Water Framework Directive (WFD)
River Basin District Management Systems

TECHNICAL REQUIREMENTS FOR GROUNDWATER AND RELATED ASPECTS

Paper by the Working Group on Groundwater

Guidance document no. GW1

This is a guidance paper on the **Technical Requirements for Groundwater and Related Aspects**. It documents the principles to be adopted by River Basin Districts and authorities responsible for implementing the Water Framework Directive in Ireland.				
REVISION CONTROL TABLE				
Status	**Approved by National Technical Co-ordination Group**	**WFD Requirement**	**Relevant EU Reporting Sheets**	**Date**
Final	March 2005	Characterisation & Monitoring	All Groundwater Reporting Sheets	September 2001

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1. Introduction

1.1 Water Framework Directive

The Water Framework Directive (2000/60/EEC) entered into force on its publication in the Official Journal of the European Communities on 22 December 2000. The Directive establishes a strategic framework for managing the water environment and sets out a common approach to protecting and setting environmental objectives for all groundwaters and surface waters within the European Community.

The Directive is probably the most comprehensive piece of EC water legislation to date.

At the heart of the Directive is the requirement to produce a strategic management plan for each river basin setting out how the objectives are to be achieved. The plan must be based on a detailed analysis of the pressures on the water bodies within the river basin, and an assessment of their impact. This allows a comprehensive programme of measures to be drawn up, tailored to the specific circumstances in each river basin district, and in particular to target improvements and monitoring effort on those water bodies most at risk of failing to meet their environmental objectives.

The implementation of the Water Framework Directive (WFD) raises challenges, which are widely shared by all Member States. These include an extremely demanding timetable, in particular in the nine preparatory years; a complex text; and a diversity of possible solutions to scientific, technical and practical questions. There is furthermore a need for further elaboration and substantiation of the technical and scientific basis for a number of fundamental aspects of Annex II and Annex V of the Directive, in order to make a successful transition from principles and general definitions to practical implementation.

1.2 Co-ordination of WFD Activities

The Department of the Environment and Local Government has established a WFD Co-ordination Group to co-ordinate and promote, at national level, implementation of the Directive. The first meeting of this group took place on 9 February 2001. The participants in the group include officials of relevant Government Departments, their related technical agencies and local authorities. These include:

The Department of the Environment and Local Government
The Department of the Marine and Natural Resources
The Department of Agriculture, Food and Rural Development
The Department of Arts, Heritage, Gaeltacht and the Islands (Dúchas)
The Department of Enterprise, Trade and Employment
The Department of Public Enterprise (represented by the Geological Survey of Ireland)
The Office of Public Works
The Environmental Protection Agency
The Central Fisheries Board
The Local Government Computer Services Board
The City and County Managers Association
The Environment and Heritage Services, Northern Ireland (observer)

In addition to co-ordination at national level, officials of the Department of Environment and Local Government, other Government Departments, and their agencies are participating in technical groups and other initiatives to promote consistent and co-ordinated implementation of the WFD in the European Community, on a North/South basis and at a regional (RBD) level.

1.3 River Basin Projects

In Ireland, practical implementation of the WFD will take place in the context of River Basin Management Projects. These will be established on the basis of a small number of areas to be known as River Basin Districts. Local authorities will have the primary role in promoting, establishing and implementing these projects which are being funded by the Department of the Environment and Local Government. These projects will provide much of the basic data requirements and necessary analysis for the characterisation of river basins, the identification of pressures and impacts, the mapping of locations and boundaries of water bodies, the establishment of integrated water monitoring programmes, the establishment of programmes of measures for the preparation of River Basin Management Plans.

It is envisaged that expenditure of some £48 million will be incurred by local authorities, and the Environmental Protection Agency, over a four year period, in relation to river basin projects.

The overall objective of river basin projects is to establish an integrated monitoring and management system for all waters within a RBD, to develop a dynamic programme of management measures and to produce a River Basin Management Plan, which will be continually updated in order to [DELG, July 2000]:

- prevent further deterioration and protect/enhance water quality and quantity of aquatic ecosystems and groundwater and associated terrestrial ecosystems;
- promote sustainable water use based upon long-term protection of available water resources;
- provide enhanced protection of the aquatic environment through specific measures aimed at eliminating and/or mitigating the impacts of pollutants; and
- assist in compliance with EU Directives and national legislation.

Groundwater characterisation and monitoring, for the purposes of the WFD, will be included in these projects.

1.4 Groundwater Working Group

A Groundwater Working Group has been established under the aegis of the WFD Co-ordination Group to assist in the technical interpretation of the Directive, and to provide guidance for River Basin Projects in the delivery and implementation of groundwater work requirements.

The working group on groundwater is led by the Geological Survey of Ireland, and consists of the following members:

Organisation	Representative
Geological Survey of Ireland	Donal Daly (WG convenor) Vincent Fitzsimons Geoff Wright
Dúchas	Jim Ryan
Department of the Environment and Local Government	Pat Duggan

Environmental Protection Agency	Conor Clenaghan Margaret Keegan Micheál MacCarthaigh
Local Authority	Billy Moore, Monaghan County Council Ray O'Dwyer, Tipperary (SR) County Council
Third Level Institutions	Paul Johnston, Department of Civil, Structural and Environmental Engineering, TCD

1.5 Purpose and Scope of Report

The purpose of this report is to provide practical technical guidance for the groundwater work that will be undertaken by river basin projects and to ensure that the approach adopted is based, as far as possible, on the requirements of the Water Framework Directive. This guidance document should be read and interpreted in conjunction with the Consultant's Brief prepared by the contracting authority and with the Directive itself.

The report *inter alia* addresses the following key issues, and recommends how they should be approached in the context of river basin projects:

- The concept of groundwater bodies and their delineation;
- Requirements, including data collection, for the characterisation of groundwater bodies;
- An understanding of good groundwater status (chemical and quantitative) and the maintenance and protection of associated surface waters and terrestrial ecosystems;
- The determination of groundwater bodies deemed to be 'at risk';
- Requirements for the monitoring of groundwater status and the interpretation and presentation of results.

The report is of necessity an interim report and modifications may be necessary over time, as the requirements of the Directive are more precisely defined at national or Community level. For example, the European Parliament and the Council have yet to adopt specific measures to prevent and control groundwater pollution for the purposes of Article 17. Such criteria are necessary to identify 'at risk' groundwater bodies and to finalise monitoring networks required under Article 8. An interim approach based on draft EPA guidelines is proposed in order that work may proceed. However, modifications are likely in light of future developments.

It is therefore envisaged that the requirements of the Directive will be further elaborated as river basin projects proceed, and that certain adaptations will have to be made to works programmes to incorporate these developments. The Groundwater Working Group will, through continued involvement in relevant EU workgroups and other activities, continue to provide technical guidance for implementation of the groundwater aspects of the Directive. These will be made available to River Basin Projects through the WFD Co-ordination Group.

1.6 Context

While this report concentrates largely on groundwater, it is essential that the technical requirements outlined should be seen as part of a broad framework encompassing surface water, groundwater, water-dependant ecosystems, and the pressures and impacts caused by human activities. It is essential that all these aspects should be linked together in the context of River Basin Projects.

The fundamental theme of the Water Policy Framework Directive is the evaluation of the hydrological cycle on a (topographic) catchment basis with particular focus on ecological interactions and dependencies. In this context, the outcome of the characterisation studies should be a basic understanding of the surface-groundwater interactions in the principal catchments. This understanding as developed could be described as a 'conceptual model', which would form the basis of any further analysis of ecological and hydrological impacts in a catchment.

Traditionally, study and management of water resources has largely focussed on surface water or groundwater as if they were separate entities. This approach will no longer be acceptable. Nearly all surface water features (streams, lakes, wetlands and estuaries) interact with and are hydraulically connected to groundwater. The interactions, while difficult to observe and measure, take many forms:

- In most situations in Ireland, surface water bodies gain water and solutes from groundwater systems. Therefore, surface water resources and temporal changes in flow regime and quality are affected by geological materials (soils, subsoils and bedrock) and groundwater.
- In some cases, particularly in karst areas, the surface water body is a source of groundwater recharge and can cause changes in groundwater quality. Therefore, contamination of surface water can cause degradation of groundwater and vice versa.
- Pumping of groundwater for water supply can deplete water in streams, lakes or wetlands.
- Two of the fundamental controls on water chemistry in drainage basins are the type of geological materials that are present and the length of time the water is in contact with those materials.

In summary, the movement of water between groundwater and surface water provides a major pathway for chemical transfer between terrestrial and aquatic systems. Therefore, understanding the mixing of groundwater and surface water, particularly regarding acidity, temperature, dissolved oxygen and hydrochemistry, can help explain the characteristics of surface aquatic environments and enable predictions of human impacts (e.g. in relation to nitrates). For instance, the very existence of some wetlands, such as turloughs, is completely dependent on groundwater and thus they are very vulnerable to changes in groundwater supply and quality. In other areas, the flow from groundwater to surface water may help explain the aquatic fauna and environment. Also, in extremely vulnerable permeable areas, groundwater can act as a significant pathway for phosphorus (and other contaminants) to lakes and streams, thereby being a potential cause of eutrophication (and contamination).

It is clear that, irrespective of the requirements of the WFD, an understanding of the interaction of groundwater and surface water is essential to water management and planning. However, work for the WFD now provides us with an opportunity to integrate all the components of the hydrological cycle. So the conceptual framework for groundwater needs to be broadened and expanded to encompass the overground components of the hydrological cycle, including meteorological, hydrological, ecological and hydrochemical aspects.

As a way of presenting the concepts and many facets of the interaction of groundwater and surface water in a unified way, it is suggested that a 3-D **'conceptual catchment'** should be used to help ensure that all aspects are integrated, understood and described. In particular it would assist water managers to visualise groundwater movement and the interactions with surface water.

2. Characterisation of the River Basin District (RBD)

2.1 Introduction

Article 5 of the WFD requires *inter alia* that member states undertake an analysis of the characteristics of each river basin district and review the impact of human activity on the status of groundwaters, in accordance with the technical specifications set out in Annex II of the Directive. A major element of groundwater characterisation is the mapping and description of 'groundwater bodies'. Characterisation is sub-divided into two stages – initial characterisation and further characterisation, where further characterisation is required for groundwater bodies deemed to be 'at risk'.

A description of the groundwater bodies concept and the requirements of initial and further characterisation are outlined in Sections 2.2 to 2.4 below.

2.2 Groundwater Bodies

2.2.1 The 'Groundwater Bodies' Concept

Virtually all of the requirements of the WFD relate specifically to 'groundwater bodies' rather than to 'groundwater' and 'aquifers'. As it is a term that is not normally used by groundwater specialists, a description and understanding of the concept is crucial to enable the requirements of the WFD to be outlined and undertaken.

There are 3 relevant definitions in the WFD:

> *"Groundwater" means all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil.*
>
> *"Aquifer" means 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.*
>
> *"Body of groundwater" means a distinct volume of groundwater within an aquifer or aquifers.*

The concept of 'Groundwater Bodies' embraces*:

- groundwater that can provide for the abstraction of significant quantities of water (i.e. the groundwater which can and should be managed to ensure sustainable, balanced and equitable water use); and
- groundwater which is in continuity with ecosystems and can place them at risk, either through the transmission of pollution or by unsustainable abstraction that reduces baseflows (i.e. the groundwater which can and should be managed to prevent environmental impacts on surface ecosystems).

The Groundwater Body is consequently the management unit under the WFD that is necessary for the subdivision of large geographical areas of aquifer in order for them to be effectively managed. This is the key aspect of the 'groundwater body' concept.

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* Acknowledgement: Much of this Section is based on a draft report from the UK WFD Technical Advisory Group. Further discussion and consideration by this Group should further clarify issues relating to groundwater bodies. One of the authors of this report – Donal Daly – is an observer on this Advisory Group.

Groundwater Bodies must be divided into those that:

- are not considered to be 'at risk' and subsequently do not require *further characterisation* or a high degree of surveillance (for the purposes of the Directive) but are still management units and will require operational controls;
- are considered to be 'at risk' and therefore require *further characterisation* and should be monitored, subjected to trend analysis, management measures and reporting, etc., as relevant.

2.2.2 Groundwater Bodies and Irish Aquifers

The definition of 'groundwater body' means that all groundwater bodies will constitute part of an aquifer or aquifers. Therefore an aquifer map must first be completed to enable groundwater bodies to be delineated.

The aquifer categories defined in *Groundwater Protection Schemes* (DELG/EPA/GSI, 1999) will be the starting point for delineation of groundwater bodies. The aquifer categories are as follows:

Regionally Important (R) Aquifers

(i) Karstified bedrock (**Rk**)
(ii) Fissured bedrock (**Rf**)
(iii) Extensive sand/gravel **(Rg)**

Locally Important (L) Aquifers

(i) Sand/gravel (**Lg**)
(ii) Bedrock which is Generally Moderately Productive (**Lm**)
(iii) Bedrock which is Moderately Productive only in Local Zones (**Ll**)

Poor (P) Aquifers

(i) Bedrock which is Generally Unproductive except for Local Zones (**Pl**)
(ii) Bedrock which is Generally Unproductive (**Pu**)

All Irish bedrock units are defined as aquifers. The only subsoil that is classed as an aquifer is sand/gravel. Consequently, **the total land area of the country**, including all bedrock units and sand/gravel aquifers, **will be sub-divided or grouped into groundwater bodies**. Other subsoils such as till, peat, clays, etc are not classed as aquifers and will not therefore constitute groundwater bodies.

2.3 Initial Characterisation

The main outputs of initial characterisation are the delineation and description of groundwater bodies.

2.3.1 Requirements of Directive for Initial Characterisation

According to the Directive (Annex II, section 2.1):
Member States shall carry out an initial characterisation of all groundwater bodies to assess their uses and the degree to which they are at risk of failing to meet the objectives for each groundwater body under Article 4. Member States may group groundwater bodies together for the purpose of this initial characterisation. This analysis may employ existing hydrological, geological, pedological, land use, discharge, abstraction and other data but shall identify:

- *the location and boundaries of the groundwater body or bodies*
- *the pressures to which the groundwater body or bodies are liable to be subject including:*
  - *diffuse sources of pollution*
  - *point sources of pollution*
  - *abstraction*
  - *artificial recharge,*
- *the general character of the overlying strata in the catchment area from which the groundwater body receives its recharge,*

- *those groundwater bodies for which there are directly dependant surface water ecosystems or terrestrial ecosystems.*

The location and delineation of groundwater bodies is based on several factors:
1. the hydrogeology, as indicated by the aquifer category;
2. catchment boundaries;
3. information on the strata (soils and subsoils) overlying groundwater bodies so that the vulnerability of groundwater and recharge to groundwater can be assessed to assist in delineating groundwater bodies 'at risk';
4. information on the pressures caused by human activities and the impact of these activities to assist in delineating groundwater bodies 'at risk'; and
5. information on ecosystems that are either dynamically linked or dependent on groundwater.

The initial characterisation includes a first-pass identification of groundwater bodies followed, for each body, by an assessment of pressures, overlying strata, and linkages with ecosystems. As a consequence of these assessments, it is envisaged that the initial identification of groundwater bodies will require revision and sub-division. Ultimately all groundwater bodies will need to be categorised into those 'at risk' and those not 'at risk'.

2.3.2 Preliminary Identification of Groundwater Bodies

2.3.2.1 Reference to Directive

Article 2, items 12 and 13
Article 5
Annex II, paragraph 2.1 and 2.2
Annex VII, paragraph A 1.2

2.3.2.2 Tasks

The first stage in mapping groundwater bodies requires consideration of the aquifers and catchment boundaries.

The tasks that need to be undertaken to carry out this stage are as follows:

1. **Production of a bedrock map of the RBD;**
2. **Collection of relevant hydrogeological data from existing sources;**
3. **Compilation of a map of karst features;**
4. **Completion of an aquifer map of the RBD;**
5. **Incorporation of the main river catchment boundaries, as these will generally act as groundwater divides;**
6. **Delineation of boundaries of groundwater body types based on the hydrogeological characteristics and resource value of the aquifers, and catchment boundaries;**
7. **A description of these groundwater body types, which would include a simple conceptual model.**

An overview is provided in Figure 2.1, while further details are given in Table 2.1.

At this initial stage, it is recommended that the aquifers be grouped as follows:

1) **Karstic (Rk) aquifers;**
2) **Gravel (Rg** and **Lg) aquifers;**
3) **Productive fractured bedrock (Rf** and **Lm**) **aquifers**;
4) **Poorly productive bedrock (Ll**, **Pl** and **Pu**) **aquifers**.

This grouping is based on similarities in a) hydrogeological properties; b) resource value; c) likely monitoring requirements; d) influence on surface water characterisation; and e) the likely measures required to manage the groundwater. They can be considered as general groundwater body types. They

are further sub-divided by catchment boundaries to give a preliminary map of groundwater bodies. This will act as a framework for further sub-division based on areas that are considered to be 'at risk' (see Section 2.3.6), and the nature of that risk.

The description of the groundwater body types should include information relevant to surface water characterisation, and should be written so as to allow easy integration with related aspects.

The Working Group on Groundwater proposes that the GSI will produce the bedrock and aquifer maps, collect and compile relevant well and hydrogeological data, compile and map karst features, and undertake the first-pass location and description of groundwater bodies (i.e. tasks 1-7 above), for the following reasons:

- to maintain consistent standards for aquifer delineation country-wide;
- to ensure that geological and aquifer boundaries match across RBD boundaries;
- to enable efficient access to relevant GSI databases and maps, and updating of these databases;
- to ensure that the experience and expertise of the GSI staff in aquifer delineation and in undertaking groundwater protection schemes are utilised in RBD projects and that the groundwater protection schemes undertaken to-date are integrated with the River Basin Management Systems (RBMSs).

The appointed RBD contractor will be responsible for co-ordinating and funding the work undertaken by the GSI within the river basin project, and for ensuring that the digital map production will be incorporated into the GIS developed by the contractor for the River Basin District GIS.

The further stages in delineating groundwater bodies are described in Section 2.3.6.

2.3.3 Impact of Human Activities on Groundwater Bodies

The evaluation of likely pressures on groundwater bodies will be undertaken by RBD contractors, on the basis of data collected, and monitoring undertaken, for these projects, as described in the Consultant's Brief. Further guidance from the Pressures and Impacts Working Group will outline recommendations on the most effective approach for the identification of significant anthropogenic pressures on groundwater and the analysis of the potential impacts of these pressures. Assessment of quantitative and qualitative monitoring results should also provide information on the pressures and impacts on groundwater bodies.

2.3.4 Strata Overlying Groundwater Bodies

2.3.4.1 Reference to Directive

Annex II, section 2.1.

2.3.4.2 Background

"Overlying strata" are the geological materials overlying the water table in unconfined groundwater bodies and overlying the top of the geological unit forming confined groundwater bodies. These strata will consist of soils (topsoils) and subsoils such as till, alluvium, lake and estuarine fine-grained sediments, peat, and sand/gravel deposits that are not classified as aquifers or groundwater bodies.

Identification of the general character of overlying strata is required to enable:

- assessment of the potential pathways of contaminants to groundwater;
- evaluation of the vulnerability of groundwater to contamination; and
- analysis of recharge to groundwater.

Information on overlying strata will also assist in risk assessment, identification of measures to prevent contamination and surface water characterisation.

2.3.4.3 Tasks

The tasks that need to be undertaken are as follows:

1. **Delivery of a soils map of the RBD** (this will also be needed for surface water characterisation)**;**
2. **Completion of a subsoils map of the RBD;**
3. **Production of a map showing rock outcrop areas;**
4. **Compilation of all existing depth to rock data;**
5. **A preliminary map of extreme groundwater vulnerability (i.e. areas with <3 m soil and subsoil);**
6. **A preliminary assessment of general recharge acceptance and runoff characteristics.**

The Groundwater Working Group propose that Teagasc produce the soils and subsoils maps of the RBD (i.e. tasks 1-2 above), for the following reasons:

- to maintain consistent standards for soils country-wide;
- to ensure that soils and subsoils boundaries match across RBD boundaries;
- to enable efficient access to relevant Teagasc databases, maps and expertise.
- facilities to undertake the required work are already at Teagasc, Kinsealy.
- it would be impracticable for another organisation to begin to undertake such work given the expertise and facilities housed in Teagasc.

The Contractor will be responsible for co-ordination and funding of the work undertaken by Teagasc within the river basin project.

The Groundwater Working Group proposes that the GSI undertakes the production of a digital outcrop and depth to rock data map (i.e. tasks 3-4 above). The reasons are that the GSI holds the relevant information on maps and in various databases and it would be impracticable to undertake the work elsewhere.

The appointed RBD contractor will be responsible for undertaking a preliminary map of extremely vulnerable areas using the information supplied by the GSI and Teagasc, and a preliminary assessment of recharge acceptance and runoff characteristics (i.e. tasks 5-6 above). The Contractor will be responsible for co-ordination and funding tasks 1-6 within the RBMS project.

Further detail on the information needs for identifying and describing overlying strata for initial characterisation are outlined in Table 2.1, together with a summary of the available information, and recommendations on the tasks that need to undertaken as part of RBMS projects.

2.3.5 Ecosystems and Groundwater Bodies

2.3.5.1 Reference to Directive

Article 1
Article 4
Article 5
Article 6
Article 8
Annex II, section 2.1
Annex IV, section 1
Annex VI, Part A (x)
Annex VII, section A 3

2.3.5.2 Background

The WFD aims at an ecologically oriented management of water bodies and requires, for the purposes of initial groundwater characterisation, the identification of those groundwater bodies for which there are directly dependent surface water ecosystems or terrestrial ecosystems. This section highlights the importance of seeing each work element in the context of the overall requirements of the WFD.

According to Article 1 (a) one of the fundamental objectives is to "*prevent further deterioration and to protect and enhance the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems*." Article 4.1.(b) (i) and (ii) states respectively that *"Member States shall..... prevent the deterioration of the status of all bodies of groundwater*" and "*shall protect, enhance and restore all bodies of groundwater with the aim of ensuring good groundwater status..... in accordance with the provisions laid down in Annex V*". In relation to a "good status" Annex V 2.1.2 defines good quantitative status for groundwater *as "the level of groundwater is not subject to anthropogenic alterations such as would result in: - failure to achieve the environmental objectives specified under Article 4 for associated surface waters. - any significant diminution of the status of such waters; - any significant damage to terrestrial ecosystems which depended directly on the groundwater body*". Annex V 2.3.2 defines a good groundwater chemical status as "*The chemical composition of the groundwater body is such that the concentration of pollutants: - are not such as would result in failure to achieve the environmental objectives specified under Article 4 for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body*".

Therefore the achievement of "good status" for groundwater is dependent on ensuring appropriate groundwater conditions for the maintenance of "good status" for surface waters and the avoidance of significant damage to the status of terrestrial ecosystems which depend directly on the groundwater body.

2.3.5.3 Groundwater dependent aquatic and terrestrial ecosystems

In defining such areas it is reasonable to assume that only aquatic and terrestrial wetland systems will be affected by changes in groundwater availability or quality. For practical groundwater-related purposes, aquatic ecosystems consist of freshwater rivers, lakes and some "transitional" waters such as estuaries and lagoons. Terrestrial ecosystems which are directly dependent on groundwater will be located in areas where groundwater discharges to the surface or to the rooting zone of the vegetation in sufficient quantity to determine the ecological potential of the site. Thus, by definition, these are wetland ecosystems.

All the Irish freshwater wetland types listed below are groundwater dependent to varying degrees. Three basic categories can be recognised:

1. Highly groundwater dependant ecosystems where reductions in quantity/quality would cause major adverse changes in ecosystem structure and function in the short to medium term. These include:
   - turloughs;
   - fens, in particular rich fens and flushes;
   - springs;
   - marl lakes; and
   - dune slacks.

2. Dependent ecosystems which, although surface water may be a dominant influence at certain times, are usually dependent on some groundwater input to retain their current ecology in the medium to long term. These include:
   - rivers;
   - lakes;
   - swamps;
   - estuaries;
   - lagoons;
   - freshwater marshes;
   - poor fens and flushes;
   - transition mire and quaking bog;
   - riparian woodland;

- wet willow-alder-ash woodland;
- bog woodland;
- non-marine caves; and
- machairs.

3. Independent to locally dependent ecosystems where surface water is the dominant influence and where groundwater is generally only locally important. Groundwater may however be very important in the maintenance of appropriate hydrological conditions. These ecosystems include:
   - raised bogs; and
   - upland and lowland blanket bogs.

Taking into account the range of ecosystems involved, many groundwater bodies will be associated with dependent ecosystems of some type. For the purposes of the River Basin Projects, the consideration of ecosystems dependent on groundwater should be confined to sites identified as being of national or international importance for nature conservation.

2.3.5.4 Tasks

The tasks that need to be undertaken are as follows:

1. **Locate all relevant ecosystems from sites which are already candidate SACs under the Habitats Directive or designated SPAs under the Birds Directive, or which have been proposed as Natural Heritage Areas (NHAs), with a view to statutory designation under national legislation. These are listed in the Protected Areas register by the Department of Arts, Heritage, Gaeltacht and The Islands.**
2. **Sub-divide these sites into the three categories (1, 2, 3) listed above and incorporate them into the RBD GIS.**
3. **Identify the groundwater bodies associated with each site and conceptualise the relationship between the groundwater body and the ecosystem.**

The appointed RBD contractor will be responsible for undertaking these tasks.

Further details on the information needed for identifying groundwater dependent wetlands is outlined in Table 2.1, together with a summary of available information and recommended tasks.

2.3.6 'At Risk' Groundwater Bodies

2.3.6.1 Reference to Directive

Article 4
Article 5
Annex II, section 2

2.3.6.2 Proposed Methodology for Delineation of 'At Risk' Groundwater Bodies

According to Annex II Section 2.2*, "Member States shall carry out further characterisation of those bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identification of any measures to be required under Article 11."* Therefore, one of the outcomes of initial characterisation is the subdivision of groundwater bodies into those that are considered to be either 'at risk' or **not** 'at risk'.

'At risk' must be interpreted in the context of the Directive, i.e. **'at risk' of failing to meet the environmental objectives set out in Article 4.** According to Article 4, "*Member States shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the state of all bodies of groundwater, …..*" Also, "*Member States shall protect, enhance and restore all bodies of groundwater, ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status at the latest 15 years after the date of entry into force of this Directive, in accordance ……"*

The advice given in this section is based on our current interpretation of the WFD. This interpretation may change somewhat a) as the work progresses, b) as the interpretations of other EU countries become available, and c) as advice is given by the EU.

1. The first-pass stage will provide the following types of groundwater body (see Section 2.3.2):
   - **Karstic (Rk) aquifers;**
   - **Gravel (Rg** and **Lg) aquifers;**
   - **Productive fractured bedrock (Rf** and **Lm**) **aquifers**;
   - **Poorly productive bedrock (Ll**, **Pl** and **Pu**) **aquifers**.

   These are then sub-divided using catchment boundaries to give the preliminary delineation of groundwater bodies.

2. Each of these groundwater bodies must be examined in terms of the following criteria:
   - the pressures on the groundwater body, including point and diffuse sources of pollution, and abstraction of groundwater;
   - groundwater chemical status including, in particular, the presence of nitrate vulnerable zones;
   - groundwater quantitative status, in particular levels of abstraction relative to recharge;
   - long-term water level monitoring data;
   - evidence of saline intrusion;
   - conservation designated ecosystems dependent on groundwater;
   - the aquifer category (i.e. the value of the groundwater resource);
   - extent of extremely vulnerable areas.

3. In the absence of criteria adopted at Community level, it is proposed (on an interim basis and pending further elaboration of groundwater protection measures at national and Community level) that the EPA list of parameters and guideline values for the assessment of groundwater quality in Ireland (Proposed Guideline Values for the Protection of Groundwaters in Ireland, EPA, in preparation) be used for assessing the **groundwater chemical status** of each groundwater body. It is envisaged that these criteria will be further elaborated as River Basin Projects proceed, and that certain adaptations will have to be made in the work programme of River Basin Projects to incorporate these developments. The Groundwater Working Group will, through continued involvement in relevant EU workgroups and other activities, continue to provide technical guidance.

4. If the existing groundwater quality data are inadequate to decide on the chemical status, further monitoring is required (see Section 3).

5. Good **quantitative status** requires that *'the level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual rate of abstraction'* (Annex V, Section 2.1.2). Therefore the principal parameter for assessing quantitative status is the groundwater level. Spring discharges should also be used, particularly in karstic and poorly productive aquifers. The most widespread impact on the quantitative status of a groundwater body is from long-term groundwater abstractions. Consequently, information on the location of abstraction points and rates of abstraction is required. Due to our relatively low levels of abstraction and generally high rainfall, it is unlikely that there will be many groundwater bodies where the quantitative status is at risk.

6. If, on the basis of results of the initial characterisation, the risk of not meeting the objectives is found to exist in only a part of a groundwater body, this area may be delineated as a separate groundwater body 'at risk', with the remainder being a groundwater body which is not 'at risk'. However, it is recommended that all groundwater bodies should:
   - have hydraulic boundaries – groundwater divides, flow lines, rivers, etc.
   - be at least 10s of km^2 in size to make them a practical unit for management.

7. The nature of development in Ireland and Irish hydrogeological conditions can give rise to localised groundwater quality problems, which are often indicated by microbiological pollution of private supplies, due particularly to the presence of nearby point pollution source/s. Whilst it is not proposed that separate groundwater bodies be identified in such instances, the contractor should propose measures to deal with the issue.

8. The following are examples of groundwater bodies considered to be 'at risk' and requiring further characterisation:
   - Where area-wide survey findings show poor groundwater quality.
   - Where area-wide survey findings show high levels of abstraction relative to recharge.
   - Groundwater bodies which encompass designated aquatic or wetland ecosystems dependent on or significantly supported by groundwater, and which are affected detrimentally by human activities or are under threat.
   - Groundwater bodies where the pressures, vulnerability and aquifer category suggest that the groundwater might be 'at risk', but where current monitoring data do not indicate problems. Work carried out during 'further characterisation' may indicate that these bodies are not 'at risk'.

9. In describing groundwater bodies, it is recommended that adjacent bodies within a river basin district should be grouped, if practicable, where there are similarities in hydrogeology, pressures and impacts. Also, grouping of small, discrete groundwater bodies in an RBD, such as gravel aquifers, is recommended where the pressures and impacts are similar. This grouping can then be applied in considering the monitoring requirements and the management measures.

2.3.6.3 Tasks for Identifying Groundwater Bodies 'At Risk'

The tasks that need to be undertaken are as follows:

1. **Identification and assessment of pressures;**
2. **Assessment of the quantitative and qualitative status of groundwater;**
3. **Assessment of potential for significant adverse impacts on ecology of designated groundwater dependent wetlands taking into account their type, sensitivity to different pressures/impacts, distribution and status;**
4. **Integration of hydrogeological, hydrochemical/water quality, ecological assessments with an evaluation of the pressures and impacts to delineate and describe groundwater bodies that:**
   - **are not considered to be 'at risk' and do not therefore require further characterisation or a high degree of surveillance; and**
   - **are considered to be 'at risk' and therefore require further characterisation and should be monitored, subject to trend analysis, management measures and reporting, etc., as relevant.**

An overview is provided in Figure 2.1, while further details are given in Table 2.1.

The appointed RBD contractor will be responsible for undertaking the above tasks.

Table 2.1 Information Needs, Existing Situation and Recommended Tasks for Initial Characterisation of Groundwater Bodies

Information Needs	Existing Situation	Recommended Tasks for RBMS projects	Objectives of Work
Bedrock			
♦ geological unit boundaries (digital) ♦ rock lithologies ♦ structural geology – faults, fracturing	♦ Digital bedrock maps and accompanying reports available in GSI for ~75% of country; the remainder will be available by mid 2002.	♦ Reconfigure maps to suit catchment boundaries. ♦ Re-register data and boundaries to a common O.S. topographic base (1:50,000). ♦ Assessment of relevant aspects of structural geology	♦ To provide boundaries of aquifers and groundwater boundaries ♦ To provide information needed in delineating aquifers
Soils			
	♦ Teagasc Soils maps (until 1980s) available for ~45% of country at 1:126,720, but not digitally. ♦ New Teagasc maps of remaining areas (FIPS-Irish Forest Soils project) will be complete in 2002. These maps are potentially more useful than existing maps - scale is 1:50k, a different classification system is used, e.g. soils sub-divided into wet & dry, maps are digital.	♦ Deliver an integrated mapping programme for the RBD.	♦ To assist in assessing the character of the overlying strata ♦ To assist in vulnerability and recharge assessments ♦ To provide essential information for surface water characterisation
Subsoil			
Subsoils Map showing main types – sand/gravel, till (boulder clay), peat, clays/silts, alluvium, etc.	♦ Subsoil maps are or will be available as part of county groundwater protection schemes for ~50% of country. ♦ GSI Quaternary Section is compiling existing information for remainder, but information is variable and is minimal for many areas. ♦ Teagasc is producing subsoils maps as part of the FIPS-IFS project. These will include the GSI information. However, current plans are that ~40% country will not be mapped.	♦ Complete full coverage of all RBDs	♦ To enable sand/gravel aquifers to be delineated ♦ To assist in assessing the character of the overlying strata ♦ To assist in vulnerability and recharge assessments
Outcrops and shallow rock			
Map showing outcrops and shallow rock	♦ Outcrops digitised for ~20% of country. ♦ Depth to rock data compiled or being compiled for ~50% of country, including delineation of outcrop areas.	**For counties with groundwater protection schemes:** ♦ Update databases and maps. ♦ Ensure that digital maps are integrated with RBD GIS. **For counties without GWPSs:** ♦ Compile and digitise rock outcrops and shallow rock areas on GSI maps. ♦ Collect existing depth to rock data and enter to database. ♦ Delineate outcrop areas; estimate 3 m soil/subsoil contour using all available data	♦ To assist in assessing the character of the overlying strata ♦ To enable extremely vulnerable areas to be located ♦ To assist in recharge assessment

Information Needs	Existing Situation	Recommended Tasks for RBMS projects	Objectives of Work
Hydrogeology			
♦ wells – depths, location, yields, drawdowns, depth to rock, etc ♦ springs – location, outflows ♦ karst features – location, type, description ♦ specific capacity, permeability, transmissivity, specific yield ♦ groundwater level data ♦ low flows in streams (from EPA and OPW) ♦ drainage density (stream length/unit area) ♦ particle size data for gravels	♦ Groundwater protection schemes are completed, in progress or planned for 50% of country. ♦ Hydrogeological chapters in county groundwater protection schemes have been written primarily for groundwater protection and development purposes. ♦ Currently, GSI Groundwater Section is undertaking permeability mapping as part of vulnerability mapping for Monaghan, Kilkenny, Roscommon, South Cork & Kildare. This has also been undertaken, at a preliminary level, for Clare and Laois. ♦ Vulnerability maps are either completed or in progress for ~50% of country. ♦ Mapping of karst features is being undertaken in Roscommon with assistance from the Department of Geography, TCD, and Teagasc. ♦ GSI has a Karst Database which contains some information on karst features; however, it is not comprehensive. ♦ GSI has 20+ years' records of water level monitoring for a limited number of wells; there are over 100 with more than one year's records. As part of its Hydrometric Programme, the EPA has monthly dipping for ~3-5 years at some 300+ groundwater locations. ♦ Initial quantification of groundwater resources and abstraction by GSI in 1979 (published by the EC in 1982). ♦ Information on drainage density and stream frequency on OPW Flood Studies Report, 1975.	♦ Re-evaluate data in counties where groundwater protection schemes have been completed (take account of any new data) and re-consider aquifer categories. Aquifer categories must not only be consistent within RBDs but also country-wide. ♦ Collect additional well/spring data from GSI, local authorities (incl. well grant data), EISs, IPCLs, waste licences, drillers, consultants, etc. for remaining areas. ♦ Develop databases for groundwater data. ♦ Attribute grid references for wells/springs & enter to database. ♦ Collect and map karst feature information & enter to database. ♦ Review sand/gravel particle size data & collect additional data. ♦ Summarise and evaluate data, taking a consistent RBD-wide approach. ♦ Delineate aquifers and produce an aquifer map. ♦ Delineate groundwater bodies. ♦ Produce a map showing 'extremely' vulnerable areas (i.e. areas with <3 m soil/subsoil and in vicinity of karst features). ♦ Carry out a preliminary assessment of recharge acceptance and runoff characteristics, concentrating on areas where the quantitative status is under threat. ♦ Identify groundwater bodies where the quantitative status is 'at risk'. ♦ Report on hydrogeology, including groundwater characterisation. ♦ Ensure that digital maps are integrated with RBD GIS.	♦ To allow categorisation of aquifers. ♦ To provide essential information for delineation of groundwater bodies. ♦ To allow an evaluation of groundwater recharge and quantitative status. ♦ To allow an evaluation of groundwater vulnerability and the relationship between this, pressures and impacts and qualitative status. ♦ To assist in characterising ecosystems dependent on groundwater. ♦ To assist in the delineation of groundwater bodies 'at risk'.

Information Needs	Existing Situation	Recommended Tasks for RBMS projects	Objectives of Work
Hydrochemical and water quality			
♦ Water quality data	♦ EPA National Groundwater Quality Monitoring Network comprises some 296 (raw) groundwater sources that are sampled twice a year. Reports on individual samples are available from the EPA regional chemist. Data is published in "Water Quality in Ireland", currently published on a three year cycle. The samples are analysed for routine chemical and bacteriological parameters. ♦ GSI reports are available on groundwater quality, as part of groundwater protection schemes: 9 are completed; 4 are in progress. These include a brief description of the hydrochemistry of the groundwater in the county; an assessment of the main indicators of groundwater contamination and the impact of human activity; an appraisal of the water quality of selected public supply wells/springs; and, where relevant, an assessment of trends. ♦ Assessments of groundwater quality carried out for EISs, IPC and Waste Licences, pollution incidents.	♦ Compilation and review of raw water quality data ♦ Evaluation of data, using the EPA Guideline Values ♦ Identification of areas where the groundwater quality is indicating that the status is under threat	♦ To assess the groundwater chemical status. ♦ To assist in the delineation of groundwater bodies 'at risk'.
Ecosystems			
	♦ Duchas have information on sites which are already designated as SACs or SPAs on the Habitats and Birds Directive respectively or are proposed for designation as NHAs under the Wildlife(Amendment) Act 2001.	♦ Abstract the relevant ecosystems from the list of SACs, SPAs and proposed NHAs and sub-divide these sites into the 3 categories: 1) highly groundwater dependent ecosystems; 2) dependent ecosystems; and 3) independent to locally dependent ecosystems. ♦ Identify the groundwater bodies associated with the sites in the three categories. ♦ Assessment of potential for significant adverse impacts taking into account the ecosystem type, sensitivity to different pressures/impacts, distribution and status.	♦ To identify surface water and terrestrial ecosystems dependent on groundwater ♦ To assist in identifying groundwater bodies with dependent ecosystems. ♦ To identify groundwater bodies 'at risk'.

Information Needs	Existing Situation	Recommended Tasks for RBMS projects	Objectives of Work
Pressures and impacts			
♦ Sectoral pressures on groundwater bodies	♦ Under Section 9(2) of the Local Government (Water Pollution Act), 1977, each local authority is required to keep a register of abstractions from waters in its functional area, but under Section 37 of the Local Government (Water Pollution Act) Regulations, 1978, it is not necessary to register an abstraction where it is less than 25 m³ in any period of 24 hrs. However, the registers, while established, may contain very little information. ♦ The EPA has a database containing some information on groundwater abstractions. ♦ The report published annually by the EPA on the Quality of Drinking Water in Ireland also contains some information on abstraction rates supplied by local authorities.	♦ All sources with abstraction rates >10 m^3/d should be located. Abstractions from each groundwater body should be estimated. ♦ Deliver a GIS based database of sectoral pressures and impacts on groundwater including information on land use, discharge, abstraction and artificial recharge.	To identify ♦ diffuse sources of pollution; ♦ point sources of pollution; ♦ abstraction points; and ♦ artificial recharge.

2.4 Further Characterisation

2.4.1 Reference to Directive

Article 2
Article 5
Annex II, Section 2.2

2.4.2 Requirements of Directive

According to Annex 11, Section 2.2:

Following this initial characterisation, Member States shall carry out further characterisation of those groundwater bodies or groups of bodies which have been identified as being at risk in order to establish a more precise assessment of the significance of such risk and identification of any measures to be required under Article 11. Accordingly, this characterisation shall include relevant information on the impact of human activity and, where relevant information on:

- *geological characteristics of the groundwater body including the extent and type of geological units,*
- *hydrogeological characteristics of the groundwater body including hydraulic conductivity, porosity and confinement,*
- *characteristics of the superficial deposits and soils in the catchment from which the groundwater body receives its recharge, including the thickness, porosity, hydraulic conductivity, and adsorptive properties of the deposits and soils,*
- *stratification characteristics of the groundwater within the groundwater body,*
- *an inventory of associated surface systems, including terrestrial ecosystems and bodies of surface water, with which the groundwater is dynamically linked,*
- *estimates of the direction and rates of exchange of water between the groundwater body and associated surface systems,*
- *sufficient data to calculate the long term annual average rate of overall recharge,*
- *characterisation of the chemical composition of the groundwater, including specification of the contributions from human activity. Member states may use typologies for groundwater characterisation when establishing natural background levels for these bodies of groundwater.*

2.4.3 Tasks

The tasks that need to be undertaken by the RBD contractor are as follows:

1. **Detailed mapping and evaluation of pressures (i.e. improving on the evaluation of pressures carried out during initial characterisation).**
2. **Acquisition and assessment of relevant hydrogeological data on the hydraulic properties of the groundwater bodies 'at risk'.**
3. **Mapping of extremely vulnerable areas.**
4. **Collection, compilation and assessment of water level and abstraction data for groundwater bodies under threat from over abstraction.**
5. **Collection and assessment of hydrochemical data, and identification of water types.** (Advice and assistance on assessing the hydrochemical facies of different water types and the water quality data would be available from the GSI).
6. **Evaluation of water quality data, assessment of trends and likely causes of water quality deterioration.**
7. **Evaluation of the groundwater quantity and quality aspects of relevant ecosystems.**
8. **Refinement, if necessary, of the boundaries of the groundwater bodies delineated at the initial characterisation stage.**

9. **Description of the relevant aspects for each groundwater body, which should include a conceptual model of the body.**
10. **Establishment of a monitoring programme (see Section 3) based on the results of further characterisation.**
11. **Identification of a programme of measures, based on the results of further characterisation, to achieve the objectives of 'good groundwater status' for 'at risk' groundwater bodies.**

Further details on the tasks are given in Table 2.2. The list of tasks that need to be undertaken is relatively comprehensive; the actual work required will vary depending on the groundwater body that is being characterised. Also, the work undertaken should be focused on the objectives and requirements of the Directive.

For some groundwater bodies, it may turn out during further characterisation that the risk, which was assumed from the initial characterisation, is negligible. Once this has become clear, continued characterisation is no longer necessary.

The outcome of 'further characterisation' will be a comprehensive assessment of the natural character (hydrogeological, hydrochemical, ecological, hydrological, as appropriate) of the groundwater body at risk, which must be linked with an assessment of pressures and impacts, and followed by the identification of appropriate measures to protect/enhance the groundwater bodies.

Table 2.2 Information Needs and Recommended Tasks for Further Characterisation of Groundwater Bodies

Information Needs	Recommended Tasks for RBMS projects
Hydrogeological	
♦ Hydraulic properties, in particular hydraulic conductivity and effective porosity of groundwater body ♦ Information on degree of confinement ♦ Hydraulic properties of superficial deposits ♦ Evaluation of stratification in groundwater body ♦ Recharge estimates for relevant areas ♦ Baseflow and water balance data	♦ Identification of relevant hydraulic properties by means of: 1. evaluation of existing data; 2. pumping tests on selected public supplies; 3. numerical modelling, if appropriate. ♦ Location and description of confined aquifers. ♦ If vulnerability maps are not already available, mapping of extremely vulnerable areas (areas with <3 m soil/subsoil, plus karst features) on 'at risk' groundwater bodies shall be undertaken. Drilling to assess depth to rock is likely to be required. ♦ Hydrograph/baseflow/water balance analysis, as appropriate. ♦ Assessment of the link between groundwater and surface water - evaluation of all relevant factors – baseflow, aquifer categories, vulnerability, etc., as appropriate. ♦ Assessment of recharge in areas where the quantitative status of groundwater is at risk (see Section 3 for further details).
Hydrochemical and water quality	
♦ Hydrochemical and water quality data ♦ Identification of groundwater types ♦ Assessment of impact of human activity	♦ Evaluation of water quality using EPA guideline values. ♦ Subdivision of chemical data into 2 categories – from sources with relatively uncontaminated water and the rest. ♦ Use of graphical methods, such as Piper or Durov diagrams, to process data from uncontaminated sources into water types. ♦ Assessment of trends.
Ecological	
♦ Inventory of nature conservation sites on the Protected Areas register. ♦ Groundwater quality and quantity requirements of the associated ecosystems.	♦ An integrated vegetation, hydrological, hydrogeological, and hydrochemical survey of the ecosystem 'at risk' to characterise the nature of the hydrogeological connections, the hydrological regimes and the hydrochemistry necessary to maintain their ecology. Guidance should be sought from Dúchas in undertaking this work.
Hydrological	
♦ Inventory of surface systems and bodies of surface water, with which the groundwater body is dynamically linked	♦ Undertake the inventory
HAZARD MAPPING AND ASSESSMENT OF PRESSURES AND IMPACTS	
See Annex II Section 2.3	♦ Advice will be provided by the Pressures and Impacts Working Group

3. Monitoring of Groundwater Status

3.1 Background

The Framework Directive requires the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each river basin district (Article 8.1). For groundwater, such programmes must cover the monitoring of the quantitative and chemical status, in accordance with the requirements of Annex V of the Directive.

For the purpose of the Directive, groundwater is seen not as a separate system but, through the hydrological cycle, is linked to surface waters and terrestrial ecosystems dependent on groundwater. The definition of good groundwater status therefore also incorporates the maintenance of these associated systems, and the design of groundwater monitoring programmes must take these interdependencies into account.

The WFD requires the establishment of monitoring networks to determine the groundwater quantitative and chemical status of groundwater bodies or groups of bodies. Monitoring points are not necessarily required to be located in all groundwater bodies but they must be located so that they are representative of all groundwater bodies within a river basin district.

In Ireland some locally important aquifers and virtually all poor aquifers, due to their hydrogeological conditions, have short flow paths and the zones of contribution associated with monitoring sites are small. Therefore the usefulness of monitoring sites in terms of being representative of the waters within a groundwater body must always be assessed. In addition the contractor will need to consider the likely importance of natural springs as representative monitoring points.

3.2 Groundwater Quantitative Status

3.2.1 Reference to Directive

Article 4
Article 7
Article 8
Annex V section 2.1 and 2.2 (quantitative status)

3.2.2 Requirements of the Directive

- *Member States shall ……. ensure a balance between abstraction and recharge of groundwater, with the aim of achieving good groundwater status …….'* (Article 4(b)(ii)).
- *Member States shall monitor, in accordance with Annex V, those bodies of water which according to Annex V, provide more than 100 m³/d as an average.* (Article 7).
- *– for groundwaters such programmes shall cover monitoring of the chemical and quantitative status,* (Article 8).
- *Review of the impact of changes in groundwater levels* (Annex II, Section 2.4)

  Member States shall identify those bodies of groundwater for which lower objectives are to be specified under Article 4 including as a result of consideration of the effects od the status of the body on:

  i. *surface water and terrestrial ecosystems*
  ii. *water regulation, flood protection and land drainage*
  iii. *human development.*

- Good status requires *'the level of groundwater in the groundwater body is such that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction.* (Annex V, Section 2.1.2).
- *The groundwater monitoring network shall be established in accordance with the requirements of Articles 7 and 8* (Annex V, Section 2.2.1).

3.2.3 Overview of quantitative status

As set out earlier, the WFD requires a monitoring programme for the quantitative status of groundwater bodies. The Directive aims to achieve 'good quantitative status'. The principal parameter for assessing the quantitative status is the groundwater level, as measured in boreholes/wells. Spring discharges may also be relevant as springs are a surface expression of the groundwater table.

The available information on the existing groundwater level network as well as the recharge information will be reviewed during the initial and further characterisation stages. These stages will assist in the preliminary identification of groundwater bodies 'at risk' i.e. groundwater bodies at risk of not achieving 'good quantitative status'.

'Good quantitative status' is established when:

- the groundwater level indicates that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction;
- the groundwater level is such that it allows the achievement of the environmental objectives set for associated surface water systems;
- it results in no significant diminution in the status of such waters; and
- it results in no significant damage to terrestrial ecosystems which depend directly on the groundwater body.

In addition, any change in flow direction as a result of a change in groundwater level should not cause saline or other intrusion nor induce a trend in flow direction likely to result in such intrusion.

A quantitative groundwater audit is required where a groundwater body does not achieve 'good quantitative status' or the groundwater body is at risk of failing to achieve this objective.

3.2.4 Designing the Quantitative Status Monitoring Network

The monitoring network must be designed to provide an early indication of any negative changes on the quantitative status of each groundwater body or representative groundwater body within the river basin district. The network shall encompass both groundwater bodies 'at risk' and those 'not at risk'. Additional considerations are required for those groundwater bodies 'at risk'; particular attention being given to the density of monitoring points to assess the impact of abstractions and discharges on the groundwater level.

In cross-border groundwater bodies the density of monitoring points should be such as to estimate the direction and rate of groundwater flow across the member state boundary.

All groundwater bodies used for the abstraction of drinking water that provide more than 100 m^3 per day as an average shall be included in the monitoring programme irrespective of whether or not they are 'at risk' or are cross-border groundwater bodies.

The distribution of monitoring sites must ensure that the spatial and temporal variability of the groundwater surface can be sufficiently well recorded within a groundwater body. The density of sites must permit the collection of the most reliable data possible, particularly in ecologically sensitive areas. The distribution and density of the monitoring points will depend on the hydrogeological conditions and also on the response of the aquifer to recharge.

According to Annex V, section 2.2.2, *the network shall include sufficient representative monitoring points to estimate the groundwater level in each groundwater body or group of bodies taking into account short and long-term variations in recharge; …* Therefore, monitoring points are not required in each groundwater body provided the network is 'representative' and allows levels to be estimated.

The frequency of monitoring shall allow assessment of the quantitative status of each groundwater body (or group of bodies) taking account of the short and long term variations in recharge and satisfying the requirements stated above. The frequency will depend on the hydrogeological conditions within each groundwater body and on the response of the groundwater body to recharge. No specific monitoring frequency is specified in the Directive. However, in some instances (e.g. unconfined karstic aquifers), high temporal variations in groundwater level are likely to arise requiring a high frequency of monitoring and data loggers will be required in these instances. The monitoring network will additionally need to distinguish between anthropogenic and natural changes in water level.

The contractor must have regard to existing groundwater monitoring networks and liase with EPA/GSI/local authorities with a view to supporting/supplementing existing networks, and thereby avoiding duplication of national effort.

Where adequate monitoring sites are not currently available, additional sites must be installed. These sites should be sufficiently far from large groundwater abstraction points to be free from short-term fluctuations caused by abstractions.

3.2.5 Tasks for Quantitative Status Monitoring

1. **Following the review undertaken during the initial and further characterisation stages, propose additional strategically located monitoring points (boreholes or springs).**
2. **Provide the basis for the location of the monitoring points and the frequency of monitoring. A review mechanism of the suitability of the monitoring points should be built into the monitoring programme.**
3. **Compile well construction data and hydrogeological data for each monitoring point.**
4. **Determine the hydrogeological regime in the vicinity of each of the monitoring locations.**
5. **Implement the groundwater quantitative status monitoring programme.**
6. **Collate and verify the data and store in a GIS compatible data management system.**
7. **Assess the groundwater quantitative status of each of the groundwater bodies (see Section 4).**
8. **For those groundwater bodies that fail to achieve good quantitative status carry out a groundwater audit.**
9. **Propose a programme of measures for those groundwater bodies that fail to achieve good groundwater quantitative status.**

3.3 Groundwater Chemical Status

3.3.1 Reference to the Directive

Article 4
Article 7
Article 8
Article 15
Article 17
Annex V, section 2.3, 2.4 and 2.5.

3.3.2 Requirements of Directive

- *Member States shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the deterioration of the status of the all bodies of groundwater* (subject to certain conditions) (Article 4(b)(i)).
- *Member States shall protect, enhance and restore all bodies of groundwater,….. with the aim of achieving good groundwater status…* (Article 4(b)(ii))
- *Member States shall monitor, in accordance with Annex V, those bodies of water which according to Annex V, provide more than 100 m³ a day as an average* (Article 7).
- *The monitoring network shall be designed so as to provide a coherent and comprehensive overview of groundwater chemical status within each river basin district and to detect the presence of long-term anthropogenically induced upward trends in pollutants (*Annex V 2.4.1).
- *Review of the impact of human activity on groundwaters.*
  For those bodies of groundwater which cross two or more Member states or are identified following the initial characterisation …. as being at risk of failing to meet the objectives set for each body under Article 4, the following information shall, where relevant, be collected and maintained for each groundwater body:
  (c) the chemical composition of water abstracted from the groundwater body,
  (f) the chemical composition of discharges to the groundwater body,
  (g) land use in the catchment or catchments from which the groundwater body receives its recharge, including pollutant inputs and anthropogenic alterations of the recharge characteristics such as rainwater and run-off diversion through land sealing, artificial recharge, damming or drainage. (Annex II, Section 2.3)
- *..identify those bodies of groundwater for which lower objectives are to be specified under Article 4(5) where, as a result of the impact of human activity, as determined in accordance with Article 5(1), the body of groundwater is so polluted that achieving good groundwater chemical ststus is infeasible or disproportionately expensive.* (Annex II, Section 2.5)
- *..use data from the surveillance and operational monitoring programmes in the identification of long term anthropogenically induced upward trends in pollutant concentrations and the reversal of such trends* (Annex V, Section 2.4.4).

3.3.3 Overview of Groundwater Chemical Status

The Directive aims to protect, enhance and restore all bodies of groundwater, which *inter alia* includes the maintenance and/or attainment of 'good chemical status'.

Good groundwater chemical status is established when the chemical composition of the groundwater body is such that the concentration of pollutants (Annex V, Section 2.3.2):

- *do not exhibit the effects of saline intrusion;*
- *do not exceed the quality standards applicable under other relevant Community legislation in accordance with Article 17;*
- *are not such as would result in failure to achieve the environmental objectives specified under Article 4 for associated surface waters nor any significant diminution of the ecological or chemical quality of such bodies nor in any significant damage to terrestrial ecosystems which depend directly on the groundwater body.*

For the purpose of establishing groundwater chemical status, the Directive requires monitoring for a set of 'core parameters'. Additionally, groundwater bodies which are identified as being at significant risk or failing to achieve good status, must be monitored for those parameters that are indicative of these risks.

As with the assessment of quantitative status, the information gathered at the initial and further characterisation stage will be used to identify groundwater bodies 'at risk' with respect to their chemical status.

It should be borne in mind that the exact requirements of the WFD are not yet fully determined at this stage. In particular, the European Parliament and the Council have yet to adopt specific measures to prevent and control groundwater pollution (Article 17) which, *inter alia*, shall include:

- Criteria for assessing good groundwater chemical status, in accordance with Annex II 2.2 and Annex V 2.3.2 and 2.4.5;
- Criteria for the identification of significant and sustained upward trends and for the definition of starting points for trend reversals to be used in accordance with Annex V 2.4.4.

Such criteria are necessary in order to:

- ♦ distinguish groundwater bodies at risk of failing to meet the objectives of Article 4 from those groundwater bodies at no risk, or only at negligible risk;
- ♦ finalise the monitoring networks under Article 8.

In the absence of criteria adopted at Community level, Member States are required to establish appropriate criteria at the latest five years after the date of entry into force of the Directive. The Environmental Protection Agency (EPA) is currently in the process of developing guideline values for the assessment of groundwater quality in Ireland (*Proposed Guideline Values for the Protection of Groundwaters in Ireland, Draft for Comment, July 2001*). The draft document sets out the Agency's proposed approach and application of guideline values for the protection of groundwater in Ireland.

It is therefore proposed, on an interim basis and pending further elaboration of groundwater protection measures at national and Community level, that these draft parameters and guideline values be used for the monitoring and characterisation of groundwater bodies for the purpose of river basin projects. Monitoring data collected during the course of these projects will further assist in the elaboration of national groundwater standards.

It is envisaged that these criteria will be elaborated as River Basin Projects proceed, and that certain adaptations will have to be made to the works programmes of projects to incorporate these developments.

In addition, the Directive does not provide precise technical specifications for:

- calculating trends and trend reversal, and
- data aggregation of monitoring data per groundwater body or group of groundwater bodies.

The European Commission, in the context of developing a Common Strategy on the Implementation of the Water Framework Directive, is currently supporting the development of technical guidance towards this end (see Section 4 – Interpretation and Presentation of Groundwater Status).

3.3.4 Designing the Chemical Status Monitoring Network

The WFD requires that a groundwater chemical status monitoring network be set up, comprising a surveillance monitoring network and an operational monitoring network. The two networks shall be used for the monitoring of groundwater status in order to establish a coherent and comprehensive overview of the chemical status of groundwater within each river basin district. The networks will also monitor groundwater bodies used for the abstraction of drinking water. The operational network shall also detect the presence of long-term anthropogenically induced upward trends in pollutants. A programme of measures to achieve 'good groundwater status' must also be proposed.

The contractor should liase with the EPA/GSI/local authorities with a view to supporting/ supplementing their groundwater monitoring network, and to avoid duplication of national effort, in order to provide a reliable assessment of the chemical status of all groundwater bodies including an

assessment of the available groundwater resource. Anthropogenic and natural changes in water quality should be distinguished from each other.

In order to be representative of the groundwater quality over a significant area, a monitoring point must be pumped for sufficient time to develop a substantial Zone of Contribution (ZOC) – of the order of 10 –100 hectares. This will mean that most monitoring points will be wells or springs that are in regular use for water supply. Where no such suitable monitoring points are available, the monitoring programme should establish new points and equip them with suitable pumping equipment.

3.3.4.1 Surveillance Monitoring

Following the initial and further characterisation of groundwater bodies and the assessment of pressures and impacts, a surveillance monitoring programme shall be established.

Surveillance monitoring will be carried out in order to:

- supplement and validate the procedure for the assessment of pressures and impacts; and
- provide information for use in the assessment of long term trends both as a result of changes in natural conditions and through anthropogenic activity.

The surveillance monitoring programme must ensure that a coherent and comprehensive overview of groundwater chemical status can be given for each groundwater body or group of bodies. The network shall be designed to detect at an early stage any changes in chemical status and to register long term quality trends and establish their causes (natural or anthropogenic).

The necessary density of monitoring points will be determined by the hydrogeological regime in the groundwater body under review and the assessment of pressures and impacts on the groundwater body. Representative monitoring of similar types of groundwater bodies may be undertaken in certain cases and the monitoring of individual groundwater bodies will not be necessary in every individual situation. Monitoring may be considered representative if:

- the quality of the groundwater recorded is considered typical of the wider area, or
- the monitored groundwater body is considered to be characteristic of a wider area in terms of the hydrogeological regime and the existing land use and risks in the recharge area.

To assess chemical status, regular samples shall be taken from the selected groundwater monitoring sites, including spring sites. A core group of parameters must be analysed in all cases. Other parameters, that are significant in the catchment area of the monitoring point and could constitute a negative influence on the groundwater quality, should be included.

The groundwater bodies shall be monitored for the following minimum set of parameters in all cases:

- Oxygen content
- pH value
- Electrical Conductivity
- Nitrate
- Ammonium

In addition, groundwater bodies that have been identified as being at significant risk of failing to meet the objectives shall be monitored for those parameters, which are indicative of the risk. In the case of cross-border groundwater bodies, they shall be monitored for those parameters, which are relevant for the protection of all of the uses supported by the groundwater flow.

On an interim basis the Working Group recommends that the draft EPA list of parameters and guideline values be used for the characterisation of a groundwater body for the purpose of river basin projects.

The frequency of monitoring shall allow assessment of the chemical status of each groundwater body and satisfy the requirements stated above. The frequency will depend on the hydrogeological conditions (vulnerability and flow regime) of the groundwater body. The monitoring frequency for surveillance monitoring should be a minimum of twice per year (spring and autumn). Groundwater bodies comprising unconfined regionally important aquifers should be monitored more frequently. In addition, monitoring sites that demonstrate strong fluctuations of concentrations over the period of the year should be examined more often. In karstic aquifers subject to large fluctuations in water quality at times of flooding, continuous monitoring may be required for certain parameters.

3.3.4.2 Operational Monitoring

The results of the surveillance monitoring programme will be used to establish an operational monitoring programme for the River Basin Districts.

Operational monitoring must be undertaken in the periods between surveillance monitoring in order to:

- Establish the chemical status of all groundwater bodies determined as being 'at risk', and
- Establish the presence of any long term anthropogenically induced upward trend in the concentration of any pollutant.

The operational monitoring programme will be carried out for all groundwater bodies or groups of bodies that have been identified, through characterisation or through surveillance monitoring, as being 'at risk' of failing to meet the objectives under Article 4. Representative monitoring may suffice for the purpose of groundwater bodies of similar types (in terms of hydrogeological regime and risks located in the recharge area). Surveillance monitoring sites that indicate increased pollutant concentrations or long term anthropogenic upward trends should also be used for operational monitoring purposes. The operational network can be extended to other sites.

The scope of parameters to be measured for 'operational monitoring' will generally include those required for 'surveillance monitoring' but will be extended as necessary to include those additional parameters that are indicative of the identified risks.

Operational monitoring shall be carried out (i) at a minimum of once per year and (ii) between the sampling dates of the surveillance monitoring programme. As stated above for the surveillance monitoring programme, the frequency of monitoring shall allow assessment of the chemical status of each groundwater body and satisfy the requirements stated above. The frequency will depend on the hydrogeological conditions and on the vulnerability and flow regime of the groundwater body.

3.3.5 Tasks for Chemical Status Monitoring

1. **Following the review undertaken during the initial and further characterisation stages, select additional strategically located monitoring points (borehole or springs).**
2. **Provide the basis for the selection of the monitoring points and the frequency of monitoring. A review mechanism of the suitability of the monitoring points should be built into the monitoring programme.**
3. **Compile well construction data and hydrogeological data for each monitoring point.**
4. **Identify and delineate the zone of contribution of each of the monitoring locations.**
5. **Implement the groundwater chemical status monitoring programme that comprises a surveillance and operational network.**
6. **Provide an estimate of the level of confidence and precision of the results provided by the monitoring programmes.**
7. **Collate and verify the data and store in a GIS compatible data management system.**

8. **Assess the groundwater chemical status of each of the groundwater bodies (see section 4).**
9. **Identify any significant and sustained upward trend in pollutant concentration from the operational monitoring programme (see Section 4).**
10. **Propose a programme of measures for those groundwater bodies that fail to achieve good groundwater chemical status.**

4. Interpretation and Presentation of Groundwater Status

4.1 Overview

The WFD requires Member States to achieve good groundwater status and to implement the measures necessary to reverse any significant and sustained adverse trend in accordance with the provisions of Article 4. However, as stated in Section 3, the Directive does not provide precise technical specifications and mathematical algorithms for:

- Calculating trends and trend reversal.
- Aggregation of monitoring data per groundwater body or group of groundwater bodies.
- Criteria for assessing good groundwater status.

The Federal Environment Agency - Austria is involved in a study called "The EU Water Framework Directive: Statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results". It is expected that the final report will be available by the end of 2001.

The two main objectives of the Austrian project are the development of:

- an appropriate aggregation method for the calculation of a representative mean value for the groundwater body, and
- an appropriate statistical method for trend assessment and trend reversal which includes the determination of the minimum requirements for calculation and the base year taken as the starting point for trend assessment.

4.2 Reference to the Directive

Article 17

Annex V, section 2

4.3 Quantitative Status

4.3.1 Interpretation

Groundwater level monitoring will be used to assess the quantitative status of the groundwater body. The interpretation of the results should take account of:

- the impact on the environmental objectives for that groundwater body;
- the impact on the groundwater dependent terrestrial ecosystems; and
- the impact on associated surface water systems.

The monitoring results for a groundwater body shall be used to assess the quantitative status of that body. The data from individual monitoring points within each groundwater body should be aggregated for the groundwater body as a whole.

The short term (e.g. 1-3 years) water level data should be compared with data obtained from the long term (10 – 30 years) monitoring records. This is required for the assessment of trends in water levels.

If the overall trend analysis of water level indicates no sustained significant lowering of water levels and no impact on groundwater dependent ecosystems or on associated surface water systems then the groundwater body may be considered to have achieved good quantitative status.

A change in local or regional water levels may have an ecological consequence. The assessment parameter in the case of groundwater dependent terrestrial ecosystems is site specific water level and therefore reference points should be used to assess any impact. For associated surface water systems, if there is a reduction in surface water flow, the long term monitoring of groundwater levels can be used to assess whether there is a causal relationship.

4.3.2 Presentation

The assessment of groundwater quantitative status will be presented on a colour coded map indicating Good: Green and Poor: Red.

4.4 Chemical Status

4.4.1 Interpretation

The WFD requires that the results of individual monitoring points within a groundwater body shall be aggregated for the body as a whole. For good status to be achieved by those groundwater bodies for which environmental quality standards have been set in Community legislation:

- the mean value of the results of the monitoring at each point in the groundwater body or group of bodies shall be calculated, and
- in accordance with Article 17, these mean values shall be used to demonstrate compliance with good groundwater chemical status.

One of the main elements of the Austrian project is the development of a data aggregation method. The interim project report (January 2001) reviewed a number of statistical methods. The outcome of the project will be a proposal of one data aggregation method suitable for small and large groundwater bodies. The final report is due in December 2001.

The results of the individual monitoring points within a groundwater body shall be aggregated in accordance with the method recommended by the Austrian project for the calculation of a representative mean value for the groundwater body as a whole.

4.4.2 Identification of Trends in Pollutants

The Commission is to propose measures for the setting of criteria for the identification of significant upward trends and for the definition of starting points for trend reversal in accordance with Article 17 of the Directive. The above mentioned working group led by Austria is examining the statistical aspects of the identification of groundwater pollution trends and aggregation of monitoring results.

The output from this working group will assist in the interpretation and presentation of the monitoring results. Pending the project outcome, Article 17(5) states that trend reversal shall take as its starting point a maximum of 75% of the level of the quality standards set out in existing Community legislation.

4.4.3 Presentation

The groundwater chemical status shall be presented on a colour coded map indicating Good: Green and Poor: Red.

A Black dot shall be used to indicate those groundwater bodies that are subject to a significant and sustained upward trend in the pollutant concentrations. Reversal of an upward trend shall be indicated by a Blue dot.

4.5 Overall Groundwater Status

Colour-coded maps indicating the groundwater quantitative status and the groundwater chemical status separately or jointly as described above are also to be presented.

The overall groundwater status shall be presented on a combined map showing both the quantitative and chemical status of each groundwater body, and colour-coded as described in Sections 4.3.2 and 4.4.3.

If separate maps are not provided, then those groundwater bodies which are subject to a significant and sustained upward trend in the concentration of any pollutant, or any reversal of such a trend, shall be identified on the combined map.

4.6 Tasks

1. **Map the resultant groundwater quantitative status on a colour-coded map.**
2. **Map the resultant groundwater chemical status on a colour-coded map.**
3. **Produce a colour-coded map of the overall groundwater status (quantitative and chemical) and indicate the groundwater bodies that are subject to a significant and sustained upward trend.**

5. References

EPA (2001) *Proposed Guideline Values for the Protection of Groundwaters in Ireland*, Draft for Comment, July 2001, 40 pp plus Appendix.

EPA (2003) *Towards Setting Guideline Values for the Protection of Groundwater in Ireland - Interim report.*

DoELG/EPA/GSI (1999) *Groundwater Protection Schemes*. Department of the Environment and Local Government, Environmental Protection Agency & Geological Survey of Ireland, 24 pp.

Official Journal of the European Communities (2000) *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy* (OJ L 327) 22 December 2000.

UK Technical Advisory Group (UKTAG) (2003) WP6a (02) Draft guidance on groundwater characterisation (01) 25-07-03 (PREA20-10-03).

WFD-GW (2001) *The EU Water Framework Directive: Statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results*. WFD-GW Trend/ Federal Ministry of Agriculture and Forestry, Austria.

Figure 2.1:
Summary of Technical Requirements for Groundwater Aspects of River Basin District Management Systems
(23rd August 2001)

Map

GSI → Aquifer Classification and Boundaries *(Section 2.3.2)*

Basin District and catchment boundaries *(Section 2.3.2)*

GSI → Preliminary delineation of Groundwater Bodies *(Section 2.3.2)*

Criteria for refined delineation of Groundwater Bodies

Overlying strata *(Section 2.3.4)*

- Soil / Subsoil type (from Teagasc) *(Section 2.3.4)*
- Extremely vulnerable areas (using data provided by GSI). *(Section 2.3.4)*

Conservation designated ecosystems dependent on groundwater *(Section 2.3.5)*

Nitrate Vulnerable Zones

Pressures *(Section 2.3.3)*

↑ *Guidance from pressures and impacts working group*

Monitor

Collate and assess existing quantitative and chemical data. Assess existing reports. *(Sections 2.3.6 & 3)* ← *Surface water monitoring*

- Surface water: flows and quality in drier summers.
- Larger springs: flows and quality.
- Wells: trends in chemical data and water levels.

Relate understanding of existing pressures in each groundwater body to:

- Existing quantitative and chemical data
- Groundwater vulnerability
- Conceptualisation of groundwater flow pathway / magnitude / direction.

Characterise

Surface water characterisation ←

Characterisation of each groundwater body to include assessments of:

- Confined/unconfined condition of groundwater.
- Hydrogeological properties
- Broad direction and depth of flow.
- General recharge acceptance, discharge and runoff characteristics.
- Water level and abstraction data.
- 'Natural' water quality.
- Existing pressures linked with vulnerability assessments and available water quality/quantity data.
- Role of the groundwater body in the hydrology and hydrogeology of the River Basin District.

Design and implement integrated groundwater monitoring programme – incorporate useful existing sites and install new sites where necessary *(Section 3)*. NB:

- Ensure flow regime and the influence of well construction is understood at all sites used.
- Coordinate with surface water programme.
- Ensure chemical monitoring programme provides a link with vulnerability and pressures.
- Maintain link between chemical and quantitative data.
- Large springs very useful.
- Karst sites may require more frequent chemical monitoring for selected parameters.
- Wells pumped infrequently will be of limited value for chemical monitoring in many situations.

Groundwater Bodies not at Risk

Refined delineation of Groundwater Bodies *(Section 2.3.6)*

Groundwater Bodies at Risk

Further Characterisation *(Section 2.4)*

Monitoring
Groundwater levels.
Chemical status.
(Section 3)

Review and present groundwater status *(Section 4)*

Devise and review measures

Key:

- ***Group of tasks undertaken by the contractor***
- *Group of tasks undertaken by public agencies but co-ordinated and funded by the contractor*
- *(Section 2.2)* *Cross – reference to further information in the main text of the technical requirements.*