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FIELD-SURVEY TECHNIQUES AND THE PROTECTION OF SOIL AND GROUNDWATER

R.J. Sporry
Heidemij/Adviesbureau Arnhm B.V., Arnhem

ABSTRACT

The use of field-survey techniques to assess the effects of hazardous activities on soil and groundwater depends on the nature of such activities, the properties of the soil and groundwater, and the limitations of the technique itself. This paper discusses in short a classification of hazardous activities and soil types. The classification leads to a restricted number of basic survey procedures for groups of hazardous activities and groups of soil types. The most important feature of each procedure lies in a phased approach in which step by step the effects of an activity become more clearly defined.

INTRODUCTION

As part of the preparations for a soil and groundwater protection bill, the Dutch Ministry of Health and Environment had carried out a series of studies, on the basis of which guidelines could be formulated. One of these studies concerned field-survey techniques in relation to the protection of soil and groundwater.

In assessing the effects of hazardous activities which will take place of already have taken place, it is most likely that several techniques of quite different natures may have to be used. The nature of such techniques generally depends on the following criteria:

- the nature of the hazardous activity,
- the geological and geohydrological conditions of the location where a hazardous activity takes place,
- possibilities and limitations of the various survey techniques.

This paper deals with a classification of hazardous activities, a classification of soil types in the Netherlands (in relation to groundwater conditions), and an inventory of available survey techniques.

To set up and describe a survey procedure for each particular hazardous activity and for each particular type of soil would result in an enormous amount of paperwork, forming an impenetrable labyrinth. Therefore another approach was developed. On the basis of a restricted classification, procedures for field-surveys can be set up in the form of flowcharts. These procedures follow a system of questions and answers through which, in a case of a hazardous activity, a selection of survey techniques is obtained.

The general philosophy behind the outline of a procedure is that the survey takes place in several phases, starting with a general outline of the effects and the affected area, then moving through each phase to a more detailed and clearly defined picture of the situation.

It is pointed out explicitly here that this paper deals only with fieldsurvey techniques and not with laboratory investigations.

CLASSIFICATION OF HAZARDOUS ACTIVITIES

In a classification of activities hazardous to soil and groundwater a number of criteria can be indicated, but to start with a main division can be made between those activities which pollute the soil and those which affects the soil (deterioration). In the latter case soil composition, properties and/of structure are changed. Further divisions relate to spatial distribution and to time. These result in the classification presented in Table 1.

TABLE 1 Division of hazardous activities.

no.	main division	spatial distribution	distribution in time	
1.1.1	pollution	local source	continuous	ACTIVITIES
1.1.2			periodical	
1.1.3			unique	
1.2.1		diffuse source	continuous	
1.2.2			periodical	
1.2.3			unique	
2.1.1	deterioration	local source	continuous	
2.1.2			periodical	
2.1.3			unique	
2.2.1		diffuse source	continuous	
2.2.2			periodical	
2.2.3			unique	

Within the main division of polluting activities a subdivision can be made based on the situation in which th pollution takes place (during storage, transport, processing or disposal), whether the polluting substance is a solid, liquid or gas and - of interest for processes

in the soil - whether it dissolves very well, only a little or not at all in water. Activities which cause soil to deteroriate can be subdivided according to the situation in which the activity takes place (earthworks, land development, agricultural activities, exploration and mining) and according to the affected soil-component (the soil itself or the groundwater in the soil).

This subdivision is not presented here. However, it may be clear from the subdivisions indicated that for different activities different survey techniques have to be used.

CLASSIFICATION OF SOIL TYPES

A classification of soil types in relation to soil survey techniques depends on two sorts of relationships: 1. the properties of the soil in relation to chemical and physical processes which take place due to hazardous activities and 2. the properties of the soil in relation to the possibilities and limitations of the survey technique itself.

Basically, we can distinguish three groups of soil properties on which a classification can be based:

- physical and chemical properties,
- (geo-)hydrological properties,
- soil-mechanics properties.

Within these groups many criteria for a classification can be indicated. If all or most of these were used it is likely this would eventualy lead only to confusion rather than a convenient arrangement

Fortunately it is possible to combine several related properties in one criterion. A practical selection of criteria should be based on two considerations: 1. which of the properties can be measured or defined in the field and 2. which properties impose limitations on the use of certain survey techniques.

In this way we arrive at a selection of criteria, but each of these has to be quantified in a way which will make a classification meaningful.

Table 2 presents a list of the selected and quantified criteria and soil type code for each of them.

Theoretically this classification leads to 72 types of soil, although several combinations will not in fact occur.

TABLE 2
Selected soil type classification.

main criteria	subdivision (quantitative)	soil type code
layering (in terms of lithology)	strongly layered (5 or more layers)	Gs
	moderately layered (3-4 layers)	Gm
	barely layered (1-2 layers)	Gw
permeability (in relation to other properties)	bad permeability k < 0.50 m/day	Ks
	bad, followed by good permeability	Ksg
	bad permeability, interlayered by good permeability	Ks(g)
	good permeability k > 0.50 m/day	Kg
	good, followed by bad permeability	Kgs
	good permeability, interlayered by bad permeability	Kg(s)
groundwater level (in relation to piezometric head)	high (< 1.20 m)	Ph
	low (> 1.20 m)	Pl
groundwater composition	fresh (chloride content < 300 mg/l)	Z
	salt (chloride content > 300 mg/l)	S

SURVEY TECHNIQUES

Basically we can distinguish three groups of survey techniques:
- collection and study of available maps, reports of studies, etc.
- survey techniques without disturbance of the soil, or with little disturbance,
- techniques with disturbance of the soil.

To a certain extent this classification of groups is defined by the way in which the survey is set-up (i.e. systematically) in which it starts with an inventory of available data, is continued using techniques which give a general (but swift) indication of the size of the affected area and the intensity of deterioration without the use of generally expensive drilling and sampling, and finishes with a detailed investigation (including drilling).

Table 3 lists a number of useful maps and studies and the information they may supply. Table 4 lists a number of techniques whithout soil disturbance and Table 5 lists techniques with soil disturbance.

TABLE 3

Reference maps and archives.

1. Topographical maps	8. Hydrogeological maps
2. Aerial photographs	9. Waterway maps
3. Soil maps	10. Landuse maps
4. Geomorphological maps	11. Atlasses on special subjects
5. Soil classification maps	12. Information systems
6. Geological maps	13. Mapping catalogues
7. Groundwater maps	14. Archieves of national survey institutes, such as geological survey, groundwater survey, soil survey, water supply, etc.

TABLE 4

Survey techniques without or with little soil disturbance.

Technique	depth of information
1. Remote sensing (various techniques)	very shallow, < 1 m
2. Geo-electrical survey	> 300 m
3. Electromagnetic survey	max. ca. 50 m
4. Refraction seismics	max. ca. 30 - 100 m
5. Geothermal survey (shallow)	max. ca. 2 m
6. Water pressure meters	max. ca. 30 m
7. Penetrometer tests	max. ca. 30 m (sometimes more)

TABLE 5

Survey techniques with soil disturbance.

Technique	depth of information
1. Permeability tests (various methods)	up to ca. 2 m
2. Tensiometers	1 - 2 m
3. Capacitive moisture meters (various types)	1 - 2 m
4. Nuclear measurements of density and moisture content	2 - 3 m
5. Thermal resistance measurements	max. ca. 2 m
6. Drilling and sampling (various techniques)	10 - > 200 m depending on technique
7. Physical well-logging (various properties)	> 200 m
8. Piezometers and groundwater sampling	> 200 m
9. Salt detectors	> 200 m
10. Transmissivity tests (various methods)	> 200 m
11 Tracer studies	> 200 m
12 Electrical density measurements	ca. 30 m

The listing of techniques does not claim to be complete with regard to the techniques proper. Furthermore, the listing would be more complete if it contained information on the soil properties measured or defined by each method and the limitations of the various techniques.

Lack of space however forces us to restrict ourselves to a mere summary of techniques.

SURVEY PROCEDURES

To present a survey procedure (consisting of a number of relevant techniques) for each hazardous activity and each soil type would lead to a confusing number of procedures. However, we may expect that we will arrive at a number of procedures which are more or less the same for certain groups of activities and for soil types which are also more or less alike. Thus the number of procedures can be restricted. A selection of such a procedure can be based on a matrix system (not reproduced here due to lack of space) which relates the procedure to a certain hazardous activity and a certain type of soil.

Since the nature of activity and type of soil also define the depth of the survey, this leads to a further division of procedures based on depth.

Thus we arrive at the following survey procedures:

For soil-polluting activities:

1 - surface surveys (0 - 2 m depth)
2 - shallow surveys (2 - 10 m depth)
3 - moderately deep surveys (10-30 m depth)
4 - deep surveys (>30 m depth)

For activities leading to soil deterioration:

1 - shallow surveys (0 - 10 m depth)
2 - moderately deep surveys (10 - 30 m)
3 - deep surveys (> 30 m).

Within each main group of hazardous activities we can set up separate procedures for handling disasters, as these have generally a quite different nature and effect than the hazardous activities. Thus we arrive at a total of 14 basic procedures. The main idea behind each procedure is that, starting from the available data, in each phase of the survey the situation becomes progressively more clearly defined in relation to the affected area and the extent of the damage.

Each procedure follows a question-and-answer system with each answer leading to the application of a particular survey technique.

In Figure 1 an example is presented of one of these procedures in the form of a flowchart. The questions are numbered, the recommended techniques are lettered. Each flowchart should be accompanied by an explanation for each step of the procedure, including remarks and comments which serve as a guidance and as a warning system for pitfalls which may be overlooked by the user.

Each procedure is based on the fact that the user can start from some data on the hazardous activity concerned and on the general (geo-) hydrological situation. Furthermore, the selection of a particular procedure can be helped by roughly defining the depth of the investigation based on considerations such as: volatility, hydrophobic character, viscosity, C.E.C., pH, oxydation, persistency, solvability in water, the presence of complex ions, non-polar combinations, etc. Finally, when the survey is carried out, the intensity of the survey (density of observations) depend on the following considerations:

- the sensitivity of the surveyed area for hazardous activities
- the poisonousness of polluting matter, as defined by the "black" and "grey" lists, which are used to regulate the use of polluting substances in the Netherlands.

Procedure 3.

Soil and groundwater pollution. Methods for moderately deep surveys (up to 30 m)

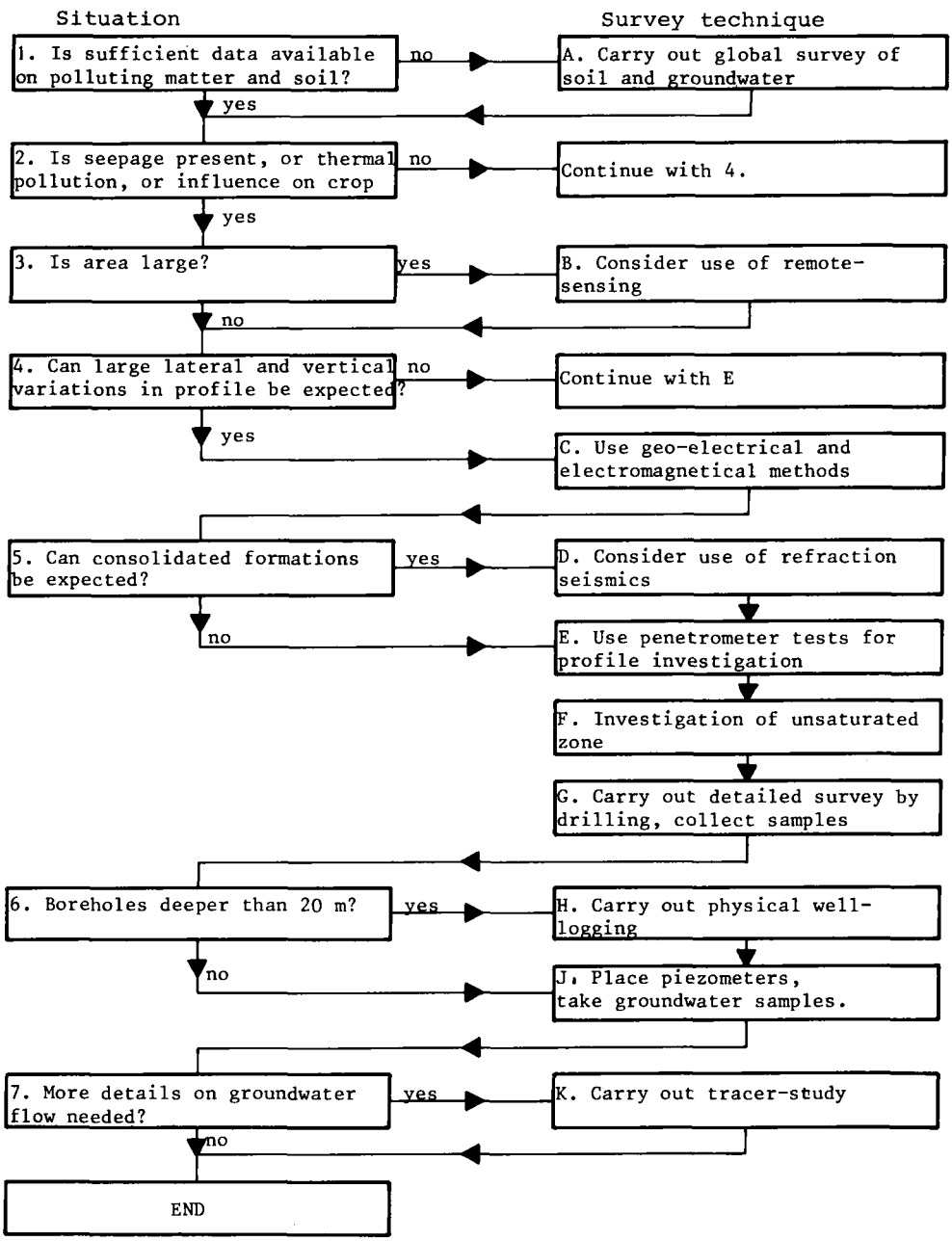

FIGURE 1. EXAMPLE OF A SURVEY PROCEDURE.