UK Technical Advisory Group On the Water Framework Directive

UKTAG Task 12(a) Guidance on Monitoring Groundwater

(Groundwater Task Team)

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 the working draft amended accordingly.

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WFD Requirement: Establishment of Long-term Monitoring Groundwater Programme

UKTAG Review: August 07

1. Purpose and scope

1.1. This paper provides guidance on establishing groundwater monitoring programmes to meet the requirements of the Water Framework Directive (WFD). These programmes include both quantitative and chemical (quality) monitoring for status and trend assessment and monitoring to support (ground) water body characterisation, 'prevent and limit' obligations and Drinking Water Protected Area (DWPA) objectives.

1.2. The establishment of high quality long-term monitoring programmes is essential if the implementation of the WFD is to be effective. Inadequate investment in monitoring, including network infrastructure and data quality and management will result in a significant risk of failure to meet the WFD's environmental objectives.

1.3. Implementation of the guidance provided in this paper will lead to consistent monitoring across the UK and the Republic of Ireland. The guidance will enable networks to be developed and maintained at high standards and thereby provide the necessary information to assess (ground)water status, identify trends in pollutant concentrations, support establishment and assessment of programmes of measures and the effective targeting of economic resources.

2. Background

2.1. Article 8 of the WFD establishes a requirement for establishing programmes for the monitoring of groundwater. They must provide information to enable the Article 4 environmental objectives to be met, in particular the assessment of groundwater quantitative status, chemical status and significant, long-term pollutants trends resulting from human activity. Programmes to meet these requirements must be operational by 22 December 2006 at the latest. In addition, programmes are needed to provide any additional monitoring requirements relevant to Protected Areas (e.g. Drinking Water Protected Areas) and to support validation of the Annex II risk assessment procedures.

2.2. The WFD sets out the requirements for the different groundwater monitoring programmes in Annex V (2.2 and 2.4) and Annex II (2.3).

2.3. The groundwater monitoring programmes must include:

- A quantitative monitoring network to supplement and validate the Annex II characterisation and risk assessment procedure with respect to risks of failing to achieve good groundwater quantitative status in all groundwater bodies, or groups of bodies. Its principal purpose is therefore to enable quantitative status assessment.

- A 'surveillance monitoring network' to: (a) supplement and validate the Annex II characterisation and risk assessment procedure with respect to the risks of failing to achieve good groundwater chemical status and (b) provide information for use in the assessment of long-term trends in natural conditions and in pollutant concentrations resulting from human activity.

- An 'operational monitoring network' to: (a). Establish the status of all groundwater bodies, or groups of bodies, determined as being 'at risk' (UKTAG Task 7(i) - Guidance on Pollution Pressures on Groundwater) , and (b). Establish the presence of significant and sustained upward trends in the concentration of pollutants.

- Monitoring to support the achievement of Drinking Water Protected Area (DWPA) objectives.

2.4. The results of the monitoring must be used to:

- establish the chemical and quantitative status of groundwater bodies;
- assist in further characterisation of groundwater bodies;
- validate the risk assessments carried out under Article 2;
- assist the design of programmes of measures;
- evaluate the effectiveness of programmes of measures;
- demonstrate compliance with DWPA and other protected area objectives
- characterise the natural quality of groundwater including natural trends (baseline) and;
- identify anthropogenically induced trends in pollutant concentrations and their reversal.

3. General Principles

3.1. Role of conceptual models.

3.1.1. Conceptual models are simplified representations, or working descriptions, of the hydrogeological system being investigated. Their development underpins much of the work carried out as part of the characterisation process. As the amount of, and confidence in, the available environmental information increases, the accuracy and complexity of the model improves, so that they become more effective and reliable descriptions of the system.

3.1.2. In this paper, two types of conceptual model/understanding are used;

- the regional conceptual model – an understanding of the groundwater body/aquifer scale factors that identifies the need to establish a monitoring network/point and how the data will be used.

- the local conceptual model – an understanding of the local factors influencing the behaviour, both in chemical and quantitative terms, of individual monitoring points;

3.1.3. A regional conceptual understanding/model will identify the specific requirement for establishing a monitoring network and the degree of monitoring, in terms of number of sites and frequency of monitoring, required. This model will be consistent with that developed and

used as part of the characterisation and risk assessment process. Figure 3.1 outlines the principles and relationship of the model to the monitoring programme.

3.1.4. The design and operation of monitoring programmes should be informed by:

- the objectives applying to the body;
- the characteristics of the groundwater body, or group of bodies;
- the existing level of understanding (i.e. the confidence in the conceptual model/understanding and) of the particular groundwater system;
- the type, extent and range of the pressures on the body, or group of bodies including the distribution of key combinations of pressures and geological pathways along with an assessment of receptor sensitivity;;
- the confidence in the assessment of risk from pressures on the body, or group of bodies; and
- the level of confidence required in the assessment of risk.

3.1.5. The amount of monitoring that is required will be proportional to the difficulty in judging (a) the status of a groundwater body, (b) the presence of adverse trends, (c) the implications of errors in such judgements and (d) the effectiveness of the Programme of Measures including those in relation to DWPA.

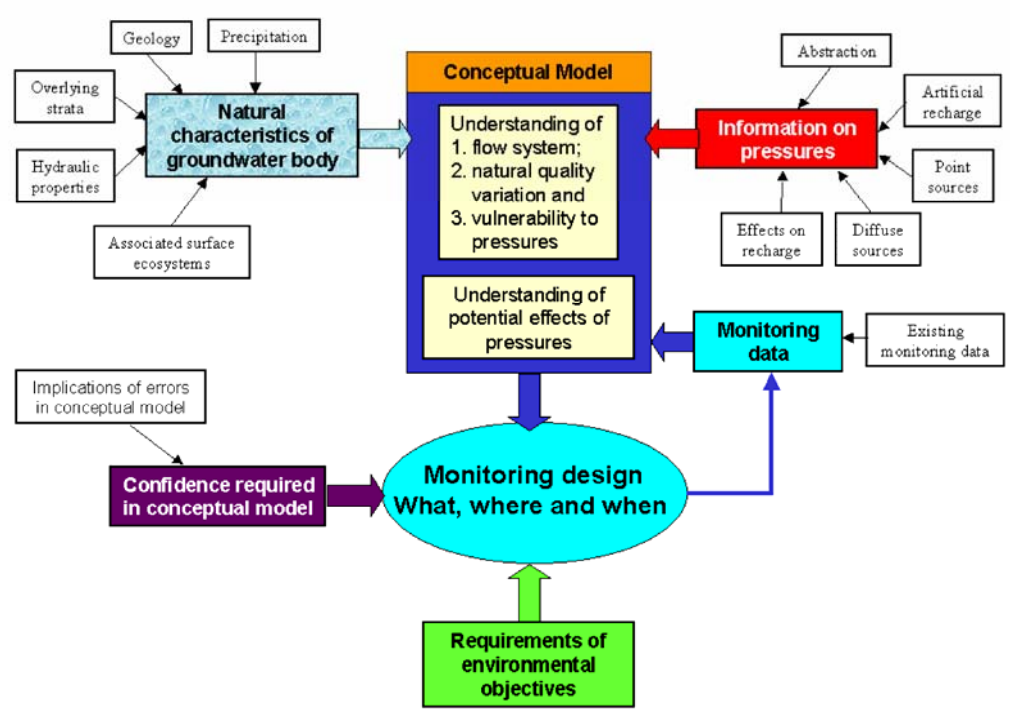

Figure 3.1. The conceptual model will represent the current understanding of the groundwater system based on the knowledge of its natural characteristics, perceived pressures and knowledge of impacts.

3.1.6. Designing the monitoring programmes on the basis of the conceptual model ensures that they will be appropriate to the hydrogeological characteristics of the system and, where relevant, the behaviour of pollutants in the groundwater system.

3.1.7. The selection of groundwater monitoring points also requires knowledge of the local environment within close proximity of the monitoring point. This enables an assessment to be made of the point's suitability for providing representative information and data to support the objectives of the monitoring programme (see 3.2). This conceptual understanding is vital for the effective operation of the monitoring programme.

3.1.8. In developing the local conceptual understanding, information on local hydrogeological and environmental conditions is required. This information includes:

- Monitoring point details;
- Hydrogeological setting;
- Understanding of recharge patterns;
- Local groundwater flow pattern(s) and regime within zone of contribution [1](ZOC)
- Abstraction impacts
- Approximate size of ZOC;
- Land use and pressures within ZOC.

3.1.9. The inclusion of a monitoring point in the relevant monitoring programme or network, e.g. quantitative status assessment network, chemical status assessment network or DWPA network, requires that a minimum level of information is known about the site for quality assurance (QA) purposes. The information needs are summarised in Appendix 1. In some cases a monitoring site may satisfy the requirements of one programme but not the others. A failure to meet a minimum level of information will exclude the monitoring point from one or more of the programmes.

3.2. Representative Monitoring

3.2.1. For a monitoring point to be representative its ZOC should reflect one or more of the key pressure/pathway combinations within the groundwater body grouping or within catchments of associated receptors. Collectively, the monitoring points within the network should be representative of the mosaic of different pressure/pathway combination across the groundwater body, group of bodies or across the catchments of associated receptors that are critical for determining status. An example is provided in Appendix 4. If the monitoring network is not representative, it will be necessary to either adjust the monitoring network or alter the groundwater body grouping i.e. drop some of the monitoring points or establish other monitoring locations e.g. through identification of existing non-monitored sources or through drilling

3.2.2. For chemical status, the significance of point source pollution pressures on ecosystems or drinking water receptors, and the proximity of the ZOC to these receptors should also be considered when assessing whether a monitoring point is representative.

3.2.3. When considering diffuse chemical pressures, monitoring points with larger ZOCs are preferred as they will be less susceptible to local impacts. The largest ZOCs will be associated with groundwater sources with high abstraction rates in areas of low recharge. Monitoring points with average daily abstraction rates in excess of 100 m^3/day are preferable, particularly for surveillance monitoring and in aquifers that are both fractured and highly vulnerable. If the network comprises monitoring points with smaller ZOCs, a greater number of points and/or a higher sampling frequency is required in order to provide the necessary level of confidence. Alternatively, a localised cluster of monitoring points with smaller ZOCs (within similar hydrogeological settings and with similar pressures) could be used to mimic a larger abstraction.

3.2.4. Identifying representative monitoring points to assess diffuse impacts in poorly productive aquifers is difficult because of the complex hydrogeological conditions that exist. Deep wells will often be supplied by old, deep groundwater and shallow wells by younger, rapid flow, near surface groundwater. It is therefore important that greater emphasis is placed on risk assessment data and the status assessment for associated surface waters or GWDTE. The recommendation for surveillance monitoring in poorly productive aquifers is to focus on high yielding springs and boreholes, and where there is significant connection with surface water, use surface water status classification as a surrogate for groundwater classification. In cases where surface water status is (or may be) poor as a result of groundwater, or direct impacts on

[1] Zone of contribution refers to the area of land surface and/or volume of aquifer surrounding a monitoring point within which natural conditions and human activities may influence the quality of groundwater.

groundwater have been identified, more detailed operational monitoring may need to be established within the relevant associated surface water/groundwater catchment(s).

3.2.5. For quantitative monitoring, representative monitoring points should be reflective of the conceptual model of risk and be representative of groundwater conditions within the monitored groundwater body, lying outside the immediate hydraulic influence of abstraction pressures such that day-to-day variations in pumping will not adversely influence the data.

3.2.6 Monitoring points will be considered unrepresentative if small-scale (relative to the groundwater body) localised affects not associated with the GW body's environmental objectives could adversely affect data quality. In these cases, the monitoring points should be screened and excluded from the relevant monitoring network. For example, points that could be influenced by farmyard runoff should not be included in monitoring to assess diffuse agricultural pressures. The screening assessments should be undertaken using desk studies and site visits, preferably supplemented by sampling information. For example, ammonia and e-coli could be used to identify sites affected by local sources of organic contamination and suspended solid used to identify poorly constructed monitoring wells.

3.3. Integrated Monitoring

3.3.1. The WFD considers the water environment as a continuum. This is reflected in the groundwater status definitions and through the recognition of the role played by groundwater in maintaining the flow, quality and ecology of dependent surface waters. Monitoring must be able to provide an understanding and assessment relating to groundwater flows between GWBs & SWBs and between GWBs and Terrestrial Ecosystems (TES).

3.3.2. Monitoring programmes for surface water and groundwater should therefore be designed and operated in an integrated way to assist in: (a) maximising the information that can be derived; (b) increasing confidence in the conceptual understanding of the interaction between groundwater and surface water and; (c) reducing the uncertainty associated with risk and status assessment. Data from both programmes can be used to inform and support interpretation of results. In particular the monitoring must be sufficient to allow the calculation or estimation of the GW flux and the degree of 'abstraction impact' on GW supported SWBS (lakes, rivers & estuaries) and GW dependant TES (terrestrial wetlands).

3.3.3. In designing both surface water and groundwater monitoring programmes, the requirements of each must be taken into account. This will contribute significantly to cost-effective monitoring. For example, when designing surface water monitoring programmes in fractured fast flow aquifers, which provide significant baseflow to surface waters and maintain terrestrial ecosystems, groundwater monitoring requirements must be taken into account. In many cases, the correct location of a surface water sampling point, e.g. close to an aquifer discharge point, may function as both a monitoring point for both programmes.

3.4. Grouping of Groundwater Bodies

3.4.1. Groundwater bodies may be grouped for monitoring purposes provided that the monitoring information obtained provides for a reliable assessment of the status of each body in the group and the confirmation of any significant upward trends in pollutant concentrations.

3.4.2. In grouping groundwater bodies, the monitoring programmes must be designed and operated to ensure that the environmental and monitoring objectives for each of the component bodies making up the group can be achieved with adequate confidence.

3.4.3. Where groundwater bodies are determined to be "not at risk" according to the characterisation process, bodies maybe grouped if they are sufficiently similar in terms of aquifer characteristics, pathway susceptibility(ies), pressure(s) and confidence in the risk assessment(s). In undertaking the grouping:

- bodies do not necessarily need to be adjacent to each other;

- a monitoring point is not required in each of the component bodies within the group provided there is sufficient overall monitoring in the group as a whole to meet the requirements of operational, surveillance, quantitative or protected area monitoring, as appropriate;
- surface water monitoring may be used to verify risk classification.

3.4.4. Where groundwater bodies are determined to be "at risk" according to the characterisation process, bodies may be grouped if they are sufficiently similar in terms of aquifer characteristics, pathway susceptibility(ies), pressure(s) and confidence in the risk assessment(s). In undertaking the grouping:

- bodies should be adjacent, or in close proximity, to each other except in exceptional circumstances (e.g. islands);
- a monitoring point is not required in each of the component bodies within the group provided there is sufficient overall monitoring in the group as a whole to meet the requirements of operational, surveillance, quantitative or protected area monitoring, as appropriate;
- operational Monitoring may be focussed in one or more component bodies selected on the basis of the conceptual model, e.g. the most sensitive body(ies). This prioritised monitoring is designed to deliver cost-effective targeted environmental monitoring.

3.3.5 Bodies that are not at risk may be included in groups of 'at risk' bodies in exceptional circumstances. However where this occurs the selection of monitoring points and the use of monitoring data must not be used to misrepresent the status of the bodies that are at risk, e.g. through data aggregation.

3.5. Aquifer Types

3.4.1 A diverse range of geological settings is found across the UK and Ireland. Correspondingly, this has produced a wide variety of aquifer types.

3.4.2 The Water Framework Directive definition of an aquifer is such that many materials previously described as *'poor' yielding'* or *'non aquifer'* now qualify as aquifers within which groundwater body management units must be delineated and subsequently monitored.

3.4.3 Whilst systematic monitoring within the major water supply aquifers is generally well established, the purpose of monitoring at specific boreholes/springs is sometimes uncertain. For minor water supply aquifers and aquifers not previously monitored, there is greater uncertainty regarding what type and density of monitoring is necessary to provide representative samples of groundwater to support the WFD objectives. For all aquifer areas, there is a need to consider the characteristics of the strata forming the aquifer with regard to flow type, storage, unsaturated zone thickness, etc, before determining the most appropriate means of monitoring. For each monitoring point, knowledge of the local hydrogeological setting around that point is required so that data collected can be interpreted in its proper context. Selected monitoring sites will be used as baseline monitoring points against which the status of groundwater bodies and the success or otherwise of future land use/water resource management strategies will be assessed. This information, and in particular any change observed, is required to be reported to Europe over several decades; hence a clear understanding of what each monitoring point is representing is needed.

3.4.4 The range of aquifer settings found across the UK and Ireland and some of the implications for monitoring is provided in Appendix 3.

4. Quantitative Monitoring

4.1 Introduction

4.1.1 A Quantitative monitoring network is required to:

- support the development and enhancement of the conceptual understanding of individual or groups of groundwater bodies,
- assist in the classification of the quantitative status,
- assist in the identification of anthropogenically induced trends,
- support the design and evaluation of programmes of measures.

4.1.2 A groundwater body will be at good quantitative status if:

- the available groundwater resource is not exceeded by the long-term annual average rate of abstraction, AND;
- the groundwater levels and flows are sufficient to meet environmental objectives for associated surface waters and groundwater dependent terrestrial ecosystems, AND;
- alteration to flow direction resulting from level change does not cause saline or other intrusion.

4.1.3 Whilst specifically required by the WFD as the means to establish the quantitative status of a groundwater body, EU monitoring guidance recognises that groundwater levels are not generally the deciding factor for status classification but provide important supporting evidence. The application of quantitative groundwater monitoring data in status classification is detailed in_UKTAG quantitative status classification guidance **<insert reference>**.____.

4.1.4 As with other networks, the monitoring design should be based on a conceptual understanding of the groundwater system and the pressures. The key elements of the quantitative conceptual understanding will be:

- assessments of recharge and the water balance, and/or;
- the degree of interaction between groundwater and related surface and terrestrial ecosystems.

4.1.5 The development of a quantitative monitoring network can be iterative; data collected from new monitoring points being used to enhance and refine the conceptual model used to locate each monitoring point and the operation of the quantitative monitoring programme.

4.1.6 Quantitative monitoring need only be undertaken in groundwater bodies assessed as being “at risk of failing to meet their environmental objectives” (poor status) or, in order “to estimate the direction and flow of groundwater across the boundary of member states” (Annex 5, 2.2.2). However, monitoring may be undertaken in groundwater bodies that are “not at risk” of failing to meet their environmental objectives, specifically in groundwater bodies dominated by:

- principle aquifers, in order to support the demonstration of their continued “good status”, or in
- poorly productive/secondary aquifers, in order to support and develop the conceptual understanding of groundwater occurrence and flow within these aquifers, validating the general principle of minimal monitoring in such settings.

4.1.7 Groundwater level monitoring in poorly productive/secondary aquifers is often of little practical use in supporting the characterisation of quantitative status. Their low transmisivities restrict the flow of groundwater and thus the potential to abstract any resource they may hold. Generally no quantitative groundwater monitoring will be carried out in groundwater bodies dominated by secondary/low transmisivities aquifers.

4.1.8 In hydrogeological circumstances that are underpinned by a robust conceptual model supported by specific evidence, flow data from an associated surface water course may be used in characterising the quantitative status of a connected and adjacent groundwater body.

4.1.9 In groundwater bodies dominated by karst aquifers, unless local hydrogeological knowledge of the aquifer indicates that groundwater levels from existing monitoring boreholes provide data representative of the groundwater body, then monitoring is most likely to consist of the measurement of flows from large springs or adjacent surface water courses.

4.2 Monitoring Parameters

4.2.1 Although the Directive identifies groundwater level as the metric for determining quantitative status, in practice, the requirements of status assessment mean that additional supporting information may be required. Recommended parameters for the purposes of quantitative assessment of groundwater include:

- groundwater levels in boreholes or wells;
- spring flows;
- flow characteristics and/or stage levels of surface water courses;
- stage levels in significant groundwater dependant wetlands and lakes.

The selection of the monitoring point and parameter must be based on a sound conceptual model of the water body to be monitored.

Additional monitoring to support groundwater characterisation and classification may also include:

- chemical monitoring for saline or other intrusions;
- rainfall and the components required to calculate evapotranspiration (to calculate GW recharge);
- ecological monitoring of groundwater dependent terrestrial ecosystems (including ecological indicators);
- groundwater abstraction (and artificial recharge).

Specific requirements for the supporting monitoring data, to supplement the knowledge gained from groundwater level monitoring, will largely be determined by the tools/methods that will be employed to support the assessment of risk or status and the confidence required in this assessment.

4.2.2 Key to parameter selection is how representative the parameter is of the hydrogeological setting being monitored and the significance of its role in determining risk or status.

4.2.3 In some hydrogeological settings monitoring groundwater levels in a borehole maybe inappropriate for the purposes of the Directive. In these circumstances the flow characteristics of associated watercourses or springs may provide better data with which to undertake an assessment. This is most likely to be the case in low permeability/fractured aquifers.

4.3 Density of monitoring

4.3.1 Monitoring may be required at two different scales to meet the various requirements of the Article 4 objectives. Firstly, where possible, groundwater levels and flows across a groundwater body will be assessed. These will be used to support various elements of quantitative status classification. Secondly, more focussed 'local' monitoring of levels and flows that relate to relevant local groundwater supported receptors, i.e. surface water bodies (rivers, lakes, estuaries) and groundwater dependent terrestrial ecosystems, may be undertaken. The latter may include supporting information e.g. salinity monitoring (with respect to saline intrusions) or ecological monitoring (as evidence of impact on ecosystems from groundwater abstractions).

4.3.2 In groundwater bodies or groups of groundwater bodies assessed as being "not at risk", monitoring can be minimised. Indeed, monitoring need not be located in each body within a group, provided that the groups are hydrogeologically comparable (Section 3.3).

4.3.3 In groundwater bodies or groups of groundwater bodies assessed as being "at risk", the distribution of monitoring points will reflect the need to understand hydrogeological conditions both at the groundwater body scale and at representative examples of receptors identified as being "at risk of failing to meet their environmental objectives" (poor status).

4.4 Frequency of monitoring.

4.4.1 The amount and frequency of monitoring will be determined by the data needed to determine risk, quantitative status, and where necessary to support the design and assessment of a program of measures.

4.4.2 In general, daily monitoring would be preferred (particularly when measuring flows) while monthly monitoring would in general be the minimum acceptable standard.

4.4.3 Examples of situations where less frequent monitoring may be acceptable include:

- Situations of higher confidence or lower risk in higher storage intergranular or dominantly intergranular aquifers
- Ecological monitoring

4.4.4 Examples of situations where sampling frequencies in excess of daily may be required are:

- Flow monitoring
- Situations of lower confidence or higher risk in karstic aquifers.

5. Chemical Status and Trends Monitoring Programmes

5.1. Introduction

5.1.1. Groundwater monitoring programmes are required to provide a "coherent and comprehensive overview of water status within each river basin, detect the presence of long-term anthropogenically induced trends in pollutant concentrations and ensure compliance with Protected Area objectives.

5.1.2. A groundwater body will be at good chemical status if the following criteria are satisfied:

i. *General water quality*: The concentration of pollutants should not exceed the quality standards applicable under other relevant Community legislation in accordance with the new Groundwater Directive;

ii. *Impacts on ecosystems*: The concentration of pollutants should not be 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*;*

iii. *Saline intrusion*: The concentrations of pollutants should not exhibit the effects of saline or other intrusions as measured by changes in conductivity.

5.1.3. The WFD requires both surveillance and operational programmes to be established to provide the information required to support the assessment of chemical status and identification and monitoring of pollutant trends.

5.1.4. Monitoring programmes specifically for addressing prevent and limit objectives, Drinking Water Protected Area objectives and further characterisation are covered separately in Sections 6 and 7.

5.2. Design of the Surveillance Programme

5.2.1 A 'surveillance monitoring' programme is required to:

- *Validate risk assessments:* supplement and validate the characterisation and risk assessment procedure with respect to risks of failing to achieve good groundwater chemical status;

- *Classify groundwater bodies:* confirm the status of all groundwater bodies, or groups of bodies, determined as not being at risk on the basis of the risk assessments; and
- *Assess trends:* provide information for use in the assessment of long-term trends in natural conditions and in pollutant concentrations resulting from human activity. Surveillance monitoring should be undertaken in each plan period and to the extent necessary to adequately supplement and validate the risk assessment procedure for each body or group of bodies of groundwater.

5.2.2. Surveillance is required in bodies or groups of bodies both at risk and not at risk of failing WFD objectives.

5.2.3. Selection of Surveillance Determinands.

The core suite will comprise DO, pH, EC, nitrate, ammonium, temperature, a suite of major and trace ions.

Additional anthropogenic contaminants (e.g. sheep dip insecticides) will be required on an infrequent basis (see below) to provide additional validation of WFD risk assessments.

When assessing natural background levels, additional selective determinands (e.g. heavy metals and radionuclides) will be required for the purposes of characterising natural groundwater quality and trends.

Further information on both core and selective determinand suite selection is provided in Appendix 2.

5.2.4 The selection of monitoring sites will be based on the representativity criteria outlined in Section 3.2.

5.2.5 In addition to the general criteria described in Section 3, criteria specific to surveillance monitoring are as follows:

- *Suitable types of site:* Surveillance monitoring is not, on its own, required to isolate the impact of individual pressures and the effectiveness of programmes of measures. Large abstractions and springs may therefore provide suitable sites as they draw water from a large area and volume of aquifer.
- *'At risk' bodies*: Locations should ideally coincide with operational monitoring points.
- *'Not at risk' bodies where confidence in the risk assessment is low*: The number of monitoring points should be sufficient to represent the range of pressure and pathway conditions in the GWB grouping and provide the data necessary to supplement the risk assessment, i.e. increase confidence. The final distribution per grouping will depend on availability of suitable surveillance sites and the distribution of pressures, but, as a general guide, at least 3 points in the most suitable groundwater body per grouping are recommended, with at least one additional point in as many as possible of the remaining bodies in the group.
- *Body groupings where pressures are limited (low or absent):* In bodies that are defined as 'not at risk' and confidence in the risk assessment is high, sampling stations will be required primarily to assess natural background levels and natural trends. Locations should therefore be selected accordingly. As a general guide, at least 1 point per grouping will be required.

5.2.4. Monitoring frequency selection will generally be based on the characteristics of the aquifer and the conceptual model. Table 1 provides suggested surveillance monitoring frequencies for different aquifer types.

Table 1. Proposed minimum monitoring frequencies for surveillance monitoring

		Aquifer Flow Type				
		Confined	**Unconfined**			
			Intergranular flow significant		**Fracture flow only**	**Karst flow**
			Significant deep flows common	**Shallow flow**		
Initial frequency – core & additional parameters		Twice per year	Quarterly	Quarterly	Quarterly	Quarterly
Long term frequency – core parameters	**Generally high-mod transmissivity**	Every 2 years	Annual	Twice per year	Twice per year	Twice per year
	Generally low transmissivity	Every 6 years	Annual	Annual	Annual	Twice per year
Additional parameters (on-going validation)		Every 6 years	Every 6 years	Every 6 years	Every 6 years	-

5.3. Design of the Operational Programme

5.3.1. An 'operational monitoring' programme is required to establish:

- the status of all groundwater bodies, or groups of bodies, determined as being at risk; and
- the presence of significant and sustained upward trends in the concentration of any pollutant. Operational monitoring has to be carried out for the periods between surveillance monitoring. In contrast to surveillance monitoring, operational monitoring is highly focused on assessing the specific, identified risks to the achievement of the Directive's objectives

5.3.2. Operational programmes are required only in bodies 'at risk' of failing to meet WFD objectives.

5.3.3. Selection of operational monitoring determinands.

- In most cases, both core and selective determinands will be required at each sampling station.
- The selection of selective determinands will be based on the initial conceptual models, the ongoing risk assessments arising out of WFD risk characterisation and results of the ongoing monitoring programmes.
- Guidance on selection of core and selective determinands is provided in Appendix 2.

- 5.3.4. The selection of monitoring sites will be based on the representativity criteria outlined in Section 3.2.

5.3.5. Where risk issues relate to <u>specific receptors</u> such as ecosystems, sampling points can be focussed in areas that are representative of key receptors and key pressures. In these cases, sampling points will often be used to help isolate impacts from different pressure types, assess the aerial extent of impacts and determine contaminant fate and transport between the pressure and the receptor.

5.3.6. Multi-level sampling points may be required to allow sampling from different depths (or depth intervals) within the aquifer or aquifer sequence (e.g. within a drift aquifer at ~10m, and within the underlying bedrock aquifer at ~30m and ~60m). The primary purpose of these multi-level sites is to assess variations in contaminant concentrations and distribution within the aquifer and at different depths so as to provide an adequate level of confidence for status assessment, design of Programmes of Measures and assessment of the effectiveness of programmes of measures.

5.3.7. Where pressures and risk issues relate to the <u>water body</u> itself, e.g. diffuse pressures, sampling points will be more distributed across the body, and where necessary focusing on the most representative or sensitive combinations of pressures and groundwater susceptibility.

5.3.8. When selecting monitoring sites, their locations should be prioritised on the basis of:

- Potential linkages with existing/planned surface water monitoring sites.
- Availability of suitable existing sites that provide representative samples.
- Potential for multi-purpose monitoring, e.g. combining requirements for Nitrates Directive monitoring, Drinking Water Protected Area monitoring, and Groundwater Directive compliance.
- Potential for supporting different WFD monitoring programmes (e.g. suitable springs can act as quality, quantity and surface water sampling stations).

5.3.9. Monitoring Frequency selection will generally be based on the conceptual model and in particular, the characteristic of the aquifer and its susceptibility to pollution pressures. Table 2 provides suggested minimum frequencies for different aquifer types.

Table 2. Proposed minimum sampling frequencies for operational monitoring

		Aquifer Flow Type				
		Confined	**Unconfined**			
			Intergranular flow significant		**Fracture flow only**	**Karst flow**
			Significant deep flows common	**Shallow flow**		
Higher vulnerability groundwater	**Continuous pressures**	Annual	Twice per year	Twice per year	Quarterly	Quarterly
	Seasonal/intermittent pressures	Annual	Annual	As appropriate	As appropriate	As appropriate
Lower vulnerability groundwater	**Continuous pressures**	Annual	Annual	Twice per year	Twice per year	Quarterly
	Seasonal/intermittent pressures	Annual	Annual	As appropriate	As appropriate	As appropriate
Trend assessments		Annual	Twice per year	Twice per year	Twice per year	-

5.3.10. Sampling frequency and sample timing at each monitoring location may require adjustment, based on:

- Statutory requirements for trend assessment, where applicable. These requirements are not yet available and will be specified in the new Groundwater Directive.
- Whether the location is upgradient, directly below, or downgradient of the pressure. Locations directly below a pressure may require more frequent monitoring.
- The level of confidence in the WFD risk assessments, and changes in the assessments over time.
- Short term fluctuations in pollutant concentrations, e.g. seasonal effects.

5.3.11. Where seasonal and other short-term effects are likely to be encountered, it is essential that sampling takes place at the same time(s) each year to enable comparable data for trend assessment, accurate characterisation and status assessment.

6. Prevent And Limit Monitoring

6.1. Groundwater quality monitoring is required to assess the effectiveness of the measures introduced to prevent or limit the deterioration of the status of groundwater. Although surveillance and operational monitoring programmes will contribute significantly to this, there may be a need for specific additional monitoring programmes aimed at point source pressures. These programme requirements may already be defined by specific regulation aimed at preventing or limiting the input of pollutants to groundwater, e.g. Landfill Directive requirements for landfill monitoring or Groundwater Regulations requirement for requisite surveillance. It may also be designed specifically to investigate other localised issues, e.g. contaminated land, accidental spillages.

6.2. **Defensive monitoring** of this type is designed primarily at ensuring compliance with site conditions and authorisations in the cases of regulated activities or for site specific investigation, i.e. **compliance monitoring**, or for the purposes of characterising site specific impacts and designing and assessing remedial action programmes, i.e. **investigation monitoring**.

6.3. The information derived from defensive monitoring should be used for characterisation and the investigation of specific issues, as well as ensuring Programmes of Measures are being effective. It should not be used specifically for status and trend assessment although some monitoring sites may potentially be used for surveillance and/or operational monitoring. However, where such sites are used, they must fully conform to the quality assurance requirements of WFD monitoring programme sites. Where sites do not comply they must be rejected.

7. Drinking Water Protected Area Monitoring

7.1. The WFD requires that monitoring programmes are able to assess the achievement of Drinking Water Protected Area (DWPA) objectives defined under Article 7. Unlike surface water bodies defined as DWPAs, the WFD does not introduce any additional specific monitoring criteria for groundwater bodies that are also DWPAs. However, the DWPA objectives require that any monitoring in these bodies is also able to provide accurate and reliable data to support DWPA management and assessment. For example this information will be needed to identify any deterioration in the quality of abstracted water that may potentially lead to an increase in the level of purification/treatment.

7.2. Monitoring in groundwater DWPAs should therefore be carried in accordance with the programmes set out for Surveillance and/or Operational monitoring as relevant to that body (see Section 5) in order to meet Article 4 objectives with the added requirement to ensure compliance with DWPA objectives (Article 7(3)) and the information requirements of Further Characterisation set out in Annex (Annex II (2.3c)).

7.3. The Article 7(3) objective to aim to prevent deterioration in the water quality of DWPAs in order to reduce treatment implies that there are background quality data for DWPAs at the date of implementation of this objective, against which any subsequent deterioration can be assessed. No specification for this is provided so it may be assumed that only monitoring sufficient to assess this objective is needed. It seems clear that raw water quality data are needed and it is logical to assume that this should be focused on potable abstraction sources.

7.4. Regular monitoring of all potable sources would not be practical, or necessary where the characterisation processes has indicated no risk. In water bodies or groups of bodies not at risk of meeting Drinking Water Protected Area Objectives it is recommended that there should be sufficient monitoring of a representative selection of significant potable sources (those to which the Drinking Water Directive applies – see note below[1]) to confirm the risk assessment.

[1] A significant potable source is defined as one intended for human consumption that comes within the requirements of the Drinking Water Directive (Directive 80/778/EEC as amended by Directive 98/83/EC). That is a source where;

This should be incorporated into and may in practice already be part of the surveillance monitoring programme. The relevant criteria from surveillance monitoring therefore apply.

7.5. In water bodies at risk of not meeting Drinking Water Protected Area Objectives, it is recommended that significant potable sources[1] should be monitored, as a minimum, at least once before and at least once within each RBMP period. Where appropriate, this monitoring may be focussed on, or restricted to, areas where the pressures and/or impacts that are giving rise to the risk are relevant to the quality of abstracted water. Subject to transposition into UK legislation, safeguard zones may be used to focus such monitoring (and subsequently to focus any necessary protection measures).

7.6. In many cases potable abstraction sources will form part of the surveillance and operational monitoring programmes. In these cases, the specific requirements of these programmes will take precedence over the monitoring outlined in 7.5 above. Where sources are part of surveillance and/or operational monitoring programmes, more frequent data than indicated above will be available and should be used for assessing compliance with Article 7 objectives.

7.7. In some cases individual groundwater abstraction points may form part of a group of sources that effectively abstract water from the same zone of contribution or safeguard zone within the DWPA. In such cases, providing that the monitoring regime is consistent and representative, not all individual sources may need to be monitored to adequately assess compliance with the Article 7 objectives.

8. Appropriate Use of Monitoring Data in Groundwater Classification

8.1. Groundwater status tests are outlined in general terms in [Tag 11b]. This section provides some guidelines on the use of groundwater monitoring data for aggregation and on the appropriate assessment of confidence and precision.

8.2. Groundwater monitoring data will play a key role in assessing status. The results from individual monitoring points as well as aggregated data for a groundwater body (or group of bodies) will be required and statistical analysis of the monitoring data will be needed. Given the frequency of groundwater sampling, the use of the mean value is recommended rather than median or 95 percentile[1] values for use in groundwater status tests.

8.3. An assessment of confidence in the monitoring results is very important when classifying the status of a groundwater body or considering the need for corrective action (programme of measures) but it may be less important in the justification for further investigation. In principle, greater confidence is needed where the outcomes of the decision making process will incur significant cost(s) and change in environment management.

8.4. When assessing confidence, a combination of hydrogeological knowledge and statistics is recommended. Hydrogeological knowledge will be provided through the conceptual model and the extent of the ZOCs and this information used to establish an appropriate monitoring

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- water abstracted from an individual supply provides 10 m³ a day or more as an average or serves at least 50 persons, unless supplied as part of a commercial or public activity in which cases the thresholds do not apply;

and that is not;:

- a natural mineral water recognised as such by the competent national authorities, in accordance with Council Directive 80/778/EEC of 15 July 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters; or
- water which is a medicinal product within the meaning of Council Directive 65/65/EEC of 26 January 1965 on the approximation of provisions laid down by law, regulation or administrative action relating to medicinal products.

[1] The 95th percentile of a distribution of measurements represents the value at which 95% of the measured values will be lower.

frequency (Tables 1 and 2). Once appropriate monitoring points and sampling frequencies have been selected, confidence will be assessed by applying standard statistical tests to the data to identify the upper and lower confidence limits[1]. Thresholds for status assessment and trends can then be assessed against these values.

8.5. Where the upper confidence limit (UCL) is below a threshold value (TV), then we are more than 95% confident that the mean value is below the TV. If the mean is below the TV but the UCL is above, then the level of confidence of the mean being below the TV is less than 95%. In this case the confidence level should be calculated and this value recorded. Where the mean is above the TV and the lower confidence limit (LCL) is above the TV then we can say we are more than 95% confident that the mean value is above the TV. If the mean is above the TV but the LCL is below the TV then we need to calculate and record the confidence level.

8.6. Given the variability and frequency of groundwater sampling, it is recommended that the statistical tests should be based on a rolling period of 6 years of data.

8.7. It is recommended that the WFD requirements for precision in the monitoring data is addressed through:

- The use of a minimum six years of data and appropriate minimum sampling frequencies in carrying out status and risk assessments;
- The use of accredited laboratories;
- The implementation of appropriate Quality Assurance and Quality Control procedures.

8.8. As discussed in Section 3.2.1, monitoring points are selected so that, collectively, they are representative of a mosaic of inputs from different pressure/pathway combinations across the groundwater body or across the catchments of associated receptors. Different elements of the mosaic will contribute differently to the overall aggregation. For certain monitoring purposes, the use of weighted means may therefore be appropriate to ensure that the variation in inputs across the mosaic is reflected in the result of the aggregation process. The weighting may, for example, be influenced by the relative areas of each of the pressure/pathway combinations within an aggregation. It may also be influenced by the relative recharge contribution of each of the pressure/pathway combinations within an aggregation. The use of weighted means reflects the principles outlined in Water Framework CIS Guidance 2.8[2] and the mention of 'appropriate aggregation' in the latest draft of the Daughter Directive.

[1] Confidence limits for the mean provide an interval estimate for the mean. Instead of a single estimate for the mean, a confidence interval generates a lower and upper limit for the mean. The interval estimate gives an indication of how much uncertainty there is in the estimate of the true mean. The narrower the interval, the more precise is the estimate.

[2] J. Grath, A. Scheidleder, S. Uhlig, K. Weber, M. Kralik, T. Keimel, D. Gruber (2001): "The EU Water Framework Directive: Statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results". Final Report. Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management (Ref.: 41.046/01-IV1/00 and GZ 16 2500/2-I/6/00), European Commission (Grant Agreement Ref.: Subv 99/130794), in kind contributions by project partners. Vienna.

Tool Box

Appendix 1: Criteria for site selection and information requirements

Critical requirements for all sampling sites

- ✓ Detailed information on the site should be available and routinely reviewed. This information should be used to assess the suitability of the site and only if the site is suitable should it be used for the relevant monitoring programme.
- ✓ Monitoring sites should be designed or selected to produce data for many years. Sites must have easy access, be secure security from vandals and potentially facilitate long-term installation of expensive water level or other monitoring equipment.
- ✓ Long term access agreement with land owners must be secured for sites and installed equipment must be secure

Monitoring point information – essential and desirable factors

Factor	Chemical monitoring points	Quantitative monitoring points
Aquifer(s) monitored	E	E
Location (grid reference), name of monitoring point and unique identifier	E	E
Groundwater body that monitoring point is within	E	E
Purpose(s) of monitoring site	E	E
Type of monitoring point – farm borehole, industrial borehole, spring, etc	E	E
Depth and diameter(s) of boreholes/wells	E	E
Description of headworks – grouting integrity, slope of ground around borehole	E	E
Depth of screened/open sections of boreholes/wells	D	D
Vulnerability or indication of subsoil thickness and type at monitoring point	E	D
Visual appraisal of recharge area (including land use and pressures, potential sources of point pressures)	E	D
Amount abstracted or discharge flow rate	E	E
Pumping regime (qualitative description – e.g., intermittent, continuous, overnight, etc.)	D	E
Drawdown (pumped water level)	D	E
Zone of contribution/recharge area	D	D
Pump depth	D	D
Static or rest water level	D	E
Datum elevation and description of datum	D	E
Artesian/ overflowing	E	E
Borehole log (geological and construction details)	D	D
Aquifer properties	D	D

KEY

E- Essential
D- Desirable

Quantitative Monitoring Sites

- ✓ Monitoring points should not be pumped or should only be pumped for very short periods at well-defined times, such that measured water levels reflect natural conditions.
- ✓ The locations should be outside the immediate hydraulic influence of the pressure such that day-to-day variations in pumping will not be evident in the data.
- ✓ Large springs may be suitable where total flows are in excess of 1 litre/sec.

Note that data from stations which function as continuous abstraction wells may be acceptable if accompanied by detailed (e.g. hourly) pumping records.

Appendix 2: Initial Guidance on the Selection of Determinand Suites

A2.1 Surveillance monitoring

The following core determinands are mandatory:

- oxygen content (DO);
- pH;
- conductivity (EC);
- nitrate;
- ammonium.

In addition, the WFD requires that this core determinand list must be supplemented by parameters that are indicative of the impact of pressures identified through the characterisation and risk assessment process.

Although not required specifically by the WFD, the core list should also be supplemented by suites of inorganic parameters to provide data for QA purposes and information on the natural quality (baseline) of groundwater and temperature.

Further generic indicator species may also be added to supplement the risk assessment process. These may include indicators of general industrial activity, e.g. TCE and PCE and urban areas, e.g. Zn and B.

For surveillance monitoring it is therefore recommended that:

- The core suite will comprise DO, pH, EC, nitrate, ammonium, temperature, a suite of major and trace ions plus, where appropriate, selected indicators.
- Parameters indicative of the risks to and impacts on groundwater from pressures identified through Annex II characterisation process were relevant.
- Temperature, DO, EC, pH should be measured in-situ (at the sampling point), while the other parameters should be measured/analysed in the laboratory.

A2.2 Operational Monitoring

In addition to the core parameters, selective determinands will need to be monitored at specific locations, or across groundwater bodies, where the risk assessments carried out as part of the characterisation process of groundwater bodies indicates that they are at risk of failing to achieve relevant objectives.

The selection of parameters will be selected on a case-by-case basis and be influenced by WFD characterisation work supplemented, where necessary, by other information including existing water quality data and local knowledge. The chemical monitoring suites must be reviewed on a regular basis to ensure that they provide representative information and data on groundwater quality and fully support the risk assessment process.

Broad land use/cover categories can be used as a basis for initial determinand selection. Table A1 provides an indication of the types of land use/cover that can be used and potential determinand types for each. Further sub-division, targeting and optimisation of determinand suites should be based on information from the characterisation process, local knowledge and pre-existing water quality data.

Table A1. Indicative determinand types for different land use/cover.

Land Use	Fungicides	Urea Herb	OPs	Acid Herb	VOCs	Pyrethroids	Organotin
Cereals	✓	✓	As needed	✓	✓	✓	
Fruit	✓	As needed	✓	As needed	As needed	✓	
Potatoes	✓	✓	As needed	✓	As needed		✓
Golf		✓		✓			
Grass		As needed		✓	As needed		
Woodland		As needed		As needed			
Sheep			✓			✓	
Amenity		✓		✓	✓		
Urban/Industrial		✓		✓	✓		As needed

Appendix 3: Aquifer settings/flow types and monitoring implications

Aquifer setting/flow type		Example areas	Monitoring considerations	Preferred monitoring
Regional Flowpaths	Intergranular	Kildare Gravels (Ireland) Thames Gravels (England)	• High rate abstraction sources boreholes generally available for 'bulk' chemistry sampling. • Regional flow patterns readily established from level monitoring boreholes. Generally low water level seasonal range.	1, 2, 4, 5
	Intergranular/Fracture	Permo-Triassic Sandstones (Midlands/Scotland/N.Ireland) Chalk (South and East England)	• High rate abstraction sources generally available for 'bulk' chemistry sampling. • Regional flow patterns readily established from level monitoring boreholes. • Commonly confined down-gradient, concentrating monitoring in unconfined recharge areas. • Unsaturated zone storage resulting in 'slow' component of recharge – delayed response to land use changes.	1, 2, 3, 4, 5
	Fracture	Jurassic Limestones (Lincolnshire)	• High rate abstraction sources generally available for 'bulk' chemistry sampling. • Regional flow patterns readily established from level monitoring boreholes. Water level seasonal ranges can be significant. • Preferential flow zones possible.	1, 2, 3, 4, 5
	Karstic	Carboniferous Limestone (Ireland/Mendips)	• High rate abstraction boreholes available but may only be representative of preferential flow zone. • Large discharge springs available for 'bulk' chemistry sampling. • Recharge zones can be complex. • Low storage leading to rapid level/quality changes with implications for monitoring frequency/timing.	1, 2, 3
Intermediate Flowpaths	Intergranular	Glacial outwash and valley sand & gravels/alluvials (UK and Ireland)	• Perched water tables.	4, 5, 6
	Intergranular/fracture	Devonian Sandstones (Scotland/Welsh Borders) Millstone Grit (England)	• Can be compartmentalised by faulting with associated complex flow patterns. • Boreholes may sample only discrete zones.	5, 6
	Fracture Fracture/karstic	Palaeogene Basalts (N.Ireland) Carboniferous/Devonian (Ireland, N England)	• Can be compartmentalised by faulting with associated complex flow patterns. • Higher abstraction rate sources less common with possibility of monitoring boreholes being located in low/no flow zones. • Low storage leading to rapid level/quality changes with implications for monitoring frequency/timing. • Layered aquifer systems with vertical flow relationships increasing complexity of data interpretation.	4, 5, 6

Local Flowpaths	Fracture/upper weathered zone	Ordovician/Silurian (Wales/N.Ireland) Metamorphic/Igneous (Scottish Highlands/Northern Ireland/Ireland/Cornwall)	• Higher abstraction rate sources for 'bulk' sampling unlikely. • Fast through-flow times and short flow paths. • Low storage leading to intermittent well/spring yields with implications for monitoring frequency/timing. • Possibility of boreholes being located in low/no flow zones. • Option for spring/surface water monitoring as representative of groundwater. • Increased significance of storage in overlying superficial deposits.	3, 6

Monitoring type

1 – High rate abstraction boreholes
2 – Large discharge springs
3 – Surface water
4 – Purpose drilled monitoring boreholes
5 – Private/low rate abstraction boreholes
6 – Low discharge springs

Appendix 4. Example of a Representative diffuse network

6 groundwater bodies have been grouped and 30% of the total area of the group has been defined with high impact potential , 25% of the total area has been defined as having moderate impact potential, 40% of the total area has been defined with low impact potential and 5% of the total area has been defined with negligible impact potential. There are 8 monitoring points within the groundwater body group. Therefore, to create a monitoring network that is representative of the impact potential in the groundwater body grouping, 30% of the total combined Zone of Contribution (ZOC) area should have high impact potential, 25% of the total combined ZOC area should have moderate impact potential, and so on. In this example, each monitoring point ZOC is approximately equal in size and the impact potential within each ZOC is homogeneous.

Therefore one monitoring point ZOC roughly equates to 12.5% of the total ZOCarea, so two monitoring points ZOCwith moderate impact potential would be required to represent the moderate impact potential of the groundwater body grouping. As an alternative or an addition to an area-based approach, this example could be adapted for incorporation of pressure loading, baseflow or recharge estimates.

Monitoring Point	ZoC Vulnerability/Risk
MP1	Low
MP2	Low
MP3	Low
MP4	Moderate
MP5	High
MP6	Negligible
MP7	High
MP8	Moderate