounds, aromatic hydrocarbons, chlorinated and non-chlorinated solvents, organic phosphorus compounds, phthalates and phenols
Rubber manufacture	Metals, cyanides, aromatic hydrocarbons, phenols, PAH, chlorinated hydrocarbons, inorganic sulphurcompounds, reactive N, P and O
Pharmaceuticals	Reagent solutions (mother lye), cleaning water, etc.
Herbicide/pesticide production	Chlorinated hydrocarbons, organic N and P compounds, aromatic hydrocarbons, organic and inorganic Hg, Sn and As compounds
Gunpowder & explosives	Metals, nitrogen compounds, TNT, RDX

Textile manufacture	Heavy metals, aromatic hydrocarbons, chlorinated and non-chlorinated solvents, phenols, cyanides, PAH and oil
Tanning	Chromium, mercury and hydrocarbons
Photographic products	Metals (Ag, Cr, Cd), nitrogen compounds
Dry cleaning	Polychloroethylene
Adhesives manufacture	Various organic compounds (including some that degrade slowly)
Polyurethane manufacture	Isocyanates, organic solvents. CFC to atmosphere
Polyester manufacture	Styrene to atmosphere
Soap & detergent manufacture	Large number of chemicals, e.g. tensides
Surface treatment with lacquer, paint or glue	Solvents, pigment residues
Food products & trade	Degradable organic substances
Pulp & paper	Mercury, heavy metals, organochlorine compounds, PCB
Fibreboard manufacture	Metals, chlorinated and non-chlorinated solvents, aromatic hydrocarbons, phenols and oil
Plywood & particle board	Urea, formaldehyde, phenols
Wood impregnation	Cr, Cu, As, creosote
Sawmills	Pentachlorophenol, mercury, fluorides, oxine copper, azoles, acetates
Surface treatment of wood	Solvents, glue and pigment residues
Impregnation facilities for rail transport	Metals (Cr, Cu, As), creosote, oil
Railroad repair shops	Oils, fats, solvents, pigment residues
Auto repair facilities	Oil, aromatic hydrocarbons, heavy metals, PAH, chlorinated solvents and glycols
Motor vehicle traffic	Metals (Pb), road salt
Airports	De-icing solutions (urea, glycol), oils
Shipping & harbours	Metals, oils, PCB
Environmental waste facilities	Waste oil, etc.
Car dismantling	Oils, glcyol, battery acid, petrol, diesel oil
Car salvage & sales	Oil, heavy metals, aromatic hydrocarbons, chlorinated solvents, glycol, PAH and PCB
Municipal dumps	Heavy metals, chlorinated and non-chlorinated solvents, chlorinated hydrocarbons, phenols, oil and nutrient salts
Sewage treatment plants	Metals, phosphorus, nitrogen, organic compounds
Incinerators	Metals, ash, cinders
Armed forces	Metals (Pb), ammunition remains, chemicals, petroleum products

Methods for inventories of

Contaminated Sites

THE WORK WITH planning for remediation of the contaminated sites in Sweden includes carrying out inventories. This is a guidance for collecting data and assessing risks on a uniform basis and with a reasonable degree of reliability. The method consists of three parts. The first one deals with environmental quality criteria for contaminated sites, including a method for risk classification. The second part provides guidance for collection of data required for risk classification. The third part, presented in a separate report, describes analytical procedures which are included in the method (report 5054).

The report is one of a series of six reports published by the Swedish Environmental Protection Agency under the heading ENVIRONMENTAL QUALITY CRITERIA. The reports are intended to be used by local and regional authorities, as well as other agencies, but also contain useful information for anyone with responsibility for, and interest in, good environmental quality.

Reports available in English are:
• Lakes and watercourses, 5050
• Groundwater, 5051
• Coast and seas, 5051

A brochure, short version, of this report is available, and can be ordered from the Agency's address below (under the headline bookstore). Abridges versions in English of all the six reports are available on the Agency's home page: www.naturvardsverket.se (under the headline legislation/guidelines).