H1 Annex J Groundwater

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Introduction

Below is a summary of changes made to this Annex since the launch in April 2010.

Annex version	**Date**	**Change**	**Template version**
Issue 2.1	December 2011	Reformatting to respond to general issues raised in the 2010 H1 public consultation. First revision since launch, Minor edits and restructuring Removal of Appendix on Water Quality Standards with new reference to more up to date information. Addition of new text on pollution prevention specific to groundwater	H1 April 2011

Introduction

About this guidance

This guide on the assessment of risks to groundwater from permitted groundwater activities is a technical annex to our *H1 Environmental Risk Assessment* framework (see Figure A).

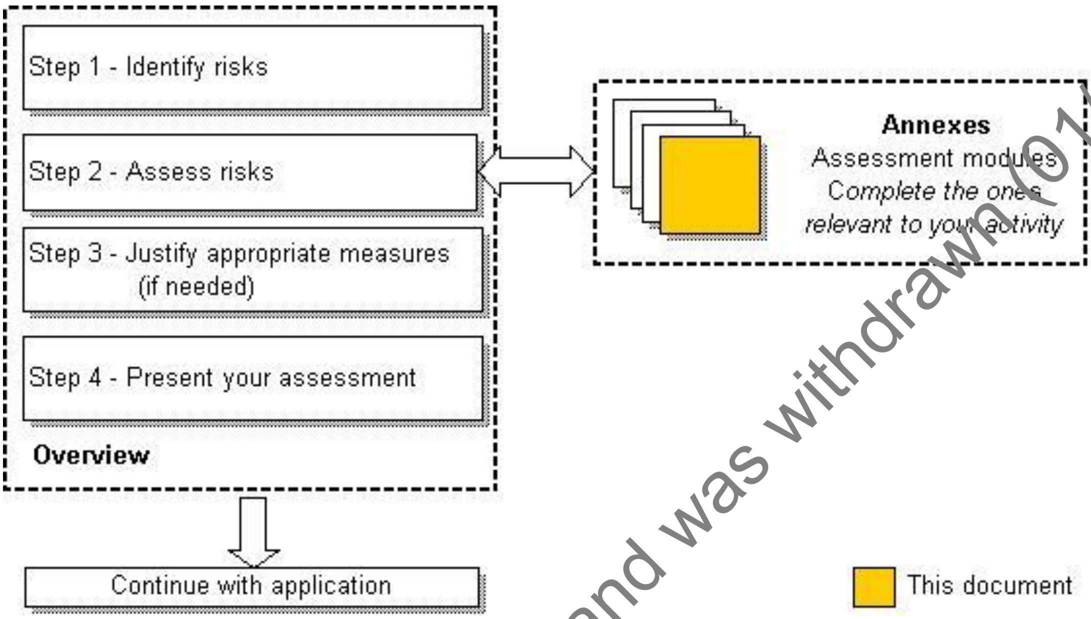


Figure A – Structure of H1 framework

This document provides guidance on how to undertake a groundwater risk assessment and points to supporting sector specific annexes that deal with different types of activities (see Figure B). If the groundwater activity is one where we have confirmed we will carry out a basic level of risk assessment for you, you do not need to read this guidance. However, if our assessment concludes that we are not able to accept the proposed activity without further evidence you may need to carry out a higher level of risk assessment, in which case this guidance and the relevant sector specific annexes will apply.

Link to our H1 guidance

It is important that you should read our H1 Environmental risk assessments for permits – overview document before reading this annex.

This H1 document provides high level guidance on the broad principles of risk assessment, which underpin our decisions on the environmental permitting of different activities that discharge to ground and /or groundwater. If appropriate, this annex then directs you to more detailed sector specific annexes (see Figure B).

Introduction

If use of our H1 guidance identifies that a groundwater risk assessment is required, then depending on your activity, it will also explain whether

(a) We will carry out the risk assessment for you; or

(b) You or the person carrying out the risk assessment on your behalf will need to prepare one for our review.

This document and the supporting groundwater annexes

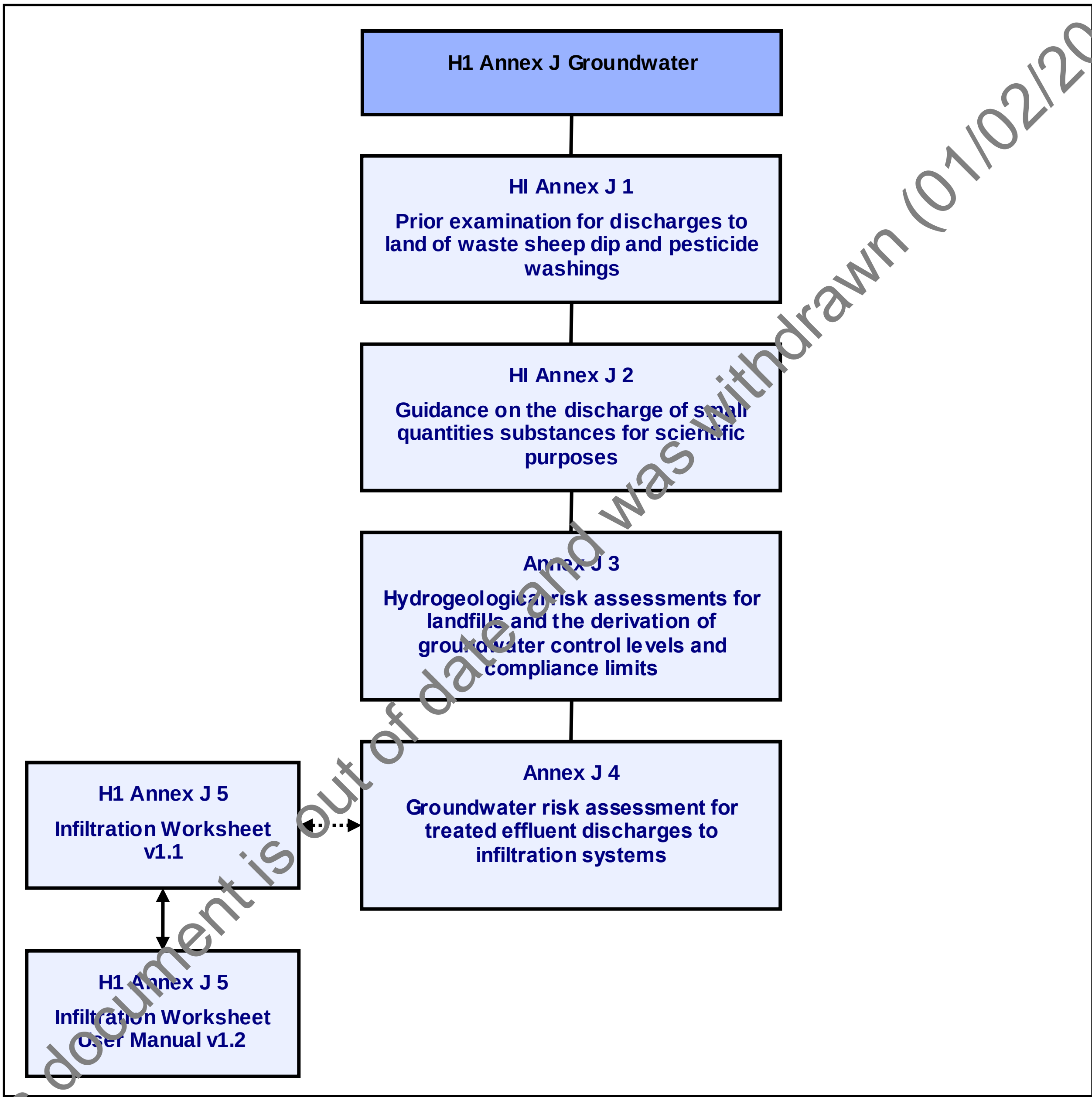
To help you understand the approach that is required, this document provides guidance on assessing risks to groundwater from a wide range of activities permitted under the Environmental Permitting Regulations (EPR).

The aim of this particular document is to explain the broad concepts, terminology and approaches common to assessing risks to groundwater from all groundwater activities. It also takes you through the different generic steps of undertaking a risk assessment.

By following this guidance (as supported by the relevant sector specific guidance), and providing the appropriate information and analysis, we will have the necessary information against which to decide whether your activity can be permitted and if so what permit conditions we need to put in place to ensure the risks of groundwater pollution remain low during the operation of your activity and aftercare of the site.

How the H1 framework is structured specific to groundwater is shown in Figure B.

Figure B. How the H1 framework is structured specific to groundwater



Introduction

Link to our Groundwater Protection document

Our Groundwater Protection documents (GP3)[1] sets out our aims and objectives for groundwater in terms of protecting its quality and quantity.

GP3 also introduces basic concepts and the principles of management, monitoring and risk assessment that we use in the protection of groundwater. It also describes the technical tools used by groundwater specialists (hydrogeologists) and the legal framework we all need to operate within.

If you are unfamiliar with groundwater concepts and groundwater risk assessment, we think you will find it useful to read our GP3 guidance before reading this document. However, we have repeated some of the information from GP3 here so that you can see how it fits together with this more focussed information on how to prepare a groundwater risk assessment.

Annex J Groundwater version 2.1

Please note that Appendix A3 – 'Selected Water Quality Standards' has been withdrawn from this version of Annex J. Following the H1 public consultation we have reviewed the most appropriate lway of providing the most up to date information on Water Quality Standards (WQSs) and consider the most comprehensive way is by the Chemical Standards database

The Chemical Standards database provides access to chemical standards in use by the Environment Agency (please note that you will need to register to use the database).

The selection of suitable Water Quality Standards is a site specific issue and all values used should be agreed by us when reviewing your permit application.

[1] Groundwater Protection: Policy and Practice (GP3) Parts 1 – 3 Environment Agency 2006

Groundwater Protection: Principles and Practice (GP3) Parts 4 & 5 Environment Agency 2012 in preparation

Chapter 1 Background information

1.0 Anticipated readership

It is intended that this guidance should be accessible to and read by anyone involved in either applying for an environmental permit or varying their existing one. As the complexity of the activity increases you will need to refer to the sector specific annexes as shown in Figure B.

This guidance applies to all groundwater activities (Appendix A5) as formally defined in the Environmental Permitting (England and Wales) Regulations (EPR)[2].

You do not need to work through this guidance if your activity does not involve discharges to ground / groundwater. Please read Appendix A5.

You should read this guide if any of the following apply to you:

- You are applying for a permit or varying an existing one under EPR and there is a requirement to carry out an assessment of groundwater risks..
- You have been advised to complete an assessment of the risks to groundwater in Step 2 of H1 Environmental Risk Assessment – Overview.
- There is no suitable standard rules permit for your activity or you do not wish to apply for one; or there is a suitable standard rules permit but you do not meet one of the necessary criteria and need to assess that particular risk further.
- We have advised or required you to carry out a site-specific risk assessment for your activity.
- Landfill operators and people involved in assessing the risks to groundwater from landfill operations will need to be fully conversant with this guidance and then use our sector specific guidance on landfills Annex J 3: Hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. Environment Agency, (2011).
- If you wish to discharge to ground any volume of trade effluent or 15 m^3/day or more of treated sewage effluent, you will need to follow this guidance and our sector specific guidance: Annex J 4: Groundwater risk assessment for treated effluent discharges to infiltration systems. Environment Agency, (2011a)
- Certain activities relating to mining waste (see Appendix A3)
- Certain solid disposals – on farm burials of animal carcasses (see Appendix A3)

[2] EPR (2010) is stated where there is a direct reference; the general term EPR would cover any future amendments

- Certain activities relating to the application of the surrender of an environmental permit (Regulation 25. EPR, 2010) – see also Section 1.1 below – notification of surrender.

1.1 Are there any special arrangements for your activity?

There are special arrangements in place for some activities. This means that some operators may not need to follow this guidance:

- Farmers who need a permit to discharge waste sheep dip, pesticides or pesticide washings to land should contact us as we will do the initial risk assessment. If further information is requested you will need to follow this guidance and be familiar with our sector specific guidance Annex J 1: Prior examination for the discharge to land of waste sheep dip and pesticide washings. Environment Agency, (2011b). We will let you know if we need further information.
- If you wish to discharge 2 m^3/day or less of treated sewage effluent to ground you do not need to read this guidance. Please see our web page on [septic tanks and sewage package treatment plants](). If your existing discharge falls within a groundwater Source Protection Zone 1 (SPZ1) you will need to apply for an environmental permit. As part of your permit application we will carry out the initial assessment for you. If our in-house assessment indicates a risk you may need to follow this guidance and Annex J 4: Groundwater risk assessment for treated effluent discharges to infiltration systems. Environment Agency, (2011a).
- If you wish to discharge more than 2 m^3/day and less than 15m^3/day of treated sewage effluent to ground please contact us as we will do the initial assessment for you. If our in-house assessment indicates a risk you may need to follow this guidance and Annex J 4: Groundwater risk assessment for treated effluent discharges to infiltration systems. Environment Agency, (2011a).
- For notification of the surrender of an environmental permit (Regulation 24 EPR, 2010), you will not need to read this guidance.
- Certain solid disposals on farm of animal carcasses of 2 tonnes or less[3] (see Appendix A3).
- Mining waste activities please refer to Appendix A3.

1.2 Activities not covered by this guidance

This guidance does not apply to the following activities and potential sources of pollution of groundwater that we do not control using EPR. These are:

- Historical activities that have led to land contamination.

[3] There must be a derogation from the Animal By-Products Regulations to bury fallen stock.

- The use of fertilisers and pesticides for beneficial use in land management.
- Activities where the source of potential pollution is deemed to be adequately contained (for example, underground petrol and diesel storage tanks) or to be of minimal significance (for example, road drainage to an infiltration system following passage through oil interceptors).

1.2.1 Exclusions

Under EPR, there are certain exclusions whereby a discharge is not classed as a groundwater activity and therefore an environmental permit is not required. If we are happy that an exclusion can apply, we will make a record of it. Please contact us if you think your proposed activity fits this category. More information on exclusions can be found in:

Groundwater Protection: Principles and Practice (GP3) Part 5 Interpreting groundwater activity exclusions (Environment Agency, 2012)

1.2.2 Land contaminated by historical activities

We do not consider that a passive release of pollutants from land contamination is a discharge that needs to be permitted under EPR as there is no surface activity to control. However, if we believe that new activities, on land which is contaminated, (for example, soil washing, piling, etc.) could lead to an increased risk of groundwater pollution, we may serve you a notice to apply for a permit to control what you are doing. In that case, we would require you to undertake a groundwater risk assessment in line with the guidance in this document and the relevant technical annex.

If a discharge is to occur on land that could have been contaminated by previous activities (for example storage of slurry on a field, diesel spill on a lorry park in an area to be used for infiltration drainage, industrial processes), then there is a chance that the soils and groundwater beneath the discharge may already be contaminated. In these circumstances, your activity could mobilise potential pollutants. Alternatively, groundwater quality may already be affected and further inputs arising from your discharge could lead to groundwater becoming polluted. If this is the case, further assessment will be needed. The risk assessment, as a minimum, needs a statement on the previous land use of the discharge area (for example pasture, brick-works clay pits, etc.).

1.3 Things to consider before you start

Before you start undertaking a groundwater risk assessment, and as part of your permit application or review, you should consider the following points regarding the costs and time associated with the risk assessment compared to the costs and time associated with:

- Not carrying out your groundwater activity at all. For example, it may be more cost effective to discharge to sewer, or tanker away for off site disposal, rather than prepare a detailed risk assessment (and undertake the associated site investigation and monitoring) for a discharge to land).
- Moving the activity to a lower risk area.
- Engineering out the risk. For example, you may be able to easily pre-treat your source by controlling inputs or adding degradation enhancers and negate the need for detailed site investigation.

You should also remember that your activity may require long term monitoring actions. In some circumstances, long term monitoring may be required after you surrender your permit. This may have financial implications. If there are errors in your design, operation or risk assessment you may face liabilities associated with groundwater pollution.

A well designed and controlled activity supported by an appropriate risk assessment can, however, provide significant cost savings to the operator and be potentially more sustainable in terms of using natural processes.

1.3.1 Site investigation

Often, some form of site investigation is likely to be required depending on the level of risk. This can lead to significant delays before the findings and subsequent monitoring data are available for use in the risk assessment. For some activities and some locations, the site investigation costs could be large and you need to consider this before progressing further.

1.3.2 Likely effort required

Collecting, collating and interpreting the required information on the activity and its setting may be achieved in a number of ways:

- Submission of a completed application form. This may require you to provide some key information on the activity and its setting;
- A groundwater risk assessment report.

The effort required will vary between activities and is strongly influenced by the polluting potential of the proposed or existing groundwater activity and sensitivity of the groundwater.

1.4 Pollution prevention

1.4.1 Overview

You should also refer to Annex A: Amenity & accident risk from installations and waste activities

Groundwater is vulnerable to pollution, not least because it is "out of sight, out of mind". It is easily polluted; leaks, spills and poor maintenance can all release significant volumes of chemicals into groundwater. Pollution caused by such leaks and poor maintenance often goes undetected for long periods of time, causing greater environmental damage. For further information please refer to GP3 (Environment Agency, 2006-2012).

1.4.2 What steps are you taking to manage risks?

You should put in place control measures to ensure that there are no significant risks from your activity and bear these in mind when you complete the assessment. Some risks to groundwater are too high for us to allow the activity to be permitted.

We consider that despite permitted controls, there are likely to be unforeseen incidents (fire, accidents), or activities outside of the permit conditions (movement of machinery, etc.) that pose risks to drinking water supplies. It is unlikely, even with good permitted controls, that overall risk can be reduced to net low risk in the most sensitive locations. Incidents should only happen very infrequently but when they do occur, the magnitude of the consequences is likely to be very high.

1.4.3 What are the chances of causing harm?

When thinking about the chances of your activity causing harm to groundwater, you should think about how you propose to operate. For example the chances of a leak are lower if you construct a suitable bund or if chemicals and pesticides are stored correctly. You should also make contingency plans, for example if your water or power is cut off. A power cut to a package sewage treatment plant, for example, could cause problems.

1.4.4 How serious could the harm be?

Groundwater pollution can affect drinking water supplies, rivers and wetlands. Once polluted, groundwater can be very difficult and expensive to clean up. It is therefore important that we protect groundwater to ensure the pollution does not occur in the first place. In order to do this, we use a risk based approach so the most vulnerable water has the highest protection. This is explained below in section 1.5.5.

1.4.5 How we classify groundwater

Aquifer designations, groundwater vulnerability maps and Source Protection Zones are key tools and are used in initial risk screening to identify areas where risks to groundwater are higher than others.

Vulnerability maps identify where a groundwater resource is at risk from pollution (should a source of pollution exist) due to the nature of the soil, unsaturated Zone or inherent characteristics of the aquifer.

Aquifer designation classifies aquifers according to their potential use for water supply and the degree to which they support river flows and habitats. The divisions are as follows:

Principal Aquifers: These are layers of rock or drift deposits that have high intergranular and / or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and / or river base flow on a strategic scale. Formerly referred to as Major Aquifers.

Secondary Aquifers: These include a wide range of rock layers or drift deposits with an equally wide range of water permeability and storage. Formerly referred to as Minor Aquifers. Secondary Aquifers are subdivided into two types:

> **Secondary A** - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
>
> **Secondary B** - predominantly lower permeability layers that may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

Secondary Undifferentiated: This designation has been assigned in cases where it has not been possible to attribute either category Secondary A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both Minor and Non-Aquifer in different locations due to the variable characteristics of the rock type.

Unproductive Strata: These are rock layers or drift deposits with low permeability that has negligible significance for water supply or river base flow. Formerly referred to as Non-Aquifers.

1.4.6 Source Protection Zones

We also need to protect drinking water abstractions from sources of pollution. We have delineated three protective zones around the supply borehole. The zones are defined as follows:

SPZ1 – Inner source protection zone: Defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.

SPZ2 – Outer source protection zone: Defined by a 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source, depending on the size of the abstraction.

SPZ3 – Source catchment protection zone: Defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the SPZ3 can be defined as the whole aquifer recharge area where the ratio of groundwater abstraction to aquifer recharge (average recharge multiplied by outcrop area) is >0.75.

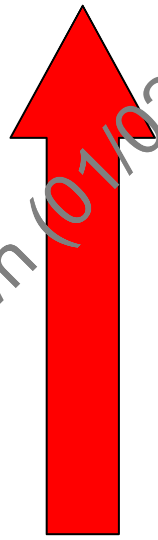
1.4.7 Other groundwater receptors

Other key receptors include:

- Water Protection Zones (WPZs)
- Drinking Water Protection Zones (DrWPAs) and Safeguard Zones (SgZs)
- Groundwater dependent ecosystems (GWDTE)
- Interactive groundwater-surface water systems

The overall risk to groundwater[4] is illustrated in Box 1.1

[4] You may have to consider other receptors not related to groundwater – see Annex A Amenity & accident risk from installations and waste activities (Environment Agency 2011)

Box 1.1 Generic risk to groundwater	
Groundwater receptor	**Increasing risk**
SPZ1	
SPZ2, SPZ3, WPZs, SgZs, Principal Aquifers, GWDTEs. Within 10 m to 50 m of groundwater fed-surface waters	
Secondary A, Secondary B Aquifers. Other dependent ecosystem and other groundwater-surface water receptors.	
Unproductive Strata.	

1.4.9 Construction (if applicable)

Construction or engineering aspects of the activity may need to be considered as part of the permit application. If the construction, engineering or operation has been put in place to control the activity, then we require:

- details (plans and cross sections) of the relevant designs;
- a description of how the quality of the construction or engineering has been or is to be controlled (e.g. Building Regulations certificates or Construction Quality Assurance).

1.5 Operation and Management

You need to tell us how you intend to operate and manage your activity and stay within the conditions on the permit. This will include any site-specific environmental mitigation measures to ensure your activity does not cause pollution. We will periodically review all permits.

1.6 Finding information

Except in cases where we have said we will do the risk assessment, you will be required to undertake your own risk assessments and therefore will be responsible for gathering and assessing the necessary data, even where these data are obtained from Environment Agency sources. In the following sections, we have set out the information that may be required as part of your risk assessment. Some of this may only be available through site investigation and monitoring, but to help you with the remaining requirements, we have set out some suggested sources of information in Section 5.1.

Chapter 2 Legislative background

2.0 Introduction

This chapter provides you with background information on why there is the need to undertake a groundwater risk assessment, how we use the results, and some of the broad principles of risk assessment process.

The purpose of a risk assessment is to assess the location of an activity, its design, operation and long term effects and to achieve a reasonable balance between the measures required and the need to protect the environment. Without our risk based approach, the issuing and review of permits would be impractical and excessively costly. GP3 (Environment Agency, 2006-2012) clearly sets out our position in terms of taking a risk based approach to protecting groundwater.

2.1 Requirement for a risk assessment

The need for groundwater risk assessment in support of permit applications links back to European Directives and is implemented in England and Wales via EPR. Some key legislation and additional guidance is summarised in Box 2.1

Box 2. Legislation and additional guidance

European Directives

The need for certain activities to be controlled by a permit comes from a number of European Union (EU) Directives including the Landfill Directive (99/31/EEC), "Mining Waste" Directive (2006/21/EC) and Water Framework Directive (2000/60/EC). The requirements for a groundwater risk assessment are driven by the Water Framework Directive (WFD) and its daughter Groundwater Directive (2006/118/EC) (GWDD).

Common Implementation Strategy for the EU Water Framework Directive

The European Commission's Common Implementation Strategy (CIS) for the Water Framework Directive Guidance Document No 17 (European Commission, 2007) gives guidance on the legislative framework, general principles, and definitions relating to 'pollution', and 'preventing direct inputs of hazardous substances' and 'limiting indirect inputs of non hazardous pollutants' in the context of the Groundwater Directive. The CIS 17 guidance also discusses 'conceptual hydrogeological models, compliance points and exemptions. The key elements of this terminology have been included in this document

River Basin Management Plans (RBMPs)

Article 4.1(b)(i) of the WFD requires the implementation of measures necessary to prevent or limit the input of pollutants into groundwater. Article 11 of the WFD requires a programme of measures to achieve this Article 4 objective and Article 11(3) requires "basic measures" which are the minimum measures that will be adopted in the programme of measures within 'River Basin Management Plans'. Article 11(3)(g) requires measures to control point source discharges and the measures to be adopted to control these in England and Wales are the Environmental Permitting Regulations (2010). The prevent or limit approach as set out in the Groundwater Directive 2006/118/EC has been applied to all discharges.

The Environmental Permitting Regulations (EPR)

The EU Directives' requirement to control certain activities using permits has been brought into force in England and Wales most recently for installations by the Environmental Permitting (England and Wales) Regulations (2007) and for all other groundwater activities by the Environmental Permitting (England and Wales) Regulations (2010). Section 7 of Schedule 22 (see Box 2.2) of these latest regulations sets out the requirement for groundwater risk assessment.

2.2 Specific regulatory requirements

EPR sets out what the Environment Agency must do when we receive an application for an environmental permit (see Appendix A5). We will also have to follow this process when reviewing existing permits.

2.3 What is groundwater pollution?

There is a legal definition of pollution from EPR (2010):

"pollution", in relation to a water discharge activity or groundwater activity, means the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may—
(a) be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems,
(b) result in damage to material property, or
(c) impair or interfere with amenities or other legitimate uses of the environment;

Protecting groundwater from pollution means, in very simple terms, preventing the activity from causing deterioration in the quality of the groundwater to an extent that would lead to a harmful effect at an existing or potential future receptor. That receptor could be, for example, an existing spring, wetland or groundwater-fed river, or could be an existing or future borehole or well, including your own or that of your neighbour. We may also wish to protect the resource potential of groundwater (see also GP3 Part 4. (Environment Agency, 2012).

2.4 Hazardous substances and non-hazardous pollutants

We are concerned with concentrations of both hazardous substances and non-hazardous pollutants.

The former Groundwater Directive 80/68/EEC (GWD) defined two lists of substances that were deemed to pose the greatest risk to groundwater from point sources. These were referred to as List 1 and List 2, with substances on List 1 being of most concern. The Water Framework Directive (WFD) and Groundwater Daughter Directive (GWDD) consider a wider range of potential pollutants, referred to as hazardous substances and non hazardous pollutants. This terminology is used in EPR and further details are provided below:

2.4.1 Hazardous substances

Hazardous substances are defined in the WFD as "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern"

Unlike the generic Lists 1 and 2, EPR will only specify 'hazardous substances' as being toxic, persistent and liable to bioaccumulate. We are required to publish a list of hazardous substances and the Joint Agencies Groundwater Directive Advisory Group (JAGDAG) will be the body that confirms these determinations. All former List 1 substances are considered to be hazardous substances. All radioactive substances are classed as hazardous substances.

2.4.2 Non-hazardous pollutants

A non-hazardous pollutant is any substance capable of causing pollution that has not been classified as a hazardous substance. The non-hazardous list of substances does not simply replace the old List 2 substances; it now includes any substance that is capable of causing pollution that is not classified as hazardous. For example, nitrate is a non-hazardous pollutant; however it was previously not a listed substance.

2.5 Direct and Indirect inputs

2.5.1 Definitions

Input: An input is any entry of a substance into groundwater from an activity or discharge, whether accidental or deliberate, point source or a diffuse source, that causes a release of a pollutant into groundwater.

Inputs can be direct or indirect:

Direct inputs can be identified by one of the following properties:

- They bypass the unsaturated zone.
- The pollution source is in the saturated zone (or discharges directly in the saturated zone).
- Seasonal fluctuations in the water table mean that the pollution source will be in direct contact with groundwater, for a significant period of time.

Indirect inputs are characterised by the discharge into groundwater after percolation through the soil or subsoil (the unsaturated zone).

2.5.2 Discernibility and prevent and limit

Discernibility: The GWD states that all measures necessary to prevent the input of any hazardous substance into groundwater must be taken. One of the criteria that defines "prevent" is that the substance being discharged is not **discernible** in comparison to either the natural background concentration of groundwater or a Minimum Reporting Value (MRV) if this is at a higher concentration.

European Commission guidance (WFD CIS Guidance Document 17, European Commission, 2007) also notes that:

1. All necessary and reasonable measures shall be taken to prevent the input of hazardous substances to groundwater by avoiding the entry of those substances into groundwater and by avoiding any significant increase in their concentration in groundwater even at a local scale[5];
2. The input of all non-hazardous pollutants to groundwater shall be restricted (limited) to ensure that such inputs do not cause deterioration in status or significant and sustained upward trends in pollutant concentrations in groundwater and ensure that pollution of groundwater does not occur.

An input of hazardous substances would be prevented if:

- There is no discernible concentration in the discharge, or
- There are no discernible concentrations of hazardous substances attributable to the discharge in groundwater immediately down-gradient of the discharge zone, subject to adequate monitoring (or in the case of new discharges a detailed predictive hydrogeological impact assessment), or
- There are (or are predicted to be) discernible concentrations in the groundwater down-gradient of the discharge zone attributable to the discharge but all of the following conditions apply:
    - Concentrations will not result in any actual pollution or a significant risk of pollution in the future; and
    - There will not be any progressive increase in the concentration of hazardous substances outside the immediate discharge zone, i.e. there will be no statistically and environmentally significant and sustained upward trend or significant increasing frequency in pollutant "spikes"; and

[5] As preventing the entry of a substance into groundwater is normally a much more restrictive requirement than preventing pollution by that substance, it is taken as read that by preventing entry, pollution is avoided.

- There is evidence that all necessary and reasonable measures to avoid the entry of hazardous substances into groundwater have been taken (see below).

It is technically difficult to demonstrate that no hazardous substances will enter groundwater. There is always a lower reporting limit for analyses. The practical interpretation of no discernible discharge is that hazardous substance concentrations must not exceed the Minimum Reporting Values (MRVs) at the point of compliance (see above). The presence of any hazardous substances should be environmentally trivial. A large amount of dilution at the water table cannot make a potentially significant hazardous substance loading 'not discernible'.

2.5.3 Necessary and reasonable measures

Assessment of necessary measures must be preceded by investigation to determine pathways and is a site-specific judgement.

A reasonable measure would be one where the necessary technical precautions to prevent inputs to groundwater are technically feasible, not disproportionately costly and are within the control of the operator. Such measures could include: source control, alteration of discharge mechanism, treatment of the discharge, interception or diversion of contaminated groundwater, and diversion to another disposal route. In addition any measures taken should not result in a net environmental disbenefit.

If there is actual pollution, or a substantial risk of such pollution, remedial measures must be taken. Cost-benefit assessment is not a factor in deciding whether to take action in such cases but may be a consideration in determining which precautions will be imposed as conditions on a permit.

2.5.4 Pollution by non-hazardous pollutants

To avoid pollution by non-hazardous pollutants we must limit inputs of these pollutants into groundwater to ensure that:

- There is no deterioration in the status of the groundwater body;
- there is no significant and sustained upward trend in the concentrations of pollutants in groundwater;
- the concentrations of pollutants remain below a level such that harm to a receptor does not occur, or that local maximum allowable concentrations (such as quality standards to protect the groundwater resource) are not exceeded.

Chapter 3 The risk assessment approach

3.1 Technical framework for risk assessment

Our approach in this document and the supporting groundwater annexes (see Figure B) are consistent with the technical framework as set out in GP3 Part 2 (Environment Agency, 2006), which is based on the Government's Guidelines for Environmental Risk Assessment and Management (Defra 2011) and includes:

- The source[6]-pathway-receptor approach.
- A conceptual model.
- A tiered approach from qualitative risk screening to detailed quantitative risk assessment.
- Identifying sources or potential hazards, examining consequences and evaluating the significance of any risk.
- Dealing with uncertainties and sensitivity analysis.
- Risk management.

The experience and effort that needs to be used to meet these requirements depends on the activity's source term, the potential receptors and the hydrogeological complexity of the area in which the activity and the potential receptors are situated.

3.2 Source-pathway-receptor approach

For a groundwater risk assessment, the source-pathway-receptor approach has the following terms:

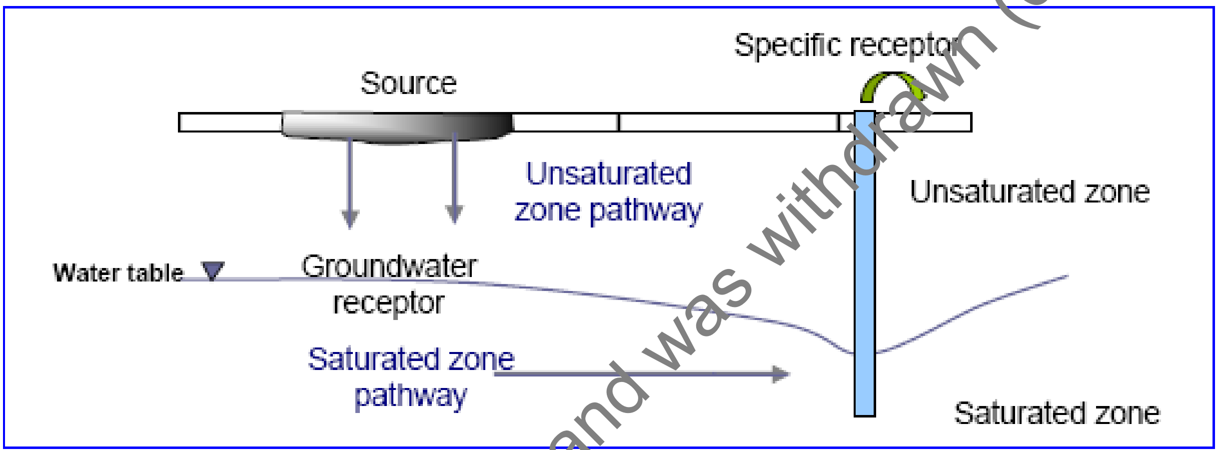
- The **source** is the activity (for example, the discharge of sewage effluent to an infiltration system, a landfill, etc.).
- The **pathway** is through engineered measures (for example, a landfill lining system, infiltration system, etc.) and the migration of contaminants through the unsaturated zone and saturated zone to an agreed receptor incorporating all the processes of attenuation that may be present.
- The **receptor** is a groundwater dependent ecosystem or use of groundwater and / or the groundwater resource itself or any other identified conservation site that may be at risk (such as a Site of Special Scientific Interest (SSSI)).

[6] The term 'source' is also referred to as the 'hazard'.

Further details on these three elements of a groundwater risk assessment and how they should relate to a groundwater conceptual model are set out in this chapter. Figure 2.1 illustrates the source-pathway-receptor approach (see also Figure 3.2).

For more information please refer to Government's Guidelines for Environmental Risk Assessment and Management (defra, 2011)

Figure 3.1 The source-pathway-receptor approach



3.3 The source term

The source term relates to the activity. This could be, for example, a discharge of treated sewage effluent to ground or a landfill. Depending on the type of activity reference should be made to the sector specific annexes (see Figure B for more detail).

3.3 The pathway term

As noted in Appendix A5 a permit may not be granted without examination of the hydrogeology of the site. A basic understanding is required before likely receptors can be identified, and this means that there is some iteration in the process (the greater understanding of the hydrogeology, the clearer it will be whether existing receptors could receive groundwater), and the clearer will be the need or not for detailed information on the 'purifying powers of the soils and subsoil' (Appendix A4). It is likely that site investigation and monitoring (Appendix A1) will be required.

Annex J Groundwater

More detailed guidance on the information we will need for the pathway term is provided in the sector specific annexes. This is based on our understanding of different activities' source terms and their potential to pollute groundwater. The main aspects of the pathway term that we usually need are:

- effective rainfall, and recharge;
- drainage, flood risk and surface water features;
- relevant geology and hydrogeology;
- character and importance of the aquifer through which any pollutants could move from beneath the activity to potential specific receptors;
- direction, rate and speed of groundwater flow;
- attenuation and dilution processes that could reduce the pollution potential of your discharge as its water moves downwards and laterally to potential receptors.

Further guidance on these aspects is set out in the sub-sections below.

3.3.1 Effective rainfall and recharge

Some of the precipitation (rainfall, snow, etc.) that falls in the area of the activity is lost due to evaporation and transpiration (collectively known as evapotranspiration) by plants (where the area of your discharge is vegetated). The remainder is termed effective rainfall. Some of this, particularly during heavy rainfall can run-off the top of the land surface (or landfill cap) into ditches and streams, the remainder is infiltration.

Infiltration to the ground (or through a landfill cap into solid wastes) can be intercepted by drains or move laterally on top of low permeability layers as interflow to streams and rivers (or artificial collection systems in a landfill) or becomes recharge to the underlying aquifer.

The groundwater risk assessment needs to point out whether effective rainfall is important for the activity and if so the quantity (for example in mm / yr) that becomes recharge, without neglect of any surface water run-off and pollution risks.

3.3.2 Drainage, flood risk, surface water features

So we can see how the location of the activity fits within the local network of streams and rivers, we need you to collate the following:

- A description of the surface water features (wetlands, ditches, streams, rivers, estuaries or coastal waters) that may influence or interact with groundwater flowing from beneath the site (or that could receive drainage from your discharge area). It will be useful to refer to the map and / or plan used for location.

- Where any of the surface water features are identified subsequently as a likely receptor for potentially polluted groundwater, then we need:
- Likelihood or evidence for or against hydraulic continuity between groundwater and surface water.
- Stream and river water quality information (for example chemical and biological status).
- Flood risk and presence of indicative flood plains. Flooding could lead to contamination of surface waters or more rapid movement of pollutants to groundwater.

3.3.3 Geology and hydrogeology

Understanding the ground conditions beneath the activity is one of the most important parts of a groundwater risk assessment.

The unsaturated zone is where (ideally) the concentration of all hazardous substances or non-hazardous pollutants in any discharge should be reduced to below detectable levels before it enters groundwater (the saturated zone). In addition, the concentration of all substances should have been sufficiently reduced so as not to cause pollution after mixing with that groundwater.

The purifying powers of the soil and sub-soil are a very important consideration (Appendix A3).

We will most commonly need:

- A description of any engineered barriers in terms of their nature (for example, clay) and thickness separating the discharge from underlying natural ground or historically placed fill. Examples include landfill liners and sand filters beneath infiltration systems.
- A description of the groundwater vulnerability. Groundwater vulnerability is discussed in more detail in GP3 Part 2 (Environment Agency 2006).
- Logs of boreholes (or wells) or excavations (for example, trial pits) that have been constructed in the vicinity of your discharge, and that provide details on what lies beneath. The locations of these boreholes should be shown on a plan of the site and the logs should be appended to the risk assessment so that we can check their quality.
- A description (geological nature and thickness) of the soils (including fill material), strata and / or rocks separating the activity from the groundwater. This should be first from the perspective of what is shown on regional maps (normally 1:50 000 scale from the British Geological Survey) and secondly using logs from any boreholes or excavations in the vicinity of the activity. It is important to describe the spatial variability in the location, nature or thickness of such strata, and this is best facilitated through inclusion of a geological map and cross section(s) in the groundwater risk assessment.

- A description of any man-made and karst or karstic features that could provide rapid pathways between the activity and groundwater. Examples of man-made features include unsealed boreholes and wells, foundations and piles from buildings and structures, and mine shafts. Karst features include sink holes, pipes, large fissures and cave systems.
- Information on the thickness of the unsaturated zone. For some activities, measurements of water levels in wet and dry periods will be needed from boreholes or wells. Seasonal variations are often important for specific types of aquifer, for example: Chalk.
- Where the risk assessment needs to progress to quantitative assessment (Chapter 4) then information will also be required on the moisture content of the unsaturated zone and saturated effective porosity of the different soils and rocks.

3.3.4 Character and Importance of the aquifer

Geological strata and rocks differ markedly in their capacity to, and the way they, transmit water to springs, wells, boreholes and rivers. Locally their importance in providing water to receptors also varies. This character and importance of the aquifer needs to be defined through describing:

- Their general capacity to transmit water (as mapped on our website). Those with the best or good capacity are described as Principal Aquifers or Secondary A or B Aquifers respectively, whilst those with little or no capacity are Unproductive Strata.
- Water features survey: The details of private and licensed groundwater abstractions in the vicinity of the proposed activity including their location on a map, their use (for example, public water supply, livestock watering, etc.) and the rate at which they are licensed to abstract. The search radius for these will depend on the activity, but typically should be ~1 km radius from your discharge area. Where the geology and hydrogeology of the area is layered, it will also be necessary to ascertain the construction details of wells and springs to check whether the abstraction is from a shallow vulnerable layer or deeper, confined and protected layer. A water features survey should also include information on surface water receptors.
- Whether they transmit water by intergranular flow, fracture flow or by both dual porosity flow.
- The presence of any geological layering or preferential pathways (for example, faults) within the strata that could affect flow and mixing.
- The background quality of the water. For some assessments, monitoring data from boreholes around the proposed activity will be required to support the descriptions. See also Appendix A1 on groundwater monitoring network.

These factors help identify whether the aquifer is important and sensitive to pollution.

3.3.5 Direction and rate of groundwater flow

The direction and rate (groundwater flow velocity[7]) are important at constraining in which direction receptors may be at risk, the ability of the underlying groundwater to dilute the concentrations of any pollutants, and the rate at which any residual pollutants could move towards the receptors. We therefore need to know:

The direction of groundwater flow, based where possible on gradients derived from water level measurements in boreholes, but in the absence of these from published maps and then least preferably by inference – groundwater usually flows naturally from hills to rivers. Account should be taken of whether the activity will affect the natural flow gradient and whether the direction of groundwater flow may change seasonally. Potential future influences on the direction of groundwater flow from minewater rebound (the flooding back of deep mines), cessation of quarry dewatering, or changes in borehole abstraction regimes. Any information should be updated accordingly.

See Chapter 4 for more information on the processes that may operate in the unsaturated and saturated zone.

3.4 The receptor term

We have a general duty to protect all groundwater, but in line with GP3 (Environment Agency 2006-2012) we use our assessment of the importance of the groundwater for current and future use to assess the degree of protection needed and inform our decisions on permitting.

While the focus of a groundwater risk assessment is on groundwater receptors or surface waters that receive groundwater discharges, the risk assessment should not neglect possible risks to surface water by run-off of contaminants or flooding caused by the activity.

Collating and recording information on receptors should be relatively straightforward using the guidance below, and the sensitivity of groundwater around the activity will often influence how much effort and (more costly) investigation needs to go into describing the pathway term.

However, without understanding in which direction groundwater flows from beneath the site, you cannot identify which specific receptors around your site could be affected. Consequently, you would have to be conservative and assume any of them could be affected, and we would then have to be conservative and use the most sensitive ones.

[7] It is recommended that this should be ascertained by a hydrogeologist

Sometimes the assessment of the activity's source term and / or pathway may demonstrate that the risk to any groundwater is very low and there are few uncertainties in the assessment. In these cases, collation and reporting of details on potential receptors will be unnecessary. Possible examples include where it has been shown that the substances in your discharge are highly unlikely to pass through the soil beneath your site or the activity is taking place on Unproductive Strata.

Elsewhere, where there is a potential risk to groundwater and specific receptors, we need to assess the protection to receptors through use of compliance points. These are discussed further in Section 4.2 and more detail can be found in the sector specific annexes.

3.4.1 Sensitivity of groundwater

For a groundwater risk assessment, we need to know the aquifer designation and whether the site lies within an SPZ (see sections 1.4.5 and 1.4.6 for more information).

3.4.2 Identifying specific receptors

In evaluating the risks from the activity and deciding whether the activity can be permitted, we also need to consider the potential impact on nearby specific receptors. Some of these are given below:

- **Nature conservation sites and groundwater dependent ecosystems** (Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar, Site of Special Scientific Interest (SSSI), National Nature Reserve (NNR), Local Nature Reserve (LNR), Ancient Woodland and Local Wildlife Site), ecological status and use of the relevant water courses or wetlands (for example, SSSI wetland, salmonid fisheries, source of agricultural or public water supply).
- **Springs, wells and boreholes** providing drinking water or water for agricultural and industrial use. This should include any Private Water Supplies.
- **Surface waters** that interact with groundwater.

Such specific receptors can be present currently, but the risk assessment also needs to consider the potential future use of groundwater. The evaluation of the potential future use should include a discussion with us of:

- resource potential (yield and quality);
- planned exploitation;
- likelihood and feasibility of water resource development.

3.5 Conceptual model

With the identification of a source-pathway-receptor you will need to develop a site conceptual model.

In order to assess whether pollution would occur as a result of the activity, it is necessary to develop a conceptual model and an understanding of all the relationships between sources, pathways and receptors within their wider hydrogeological setting.

The European Commission CIS Guidance Document 17 on the WFD CIS17 (European Commission, 2007) sets out the key considerations for a conceptual hydrogeological model (see Box 3.1). Further background reading in addition to the guidance provided in the following sections is given in our "Guide to good practice for the development of conceptual models and the selection and application of mathematical models of contaminant transport processes in the subsurface" (Environment Agency, 2001).

Box 3.1 CIS guidance on conceptual models

CIS17 (European Commission, 2007) notes that a conceptual hydrogeological model should aim to describe:

"1. the physical and chemical nature of the discharge or source of contamination (installation or contaminated part of the subsurface);

2. the physical and chemical characteristics of the aquifer;

3. the subsurface processes, e.g. dilution and degradation, that act on the pollutant as it moves down towards the water table or moves within the groundwater flow;

4. the location of all the receptors and their relationships to groundwater flow; and

5. the environmental standards (for water quality) that apply to the receptors and by which harm can be measured, as well as criteria for groundwater ecosystem.

A conceptual hydrogeological model is therefore the schematisation of the key hydraulic, hydro-chemical and biological processes active in a groundwater body. This characterisation is essential for an understanding of the basic physical, chemical and biological processes influencing groundwater quality. As pollutants often travel through the unsaturated zone to reach groundwater, the processes acting on pollutants in the unsaturated zone should also be included where appropriate."

Further information on developing conceptual models is available in our related guidance (Environment Agency, 2001, 2002), in GP3 (Environment Agency (2006) and in CIS17 (European Commission, 2007).

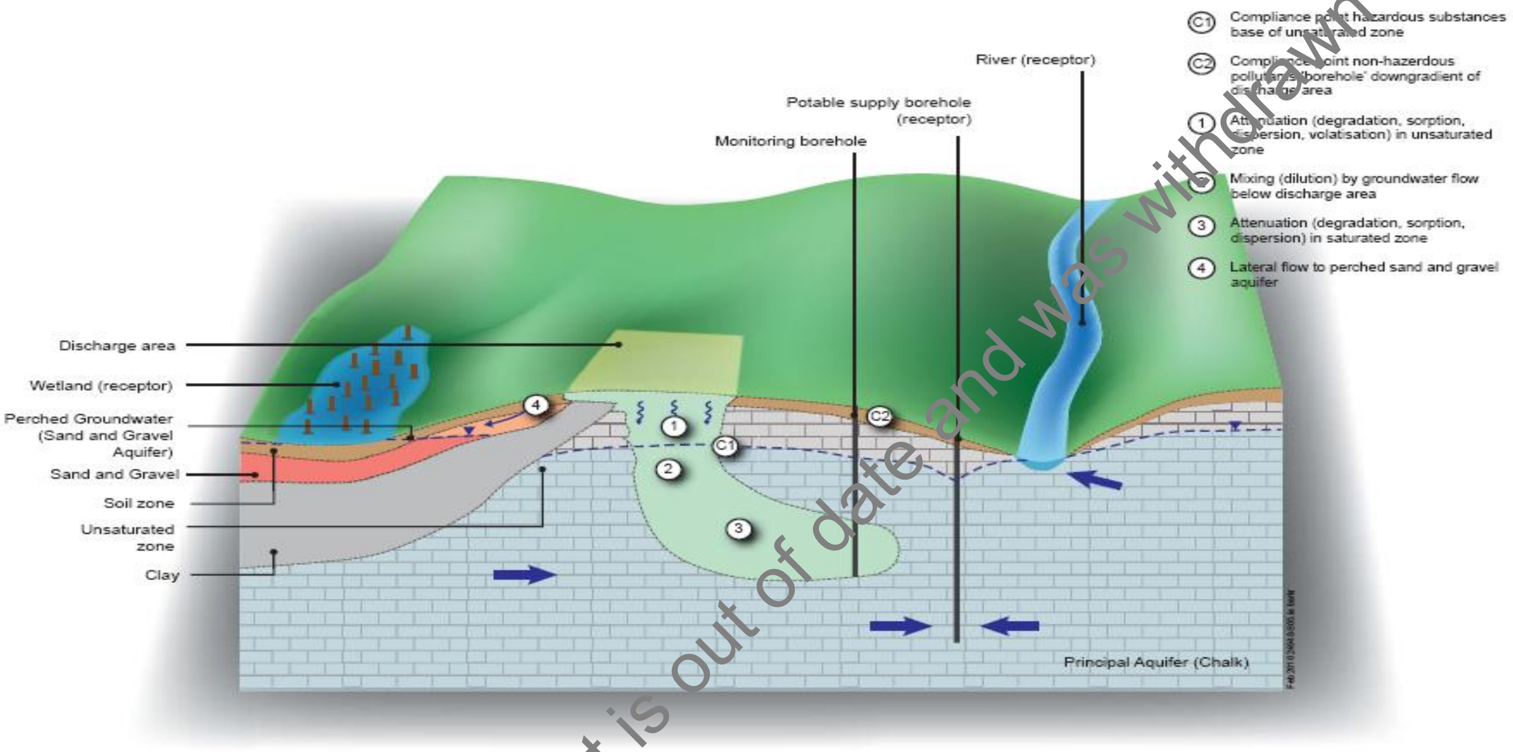
If necessary, any initial conceptual model should be updated and refined accordingly throughout the assessment or ongoing activity as more site specific data becomes available or parameters change.

Having collated and described the information on the activity's source-pathway-receptor pollutant linkages, the hydrogeological conceptual model should explain and illustrate how these all connect in terms of what happens between the point of discharge from the source to identified receptors.

One of the clearest ways of demonstrating the understanding of your hydrogeological conceptual model is to illustrate how water moves and the attenuating processes on an annotated hydrogeological conceptual model plan / map and cross section. The cross section should be orientated in the direction of groundwater flow. Figure 3.2 gives an example of a typical annotated hydrogeological conceptual model.

Where there is continuing uncertainty on key pollutant linkages we may have to make conservative assumptions and be more precautionary in our assessment of the suitability of your activity for permitting.

Figure 3.2 Typical annotated hydrogeological conceptual model



Chapter 4 Risk Assessment Approach

4.1 Introduction

Having described your activity and its setting, and developed a conceptual hydrogeological model (of where water from your discharge will go and the attenuating processes that are likely to occur), the source-pathway-receptor aspects and links of your activity will have been defined. The next step is to undertake the risk assessment itself. Our approach to tiered risk assessment is based on 'Guidelines for environmental risk assessment and management' (Defra, 2011).

4.2 Tiered approach

Some activities will be low risk and will normally be dealt with by us. With increasing complexity and site sensitivity we would expect more detailed information. This is why we adopt a tiered approach to assessing the risks.

A **tiered approach** is needed so that the cost, time and effort in undertaking a risk assessment are proportional to the effort or measures required to make the risks from an activity acceptable. The three tiers are:

Tier 1. Qualitative risk screening (QRS)

Tier 2. Generic quantitative risk assessment (GQRA)

Tier 3. Detailed quantitative risk assessment (DQRA)

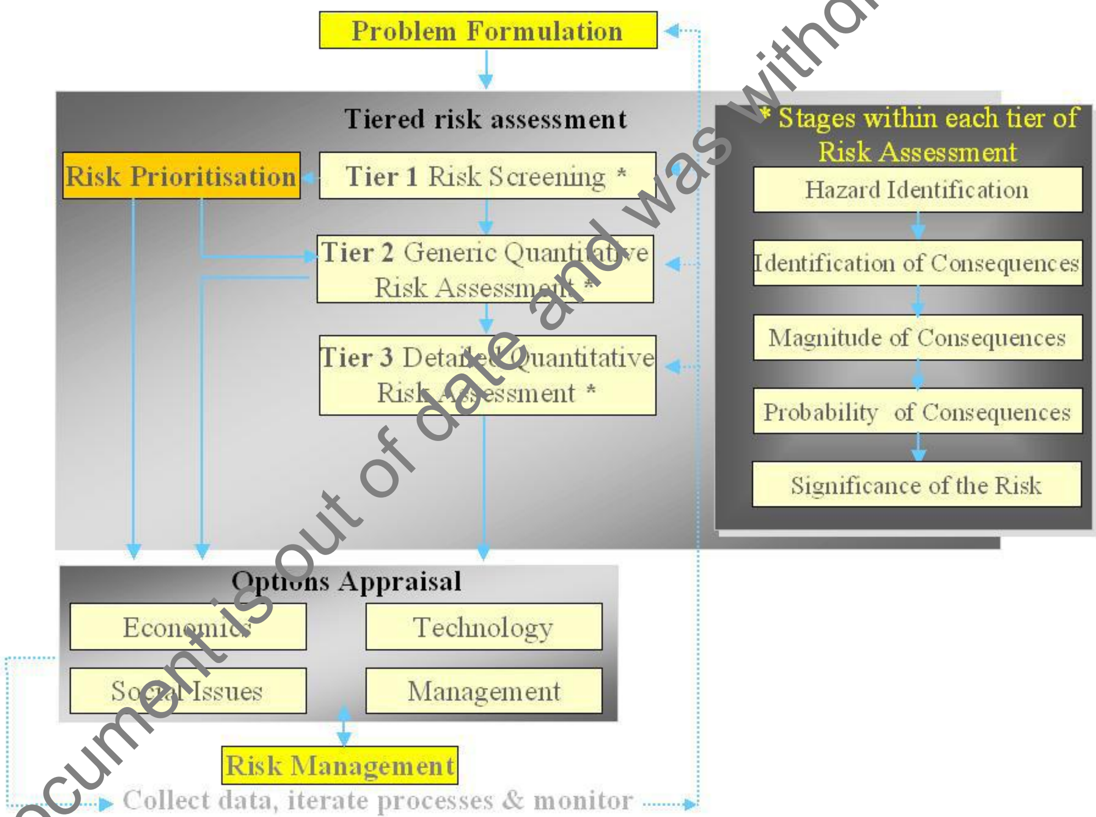
The tiered approach to risk assessment should ensure that the effort required is consistent with the complexity of your activity and its setting, uncertainties, the potential risks to groundwater and the consequences of polluting groundwater (and affecting other receptors). The assessment should be as simple as these factors allow and summarised in the conceptual model.

The location of the compliance points (Section 4.6) for the activity will also significantly affect the effort involved in the risk assessment. For example, if you can demonstrate a low risk of a chemical passing through the soil, such that you would achieve compliance with the risk assessment criteria then detailed quantification of the risks for movement of that particular chemical through underlying layers will be unnecessary.

If conservative assumptions have been made about some aspect(s) of the activity or its setting, then the initial assessment of risks may be unsatisfactory. This then either leads to revising assumptions on (stricter) operational control, more data collection or more detailed (less conservative) risk assessment. Some iteration of the risk assessment is therefore likely.

Even for the same type of activity, the effort will increase if groundwater is sensitive or the consequences of pollution are serious.

Figure 4.1 Our approach to tiered risk assessment based on 'Guidelines for environmental risk assessment and management (Defra, 2011)



4.3 Qualitative risk screening (and prioritisation)

Qualitative risk screening helps work out whether the activity needs more detailed assessment and if it does, what the most important aspects for further evaluation (risk prioritisation) are.

As specified earlier, in certain cases we will carry out the initial risk screening process for you. In all other groundwater activity cases, you will need to include a risk screening section in the risk assessment, which considers factors such as those set out in Box 4.1. Qualitative risk screening should be carried out by appropriately qualified persons.

Box 4.1 Examples of Factors as basis of risk screening

From a qualitative assessment of the site, can the discharge be shown to be acceptable based on one or more of the following?

- The discharge has concentrations of hazardous substances in accordance with what is discussed in Chapter 2 or the natural background level in groundwater (whichever is the higher concentration).
- The discharge has concentrations of non-hazardous pollutants less than the relevant environmental standard or natural background level applicable to the receiving groundwater.
- The presence of unproductive drift or unproductive bedrock strata (there are no aquifers present or near your activity) and remoteness from surface waters means that risk to any identified groundwater fed receptor is very low.
- The volume or hydraulic loading rate of the discharge is very small such that only minimal dilution in underlying groundwater will be required to avoid pollution by non-hazardous pollutants.

The output from the risk screening assessment should be:

- Justification of the level of risk assessment to be used;
- Prioritisation of the more important source-pathway-receptor linkages for further (simple or complex risk assessment) evaluation (if appropriate).

Further guidance on deciding whether simple or complex risk assessment will be appropriate for your activity and its setting is set out in the sections below. It is recommended that suitably qualified persons undertake more complex risk assessments on your behalf.

4.3.1 Scoping calculations

The potential risks to a receptor can be evaluated, at least initially as part of a qualitative risk assessment, by carrying out some basic calculations. Using conservative, or well-supported, data inputs, these scoping calculations may be sufficient to demonstrate the risk to the receptor(s) is acceptably low. We recommend that you make these calculations, before undertaking more complex calculations or modelling because they:

- may be adequate for a qualitative risk assessments and negate the need for further calculations or modelling in a more complex risk assessment;
- are transparent in demonstrating the key factors affecting risks;
- are straightforward to audit / check;
- provide an indication of what more complex calculations or probabilistic modelling should produce.

Our recommended basic scoping calculations are set out in the accompanying sector specific guidance (see Figure B)..

To save unnecessary effort, we recommend you undertake your calculations in the following order and only move to the next stage for a selected substance when you have checked if the factor or combined factor would not reduce the concentration of hazardous substances and non-hazardous pollutants to acceptable concentrations:

Calculate the dilution factor for the discharge diluted by groundwater flowing in the mixing zone beneath the site.

Calculate the attenuation factor for each of your selected substances for downwards movement from your discharge to the point of arrival in groundwater beneath the site. It will often be sensible to calculate separate attenuation factors for movement through different layers (for example, soil, drift, unsaturated bedrock) where these have different properties and where confidence in their properties varies due to data availability.

4.4 Generic quantitative risk assessment

A generic quantitative risk assessment (Tier 2) should be carried out when the previous qualitative risk screening (Tier 1) is insufficient for us to make an informed decision on the risk posed by the site. This approach can be used when the potential source, pathway and receptor terms can be defined with sufficient certainty as to be confidently represented by conservative assumptions. This includes activities where the source can be well defined and the known properties of the soil are sufficient to reduce risks to underlying groundwater to low regardless of uncertainties in the thicknesses and properties of underlying strata.

Basic quantitative risk assessments will typically use conservative assumptions as input values to relatively simple scoping calculations of, for example, dilution, unretarded and retarded travel time, and attenuation factor.

If the receptor has been agreed with us to be at some lateral distance from your discharge, rather than the groundwater resource beneath your site, then calculate the attenuation factor for lateral movement to this receptor.

These calculations can easily be done in a spreadsheet such as Microsoft Excel. This approach allows you to test the sensitivity of the predicted risk to changing input values and can therefore be used for sensitivity analysis (see Section 4.10). If you have set up such a spreadsheet, we will typically ask you to provide us with an electronic copy of the spreadsheet to allow us to check your approach and undertake our own sensitivity analysis

4.5 Detailed quantitative risk assessment

Detailed quantitative assessments should be carried out where it is clear that there are definite source-pathway-receptor linkages in particular where:

- The **site setting is sensitive** – for example, on permeable strata (such as Principal or Secondary A Aquifers), within an SPZ or close to sensitive surface water bodies;
- The **uncertainty** in aspects of the source, pathway and receptor terms cannot be overcome using conservative assumptions, because those assumptions lead to an unsatisfactory outcome in terms of risks to groundwater.

A detailed quantitative risk assessment will typically use a probabilistic approach to assess the impact of uncertainties in input data (often being provided by site investigations). They may also be needed where the quantity and quality of your activity's discharge may change significantly through time (as is the case with non-inert landfills).

4.5.1 Groundwater properties

For more detailed quantitative risk assessment we will need:

- the hydraulic gradient in the direction of groundwater flow (and whether this changes seasonally or is affected by your discharge);
- the cross flow width of your discharge, (the width of the area over which your discharge occurs measured perpendicular to the direction of groundwater flow);
- the saturated thickness over which groundwater flows laterally;

- the mixing zone depth over which any pollutants from your discharge are diluted;
- the hydraulic conductivity (permeability) and effective porosity of the aquifer;
- the groundwater flow rate in the mixing zone, calculated as the product of the hydraulic gradient, cross flow width, mixing zone depth and hydraulic conductivity.
- the groundwater flow velocity for water moving from beneath your site, calculated as the product of the hydraulic gradient and hydraulic conductivity divided by the effective porosity.

4.5.2 Attenuation processes and dilution

Once the way water moves down to the water table and then away from your discharge has been understood, then the natural processes that could reduce the concentration of hazardous substances and non-hazardous pollutants need to be examined. Examination of these processes fulfils the legislative requirement (see Appendix A5) to examine "the possible purifying powers of the soil and subsoil" (Appendix A4).

Many of these processes affect different substances to different extents and also vary between different soils and substrata and different settings (for example, in the hyporheic zone around streams and rivers). This part of the risk assessment therefore needs to focus on the main processes that will affect the substances in the discharge as the discharged water migrates down and laterally beneath your discharge area. Processes that the risk assessment could consider include:

- **Physical** processes such as volatilisation, filtration, dispersion, dilution;
- **Chemical** processes such as precipitation, sorption, retardation, oxidation, reduction, hydrolysis;
- **Biological** processes such as nitrification, biodegradation.

It is important to note that although physical and chemical processes may occur throughout the movement of the discharged water, biological activity and processes become much less significant below the soil zone and away from the hyporheic zone.

4.5.3 Probabilistic calculations

The simplest form of probabilistic calculation of risks is to use a range of pessimistic, likely and optimistic input values in scoping calculations to illustrate what the outcome might be under the combination of these. Getting an acceptable result with all pessimistic values combined[8], suggests a low risk; getting an unacceptable result with all optimistic values, suggests a very high risk that will not be reduced without risk management. A mixture of answers suggests you need to do probabilistic calculations.

Probabilistic calculations use ranges of realistic input values, with an informed assumption of the distribution (e.g. normal, log normal) of values within the range, to produce a distribution of output values. We have produced guidance (Environment Agency, 2001) on assigning distributions to uncertain parameters.

Probabilistic calculations can be set up by using add-ins to spreadsheets such as the Crystal Ball™ add in Microsoft Excel, but we have also developed probabilistic tools for use with some activities. Our supporting sector specific annexes give further advice on probabilistic tools suitable for those activities. Some commercial organisations have also developed risk assessment models using the same principles.

In terms of judging the acceptability of the range of output values produced by this approach, we will normally expect the 95th percentile concentration to meet acceptable concentrations. This means that the concentration predicted in 95% of all calculations / model runs, which use sensible and justified ranges of input data and have a sound underpinning hydrogeological conceptual model, should be lower than an agreed target concentration. In sensitive settings, we may be more precautionary and require a higher percentile value (for example, the 99th percentile) to be acceptable.

4.5.4 Further reading

General Guidance

Guidance on the assessment and monitoring of natural attenuation of contaminants in groundwater. R&D Publication 95, Environment Agency, 2000.

The Effects of Contaminant Concentration on the Potential for Natural Attenuation. R&D Report P2-228/TR, Environment Agency, 2002a.

Groundwater-surface water interactions in the hyporheic zone, Science Report SC030155/SR1. Environment Agency, 2005a, ISBN 1844324257

Substance-Specific Guidance

Review of ammonium attenuation in soil and groundwater, NGWCLC report NC/02/49, Environment Agency, 2003a, ISBN: 1 84432 110 1.

Attenuation of mecoprop in the subsurface. Report NC/03/12, Environment Agency, 2004.

[8] Some parameters are interdependent which means that combined use of their pessimistic values is unrealistic. An example of this is the combination of a high hydraulic gradient and high hydraulic conductivity as together they suggest very high rates of groundwater flow. Some parameters (e.g. hydraulic gradient and hydraulic conductivity) also have opposite effects on the outcome of dilution and ***attenuation*** factors.

Attenuation of nitrate in the subsurface environment. Science Report SC030155/SR2, Environment Agency, 2005b, ISBN: 1844324265.

Attenuation of mine pollutants in the hyporheic zone, Science Report: SC030155/SR6, Environment Agency, 2006b, ISBN: 1844325709.

Fate and Transport Modelling Guidance

Guidance on the Assessment and Interrogation of Subsurface Analytical Contaminant Fate and Transport Models, NGCLC report NC/99/38/1, Environment Agency, 2001a, ISBN: 1 857 05486 5. (Note there are two other related volumes).

Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface. NGWCLC report NC/99/38/2. Environment Agency, 2001b

Remedial Targets Methodology – Hydrogeological Risk Assessment for Land Contamination, Product Code GEHO0706BLEQ-E-E, Environment Agency, 2006.

4.6 Compliance points

Choosing compliance points and agreeing these with us is an important part of the risk assessment process and can significantly affect the effort and costs involved. Compliance points can be located at a number of different points between the source and the identified receptor(s). Their purpose is to define a (modelled or real monitoring) point where, if a compliance value is achieved, the receptor(s) will be protected.

More information on compliance points is given in the sector specific annexes.

Compliance point monitoring and requisite surveillance, compliance values and limit values are discussed further in Appendix A1 and further discussion on compliance points is provided in CIS17 (European Commission, 2007).

4.7 Substances to model

The risk assessment needs to focus its effort on those substances in the discharge that are most likely to have an effect on groundwater or associated sensitive receptors. For some activities there is likely to be a single substance on which the risk assessment should focus. On others, there may be a range of substances (for example, in treated sewage effluent) that can be represented by a few constituent substances. Other discharges may contain a large number of potentially polluting substances and will typically require a more complex risk assessment and potentially the use of site specific data (such as landfill).

The risk assessment for the activity needs to include a section on how it has been decided which substances are to be modelled. The supporting annexes give further advice on this for specific activities, but in general both hazardous substances and non-hazardous pollutants should be selected for modelling based on the following criteria:

- High concentration of **hazardous substances** compared to Minimum Reporting Values and background concentrations in groundwater;
- High concentration of **non-hazardous pollutants** compared to the appropriate Water Quality Standards

From these two groups, those substances that, during the discharged water's movement down through the subsurface soils, rocks and strata, are:

- least likely to be attenuated (and could be used as a marker substance in monitoring); and
- attenuated by different mechanisms (for example, the metal cadmium being attenuated by sorption / precipitation or a pesticide being attenuated by sorption and biodegradation).

4.8 Lifecycle phases and scenarios to assess

All risk assessments need to consider or evaluate the potential effects on groundwater throughout the 'life' of the activity.

For many activities, the discharge will only occur during operation, and this usually means that a single risk assessment scenario is appropriate. There may, however, be occasions when the activity's setting changes, such as groundwater levels rise as a result of cessation of dewatering activities in a nearby mine or excavation. If such a change in setting is reasonable, then a second scenario should be assessed to check if the discharge will also be safe under these changed circumstances.

For other activities (particularly landfill, where the discharge occurs as a result of leaching of solid wastes), the discharge will continue long after the operational period. In the time following operation, the discharge rate may change as a result of deterioration of barrier and collection systems. However, the quality of the discharge may improve with time. Where such activities have planned / anticipated phases of operation and aftercare, or the discharge may change as a result of deterioration in an irreplaceable barrier or control system, then scenarios reflecting these different lifecycle phases need to be modelled.

The supporting sector specific annexes to this document provide further guidance on life cycle phases and scenarios to assess for specific activities. The risk assessment for your site needs to include a section on how you have decided on the scenarios to assess if they are applicable.

4.9 Uncertainties

4.9.1 Uncertainty defined

As described in GP3 Part 2 (Environment Agency, 2006) 'uncertainty is a measure of how far the result of an assessment is likely to be from the actual situation. Dealing with uncertainty is an important part of risk assessment and management. It affects all stages of the risk process. Analysing the sources and magnitudes of uncertainties can help to focus discussion, identify gaps in our knowledge and support decision making.'

4.9.2 Source of uncertainties

There are uncertainties in many of the data inputs that feed into a risk assessment, but uncertainties in some parameters have a bigger effect on the outcome than others.

Uncertainties in data inputs in terms of:

- whether the activity can be controlled as well as predicted;
- the quality and of the data that has been generated;
- whether conservative assumptions for data are valid;
- uncertainties in the hydrogeological conceptual model (do we really understand what will happen to the contaminants in your discharge?);
- uncertainties in the ability of science to simulate natural processes through the use of mathematical expressions (this is not your problem, but something to keep in mind); if we are not confident in your hydrogeological conceptual model we will take a precautionary approach to your application for a permit.

4.10 Sensitivity analysis

Sensitivity analysis is an important part of risk assessment as it helps identify the most important factors affecting the outcome and consequently allows variability in these factors to be better constrained or controlled through permit conditions. Some parameters and their input values have a much bigger influence on the predicted effect of the discharge / activity on groundwater and related receptors.

As part of the risk assessment for your site, we require:

- A discussion / appraisal of the key uncertainties in the risk assessment that may affect the predicted outcome.
- A sensitivity analysis section discussing / illustrating how the predicted effect on groundwater (or associated receptors) may change if more pessimistic (conservative) than likely input values are used.

This is an essential part of a DQRA.

Chapter 5 Additional information

5.1 Sources of information including site investigation

For some activities, site investigation will be required to collect the necessary information required to inform the risk assessment. Carrying out site investigation will normally be your responsibility and most often through use of consultants or contractors. Site investigation may include soil and water sampling, the excavation of trial pits and / or the drilling, construction, testing and sampling of boreholes. The cost of site investigation can be significant, so we recommend that you contact us with your plans. We may feel the plans are inadequate, excessive or the works themselves (for example, the drilling of boreholes through contaminated soils) may pose a risk to groundwater.

5.2 Reporting

Reporting on groundwater risk assessments may be achieved in a number of ways:

- A risk screening / scoring form completed and placed on file by us (where we have said that we will carry out the risk assessment on your behalf).
- A chapter in a groundwater risk assessment report.
- A separate report that is to be used in conjunction with an underpinning activity and site setting report. An example of this is a report based on our Hydrogeological Risk Assessment (HRA) report template designed for use in permit applications for landfill.

Common to each of these is the need for transparent justifications or calculations.

5.3 Risk management

Once the risk assessment is complete, the next step is to identify and evaluate options for risk management such as pre-treating the source material, enhancing the engineering measures (for example, a different landfill liner) or tightening the operational and aftercare controls.

Risk management also includes reducing the likelihood and / or consequences of accidents.

5.4 Accidents and their consequences

Please also refer to HI Environmental Risk Assessment: Annex C. In addition to your risk assessment considering the potential effect of your activity on groundwater and related receptors under normal / planned operation, we also want to understand the potential consequences of any plausible accidents.

Accidents are considered to be unintentional incidents that could reasonably occur, which are unforeseeable at their time of occurrence. However, with adequate foresight, design and mitigation (preventative measures), they can normally be avoided.

Where the consequences of plausible accidents are serious, efforts should be made to mitigate the chance of such accidents happening and /or the consequences should they happen. This is part of risk management.

We would expect a section in the risk assessment for your activity that describes possible accidents (that could affect risks to groundwater) and their consequences in terms of groundwater pollution.

5.5 Linking risk assessment to permit conditions

Assuming the risk assessment for your activity and its setting has demonstrated an acceptable outcome, then to ensure that outcome is sustained during the operation (and aftercare) of your activity and site, we will normally set conditions in your permit. We could typically set permit conditions on aspects such as:

- discharge rate, quality, timing, location;
- engineering measures (such as thickness of landfill liner)
- operational controls (such as maintenance of leachate levels)
- compliance values and limit values.

Monitoring requirements are discussed in Appendix A1

References

British Standard, 2009	British Standard BS ISO 5667-11:2009 (Guidance on sampling of groundwaters).
Defra, 2011	Government's Guidelines for Environmental Risk Assessment and Management, 2011
EC 2000	Water Framework Directive (2000/60/EC).
EC 2006a	Management of Waste from Extractive Industries (2006/21/EC).
EC 2006b	Groundwater Daughter Directive (2006/118/EC – on the protection of groundwater against pollution and deterioration) (*GWDD*).
EC 2007	Common Implementation Strategy (CIS) for the Water Framework Directive Guidance Document No 17, European Commission, 2007.
EC 2007, 2010	Environmental Permitting Regulations (2007, 2010)
EEC 1999	Landfill Directive (99/31/EEC),
Environment Agency, 2000	Guidance on the assessment and monitoring of natural attenuation of contaminants in groundwater. R&D Publication 95, Environment Agency, 2000.
Environment Agency, 2001a	Guidance on the Assessment and Interrogation of Subsurface Analytical Contaminant Fate and Transport Models, NGCLC report NC/99/38/1, Environment Agency, 2001, ISBN: 1 857 05486 5. (Note there are two other related volumes).
Environment Agency, 2001b	Guide to Good Practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface. NGWCLC report NC/99/38/2,
Environment Agency, 2002	The Effects of Contaminant Concentration on the Potential for Natural *Attenuation*. R&D Report P2-228/TR, Environment Agency, 2002.
Environment Agency, 2003a	Review of ammonium attenuation in soil and groundwater, NGWCLC report NC/02/49, Environment Agency, 2003, ISBN: 1 84432 110 1.
Environment Agency, 2003b	Guidance on Monitoring of Landfill Leachate, *Groundwater* and Surface Water (Environment Agency, February 2003).
Environment Agency, 2004	Attenuation of mecoprop in the subsurface. Report NC/03/12, Environment Agency, 2004.
Environment Agency, 2005a	Groundwater-surface water interactions in the hyporheic zone, Science Report SC030155/SR1. Environment Agency, 2005, ISBN 1844324257
Environment Agency, 2005b	Attenuation of nitrate in the subsurface environment. Science Report SC030155/SR2, Environment Agency, 2005, ISBN: 1844324265.
Environment Agency, 2006a	Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093. Environment Agency January 2006, ISBN: 1844325342.
Environment Agency, 2006b	Attenuation of mine pollutants in the hyporheic zone, Science Report: SC030155/SR6, Environment Agency, 2006, ISBN: 1844325709.

Environment Agency, 2006c	Remedial Targets Methodology, Hydrogeological Risk Assessment for Land Contamination, Product Code: GEHO0706BLEQ-E-E
Environment Agency, 2006	Groundwater Protection: Policy and Practice, Parts 1-3, Environment Agency 2006-2008.
Environment Agency, 2011a	Groundwater risk assessment for treated effluent discharges to infiltration systems
Environment Agency, 2011b	Prior examination for discharges to land of waste sheep dip and pesticide washings
Environment Agency, 2011c	Hydrogeological risk assessments for landfills and the derivation of groundwater control and compliance limits
Environment Agency, 2012	Groundwater Protection: Principles and Practice (GP3) Part 4 and Part 5 (Environment Agency 2012 – in preparation)

List of abbreviations and glossary

List of abbreviations

EPR	Environmental Permitting Regulations
EQS	Environmental Quality Standard
GP3	Groundwater Protection: Policy and Practice
GWDD	Groundwater Daughter Directive
LNR	Local Nature Reserve
MRV	Minimum Reporting Value
NNR	National Nature Reserve
SAC	Special Area of Conservation
SPA	Special Protection Area
SPZ	Source Protection Zone (groundwater)
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
WFD	Water Framework Directive
WQS	Water Quality Standards

AF	Attenuation Factor
BGS	British Geological Survey
BOD	Biological oxygen demand
BS	British Standard
COD	Chemical oxygen demand
DF	Dilution Factor
DQRA	Detailed Quantitative Risk Assessment
DWF	Dry Weather Flow
DWS	Drinking Water Standard
EPR	Environmental Permitting Regulations
EQS	Environmental Quality Standard
GP3	Groundwater Protection: Policy and Practice
GQRA	Generic Quantitative Risk Assessment
IEPA	Irish Environmental Protection Agency
LOD	Limit of Detection
MRV	Minimum Reporting Value
PPG	Pollution Prevention Guidelines
PTP	Package Treatment Plant
RS	Risk Screening
S-P-R	Source-Pathway-Receptor

List of abbreviations and glossary

SPZ	Source Protection Zone
STW	Sewage Treatment Works
SuDS	Sustainable Drainage Systems
UWWTD	Urban Waste Water Treatment Directive
WFD	Water Framework Directive
WIA	Water Industry Act 1991

Glossary

Aquifer — A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater (WFD, 2000).

Attenuation — A decrease in contaminant concentration or flux through biological, chemical and physical processes, individually or in combination (e.g. dispersion, precipitation, ion exchange, biodegradation, oxidation, reduction). See also “natural attenuation”.

Biodegradation — The breakdown of a substance or chemical by biological organisms, usually bacteria.

Compliance point — A suitable point along the contaminant pathway between the source and a receptor at which you set a compliance value. The compliance point may be a virtual point (for the purpose of predictive assessments) or it may be a physical monitoring point such as a borehole. In some cases the compliance point may be the receptor itself.

Compliance value — The concentration of a substance at the compliance point that should not be exceeded. Depending on the level of assessment, a compliance value may take account of some or all of the dilution and attenuation processes along the contaminant pathway to the receptor(s).

Conceptual model — A simplified representation or working description of how the real (hydrogeological) system is believed to behave based on qualitative analysis of field data. A quantitative conceptual model includes preliminary calculations for the key processes.

Contamination/ contaminant — The introduction of any substance to water at a concentration exceeding the baseline concentration. A contaminant is any such substance.

Declining source term — The predicted long term reduction in the concentration of substances leaching out of solid wastes.

Dilution — Reduction in concentration brought about by mixing (typically with water).

Dilution factor — The amount of dilution of the discharge by groundwater flow, calculated from the ratio of groundwater below the drainage field and the discharge to the drainage field.

Discernible Discharge — The GWDD states that all measures necessary to prevent the input of any hazardous substance into groundwater must be

	taken. One of the criteria that defines "Prevent" is that the substance being discharged is not discernible in comparison to either the natural background concentration of groundwater or a minimum reporting value (usually the limit of detection or other value prescribed by legislation) if this is at a higher concentration.
Discharge	A release of effluent to the ground surface or to an infiltration system or directly to groundwater via a borehole, etc.
Dispersion	Irregular spreading of solutes due to heterogeneities in groundwater systems at pore-grain scale (microscopic dispersion) or at field scale (macroscopic dispersion).
Down-gradient	In the direction of decreasing water level (in groundwater this is following the hydraulic gradient)..
Dual porosity flow	A combination of intergranular and fracture flow.
Effective porosity	The volume of the void spaces through which water or other fluids can travel in a rock or sediment divided by the total volume of the rock or sediment.
Effective rainfall	The amount of precipitation (rainfall, snow, etc.) available for recharge following losses due to evapotranspiration (evaporation and transpiration)
Groundwater	All water below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.
Groundwater activity	See Appendix A5
Groundwater flow rate	The groundwater flow rate in the mixing zone is the product of the hydraulic gradient, cross flow width, mixing zone depth and hydraulic conductivity.
Groundwater flow velocity	The product of the hydraulic gradient and hydraulic conductivity divided by the effective porosity.
Groundwater risk assessment	A risk assessment aimed at protecting groundwater. Also referred to as a hydrogeological risk assessment.
Hazardous substances	Defined in the WFD as: "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and other substances or groups of substances which give rise to an equivalent level of concern."
Hydraulic conductivity	A coefficient of proportionality describing the rate at which a fluid can move through a medium. The density and kinematic viscosity of the fluid affect the hydraulic conductivity, so that this parameter is dependent on the fluid as well as the medium. Hydraulic conductivity is an expression of the rate of flow of a given fluid through unit area and thickness of the medium, under unit differential pressure at a given temperature. (See also

	"permeability").
Hydraulic gradient	The change in total head (of water) with distance in a given direction. The direction is that which yields a maximum rate of decrease in head.
Hydrogeological conceptual model	A simplified representation or working description of how the real (hydrogeological) system is believed to behave based on qualitative analysis of field data. A quantitative conceptual model includes preliminary calculations for the key processes.
Hydrolysis	Chemical decomposition in which a compound is split into other compounds by reacting with water.
Hyporheic zone	Zone beneath and adjacent to a river or stream where groundwater and surface water mix.
Infiltration	The amount of effective rainfall (minus any runoff) that infiltrates the soil.
Infiltration system	An infiltration system is defined by BS6297:2007(+A1:2008) as "a series of infiltration pipes, placed in either single trenches or one large bed, used to discharge effluent in such a way that it percolates into the disposal area".
Karst (or karstic)	Typically a limestone terrain characterised by sinkholes, ravines, fissures and cave systems. Can be used to describe all similar environments.
Limit value	A compliance value specifically set in your activity's discharge such that if it is exceeded, the receptor will be at risk of being polluted.
Minimum Reporting Value (MRV)	The lowest concentration of a substance that is reported in the results of an analysis. It is not necessarily the detection limit.
Moisture content	Ratio between the mass of water present in a sample and the dry mass of the solid (usually expressed as % weight)
Natural attenuation	Natural processes that, without human intervention, reduce the concentration, mass, flux or toxicity of contaminants in groundwater and surface water.
Non-hazardous pollutant	Any substance capable of causing pollution that has not been classified as a hazardous substance.
Pathway	The route along which a particle of water, substance or contaminant moves through the environment e.g. the route contaminants are transported between the source of landfill leachate and a water receptor.
Permeability	A measure of the rate at which a fluid will move through a medium. The permeability of a medium is independent of the

	properties of the fluid. See also "hydraulic conductivity".
Pollutant	Defined in the WFD as "any substance liable to cause pollution, in particular those listed in Annex VIII [of the WFD]".
Pollution	Defined in EPR (2010) in relation to a water discharge or groundwater activity as: "the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems, which result in damage to material property, or which impair or interfere with amenities or other legitimate uses of the environment."
Porosity	The ratio of the volume of void spaces in a rock or sediment to the total volume of the rock or sediment.
Potable water	Water of suitable quality for drinking.
Principal Aquifer	Geological strata that exhibit high intergranular and/or fracture permeability. They usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. Principal Aquifers equate in most cases to aquifers previously designated as major aquifer.
Receptor	An entity/organism, material property or any existing or potential active or passive use of water that is being or could be harmed by a potential pollutant, including groundwater or surface water resources, amenity uses or abstraction points.
Recharge	The amount of water added to the groundwater system by natural or artificial processes.
Retardation	A measure of the reduction in solute velocity relative to the velocity of the flowing groundwater caused by processes such as adsorption.
Risk	A quantitative or qualitative combination of the probability of a defined hazard causing an adverse consequence at a receptor, and the magnitude of that consequence.
Risk assessment	The process of identifying and quantifying a risk, and assessing the significance of that risk in relation to other risks.
Saturated zone	The zone in which the voids of the rock or soil are filled with water at a pressure greater than atmospheric. The water table is the top of the saturated zone in an unconfined groundwater system. In general, flow on a macro scale is horizontal and typically faster than for unsaturated zone flow. Flow rates between different types of strata vary over several orders of magnitude.
Secondary Aquifer	These include a wide range of geological strata with a correspondingly wide range of permeability and storage.:

List of abbreviations and glossary

Sensitivity analysis	An analysis focusing on the effects of uncertainties in data inputs and assumptions used in the conceptual model and risk assessment illustrating how the predicted effect on groundwater (or associated receptors) may change if more conservative than likely input values are used.
Sewage effluent	Generally applies to the liquid effluent generated from raw sewage treatment from domestic properties. Non-domestic sources of sewage effluent may have distinct characteristics that produce higher or lower strength effluent. Compare trade effluent.
Sorption	Absorption and adsorption considered jointly.
Source	For permitting purposes, the source is the groundwater activity.
Source-Pathway-Receptor	A viable pollutant linkage.
Source Protection Zones	SPZ1 Inner Protection Zone – 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres around the source. SPZ2 Outer Protection Zone – 400 day travel time from a point below the water table. This zone has a minimum radius of 250 or 500 metres around the source depending on the size of the abstraction. SPZ3 – Source Catchment Protection Zone (also referred to as the Total Capture Zone or total catchment) – the area around a source within which all groundwater recharge is presumed to be discharged at the source.
Unproductive Strata	These are geological strata with low permeability that have negligible significance for water supply or river base flow (formerly part of the Non-Aquifers).
Unsaturated zone	The zone between the land surface and the water table. The pore space contains water at less than atmospheric pressure, as well as air and other gases. Saturated bodies, such as perched groundwater may exist in the unsaturated zone. Also called the vadose zone.
Up-gradient	In the direction of increasing hydraulic head (i.e. in groundwater this is moving up the hydraulic gradient).
Volatilisation	Change in state of contaminants dissolved in groundwater (aqueous state) into the vapour phase (gas state).
Water table	The upper surface of an area filled with groundwater, separating the unsaturated zone from the saturated zone.

Appendix A1 Monitoring

A1.1 Purpose of this section

With a robust[9] hydrogeological conceptual model in place and a risk assessment that indicates an acceptable potential effect of the activity on groundwater (and associated receptors), the last part of the assessment is to check if your activity and its effect can be adequately monitored.

This appendix provides broad guidance on the objectives of this monitoring, the aspects of your activity that need to be monitored, whether compliance points including groundwater and other water based receptors need to be monitored, and if so how. We use the term **requisite surveillance** of groundwater to describe monitoring of groundwater where and when we feel this is necessary.

Each of the sector specific annexes provides more detailed guidance on monitoring relevant to those activities, but this section discusses the main themes.

A1.2 Objectives for monitoring

Monitoring of the activity and where appropriate its effect on groundwater and related receptors is a crucial element of the risk assessment process as it:

- Checks and records whether the activity is being operated within the limits assumed in the risk assessment.
- Checks whether environmental conditions around the site have changed outside those assumed in the risk assessment (the most common example of this being measurement of groundwater levels that have been used as the basis for an assumed thickness of unsaturated zone and to determine the hydraulic gradient and groundwater flow direction).
- Confirms whether risk management options have been put in place and if so whether they are meeting their aims.
- Helps validate the risk assessment outputs by checking the actual effect on groundwater and the wider environment remains acceptable by monitoring compliance points.

We set out the regulatory requirements for groundwater risk assessment in Appendix A5 and re-iterate here that an environmental permit may only be granted if we have checked that the groundwater (and, in particular, its quality) will undergo the requisite surveillance.

[9] Robust but also fit for purpose – different levels of understanding will be required for simple and complex activities in simple or complex hydrogeological settings.

A1.3 More detailed guidance on monitoring

Further guidance on monitoring of specific activities is provided in the supporting sector specific annexes and in the generally applicable guidance is given below:

Guidance on monitoring of landfill leachate, groundwater and surface water (Environment Agency, February 2003b).

Guidance on the design and installation of groundwater quality monitoring points, Science Report SC020093. Environment Agency January 2006a, ISBN: 1844325342.

Guidance on the assessment and monitoring of natural attenuation of contaminants in groundwater. R&D Publication 95, Environment Agency, 2000.

A1.4 Monitoring of the activity

We need to make sure that, if permitted, the activity is carried out within any limits assumed in the risk assessment. The risk assessment for the activity should therefore set out which aspects you will monitor and how you will record and report monitoring information to us. We will review these proposals and, if we grant you a permit, will include conditions in your permit on these aspects.

A1.5 Frequency of monitoring

For infrequent activities, such as disposal of waste sheep dip to land, all the relevant details of the discharge (such as the volume, substance, concentration / dilution, etc.) can be and should be recorded on the date of that event.

Where the activity will have a continuous discharge, however, such as leakage of leachate from the base of a landfill, continuous monitoring is not usually practicable and so your risk assessment needs to set out and justify the frequency (for example, weekly, monthly, etc.) of any monitoring. The frequency of monitoring should be linked to the expected variability in the rate or quality of your discharge, or the factors (for example, the level of leachate above the base of the landfill) that control these aspects. Further guidance on this is provided in the sector specific annexes.

A1.6 Records and reporting

We will require that records are kept. For some activities, the records may be as simple as an entry in a log book, but for others monitoring data will need to be stored electronically, often in databases, to allow easier reporting and review.

If your permit application is successful, we will set conditions in your permit on record keeping as we want to ensure that records are made promptly, legibly, are readily accessible and stored safely for our inspection at a future date or are submitted to us routinely for review.

A1.7 Monitoring of groundwater levels

Unlike most other aspects of the site setting, groundwater levels will change seasonally and their variation can sometimes help understand changes in groundwater quality. Groundwater levels affect the thickness of unsaturated zone and the slope and direction of the hydraulic gradient. Where groundwater levels affect the outcome of your risk assessment, you should set out your proposals to monitor them in terms of location, frequency and method.

A minimum of three monitoring points in triangular formation is required to define a gradient and routine monitoring of each of these will allow a check on whether this gradient changes from that assumed in your risk assessment. Where the geology and hydrogeology beneath your site is complex, with groundwater present in two or more separated layers, then this minimum system of monitoring will be required in each layer. Additional monitoring points are likely to be required if your site is complex.

A1.8 Compliance point monitoring and requisite surveillance

We have discussed compliance points and their importance in risk assessment in Section 4.6.

Some compliance points are theoretical or conceptual only as they cannot be physically monitored, at least realistically. For example, it is technically very difficult to monitor the quality of water arriving at the water table (a compliance point), yet the risk assessment needs to demonstrate that entry of hazardous substances into groundwater will be prevented.

It is feasible to monitor the quality of any discharge and in a borehole (or spring) after the attenuated discharge has mixed with groundwater flowing beneath your site. We can also monitor the quality of water in a stream receiving discharge of groundwater if that stream is deemed to be the main receptor or supplies water to the main receptor (such as a wetland or abstraction). At some of these monitoring points, we can check if, for example, the entry of a hazardous substance into groundwater has been prevented to the extent that it is not discernible in an analysis of sampled water.

Due to costs, and practical considerations, installing boreholes for monitoring groundwater will not always be feasible, and so this means compliance point monitoring may need to be at a point beneath the site where you or we can easily check that things are happening as envisaged in your risk assessment. An example of this is checking that waste sheep dip chemicals do not move beneath the base of the soil layer by sampling and testing soils.

Your risk assessment needs to set out which compliance points can be monitored, the compliance values (or if it is your activity's discharge, the limit values that have been derived from your assessment and the frequency that you propose to undertake this compliance monitoring.

A1.8.1 Compliance values and limit values

Compliance values and limit values are outputs from your risk assessment, in that the risk assessment should work out, for example, what the concentration of a substance should be in the discharge (the limit value) and in a borehole at the down-gradient edge of your activity (a compliance value) to ensure the risks to the identified receptors are acceptable.

The compliance value at a receptor is the relevant MRV, WQS or background concentration that needs to be achieved to prevent pollution of that receptor. Compliance values at compliance points between your source and the receptor should ensure that the receptor is protected to the same extent.

A limit value is a compliance value specifically set in the activity's discharge such that if it is exceeded, the receptor will be at risk of being polluted.

Further guidance on compliance and limit values is provided in CIS17 (European Commission, 2007

A1.9 Requisite surveillance of groundwater

Where risks have been shown to be very low or negligible, usually as a result of risk screening or qualitative risk assessment for a simple hydrogeological conceptual model using conservative assumptions, then we may be sufficiently confident to decide that groundwater monitoring at your site is unnecessary. In such cases, we may accept that monitoring of potential impact on groundwater can be achieved by monitoring of the discharge against limit values.

More usually, and especially for larger and more complex operations where there is a risk (at least probabilistically) of affecting groundwater, groundwater monitoring will be needed as a check on the real effect of your activity – this is requisite surveillance of groundwater.

A1.10 Strategic / operational monitoring of groundwater bodies

Under the WFD, we have a responsibility to monitor the quality of water across large areas that have been designated as groundwater bodies. This monitoring is referred to in Europe and England and Wales as groundwater body 'surveillance and operational monitoring', whereas the compliance point monitoring and requisite surveillance of groundwater discussed in the above sections is referred to as 'prevent and limit monitoring' (in some documents this is also referred to as defensive monitoring).

The surveillance and operational monitoring is aimed at providing background water quality data across each groundwater body, helping to define areas that are at risk of failing quality status thresholds and for identifying significant trends in natural conditions or pollutant concentrations. This monitoring network is purposely located away from existing regulated facilities and is unlikely to be suitable for monitoring the effect of your activity. It is likely however, to provide background water quality data.

A1.11 Groundwater control levels and compliance limits

The terms groundwater **control levels and compliance limits** are specific to landfill, being a requirement of the EU Landfill Directive (1999/31/EC) as enacted through the EPR.

For further details please refer to our sector specific annex on Hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. (Environment Agency, 2011c).

A1.12 Design of groundwater monitoring

Where groundwater monitoring is needed it requires planning, usually on a case-by-case basis, to determine parameters to be measured or sampled and analysed, frequency of measurement / sampling and location of monitoring points. For more detail on the sampling of groundwater please refer to: British Standard BS ISO 5667-11:2009 (Guidance on sampling of groundwaters).

In line with CIS17 (European Commission, 2007) we recommend that you consider the following points when designing a groundwater monitoring programme:

- Up-gradient and / or background monitoring: It may be necessary to report on the unaffected/background situation in the subsurface either before a new activity is set up or up-stream of an existing source of contamination.
- Monitoring intervals (frequency) should take into account the behaviour (such as travel times) of the known pollutants and their degradation products.

- Construction (technical) characteristics of the monitoring wells and the depth of monitoring within each observation well should be dependent on the nature of the input and on the seasonal water level fluctuation.
- Sampling methods, sample preservation and analysis methods will be dependent on the nature of the input and its expected pollutant concentration. Commercial analytical laboratories can advise on sample preservation and analysis.
- The parameters monitored at each well should be indicative of the type of pollutant(s) and their expected impact. Possible indicator parameters (redox, pH, electrical conductivity, temperature, salts) could be used to reduce the monitoring effort.
- The cost-benefit of the number of wells versus the level of information that will be obtained.

Monitoring geometry will depend on the definition of the points of compliance, which in turn strongly depends on the characteristics of the groundwater body described in the hydrogeological conceptual model and the regulatory requirements.

A1.13 Monitoring reporting

If your risk assessment and monitoring proposals are acceptable, we will set out monitoring reporting requirements in your permit. You may however, put forward your suggested monitoring reporting strategy through consideration of the following types of reporting:

A1.13.1 Routine Survey documentation

Routine Survey Documentation is primarily concerned with conveying to site management the details of works undertaken, results obtained and the implications of the results. This information does not necessarily need to be compiled into a formal report, although it should be available for inspection by us on request. This documentation should be up-dated following each monitoring event and should conclude with statements regarding:

- whether any breaches in early warning or compliance values have been noted;
- whether any adverse trends are apparent;
- any significant changes in the rate of change of concentrations of constituents;
- proposals for varying the frequency and range of monitoring.

A1.13.2 Notification reports

Notification Reports should be seen as the prime means of disseminating information for which action is required by site management and/or from us. Notification reports should be issued when breaches in early warning, limit or compliance values have occurred. These reports should provide clear, concise information and carry a recommendation for action (or advice of action taken). The time scales for issuing reports will be specified by the permit conditions.

In instances where early warning, limit or compliance values are regularly being breached and action is being implemented by the site operator, alternative ongoing reporting procedures should be agreed between you and us to avoid unnecessary duplication of notification reports.

A1.13.3 (Annual) review or compliance reports

Review or Compliance Reports should be prepared at least annually as required by the environmental permit. They should summarise the monitoring data collected at the site with respect to compliance with the early warning, limit or compliance values set for the site. The main purpose of this report is to inform site management and the Environment Agency of the environmental performance of your activity as well as the performance of the monitoring programme. Recommendations for improving the monitoring plan should be made and discussed with us.

Appendix A2 Discharges of hazardous substances to groundwater - MRVs for selected substances in clean water

The table below presents typical Minimum Reporting Values (MRVs) for selected hazardous substances in clean groundwater (as required of Environment Agency National Laboratory Service).

Substance	MRV (µg/l)	Comment
1,1,1-trichloroethane	0.1	
1,1,2-trichloroethane	0.1	
1,2-dichloroethane	1	
2,4 D *ester*	0.1	methyl, ethyl, isopropyl, isobutyl and butyl each to 0.1
2,4-dichlorophenol	0.1	
2-chlorophenol	0.1	
4-chloro-3-methylphenol	0.1	
aldrin	0.003	
atrazine	0.03	
azinphos-ethyl	0.02	
azinphos-methyl	0.001	
benzene	1	
cadmium	0.1	
carbon tetrachloride	0.1	
chlorfenvinphos	0.001	
chloroform	0.1	
chloronitrotoluenes	1	2,6-CNT; 4,2-CNT; 4,3-CNT; 2,4-CNT; 2,5-CNT each to 1µg/l
PCB (individual congeners)	0.001	
demeton	0.05	demeton-s-methyl only
diazinon	0.001	
dieldrin	0.003	
dimethoate	0.01	
endosulfan	0.005	endosulphan a and endosulphan b, each to 0.005µg/l
endrin	0.003	
fenitrothion	0.001	
fenthion	0.01	
hexachlorobenzene	0.001	
hexachlorobutadiene	0.005	

Substance	MRV (µg/l)	Comment
hexachlorocyclohexanes	0.001	α-HCH, γ-HCH and δ-HCH each to 0.001µg/l β-HCH to 0.005µg/l
isodrin	0.003	
malathion	0.001	
mecoprop	0.04	
mercury	0.01	
mevinphos	0.005	
op DDT	0.002	o = ortho; p = para
pp DDT	0.002	
op DDE	0.002	
pp DDE	0.002	
op TDE	0.002	
pp TDE	0.002	
parathion	0.01	
parathion methyl	0.015	
pentachlorophenol	0.1	
permethrin	0.001	cis and trans-permethrin both to 0.001µg/l
simazine	0.03	
tetrachloroethylene	0.1	
toluene	4	
tributyltin compounds	0.001	
trichlorobenzene	0.01	135 tcb; 124 tcb; 123 tcb each to 0.01
trichloroethylene	0.1	
trifluralin	0.01	
triphenyltin compounds	0.001	
xylenes	3	o-xylene and m/p-xylene each to 3µg/l. May not be possible to separate m- and p-xylene.

Appendix A3 Mining waste activities and solid disposals

A3.1 Mining waste operations

Under the Mining Waste Directive (MWD[10]), any heaps of **extractive waste** associated with mines or quarries that closed before 01 May 2008, will not be required to be covered by an environmental permit. An environmental permit under the MWD will be required if work is being undertaken on the waste that leads to it having an increased footprint. This would also apply to any waste that arises from treatment or re-processing of the heap.

However, if the activity is a groundwater activity (Appendix A5) then an environmental permit will be required. A permit is required whether it is part of a mining waste operation or is stand-alone. In both cases you will need to read this guidance.

Operational mines, quarries and other extractive industries that manage extractive waste will be **Mining Waste Operations**. They may also have a groundwater activity. In some cases the groundwater activity will be separate to the mining waste operation. This is referred to as a stand-alone groundwater activity. An example of a stand-alone groundwater activity would be a closed mine:

- If a closed mining facility is causing serious negative environmental impact or may become a serious threat to human health or the environment in the short or medium term, then it will be included on an inventory of closed facilities. Should works be carried out to manage, prevent or remedy the environmental impact or stability of the closed mining facility, there may be a need to impose controls to protect groundwater. This would require an environmental permit so it is recommended that you follow this guidance.
- If a closed mining facility has a discharge that is leading to the input to groundwater of any hazardous substances or non-hazardous pollutants then this would be regulated under EPR. We would seek to control the discharge via an environmental permit.

In other cases, the groundwater activity will be an integral part of the mining waste operation. Examples of groundwater activities integral to a mining waste operation are re-working of spoil heaps including further extraction of mineral or change in location of a mining waste operation involving deposit of non-inert extractive waste:

- For the reworking and treatment of an old waste facility – including a spoil heap, an environmental permit will be required.
- For the construction of a new facility or the re-opening of a closed facility, an environmental permit would also be required. These works may include regular planned deposits of mining waste as part of the operation of active mineral extraction/treatment or moving an existing closed facility to a new location.

[10] The Mining Waste Directive relates to the Management of Waste from Extractive Industries (2006/21/EC). This should be referenced for further information on mining waste operations and activities.

For your mining waste operation, if you need to follow this guidance and submit a groundwater risk assessment to support your environmental permit then you will also need to refer to the principles outlined in our technical annex: Hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. (Environment Agency, 2011c).

The outcome of the H1 risk assessment for a groundwater activity integral to a mining waste operation should be included in the Waste Management Plan that is part of the permit application.

The preferred option is always voluntary remediation or through an environmental permit. However, if necessary we may use our enforcement powers via Anti Pollution Works Notices under section 161A Water Resources Act 1991 or, with the local authority, consider the use of Part 2A of the Environmental Protection Act 1990. There are limits on when Part 2A can be applied when other enforcement powers or permitting regimes can be used.

A3.2 Solid disposals of animal carcasses

Solid disposals would principally relate to the burial of animal carcasses in an emergency or circumstances where a derogation applies to the Animal By-Products Regulations to allow burial of fallen stock. Unless these circumstances apply, fallen stock should not be buried. Such disposals potentially represent a high risk to groundwater from putrefaction, veterinary medicines and pathogens. Disposals need to be adequately assessed and controlled to prevent pollution. For more information, please refer to GP3 Part 4 (Environment Agency, 2012)

You need to obtain the necessary permit from us before any animal burial takes place. However, small burials of 2 tonnes or less per farm unit do not need a permit provided they follow good practice. This activity is no longer covered in the Code of Good Agricultural Practice so we are planning to include an updated section in GP3, which is scheduled for completion in 2012.

Additional burials of this size may be made in the same year without authorisation provided no two burials are within 500 m of one another on any given farm unit. We may also elect not to permit burials up to 8 tonnes in some cases depending on outcome of a screening assessment. We will carry out the initial assessments for you but you may need to follow this guidance if further information is required. You will need to provide more information in all cases where the burial exceeds 50 tonnes – in such cases, engineered containment and site management controls will also be required. We would recommend that you follow the principals outlined in our sector specific annex on landfills (Hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. (Environment Agency, 2011c).

Appendix A4 The purifying powers of soils and sub-soils

The term **"purifying powers of the soils and sub-soils"** although used in the Groundwater Directive, is not defined there.

There are several documented processes that can take place in the soil and the unsaturated zone that may, to some extent, attenuate the passage through to the saturated zone of contaminants present in discharges. These processes may be used to explain observed phenomena such as lower than predicted concentrations of specified determinands in groundwater affected by landfill sites.

However, such processes often depend on a complex balance of a whole range of variables such as the mineralogical composition of the soil, a range of chemical properties associated with the ions contained in the leachate (ionic radius, electronegativity and charge, etc.) and the pH and redox potential of both the soil and any fluids percolating through it.

Conditions will alter with both time and distance and the extent to which attenuation occurs is often sensitive to minor changes in any one of the variables. In some circumstances the processes may even be reversible. It is therefore difficult to predict with any confidence the extent to which attenuation will occur and any estimate of attenuation capacity used in a risk assessment should be treated with caution.

However, this should not rule out the proper consideration of attenuation processes in soils and sub-soils, but the above difficulties should be recognised and the reliance on such mechanisms should be tempered accordingly.

Appendix A5 Groundwater activities and regulatory requirement for a risk assessment

Box A5.1 Groundwater activities

Schedule 22 of EPR (2010):

3.—(1) Subject to sub-paragraphs (2) and (3), "groundwater activity" means any of the following—
(a) the discharge of a pollutant that results in the direct input of that pollutant to groundwater;
(b) the discharge of a pollutant in circumstances that might lead to an indirect input of that pollutant to groundwater;
(c) any other discharge that might lead to the direct or indirect input of a pollutant to groundwater;
(d) an activity in respect of which a notice under paragraph 10 has been served and has taken effect;
(e) an activity that might lead to a discharge mentioned in paragraph (a), (b) or (c), where that activity is carried on as part of the operation of a regulated facility of another class.

(2) A discharge or an activity that might lead to a discharge is not a "groundwater activity" if the discharge is—
(a) made, or authorised to be made, by or under any prescribed statutory provision; or
(b) of trade effluent or sewage effluent from a vessel.

(3) The regulator may determine that a discharge, or an activity that might lead to a discharge, is not a groundwater activity if the input of the pollutant—
(a) is the consequence of an accident or exceptional circumstances of natural cause that could not reasonably have been foreseen, avoided or mitigated;
(b) is or would be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater; or
(c) is or would be incapable, for technical reasons, of being prevented or limited without using—
(i) measures that would increase risks to human health or to the quality of the environment as a whole, or
(ii) disproportionately costly measures to remove quantities of pollutants from, or otherwise control their percolation in, contaminated ground or subsoil.

Box A5.2 Regulatory requirement for a groundwater risk assessment

Schedule 22 of EPR (2010)

Applications for grant of environmental permit

7.—(1) This paragraph applies to an application for the grant of an environmental permit relating to—
(a) a discharge mentioned in paragraph 3(1)(a), (b) or (c); or
(b) an activity that might lead to such a discharge.

(2) When the regulator receives an application, it must ensure that all necessary investigations have been carried out to ensure that it grants any permit in accordance with paragraph 6.

(3) If it grants the permit, it must include conditions requiring all necessary technical precautions to be observed to ensure the objectives of paragraph 6 are achieved.

(4) A permit may not be granted—
(a) without examination of—
(i) the hydrogeological conditions of the area concerned,
(ii) the possible purifying powers of the soil and subsoil, and
(iii) the risk of pollution and alteration of the quality of the groundwater from the discharge, and
(b) without establishing whether the input of pollutants to groundwater is a satisfactory solution from the point of view of the environment.

(5) A permit may only be granted if the regulator has checked that the groundwater (and, in particular, its quality) will undergo the requisite surveillance.

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