UK Technical Advisory Group on the Water Framework Directive

Defining & Reporting on Groundwater Bodies

This Guidance Paper is a working draft defined by the UKTAG. It documents the principles to be adopted by agencies responsible for implementing the Water Framework Directive (WFD) in the UK. This method will evolve as it is tested, with this draft being amended accordingly.			
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1 Introduction

This paper sets out guidance on the delineation and characterisation of groundwater bodies as required under Article 5 of the Water Framework Directive (WFD) and detailed in Annex II of the WFD. The guidance is required to ensure the requirements of the WFD are met in the 2nd River Basin Management Planning cycle and that future WFD assessments will produce comparable results for each Agency. This paper supersedes UKTAG paper 6(a) on groundwater delineation and characterisation.

2 Background

Groundwater bodies are the management units of the WFD and should therefore reflect the conceptual understanding of the hydrogeology and the source-pathway-receptor model. They are the units assessed for the Article 5 risk assessment(s), and the following Article 4 objectives of the WFD:

- achievement of good groundwater status (i.e. good groundwater chemical status and good groundwater quantitative status);
- prevention of deterioration in status of groundwater;
- achievement of objectives and standards for protected areas; and
- reversal of significant and sustained upward trends in pollutant concentrations in groundwater

Groundwater bodies must be assigned to a River Basin District and are the units used for reporting to Europe and implementing programmes of measures.

Groundwater management has to consider groundwater in relation to its use as a water supply (both in terms of sustainable yield and quality) and its interactions with surface water and wetlands. Decisions on groundwater body delineation therefore depend on the nature of the aquifer and the management practices that are needed. Therefore, groundwater bodies may follow surface water catchments where the aquifers are mainly unconfined; with confined aquifers more likely to follow a regional groundwater flow system.

Groundwater is defined by the WFD as “all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil”. In reality, pore waters in low permeability subsoils (e.g. clays) do not represent groundwater as a receptor, because they do not provide a useful water resource and pollutants going to surface water receptors travel at velocities that are measured on a millimetre-scale per year. Therefore, water in these deposits should not be subject to the same management objectives as, for example, aquifers or groundwater bodies. Similarly, groundwater that exists at extreme depth and is permanently unsuitable for use as a resource, e.g. due to high salinity, should not be considered as a groundwater body. Conceptually, Table 1 shows the linkages between the different forms of sub-surface water and groundwater bodies.

Table 1 Roles of sub-surface water in Environmental Management

Zone	Terminology	Role
Water in unsaturated zone	Pore water	Pore water above the water table. Protect as a vertical pathway to groundwater.
		Pore water in low permeability deposits. The concept of the zone of saturation is not relevant in these deposits as it is usually not feasible to define a water table where lateral percolation is impeded. The main role of these strata is as a protecting layer for groundwater.
Water in saturation zone	Groundwater in strata overlying or underlying groundwater bodies	Groundwater has a value as a lateral or vertical pathway to other receptors. May be usable, but only for local supplies <10m^3/day.
	Groundwater in a groundwater body	Groundwater is part of an aquifer and is a receptor as a long term resource that can be exploited for human activities or support surface flows & ecosystems.
	Groundwater that is permanently unsuitable for use	Groundwater which has neither pathway nor resource value. For example, where salinity is greater than seawater.

Successful management of groundwater requires consideration of the spatial extent of the groundwater body. The focus of the WFD status assessment(s) is on regional management issues; with local scale "prevent or limit" management issues largely falling under the remit of other legislative and regulatory controls, e.g. Habitats Directive, IPPC Directive, Groundwater Directive etc.

3 Groundwater Body Delineation Principles

European CIS[1], UKTAG[2] and Agency specific[3] guidance on the delineation and characterisation of groundwater bodies were used as the basis for the delineation and characterisation of groundwater bodies during the 1st River Basin Management Planning cycle.

1. Groundwater bodies, according to Article 2.12 of the WFD, are defined as "a distinct volume of groundwater within an aquifer or aquifers". According to EU CIS guidance on risk (EC, 2010); they are units for the management of groundwater resources that are either exploited by man or support surface ecosystems.

2. A portion of an aquifer can be defined as a groundwater body if anthropogenic pressures could lead to one of the status objectives being compromised. The resulting groundwater body must be at least of sufficient scale either to supply 10 m^3/d as an average or 50 persons or to support the ecological quality of a surface water body or groundwater dependent terrestrial ecosystem. However, in practice, groundwater bodies should only be as big as is necessary to manage pressures on groundwater resources

[1] CIS Horizontal Guidance on the Identification of Water Bodies for the WFD
[2] UKTAG Guidance 6a on Groundwater Delineation and Characterisation
[3] e.g. Irish Working Group on Groundwater Guidance Report GW2

at the river basin district level. Groundwater bodies will therefore usually be on the scale of 10s to 100s of square kilometres in size but can be smaller if necessary depending on the nature of the pressure, groundwater pathway and receptors. The minimum size of a groundwater body is 10 km^2, set to correspond with the minimum catchment area of surface water body as set out in WFD Annex II (1.2.1). The most likely examples of situations where it is appropriate for a groundwater body to be smaller than 10 km^2 are:

- A designated terrestrial ecosystem or surface water body is dependent on a volume of groundwater which is greater than 10m^3/day and this groundwater requires distinct management in order to protect the ecosystem.
- A hydraulically isolated area (e.g. a small island or gravel deposit surrounded by unproductive strata), which is supplying 10m^3/day or least 50 people with drinking water and this groundwater requires distinct management in order to protect the supplies.

3. Where groundwater bodies are delineated, their lateral boundaries can be identified using the following features:
   - Groundwater flow divides, using surface water catchments and geological boundaries as proxies where information is limited.
   - Pressure variations, where these are significant at a river basin level and where they require variations in management.
   - Natural chemistry variations, where they impose a limit on the value of the resource for potable abstraction, or where they influence the susceptibility to, and management of, pressures. For example, groundwater is considered to have limited resource value where its natural salinity exceeds the limit for human consumption, and is considered to have no resource value where it exceeds that of seawater.
   - Coastline, unless there is specific evidence to suggest that groundwater beyond the coastline has a resource value.

   Hydraulic boundaries should be used wherever feasible to avoid the requirement under WFD to calculate flows between groundwater bodies.

4. The depth boundaries of a groundwater body are identified using the same principles as lateral boundaries and are discussed in more detail in Section 4.

4 Groundwater Body Depth

As a distinct volume of groundwater within an aquifer or aquifers a groundwater body must be three-dimensional in nature.

The main driver for delineating groundwater bodies in three dimensions is groundwater body management; particularly with regard to the maximum depth that groundwater bodies need to be managed under the WFD. As mentioned in Section 2, the drivers for groundwater body management relate to its use as a water supply or its contribution to surface water systems. The latter focuses on the unconfined aquifers and, to a lesser extent, discharge from confined aquifers (which could be from depth, e.g. geothermal waters). Therefore, management of groundwater at greater depths mainly relates to its use for water supply.

The upper extent of the groundwater body is the water table. Where information on the level of the water table is not available across the groundwater body as a whole, the upper extent can be considered to lie at ground level.

At some depth, depending on the nature of the aquifer, groundwater loses its value as a resource that can be either exploited for human activities or support surface flows & ecosystems. Default depth values for the UK and Ireland, which relate to its value for exploitation or connection with surface water receptors, are presented in Table 2. These should be amended using local information if available. This information should comprise hydrogeological and hydrochemical information to identify the resource boundaries, preferably through the use of water table information and structural or stratigraphic features that represent aquitards.

Table 2 Guideline default values for groundwater body thickness

UK and Ireland Generic types of aquifer	UK and Ireland examples	Formation Type - EU CIS criteria	Depth of main part of the GWB* - CIS criteria	Default Max. Thickness*
Porous superficial	Sand & Gravel	Porous aquifer – highly productive	0-20 m	40 m
Dominantly porous bedrock	Sherwood Sandstone	Porous aquifer – highly productive	50-200 m	400 m
Dual porosity high transmissivity	Chalk	Porous aquifer – highly productive	50-200 m	400 m
Moderate transmissivity bedrock	Carboniferous sandstones	Fissured aquifer – moderately productive	50-200 m	400 m
Low transmissivity bedrock	Dalradian	Insignificant aquifers – local and limited groundwater	20-50 m	100 m
Karst	Carboniferous limestones	Fissured aquifer – highly productive	50-200 m	400 m

**Default values should be altered using local information, if available.*

5 Information Requirements for the Dimensions of a Groundwater Body

Article 15 of the WFD required the submission of River Basin Management Plans to Europe in 2010. These plans included, amongst other things, a general description of the characteristics of the groundwater bodies and the risk assessment results identified under Article 5 and Annex II of the WFD in 2005, including the mapping of the location and boundaries of groundwater bodies.

Since the Article 5 submission on groundwater body characterisation, reporting templates, such as WISE reporting, have included many additional fields that should be reported on groundwater bodies, some of which are mandatory. These fields are identified in Appendix 1. These additional reporting requirements include information on the lateral extent and the hydrogeological properties of the aquifer that provides the basis for the groundwater body. These properties and the aquifer types are to be assigned into a series of generic categories:

- **Layered (Y/N)** - Is the groundwater body overlaid by (a) groundwater bodies or (b) overlaying other groundwater bodies;
- **Groundwater body horizon –** Depending on the position of the groundwater body, it should be assigned to one of the horizons below:

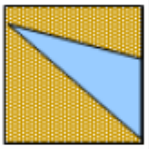
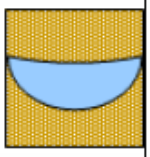
Horizon Code	Brief description
1	First horizon from the surface
2	Second horizon from the surface
3	Third horizon from the surface
4	Fourth and deeper horizons from the surface

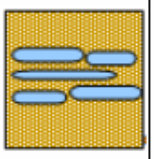
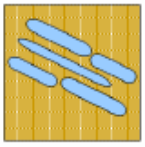
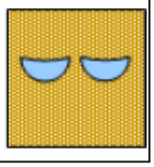
  An interpretation of groundwater body horizons is provided in Section 5.1.
- **Average depth to groundwater body (m)** - Area-weighted mean distance between the 'groundwater surface' and the land surface;
- **Average thickness of groundwater body (m)** - Area-weighted mean thickness of the GWB. The thickness is the vertical distance between the bottom of the groundwater body and the water table. Default thicknesses for different aquifer types in the UK and Ireland are provided in Table 2.
- **Assignment to a depth range where the main part of the GWB is situated in depth ranges:**
  - 0-20 m;
  - 20-50 m;
  - 50-200 m;
  - >200 m.

  Default depth ranges for different aquifer types in the UK and Ireland are provided in Table 2.

- **Directly dependent aquatic ecosystems (Y/N)** - Are there any aquatic ecosystems directly dependent on the groundwater body;
- **Directly dependent terrestrial ecosystems (Y/N)** - Are there any terrestrial ecosystems directly dependent on the groundwater body;
- **Geological formation** – aquifer type (according to the predefined EU-WISE typologies below):
    - Porous aquifer – highly productive;
    - Porous aquifer – moderately productive;
    - Fissured aquifers, including karst – highly productive;
    - Fissured aquifers, including karst – moderately productive;
    - Insignificant aquifers – local and limited groundwater.

  Examples of typical geological units for different aquifer types in the UK and Ireland are given in Table 2.
- **Volume of aquifer (m^3)** – estimated volume of the aquifer (Area x Maximum Thickness);
- **Type of vertical orientation of GWB** (indicated by category and visualised by symbols below):

Type	Description	Symbol
1a	Horizontal, mainly continuous body	
2a	Declining, mainly continuous body	
3a	Declining and cumulative, mainly continuous body	
4a	Boat form, mainly continuous body	
5	Other	

Type	Description	Symbol
1b	Horizontal, mainly smaller individual formations	
2b	Declining, mainly smaller individual formations	
3b	Declining and cumulative, mainly smaller individual formations	
4b	Smaller individual boat formed formations	

5.1 Interpretation of groundwater body horizons

Many of the European reporting requirements since the Article 5 characterisation report in 2005 (e.g. WISE) have requested information on the groundwater body depth and the connection of the body with overlying or adjacent groundwater bodies. To ensure a common approach on reporting groundwater body information, EU CIS guidance (EC, 2009) has been developed to reflect reporting on additional attributes associated with groundwater bodies. This guidance indicates that groundwater body horizons should be developed to coincide with depth ranges, with the closest groundwater body to the surface being the first of four horizons. Where data for more than four horizons exist, all horizons beneath horizon 3 should be combined into horizon 4.

Assigning groundwater bodies to the first horizon, second horizon etc. depends on how individual member states plan to manage their groundwater bodies. For example, a member state may choose not to define upper sand and gravel aquifers as groundwater bodies if they plan to manage them in connection with the bedrock aquifer beneath.

The approach of defining the first encountered aquifer as the first horizon has led to inconsistency in approach between Member States, and this has become evident during recent WISE reporting, with neighbouring Member States defining horizons in a different manner (Duscher, 2010). For example, this has resulted in the same aquifer being assigned to different horizons on either side of a national boundary.

An additional complication is that in many aquifers in the UK and Ireland have areas that are both confined and unconfined, and are not simple layered aquifer systems, with the second aquifer being fully confined by an upper aquifer. From a management perspective it is not sensible to delineate the confined portion of an aquifer as one groundwater body and the unconfined portion as a separate groundwater body.

Therefore, for the purposes of the 2nd River Basin Cycle, UKTAG recommend that there is currently insufficient geological information to map groundwater bodies fully in three dimensions. Furthermore, all groundwater bodies in the UK and Ireland outcrop at the surface at some point. As a consequence, it is recommended that default values for these horizon code categories should be as follows:

- **Horizon 1** – unconfined gravel aquifers;
- **Horizon 2** – all unconfined and confined bedrock aquifers.

This decision to assign gravel bodies to horizon 1 and the remaining bodies to horizon 2 has been supported through correspondence with Klaus Duscher from the EC Working Group D on GIS.

5.2 Updating and reporting changes made to Groundwater Bodies

In addition to these additional reporting requirements, experience gained during the 1st River Basin Planning cycle has led to a requirement for the revision of some of the groundwater body boundaries.

Groundwater bodies that are re-delineated, such that their extent has changed, must be given a new groundwater body code and a record must be kept that identifies the original groundwater bodies that have changed, what they have changed to and the reasons for change. Note that it is likely that where one groundwater body changes, the adjacent groundwater bodies will also change.

In general, the naming convention used in the WISE reporting sheets (horizon 1 or 2) should be used and groundwater bodies should also be assigned to an aquifer type, based on the geological formation and productivity, e.g. porous aquifer – highly productive.

5.3 Visualisation of Groundwater Bodies

While conceptual models consider the groundwater body in three dimensions, for the purpose of the WFD, groundwater bodies were displayed in two dimensions (outcrop at the surface) during the 1st River Basin Planning cycle. Although groundwater bodies may be managed differently at different depths; in many cases, not enough data are available to develop three-dimensional models of groundwater bodies. Therefore, to ensure consistency, the visual representation of groundwater bodies under the WFD will remain as two-dimensional polygons (EC, 2009). Therefore, the lateral and hydrogeological properties should be retained as attributes associated with the two dimensional shapefile. Visually is will be possible to view each separate horizon in a geographical information system (e.g. see Appendix 2).

6 Implications

This paper provides clear criteria for the UK and Ireland agencies to facilitate consistent and transparent application of:

- New EU WISE reporting criteria for groundwater bodies, particularly in relation to assigning groundwater bodies to different “horizons”.
- Reviews of groundwater body boundaries, where necessary.

Amending the boundaries of groundwater bodies requires additional effort in terms of assessing pressures, impacts, and environmental objectives, and in terms of database management. As

described in Sections 2 and 3, groundwater bodies are the groundwater management units of the WFD and should only be amended if there is a hydrogeological basis for doing so, or where there is a specific need to manage a particular pressure on groundwater resources. Amending groundwater body boundaries will therefore only be undertaken where there is a net environmental benefit, for example in helping to focus environmental management measures on the correct location or correct depth within an aquifer.

7 References

Duscher, Klaus (2010) *Compilation of a Groundwater Body GIS Reference Layer*, Presentation at the WISE GIS Workshop 16th-17th November 2010 in Copenhagen.

European Commission (2003) – Guidance Document No 2: *Identification of Water Bodies.* ISBN 92-894-5122-X. European Communities, Luxembourg.

European Commission (2009) - *Guidance Document No. 22. Guidance on Implementing the Geographical Information System (GIS) Elements of the EU Water policy.* Tools and services for reporting under RBMP within WISE. Guidance on reporting of spatial data for the WFD (RBMP).

European Commission (2010) - *Guidance Document No. 26. Guidance on Risk Assessment and the use of conceptual models for groundwater.*

Irish Working Group on Groundwater (2005) – *Approach to Delineation of Groundwater Bodies*, Guidance Document No.2

UKTAG 6a (2003) *Guidance on Groundwater Delineation and Characterisation*, UK Technical Advisory Group on the Water Framework Directive

Appendix 1 - WISE Reporting Sheets

Mandatory Fields

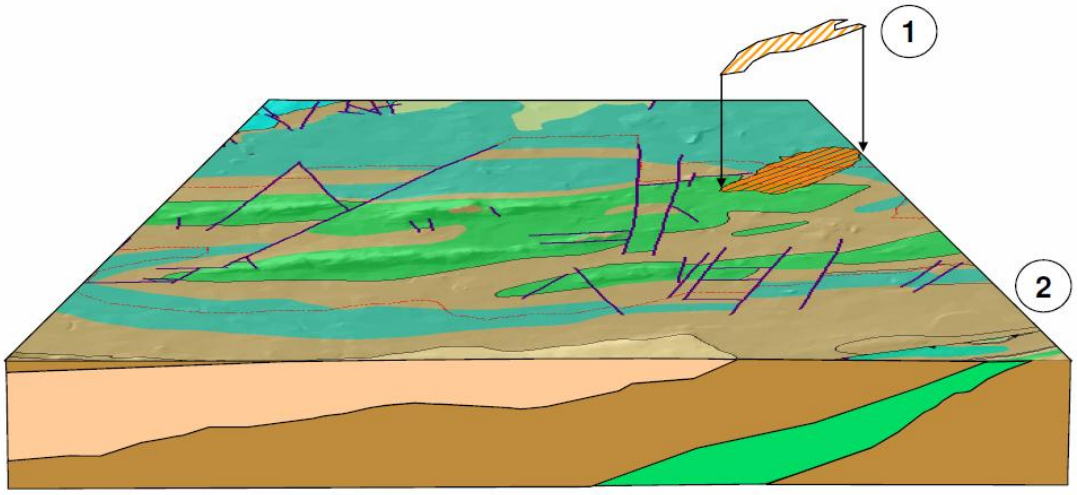
Field name	Field Definition
CountryCode	Abbreviation of EEA Member or Collaborating Country
GWB_Code	International code of gw body (not regarding whether the gw body was delineated for the use within EIONET or according to the WFD Art.5)
Waterbase_GWB_Code	Modified international code of gw body
WFDbody_confirmed by_country	Information, whether gw body was confirmed by country as WFD Art.5 gw. Body
National_GWB_Code	Nationally assigned identifier of groundwater body.
RBDcode	River Basin District Code, as defined in the codelist.
RBDname	Name of the River Basin District.
Area	Area of the groundwater body in km^2.
Latitude	Latitude of the centre of the GWB in ETRS89 projection
Longitude	Longitude of the centre of the GWB in ETRS89 projection

Optional Fields

Field name	Field Definition
No_of_Horizon	Vertical position of a groundwater horizon in which a groundwater body is situated.
Layered	Indicator for groundwater bodies with deeper relevant layers 0 = no deeper layers 1 = deeper aquifer layers
Out_of_RBD	Indicator if any part of GWB falls outside RBD
LastDelivery	Last year, when the gw body was reported (starting from the year 2008)
GW_body_name	Name of the groundwater body.
Reference_year	Last year of revision of update of characteristics.
Thickness_Min	Minimum thickness of the groundwater body in m.
Thickness_Mean	Mean thickness of the groundwater body in m.
Thickness_Max	Maximum thickness of the groundwater body in m.
Max_Width	Maximum width of the groundwater body perpendicular to groundwater flow direction in km.
Max_Length	Maximum length of flow path within the groundwater body in km.
Petrographic_Description	Short petrographic description of the dominant components of the stratigraphy of the groundwater body.
Stratigraphy	Description of the stratigraphy (geological period) of the groundwater body, as defined in the codelist.
Main_Aquifer_Type	Predominant aquifer type, as defined in codelist.
Overlying_Strata	Description of the groundwater body's overlying strata.
Confined	A confined aquifer is a aquifer that is confined or overlain by a layer that does not transmit water in any appreciable amount or that is impermeable. An unconfined aquifer is a aquifer with water table open to the atmosphere through permeable overlying material.
Associated_Aquatic_Ecosystems	Aquatic ecosystems associated with the groundwater body, as defined in the codelist.
Associated_Aquatic_Ecosystems_Purpose	Description of the aquatic ecosystems associated with the groundwater body.

Main_Infrastructures	Main infrastructures affecting the dynamics of the groundwater body, as defined in the codelist.
Main_Infrastructures_Purpose	Description of the main infrastructures affecting the dynamics of the groundwater body.
Hydraulic_Conductivity_Min	Minimum hydraulic conductivity of the groundwater as a kf-value.
Hydraulic_Conductivity_Mean	Mean hydraulic conductivity of the groundwater as a kf-value.
Hydraulic_Conductivity_Max	Maximum hydraulic conductivity of the groundwater as a kf-value.
Annual_GW_Level_Amplitude_Min	Minimum of the range between the lowest and highest groundwater level within a year in m.
Annual_GW_Level_Amplitude_Mean	Mean of the range between the lowest and highest groundwater level within a year in m.
Annual_GW_Level_Amplitude_Max	Maximum of the range between the lowest and highest groundwater level within a year in m.
Annual_Precipitation_Min	Minimum long term annual precipitation over the groundwater body area in mm.
Annual_Precipitation_Mean	Mean long term annual precipitation over the groundwater body area in mm.
Annual_Precipitation_Max	Maximum long term annual precipitation over the groundwater body area in mm.
Water_Abstractions	Water abstracted from the groundwater body, as defined in the codelist.
Water_Abstractions_Purpose	Purpose for which water is abstracted from the groundwater body.
Artificial_Recharge	Artificial recharge of the groundwater body, as defined in the codelist.
Artificial_Recharge_Purpose	Purpose for the artificial recharge of the groundwater body.
Main_Recharge_Source	Main source recharging the groundwater body, as defined in the codelist.

Appendix 2 Example of Groundwater Body Horizons



Legend

Productive Fissured bedrock GWB

Karstified bedrock GWB

Poorly Productive bedrock GWB

Sand & Gravel GWB

syncline axis

fault

thrust zone

1 Horizon in GIS

* Note, in this example, the unconfined and confined components of the bedrock aquifers are considered to be part of Horizon 2