UK TECHNICAL ADVISORY GROUP ON THE WATER FRAMEWORK DIRECTIVE
Guidance on the Selection of Monitoring Sites and Building Monitoring Networks for Surface Waters and Groundwater

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 working draft being amended accordingly.			
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UK Technical Advisory Group On The Water Framework Directive

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Introduction

This guidance paper sets out the principles by which monitoring programmes should be developed and adapted to meet the requirements of the Water Framework Directive and other relevant legislation in an integrated and cost-effective manner**.** For the first time, a truly integrated approach to determining the ecological and chemical status of surface water and the chemical and quantitative status of groundwater is demanded. In developing the Water Framework Directive it was recognised that we need to move away from the old static, blanket requirements for monitoring for a narrow range of chemicals of the older Directives, to a more dynamic risk based approach, where pressures are linked to impacts on biological and physico-chemical indicators of environmental quality. The use of biological indicators as one of the main mechanisms for determining the status of the aquatic environment helps us focus on the real problems which need to be resolved and on the pressures which need to be changed to achieve environmental objectives. As a result, a major change in the way monitoring programmes are managed is required and some significant technical challenges will need to be overcome.

This guidance covers surface water environmental monitoring in chapter 1 and groundwater monitoring in chapter 2. It does not address licence or discharge consent condition compliance monitoring.

The guidance presented here applies to the whole of the UK and covers the period from 2005 to 2015 encompassing the first River Basin Management Plan period. It is a living document and will be subject to periodic review as new information becomes available. Once agreed, this 'high level' document should guide the content of operational strategies and detailed operational guidance manuals for monitoring by the administrations as will agencies associated with UKTAG.

The WFD will run concurrently with a number of other Directives and drivers for monitoring and reporting which are shown in Appendix 1(refer to page 47-48). It provides a framework within which all other water Directives will operate and therefore provides an opportunity to develop multi-purpose monitoring programmes. With good planning and co-operation between conservation bodies and environment agencies, data need only be collected once to satisfy multiple drivers.

Discussions are taking place within the separate Administrations on how to manage the overlap and transition from current reporting of environmental quality and Directive compliance to the Water Framework Directive requirements. When certain current Directives (listed in Article 22) are repealed, mostly in 2013, their monitoring and reporting obligations will cease, leaving the WFD requirements and those of the Directives which continue. Essentially, the information needed for those Directives being repealed will be superseded more effectively by the WFD. For example, monitoring for specific pollutants and priority substances will provide the information necessary to protect the environment from the substances currently the subject of Directive 76/464/EEC 'the Dangerous Substances Directive'. Under the Water Framework

Directive and subsequent daughter Directives, reporting on progress in dealing with dangerous substances will be improved.

Where necessary, monitoring data will be collected between 2005 and 2006 for building, testing and refining WFD status assessment tools and informing further characterisation as mentioned in Annex II para 1.5 of the WFD. Data collected after 2006, when WFD monitoring programmes will be in place, will be required to determine water bodies' status, refine risk assessment and to iteratively refine monitoring programmes during the first River Basin Management Plan period (2009 to 2015).

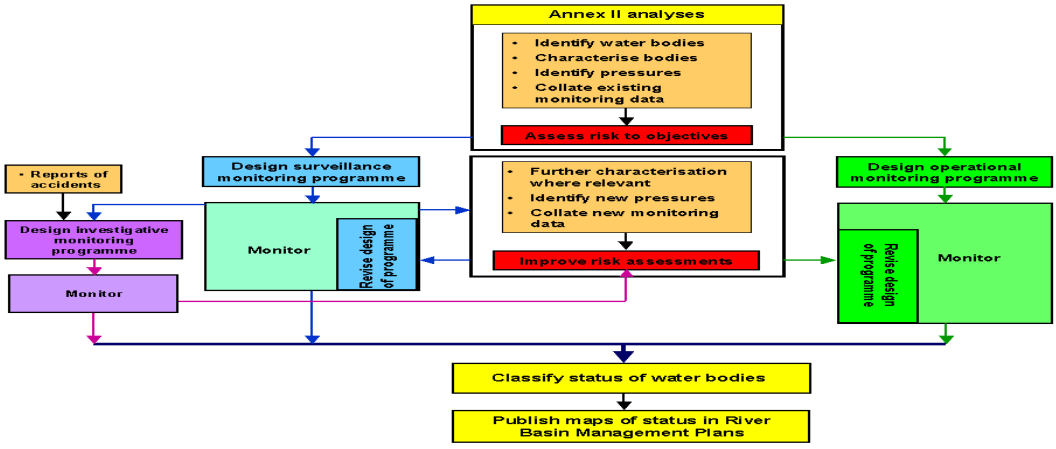
The monitoring requirements for assessing chemical status may be further elaborated in a daughter Directive which the Commission is expected to propose in 2005.

Background

The purpose and requirements of surveillance, operational, investigative and some protected area (Drinking Water and Natura 2000 protected areas) monitoring are laid down in the WFD, Annex V. and guidance on these requirements is provided in CIS working group 2.7, 'Guidance on Monitoring for the Water Framework Directive - 15/10/2003'. For groundwater, this will in due course be supplemented by guidance from CIS Working Group C In order to design, plan the chronology and evaluate the cost of monitoring for the WFD, agreed criteria or 'rules' for monitoring are required. The UKTAG Monitoring Task Team (MonTT) was set up to draft these 'rules' which should provide simple policy guidance for selecting risk based site networks, using the outputs from River Basin Characterisation (Article 5 and Annex II). For surface waters, monitoring networks will change from year to year in response to changing status classifications and improvement of the risk assessments. More stability is required for groundwater monitoring networks due in part to the requirements for trend assessment and the capital cost of constructing monitoring installations.

The risk assessments and existing data will allow the design of a monitoring programme to provide information to classify water bodies with known statistical confidence. This programme will be more complex and dynamic than current programmes and Figure 1 illustrates how risk analysis and the different monitoring programme types are linked together for surface waters. There will however, need to be a stable core network of sites to assess long-term changes across the spectrum of status and water body types (Surveillance sites). An understanding of long term trends is required so that status change as a result of natural or global cycles may be distinguished from changes resulting from anthropogenic pressures and domestic programmes of measures.

Figure 1. Schematic diagram illustrating the relationship between Article 5 and Article 8 in the design of surface water monitoring programmes



Using Risk Assessment to Design Monitoring

An initial analysis of the pressures and impacts on water bodies has been undertaken in accordance with Article 5 of the WFD to determine whether a water body is at risk of failing to achieve its relevant environmental objective in 2015. The assessment was carried out against the best understanding of Good Status and other objectives relevant to protected areas.

Initial risk assessment has placed each water body into one of four categories (1a, 1b, 2a and 2b) shown below (Table 1), as agreed by UKTAG. These four categories were produced to allow prioritisation of monitoring and follow up action.

Therefore monitoring effort should be targeted towards water bodies assessed as being in risk categories 1b and if resources allow the 2a category. Clearly, stratified surveillance surveillance (for surface waters) and operational monitoring will be undertaken from December 2006 at representative water bodies in the 1a and 2b risk categories in order to carry out status classification.

Table 1. Risk categories as defined in UKTAG guidance

Risk Category	UKTAG Definition
1a	Water bodies at significant risk
1b	Water bodies probably at significant risk, but for which further information is needed.
2a	Water bodies not at significant risk on the basis of available information
2b	Water bodies not at significant risk

Note: UKTAG 2003 risk assessment guidance WP 7a – g are published on the UK TAG website http://www.wfduk.org/tag_guidance/Article_05/Folder.2004-02-16.5332/view

The main purpose of risk assessment was to identify water bodies at risk of failing WFD good status in 2015. There may be water bodies labelled not at risk that are already below 'good' status as well as water bodies labelled at risk, that are achieving good status and which should not be allowed to deteriorate in status. Risk of failing good status should not be confused with actual status as determined from monitoring results. Whatever the status of a water body, the WFD requires that it be protected from deteriorating to a worse status. Both risk assessment and actual status will be used to set water body objectives and derive the programmes of measures to achieve these objectives.

Chapter 1. Surface Waters

1. 2005-2006, Monitoring for intercalibration, classification tool building and further characterisation

During this period, the priorities for data collection are for classification tool building, intercalibration, classification tool refinement and informing further characterisation. Initial risk assessments were carried out using existing national data sets of pressure and environmental quality against the thresholds agreed by UKTAG as the best approximation to the boundary criteria for 'good' ecological and chemical status. Of necessity the risk assessments were made before 'good' status classification thresholds were known for most of the biological elements. Indeed, these boundaries will not be known until classification schemes are implemented and the boundaries in these schemes will be informed by EU intercalibration.

Data are required from water bodies along gradients of pressures for each of the biological elements. This will allow the building of pressure specific classification tools if relationships can be established between biological metrics and pressures and facilitate tool testing on independent data sets. UKTAG partner organisations are to continue collaboration on collecting and sharing data, particularly for those water categories and elements where data are scarce, mainly lakes and transitional and coastal waters.

Guidance

1.1. Monitoring will be designed to collect data for the pressures and elements required for classification tool building including error estimation, and for the EU intercalibration exercise. For example, the Northern Geographical Intercalibration Group (GIG) working on rivers and lakes requires data for the pressures and elements shown in Table 2.

Table 2. Summary of quality elements required for intercalibration – Northern GIG

Pressure	Element	Provisional metrics
Eutrophication (lakes)	Phytoplankton	Chl.a, Biovolume, %age cyanobacteria
Eutrophication/organic loading (rivers)	Macroinvertebrates	ASPT, DSFI, STAR/AQEM-metrics
Acidification (rivers and lakes)	Macroinvertebrates	Raddum index, Medin's index, STAR
Acidification (rivers and lakes)	Fish	CPU, % acid-sensitive species

(ASPT=Average Score per Taxon, DSFI= Danish Stream Fauna Index. STAR=Standardisation of River Classification, AQEM=Integrated Assessment System for Ecological Quality of streams and rivers using Benthic Macroinvertebrates, CPU=catch per unit effort)

1.2. Additional monitoring may be required to further investigate the risk of water dependent Natura 2000 sites failing to achieve their (water related) conservation objectives. It is expected that the environment agencies will work closely with the conservation bodies to develop monitoring priorities for these sites.

1.3. Monitoring for the EU intercalibration exercise can be used for verifying and testing the initial risk assessments.

1.4. To allow further characterisation (WFD Annex ii, 1.5), monitor water bodies within 1b and 2a risk categories during 2005 and 2006. Effort should firstly be directed at category 1b water bodies and secondly at 2a water bodies depending on available resources (Table 3). Within these water bodies, sites representative of the pressures should be selected and monitored for those element(s) most indicative of the pressures (as shown later in the document in Tables 4, 5 and 6). Where more than one element is indicative of a pressure, expert opinion should be used to choose which element(s) to monitor.

Table 3. A summary of the risk category and outcome for driving WFD monitoring until 2006

Risk Category	Drivers for WFD Monitoring (2005-2006)
1a	Classification tool building and intercalibration.
1b	Classification tool building, intercalibration and further characterisation.
2a	Classification tool building, intercalibration and if resources allow, further characterisation.
2b	Classification tool building, including collection of reference condition data and intercalibration.

1.5. For priority substances discharged into a water body, a screening exercise should be conducted in water bodies assessed as risk category 1b and if resources allow, 2a for this pressure. Concentrations of priority substances should be judged against the proposed draft EQSs emerging from negotiations on the Article 16 Daughter Directive. This screening exercise would form the basis of deciding whether a water body should go forwards into operational monitoring for statistically robust assessment of EQS compliance. Altered or new EQSs for priority substances will trigger new risk assessments.

Therefore, priorities for monitoring for specific pollutants (Annex VIII indicative) will be in water bodies assessed as risk category 1b and if resources allow, category 2a for this pressure. This will be as indicated through risk assessment or from more recent local knowledge of the presence or discharge in significant quantities of these substances. In this context 'significant' means likely to fail the relevant EQS. Surveillance and operational monitoring after 2006 will cover the other risk category water bodies. The UKTAG Chemistry Task Team is commissioning EQS development for an initial tranche of substances known to be discharged to the environment in significant quantities.

1.6. The determinand list that constitutes Annex VIII will be agreed through the UKTAG Chemistry Task Team. This list should consider substances that are accidentally or illegally present as well as those from authorised emissions.

1.7. The results of the 2005 and 2006 monitoring for further characterisation will assist with the design of the following years' monitoring network. Recommendations on grouping of water bodies for monitoring are given in section 3.6.

2. Monitoring Programmes from December 2006 Onwards

This is when monitoring to assess water body status as laid down in Article 8 formally starts in order to: '*establish a coherent and comprehensive overview of water status within each river basin district:*

For surface waters such programmes shall cover:

- *The volume and level or rate of flow to the extent relevant for ecological and chemical status and ecological potential*
- *The ecological and chemical status and ecological potential'*

The quality elements, categories of water, normative definitions of status, method of setting chemical standards, details of the different types and frequency of monitoring, the intercalibration exercise and the presentation of status results are all laid out in Annex V of the Directive.

Monitoring (Annex V, 1.3.) is to 'provide a coherent and comprehensive overview of ecological and chemical status within each river basin and shall permit classification of water bodies into five classes consistent with the normative definitions'. The monitoring programme must cover inland surface waters, transitional waters (estuaries and lagoons), coastal waters and groundwater.

2.1. Types of Monitoring

Monitoring drivers may be grouped into four basic types (WFD Common Implementation Strategy (CIS) guidance for monitoring, working group 2.7) namely:

1. Surveillance
2. Operational
3. Investigative
4. Other drivers, such as protected areas and to enable further characterisation in Accordance with Annex II, 1.5.

Surveillance monitoring programmes must be designed on the basis of the results of Annex II characterisation and risk assessment procedure. Operational monitoring programmes must be designed on the basis of the characterisation and risk assessment as refined by the data from the surveillance monitoring programmes.
Operational monitoring is for classifying water bodies, or groups of water bodies, at risk of failing good ecological status. The results may show that some bodies or groups of bodies, considered likely to fail to achieve environmental objectives on the basis of the Annex II risk assessment and the surveillance monitoring programme are in fact achieving good status. These water bodies would subsequently be covered by the surveillance programme.

2.2. Surveillance

i. 'Supplementing and validating the impact assessment procedure detailed in Annex II'
ii. 'The efficient and effective design of future monitoring programmes'
iii. 'The assessment of long-term changes in natural conditions, and'
iv. 'The assessment of long-term changes resulting from widespread anthropogenic activity'

The results of such monitoring shall be reviewed and used, in conjunction with the impact assessment procedure described in Annex II to determine requirements for monitoring programmes in the current and subsequent river basin management plans.

Selection of monitoring points

Surveillance monitoring *'shall be carried out at sufficient surface water bodies to provide an assessment of the overall surface water status within each catchment or subcatchments within the river basin district. In selecting these bodies Member States shall ensure that, where appropriate, monitoring is carried out at points where:*

- *The rate of water flow is significant within the river basin district as a whole; including points on large rivers where the catchment area is greater than 2,500 km^{2,}*
- *The volume of water present is significant within the river basin district, including large lakes and reservoirs.*
- *Significant bodies of water cross a Member State boundary,*
- *Sites are identified under the Information Exchange Decision 77/798/EEC, and*

At such other sites as are required to estimate the pollutant load which is transferred across Member State boundaries, and which is transferred to the marine environment' (Annex V, 1.3.1.).

Selection of quality elements

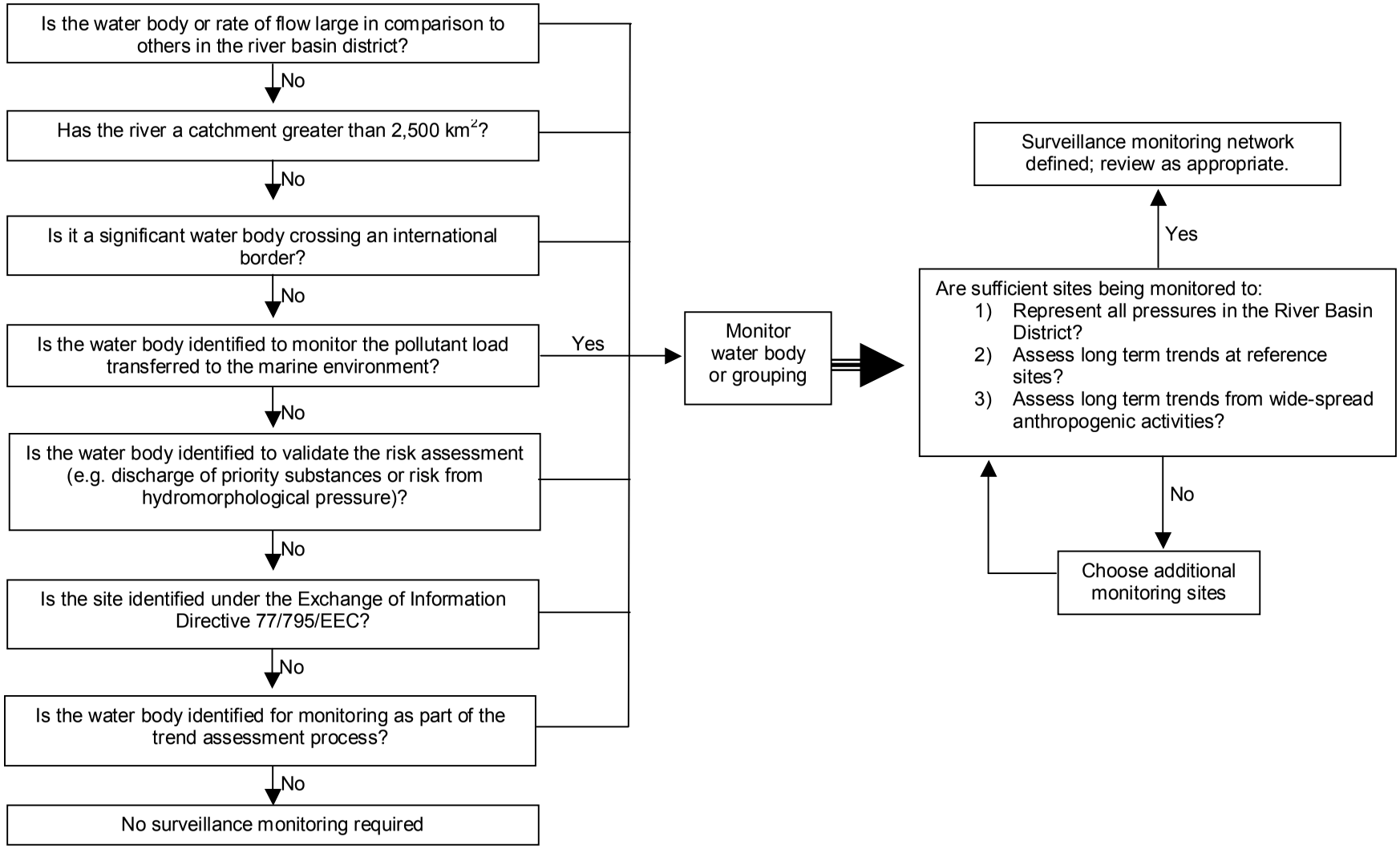
Surveillance monitoring shall be carried out for each monitoring site for a period of one year during the period covered by a river basin management plan for:

- *Parameters indicative of all biological quality elements*
- *Parameters indicative of all hydromorphological quality elements*
- *Parameters indicative of all physico-chemical elements*
- *Priority list pollutants which are discharged into the river basin or sub-basin, and*
- *Other pollutants discharged in significant quantities in the river basin or sub-basin.*

Unless the previous surveillance monitoring exercise showed that the body concerned reached good status and there is no evidence from the review of impact of human activity in Annex II that the impacts on the body have changed. In these cases, surveillance monitoring shall be carried out once every three river basin management plans.'

Surveillance monitoring serves several purposes as set out in the WFD above and Figure 2 provides a flow diagram to clarify the criteria for selecting surveillance sites.

Figure 2. Flow diagram for selecting surveillance monitoring sites for surface waters



2.3. Supplementing and validating the results of the pressures and impacts analyses

To enable the efficient management of the monitoring programmes, the monitoring effort required will need to be spread as evenly as possible over the planning cycle. This means that the focus of monitoring may need to shift a number of times during the cycle in order to provide sufficient information at the right time to support the various planning decisions required. This dynamic element to the focus of the monitoring regimes is described below in the context of the surveillance monitoring programme.

Prior to the production of the first river basin management plan, the priority for basin planning will be to better characterise the risk to those water bodies identified in 2004 as probably at significant risk (See Section 1). This is necessary to enable the timely design of suitable programmes of measures. It will principally be achieved by focusing monitoring effort at the start of the monitoring programmes on operational monitoring for these water bodies (See Section 2.7). However, some surveillance monitoring for water bodies identified as 'not being at risk' may also be needed to help determine whether or not bodies identified as 'probably at significant risk' are 'at significant risk'. Where this is the case, such monitoring will be the priority for the surveillance programme in the first years of monitoring.

Once sufficient data has been obtained through operational and surveillance monitoring to design programmes of measures for water bodies identified as being at risk, the focus of monitoring effort overall will shift. The surveillance programme will be expanded and targeted on water bodies identified in 2004 as 'not at significant risk' on the basis of the information available at that time (See Table 1 on page 7). The data obtained from such monitoring will be used to help inform the review of the pressures and impacts analyses in 2013.

Where the surveillance monitoring data indicates a significant risk to the achievement of the Directive's environmental objectives, the water body, or group of bodies, will be re-categorised as being 'at risk' and further information gathered, where necessary, through the operational monitoring programme.

Some water bodies have been identified as 'at', or 'probably at', 'significant risk' as a result of one type of pressure but identified as 'not at significant risk' from another type of pressure on the basis of the information available in 2004 (2a risk category - See Table 1). This means that a proportion of water bodies 'at risk' will be subject to both operational and surveillance monitoring. Because surveillance monitoring covers the full spectrum of quality elements, the information it provides will help comprehensively supplement and validate the risk assessments for those water bodies identified as 'at risk'.

For surveillance sites, all relevant quality elements[1] must be monitored in at least one year[2] during the period covered by a river basin management plan (i.e. monitored in one Year before 2015 for the purposes of the first planning cycle). For some quality elements this will be adequate. For others, several consecutive years' monitoring may be needed to provide the information necessary to validate the results of the pressures and impacts analysis.
In the last few years of the first planning cycle, the focus of monitoring effort overall will shift back again to operational monitoring for water bodies at risk. The data obtained will support an initial assessment of the effectiveness of the first programmes of measures and so contribute to the production of the second river basin management plan in 2015.

In addition to the surveillance monitoring described above, the surveillance programme will include, from the outset, a network of long-term monitoring sites. Among other things, these sites will be used for the purposes of assessing long-term changes resulting from widespread anthropogenic activity or long-term changes in natural conditions (see Section 2.4.). In time, such information will be used to supplement the results of the pressures and impacts analysis.

2.4. Assessment of long term changes in natural conditions or resulting from widespread anthropogenic activity

WFD surveillance monitoring requires that all biological and physico-chemical elements be assessed and it is envisaged that the long term surveillance network will provide the baseline for assessing long term change. Assessing long term natural change requires sites in areas not impacted by local anthropogenic pressure whereas assessing changes in widespread anthropogenic pressure requires sites in water bodies representative of these pressures.

Water bodies subject to similar pressure and of the same type or sensitivity can be grouped (see section 3.6.) and representative fixed sites chosen to assess the long-term trends in impact resulting from altering anthropogenic pressure. These sites could also double as operational sites. e.g. as part of the network of sites to classify water bodies at risk from diffuse agricultural pollution.

2.5. Frequencies

The WFD states that surveillance must be conducted for 1 year in each 6-yearly river basin plan period, The frequency of sampling within that year will be determined by the number of samples or surveys required to give adequate confidence in classification. Until the detail of how classification schemes for each of the biological and physico-chemical elements perform it is not possible to provide new guidance about sampling frequency.

[1] The relevant quality elements include: parameters indicative of all the biological quality elements; parameters indicative of all the hydromorphological quality elements; parameters indicative of all the general physico-chemical quality elements; any priority substances known to be entering the river basin upstream of the monitoring site; and any other pollutants known to be entering the river basin upstream of the site in quantities that may cause the exceedance of an EQS.

[2] Requirements relating to monitoring frequencies in this year are specified in Annex V to the Directive. For biological and hydromorphological quality elements, monitoring must be carried out at least once. For general physico-chemical quality elements and specific pollutants four samples are required, and for priority substances twelve samples, unless lower frequencies are justified on the basis of technical knowledge and expert judgement. Such judgements should take account of the purpose for which the data are required.

2.6. Guidance

i. To capture and understand the range of ecological or physico-chemical responses to a pressure, a number of water bodies of the same type are required in each risk category. Therefore choose surveillance water bodies in each risk category, in proportion to the number of water bodies in each type. e.g. if there are sufficient resources to carry out surveillance on 25 of the 250 in risk category 1a then, the 25 selected should be distributed according to the proportion of each type in this risk category.

ii. For assessing long term trends, it is important to select water bodies typical of a river basin. An appropriate number of sites (number determined by precision required in relation to variability) should be selected in areas of little local pressure for assessing natural changes. For water bodies suffering 'widespread' anthropogenic pressure choose sufficient sites in water bodies representative of the pressure and type.

Take account of sites where long term data already exist to increase the statistical confidence in trend assessment and classification. To detect long term trends the surveillance network should include appropriate Environmental Change Network sites, National Marine Monitoring Programme sites and some of the high/good intercalibration sites with lengthy data records.

iii. Data from surveillance sites will be collected for all the biological, hydromorphological, general physico-chemical elements, and priority list pollutants discharged and other pollutants discharged in significant quantities.

Screening will also be required for those substances which may be ecologically damaging but which are not authorised as being discharged. Before instigating costly chemical analysis, however, it would be prudent to check for a biological impact. Clearly, if a biological impact is apparent then investigative monitoring should consider the presence of Priority Substances and Other Specific Pollutants.
Where no biological impact is apparent a more preventative approach may be required. This would entail monitoring for activities and pressures likely to give rise to these pollutants in the environment and involve a screening exercise. New low cost technologies and other novel techniques could be employed for screening some of these pollutants (see section 2.8).

iv. For cross boundary transport or release to sea of pollutant loads, the existing network of Harmonised Monitoring and OSPAR sites should be used. Although Annex V 1.3.1. refers to surveillance monitoring, i.e. all elements at these trans-boundary or freshwater limit sites, the objective is to *'estimate the pollutant load'* which implies measurement of flow and concentration only. It is suggested however, that a biological site should be associated, with such boundary sites **a**, in order to comply with the Directive requirement that surveillance must cover parameters indicative of all elements and **b**, to assess whether there are any ecological impacts or relationships associated with the pollutant loads. It is recognised however, that many of these sites for estimating pollution loads are at the very end of river systems and may not be suitable for biological sampling therefore, an upstream site must be chosen so long as there is no interfering change in pressure.

v. Surface water bodies identified as not at risk of failing to achieve good status must be classified as either good status or high status[3]. Predictions provided by risk analyses and validated by surveillance monitoring information will be used in determining status class. The surveillance monitoring programmes will be designed to provide sufficient information from groups of water bodies to validate that risk analyses have correctly distinguished bodies subject to no or only very minor pressures (i.e. high status bodies) from those at good status. Principles relevant to the grouping of water bodies are set out in Section 3.6 (i).

2.7. Operational

The WFD Annex V.1.3.2. states; '*Operational monitoring shall be undertaken to: establish the status of those bodies identified as being at risk of failing to meet their environmental objectives and assess any changes in the status of such bodies resulting from the programme of measures*'

(This refers to the environmental objectives laid down in Article 4 and includes those objectives for protected areas such as Natura 200 sites.)
'The programme may be amended during the period of the river basin management plan in the light of information obtained as part of the requirements of Annex II or as part of this Annex, in particular to allow a reduction in frequency where an impact is found not to be significant or the relevant pressure is removed'.

Operational monitoring only needs to assess pparameters indicative of the quality elements most sensitive to the pressures to which the water bodies are subject. Tables 4, 5 and 6 provide expert judgement as to which elements are most appropriate for specific pressures. The tables provide a means of focusing monitoring effort to aid efficient use of resources. Where more than one element is sensitive to a pressure e.g. all are sensitive to eutrophication, expert opinion should be employed to choose the most sensitive elements for the category of water concerned.

Water bodies at risk are classified according to the results of operational monitoring though as mentioned above in section 2.1. It is expected that a site used for surveillance could double as an operational site, with the element providing the worst result with adequate confidence of class being used to classify**.** Annex V 1.3.2. suggests that operational monitoring is only applicable to water bodies identified as being at risk. Therefore surveillance must be used to classify water bodies in the 'not at risk' category. Operational monitoring will also provide a check for 'no deterioration in class'. It should also be possible to identify water bodies that are near the class boundary and are therefore at greater risk of deteriorating into a lower class.

[3] Or in the case of artificial or heavily modified water bodies, good ecological potential and good surface water chemical status; or maximum ecological potential and good surface water chemical status.

Table 4. Quality elements sensitive to the pressures affecting rivers

SOURCE PRESSURE	CATEGORY OF EFFECT	EXPOSURE PRESSURE	MACROPHYTE	PHYTOBENTHOS	MACRO-INVERTEBRATES	FISH	MORPHOLOGY	HYDROLOGY	GENERAL PHYSICO-CHEMICAL	SPECIFIC POLLUTANTS	PRIORITY SUBSTANCES	PRIORITY HAZARDOUS SUBSTANCES
NUTRIENT ENRICHMENT	Primary effect on biology	Change in nutrient concentration in defined water body. Enhanced biomass, changes to other primary producers	X	X				X	Nutrient suite			
ORGANIC ENRICHMENT	Primary effect on biology	Increased organic enrichment; change in biological community structure			X			X	Organic suite			
ANNEX 8 AND ANNEX 10 POLLUTANTS	Primary effects on sediment and water quallty	Increased concentrations of contaminants (water column and sediments)			X			X	General suite	X	X	X
HYDROLOGICAL	Primary effect on biology	Changed water levels from abstraction; altered flow regime impacting biology	X	X	X	X	X	X	General suite			
MORPHOLOGICAL	Primary effect on biology	Riparian and channel modification, Altered sediment characteristics (e.g. size), smothering and damage to river bed	X		X	X	X	X				
ACIDIFICATION	Primary effect on biology	Change in ANC & Ph; change in biological community & toxicity synergies		X	X	X			Acidification suite			

Table 5. Quality elements sensitive to the pressures affecting lakes

SOURCE PRESSURE	CATEGORY OF EFFECT	EXPOSURE PRESSURE	PHYTOPLANKTON	MACROPHYTE	PHYTOBENTHOS	MACRO-INVERTEBRATES	FISH	MORPHOLOGY	HYDROLOGY	GENERAL PHYSICO-CHEMICAL	SPECIFIC POLLUTANTS	PRIORITY SUBSTANCES	PRIORITY HAZARDOUS SUBSTANCES
NUTRIENT (& ORGANIC) ENRICHMENT	Primary effect on biology	Change in nutrient concentration in defined water body. Enhanced biomass, changes to other primary producers	X	X	X				X	Nutrient suite			
ANNEX 8 AND ANNEX 10 POLLUTANTS	Primary effects on sediment and water quality	Increased concentrations of contaminants (water column and sediments)				X			X	General suite	X	X	X
HYDROLOGICAL	Primary effect on biology	Changed water levels from abstraction; altered flow regimes impacting biology; concentration of nutrients	X	X		X		X	X				
MORPHOLOGICAL	Primary effect on biology	Shoreline and channel modification, altered sediment characteristics (e.g. size), smothering and damage to river bed		X		X		X	X				
ACIDIFICATION	Primary effect on biology	Change in ANC & pH; change in biological community & toxicity synergies			X	X	X		X	Acidification suite			

Table 6. Quality elements sensitive to the pressures affecting transitional and coastal waters

SOURCE PRESSURE	CATEGORY OF EFFECT	EXPOSURE PRESSURE	PHYTOPLANKTON	MACROALGAE	ANGIOSPERMS	BENTHIC INVERTEBRATES	FISH (Transitional Only)	MORPHOOLOGY	HYDROLOGY	GENERAL PHYSICO-CHEMICAL	SPECIFIC POLLUTANTS	PRIORITY SUBSTANCES	PRIORITY HAZARDOUS SUBSTANCES
NUTRIENT ENRICHMENT	Primary effect on water quality	Change in nutrient concentration in defined water body [DIN], [DIP], N:P, N:Si (current and changes over time)	X	X	X					X			
ORGANIC ENRICHMENT	Primary effect on sediment quality	Increased deposition of organic carbon to seabed				X				X			
	Primary effect on water quality	Increased organic enrichment of water column				X				X			
	Secondary effects on water quality	Reduced oxygen availability (reduced dissolved oxygen in water column, and anaerobic sediments)				X	X			X			
POINT HAZARDOUS SUBSTANCES	Primary effect on sediment and water qualty	Increased concentrations of contaminants (water column and sediments)				X	X				X	X	X
INDUSTRIAL ABSTRACTION	Primary effect on biology	Entrainment of fish and invertebrates					X		X				
	Primary effect on water quality	Altered temperature regime of water column (mean seasonal temp, spatial temp pattern, degrees above surrounding water)					X			X			
	Secondary effects on water quality	Reduced oxygen availability (reduced dissolved oxygen in water column, and anaerobic sediments)					X			X			
CATCHMENT ABSTRACTION	Primary effect on hydrology	Altered salinity regime of estuary (salinity of water body)				X	X		X	X			
	Primary effect on hydrology	Reduced flushing leading to reduced oxygen availability				X	X			X			
MORPHOLOGICAL (INCLUDING: SHORELINE REINFORCEMENT, BARRAGES, WEIRS, SLUICES, LAND RECLAIMATION, DREDGING AND DREDGED MATERIAL DISPOSAL, AGGREGATE EXTRACTION)	Primary effect on morphology	Removal of intertidal or subtidal area (area lost), Increased availability of hard substrata (area added), altered sediment characteristics (e.g. size), smothering and damage to seabed structures (e.g. increased sedimentation)		X	X	X	X	X	X	X			
	Secondary effects on hydrology	Barrier to movement of mobile fauna, reduced flushing, altered tidal range, decreased / increased saline intrusion	X	X	X	X	X		X	X			
	Secondary effects on water quality	Reduced oxygen availability (reduced dissolved oxygen in water column, and anaerobic sediments), increased turbidity, change in nutrient concentrations	X	X	X	X	X			X			
COMMERCIAL FISHING	Primary effect on morpholgy	Altered distribution of sediment & seabed topography			X	X		X					
	Primary effect on biology	Damage to sensitive habitats			X	X		X					
	Primary effect on biology	Removal of target and non-target species				X	X						
AQUACULTURE	Primary effect on sediment quality	Increased deposition of organic carbon to seabed				X				X			
	Primary effect on water quality	Increased organic enrichment of water column	X							X			
	Primary effect on sediment and water quality	Increased concentrations of contaminants (water column and sediments)				X	X				X	X	X
	Secondary effects on water quality	Reduced oxygen availability (reduced dissolved oxygen and anaerobic sediments)				X				X			
	Secondary effects on water quality	Reduced carbon availability (shellfish farming)	X			X	X						
ALIEN SPECIES	Primary effect on biology	Invasion and / or replacement of native fauna	?X	?X	?X	?X	?X						
	Secondary effects on morphology	Altered sediment / substrata characteristics (specific species)			X	X		X	X				

Pressure from alien species will be present in some water bodies; it is assumed that the monitoring of this pressure will be incorporated in the other classification tools (e.g. signal crayfish will be assessed as part of the macro-invertebrate techniques).

2.8. Investigative

The WFD Annex V.1.3.3 states, *'Investigative monitoring shall be carried out:*

- *Where the reason for any exceedances is unknown*
- *Where surveillance monitoring indicates that the objectives set out in Article 4 for a body of water are not likely to be achieved and operational monitoring has not already been established: in order to ascertain the causes of a water body or water bodies failing to achieve the environmental objectives, or*
- *To ascertain the magnitude and impacts of accidental pollution and,*
- *Shall inform the establishment of a programme of measures for the achievement of the environmental objectives and specific measures necessary to remedy the effects of accidental pollution'.*

Currently, investigative monitoring is carried out by the environment agencies as part of their duty to protect the environment and is focused on water quality impacts. Monitoring is undertaken to: (a) ascertain the magnitude and impacts of pollution incidents; and (b) identify the reason for any water quality impacts, the causes of which are unknown.

For river basin management, investigative monitoring will similarly be undertaken as part of special projects to answer specific questions e.g. where an EQS has been exceeded or good status not achieved or status has deteriorated without good scientific understanding of the reasons for these failures. Investigative monitoring will be targeted at:

- Pollution incidents – where the magnitude of impact and source of pollution (pressure) will be determined.
- Unexplained failures in status or related environmental objectives – where the magnitude of the impact is known, but the source of pressure is not well understood, therefore limiting measures that can be taken to reduce impact.

Investigative monitoring is required when status has been confirmed as being worse than good or a water body has deteriorated in status, where it's unclear as to the cause of the failure or deterioration. This will include the investigation of the effects of accidental pollution and any impacts from groundwater inputs. Investigative monitoring will be required to inform and justify relevant programmes of measures to remedy the effects of accidental pollution.

Investigative monitoring is not used to classify directly, but to help define the operational network. If the investigative monitoring produces data suitable for applying the classification tools, then clearly a classification could be carried out.

2.9. Guidance

i. Use a toolbox of appropriate methods to understand why status is less than good. The tool box would include existing methods, bio-assay, ecotox, passive pollutant absorption techniques, immuno-assay, bio-markers, pressure assessment, flood event monitoring, remote sensing techniques, and novel techniques developed through R&D.

ii. Data from investigative monitoring may be needed for consent setting or catchment management models or for designing a programme of measures.

iii. Investigation projects may include gathering data on flow regime, morphology, land use and screening for previously undetected or novel polluting substances.

3. Protected areas, site selection, grouping and other issues

3.1. Protected Areas

Protected areas include those areas identified in Annex IV of the Directive. In short, these include: drinking water protected areas, water dependent Natura 2000 sites, Bathing Waters, Shellfish Waters, and waters identified under Freshwater Fish Directive; or as Eutrophic and Nitrate Sensitive Areas, Polluted Waters (Eutrophic) and Nitrate Vulnerable Zones'.

Monitoring information will be required to support the achievement of the drinking water protection objectives for those surface water bodies identified as Drinking Water Protected Areas[4]. The objectives[5] for Drinking Water Protected Areas are to:

- Meet the requirements of Directive 98/83/EC (the 'Drinking Water Directive'); and
- Aim to avoid deterioration in the quality of the water abstracted, or intended to be abstracted, for human consumption in order to reduce the level of purification treatment required in the production of drinking water[6]

With respect to the first objective, the monitoring required by the Drinking Water Directive is specified by its Article 7 and Annex II. Such monitoring is additional to that needed for monitoring water status and will continue to be delivered by the monitoring programmes that have been established to implement the Drinking Water Directive.
The second objective for Drinking Water Protected Areas requires the protection of the quality of the water that is to be abstracted from the water body. To support the achievement of this objective, monitoring information is needed to:

- Establish the concentrations of the parameters of concern in the water to be abstracted where a risk to the quality of that water has been identified;
- Assess the effectiveness of the measures implemented to protect the quality of water to be abstracted where a risk to its quality has been identified; and
- Identify the presence of any long-term upward trends in the concentrations of parameters that may adversely affect the quality of the water to be abstracted, in particular, whether this would cause a change in treatment level at the abstraction point in order to meet drinking water standards in the supplied water.

The operational monitoring required for water bodies at risk of failing to achieve good status and the surveillance monitoring required for assessing long-term trends will contribute to these information needs.

Additional monitoring will be required for Drinking Water Protected Areas identified as being at risk where:

[4] Section 1.3.5 of Annex V to the WFD
[5] Paragraph 2 and 3 of Article 7 of the WFD
[6] UKTAG will provide further guidance on the requirements of this objective

- The locations of the monitoring points for monitoring surface water status are not suitable for establishing, or adequately monitoring the effectiveness of the measures taken to protect, the quality of the water to be abstracted from the body;

- The frequency of monitoring needed for monitoring status[7] is less than the frequency required for drinking water protected area monitoring; or

- The risk to the quality of water to be abstracted results from a parameter (i) not relevant to status assessment (e.g. bacteriological parameters); or (ii) for which a more stringent standard is necessary to protect the drinking water source than to protect water body status. In such cases, the water body may not be at risk of failing to achieve good status but be at risk of failing to achieve its drinking water protection objectives.

If additional monitoring is required for a surface water drinking water protected area at risk and that area provides more than 100 m^3 a day as an average, the monitoring frequencies applied must not be lower than those set out in Table 7.

Table 7: Minimum monitoring frequencies for surface water Drinking Water Protected Areas providing more than 100 m^3 per day and in which there is a risk to the quality of the water to be abstracted

Community served	Minimum Frequency
< 10,000	4 samples per year
10,000 – 30,000	8 samples per year
> 30,000	12 samples per year

The additional monitoring information that may be needed for drinking water protected areas may be obtained by monitoring water bodies or groups of water bodies, as appropriate (see Section 3.6. on grouping).

The WFD monitoring of requirements for water dependent Natura 2000 protected areas are described in Annex V (1.3.5), where *'monitoring shall continue until the areas satisfy the water-related requirements of the legislation under which they are designated and meet their objectives under Article 4'*.

Article 4 (2) states that: '*where more than one of the objectives under (Article 4) para 1 relates to a given body of water, the most stringent shall apply'.* For species and habitat protected areas, agreement will be required between the conservation agencies and the environment agencies on the parameters and values that constitute the most stringent water related standards or objectives for these areas.

Where a protected area forms a small part of a water body, the most stringent standards and objectives should apply to as much of the surrounding water body or bodies, or to as many of the upstream water bodies, as is required to achieve compliance within the protected area boundary. Where the whole water body is part of a larger Protected Area, all the standards and objectives for that water body shall be the most stringent as described above.

[7] The WFD sets out guideline minimum monitoring frequencies for operational monitoring of surface water status. These are 12 samples per year for any priority substance at risk of exceeding its EQS and 4 samples per year for any other pollutant at risk of exceeding its EQS. Member States may use lower frequencies where these would be justified on the basis of technical knowledge and expert judgement.

Monitoring at Natura 2000 sites at risk of failing either Article 4(1c) or WFD good status, must be carried out within the operational monitoring programme (Annex V, 1.3.5.). It is expected that protected area specific monitoring plans will be drawn up between the operational arms of each 'competent authorities' (for habitats and birds Directive and the WFD), with agreements formed to optimise data gathering and sharing.

Existing EC monitoring programmes (e.g. bathing waters, shellfish waters, dangerous substances, freshwater fish Directives) must be maintained until such time as these directives are repealed (Table 1). Following repeal, risk based monitoring under the WFD will provide the information necessary to inform management of these protected areas.

3.2. Guidance

i. The conservation bodies will assess compliance with the conservation objectives[8].

ii. As a general principle, monitoring effort should be divided up according to the skills and competencies of the partner bodies. Arrangements should be put in place so that data collection by the partners is not duplicated and that data are shared between conservation bodies and environment agencies in a timely fashion.

iii. Partnership agreements should be set up between the relevant organisations for monitoring at Natura 2000 sites, the presumption being that monitoring sites for assessing the water related parameters will be located to serve the needs of habitat and species protected area.

It is expected that more detailed guidance will be produced within the administrative regions of the UKTAG before monitoring programs under these requirements are implemented.

3.3. Groundwater

For good status to be achieved for groundwater, the environmental objectives for any associated surface water (including groundwater dependent terrestrial ecosystems) must not be compromised as a result of anthropogenic alterations in groundwater level or pollutant concentrations. Therefore monitoring programmes for both surface water and groundwater should be designed and operated in an integrated way to enable an effective exchange of information and adequate confidence in status assessment for groundwater.

It is important therefore that, when designing monitoring networks, the requirements of each water category are taken into account. For example the ecology, chemistry and flow within the surface water systems (including groundwater dependant terrestrial ecosystems, lakes and rivers) may be significantly influenced by groundwater inflow (and vice versa). Where appropriately located, the data from each of the respective monitoring networks should be used to inform sampling programmes and contribute to characterisation and classification of the water bodies.

[8] Birds Directive 79/409/EEC and Habitats Directive 92/43/EEC.

In some cases, it may be possible to use surface water monitoring points to provide relevant information on groundwater quality and quantity. For example in the upper reaches of rivers where groundwater baseflow is significant and surface water quality/quantity is dominated by groundwater quality and flow. In these situations, surface water network design and operation should take into account this inter-relationship.

Chapter 2 of this document covers all the specific monitoring requirements for groundwater status, trend assessment and relevant Protected Area monitoring.

3.4. Small Water bodies and small waters not identified as water bodies

The principles laid down in TAG paper Task 3a. 'Identification of small surface water bodies' should be used to guide decisions on monitoring. Small water bodies have been identified according to their significance in the context of the Directive's purpose and provisions (e.g. ecological importance; importance to the objectives of a protected area, significant adverse impacts on other surface waters in the river basin district). These water bodies have been risk assessed and therefore will attract a WFD classification. In many cases, these small water bodies will be collections of similar water bodies within a protected area. Therefore a representative water body should be chosen in order to classify the collection of water bodies within the protected area.

There are also 'small waters' which have not been identified as water bodies and not risk assessed which are nevertheless considered to comply with the 'importance' criteria mentioned above. These waters should be identified and considered for delineation during further characterisation.

Guidance

- Small waters that have not been identified as water bodies may be subject to investigative monitoring where they influence the status of a delineated water body or there are other clear reasons for assessment.

- Small waters delineated within Natura 2000 protected areas will require classification against the appropriate objectives. These may be classified by sampling a representative water body within the protected area. It should be noted that these waters may be of good WFD ecological status, but the protected area as a whole may not be achieving favourable condition and thus will require a programme of measures due to its failure to meet conservation objectives.

- If an agency wished to monitor a small water, it must either: qualify as suitable for “identification as a separate water body” under section 5.1 of UKTAG guidance 3a, and be monitored under the appropriate operational or surveillance regime or: be monitored under the investigative monitoring regime.

3.5. Potential heavily modified and artificial water bodies

One of the tests prior to designation is whether the water body is achieving good ecological status. When designation is confirmed, maximum and good ecological potential must be set as referred to in Article 4. It is not expected that every potential heavily modified or artificial water body will require monitoring for all biological elements in order to determine status prior to designation. In most cases

it will be readily apparent that a water body cannot achieve 'good' status given its legitimate use and reasonable mitigation measures.

The element to confirm designation as a HMWB/AWB will be that most sensitive to the modification or use which gives rise to the HMWB/AWB.

Monitoring of HMWB/AWB follows the same principles for surveillance and operational monitoring as for normal water bodies. Maximum and good ecological potential will be set for each element according to how well that element can perform given the modification and application of reasonable mitigation. The operational programme for HMWB/AWB should choose the element that is indicative of the mitigation measures taken.

3.6. Generic site selection, scale and frequency issues

i. Grouping

Water bodies can be grouped for monitoring and assessment purposes. This is to ensure the most efficient and effective use of monitoring resources. Water bodies should be grouped wherever monitoring of a selection of the water bodies will provide the information needed to make the necessary management decisions about all the bodies in the group.

Generic scenarios illustrating the circumstances in which the grouping of water bodies may be appropriate are outlined in Table 8. Specific examples may include representative monitoring for standing waters located in areas of similar geology and subject to similar levels of acid deposition; and sub-sampling of river flows in a group of rivers in order to validate the reliability of modelled estimates of flows for all the bodies in the group.

Individual water bodies, many of which are very large, will often be subject to several pressures of the same type at different locations within the body. In such cases, representative monitoring sites can be selected within the water body for monitoring and assessment purposes. The selection of these sites should be based on similar technical criteria to those used to decide on the appropriateness of grouping water bodies.

ii. Within any water body selected for monitoring, appropriate monitoring site(s) for each biological and physico-chemical element must be chosen. It is unlikely that these can always be co-located but they should all be subject to the same magnitude and mix of pressures.

Table 8: Example of criteria for grouping bodies (or selecting representative monitoring sites within bodies) for monitoring purposes

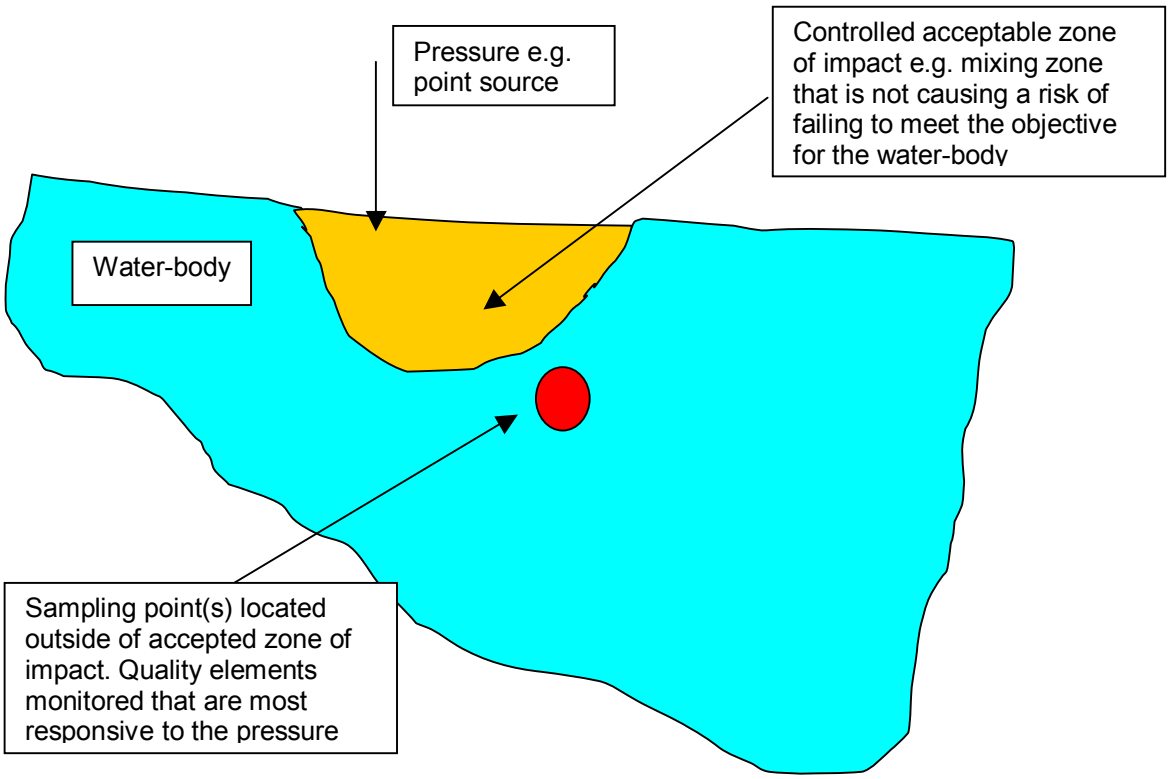
Grouping scenarios	Surveillance		Operational
	Validation that the water bodies are at risk	Validation that the bodies are not at risk	Classification of bodies identified as at risk
➢ ***Comparable sensitivity to the pressure*** ➢ ***Comparable magnitude of the pressure***	Random representative sub-sample	Random representative sub-sample	Random representative sub-sample
➢ ***Different sensitivity to the pressure*** ➢ ***Comparable magnitude of the pressure***	Sample of least sensitive	Sample of most sensitive	Group if a sub-sample is sufficient to validate robustness of modelled estimates of impacts
➢ ***Comparable sensitivity to the pressure*** ➢ ***Different magnitude of the pressure***	Sample of those subject to least pressure	Sample of those subject to the greatest pressure	Group if a sub-sample is sufficient to validate robustness of modelled estimates of impacts
➢ ***Different sensitivity to the pressure*** ➢ ***Different magnitude of the pressure***	Group if a sub-sample is sufficient to validate robustness of the risk assessment model	Group if a sub-sample is sufficient to validate robustness of the risk assessment model	Group if a sub-sample is sufficient to validate robustness of modelled estimates of impacts

Note: 'Sensitivity' takes account of (i) the natural characteristics of the ecosystems that affect their susceptibility to the pressure; and (ii) the effects on susceptibility of other pressures to which the ecosystems are subject.

iii. Within any water body there will be a mix of habitats. It will be impractical to monitor all habitats; therefore, select the dominant habitat supporting the quality element most sensitive to the pressure. For example, a transitional water may be primarily characterized by mud flats but also possess rocky shore areas and a few sand bars supporting angiosperms. If morphological pressure is dominant then according to Table 6 all of the biological elements are sensitive to this pressure. Then, because mudflats are the dominant habitat they should be chosen for monitoring provided they would show a response to the pressure(s). In some cases more than one habitat (or a minor habitat) may have to be monitored if there are multiple pressures acting on the water body which will trigger a response in more than one quality element.

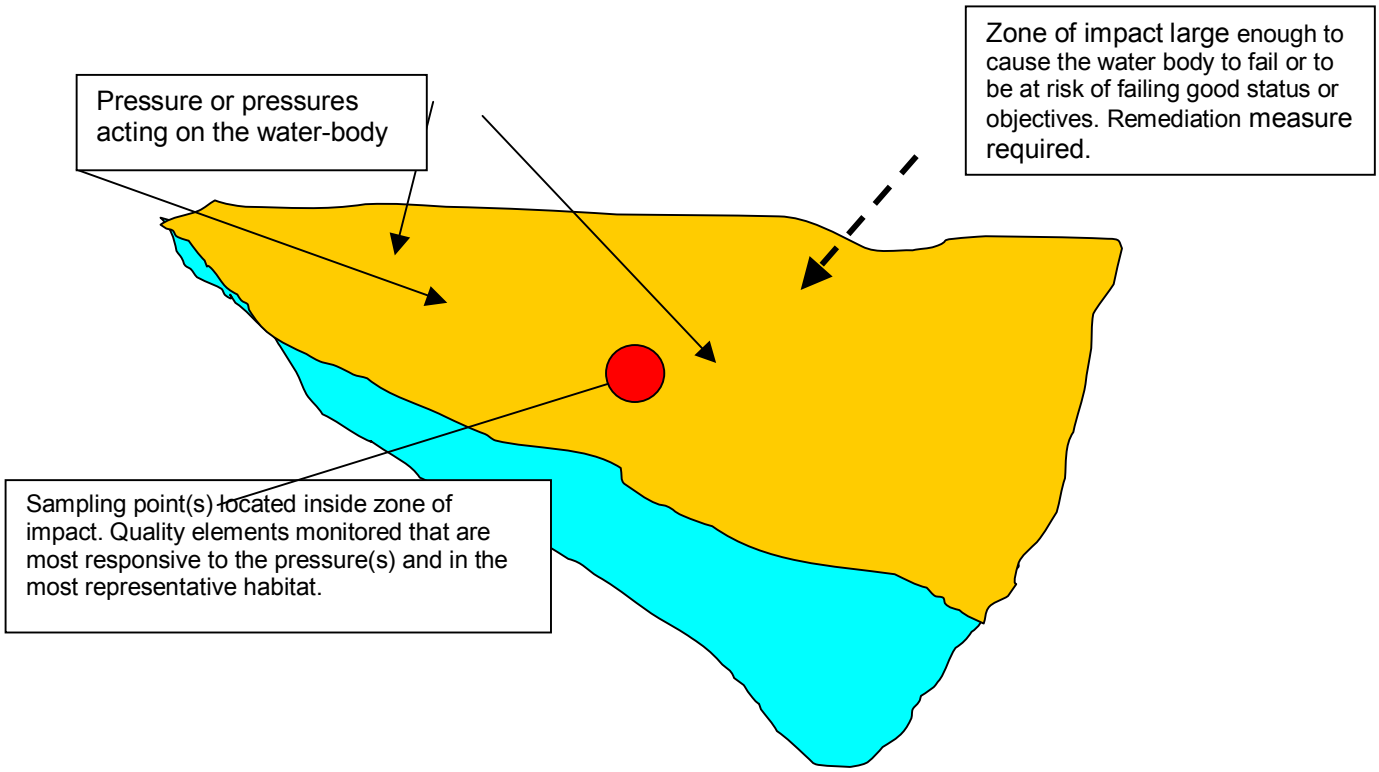
iv. For water bodies that contain small areas affected by point source or other pressures, apply the mixing zone principle (as outlined in the World Health Organisation publication *Water Quality Monitoring* 1996) and choose sites outside, but not remote from, the mixing zone that will provide a status assessment representative of the water body as a whole. It would not be reasonable to downgrade a large water body because it contained a small area of impact that is already under regulatory control. Figure 3 below shows an example of this scenario:

Figure 3. Water body status monitoring outside a mixing zone



The scale and magnitude of the pressure that needs to be controlled should dictate the location and distribution of sampling sites. In some cases a water body will be subject to pressure(s) that cause either a failure of good status or protected area objectives or cause a significant risk that they will not be achieved. In this case sampling point(s) should be located within the known or predicted zone of impact to monitor either that the status objectives are being achieved and the pressures are under control, or that over the longer term remediation measures are having the planned effect. Figure 4 below shows an example of this scenario:

Figure 4. Water body status monitoring within zone of impact



There will be other different scenarios, of course, such as water bodies with multiple controlled pressures that may require several sampling points to ensure that they remain in control and that no deterioration occurs to the status of the water body. Sampling locations may be required to monitor different quality elements in response to individual pressures.

v. The WFD sampling frequencies (Annex V, 1.3.3.) are minimum recommendations, but are generally recognised (CIS working group 2.7) as being too low, particularly for assessing long term trends and EQS compliance. The frequency of sampling for operational monitoring will be dictated by the capability of the classification tool for producing status class within acceptable probability of class. The IEM (Improved Environmental Monitoring) software may be a useful tool in deciding frequency in relation to variability of the quality element and the desired confidence of class or certainty of compliance with an EQS.

vi. In order to avoid uneven workloads, sampling may be based on rolling programmes.

3.7. Methods

Guidance

i. The methodologies for sampling quality elements must be agreed and standardised within the UK. Some methods will be generated during classification tool building. Ideally these should eventually be approved through BSI and CEN. In some cases the level of detail set out in BSI or CEN standards may not be sufficiently developed for operational purposes. Any further interpretation of BSI / CEN standards must be fully justified and clearly set out in operational guidance manuals with appropriate referencing of BSI / CEN standards. Other methods are

already CEN approved and referred to in the WFD and some have been published more recently or are under development.

ii. Methods for chemical analysis are being agreed through the EU Analytical Methods Procedures group. The principle has been established by negotiation at the EU Analytical Methods Procedures Group that the most sensitive and modern analytical methods may be used, even though these may not yet have been adopted by BSI/CEN.

iii. Member State organisations should use the methods agreed through the Analytical Methods Procedures Group. However, a protocol for ensuring analytical quality control across these organisations is required.

4. Concluding Remarks

Surface water environment monitoring networks across the UK have to be substantially changed and enhanced to meet WFD requirements.

This guidance is designed to inform the required changes, which will give new monitoring coverage of the impacts of hitherto much less investigated pressures, particularly in areas where these pressures have not previously been subject to regulation. It should also lead to better integration of monitoring work undertaken within and between the official environment agencies and conservation agencies.

As indicated in the opening section, it is recognised that this guidance will not satisfactorily answer all the questions that will arise at an operational level in respect of previously unmonitored pressures. It is anticipated that the guidance will be informed by the early results of the monitoring strategies it outlines, that these new data will be used both to further refine the initially established networks and also to further develop this guidance.

Chapter 2 - Guidance on Monitoring Groundwater

1. Purpose and scope

1.1. This chapter 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. 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

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.

3.1.1. 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 identify 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;

3.1.2. 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 5 outlines the principles and relationship of the model to the monitoring programme.

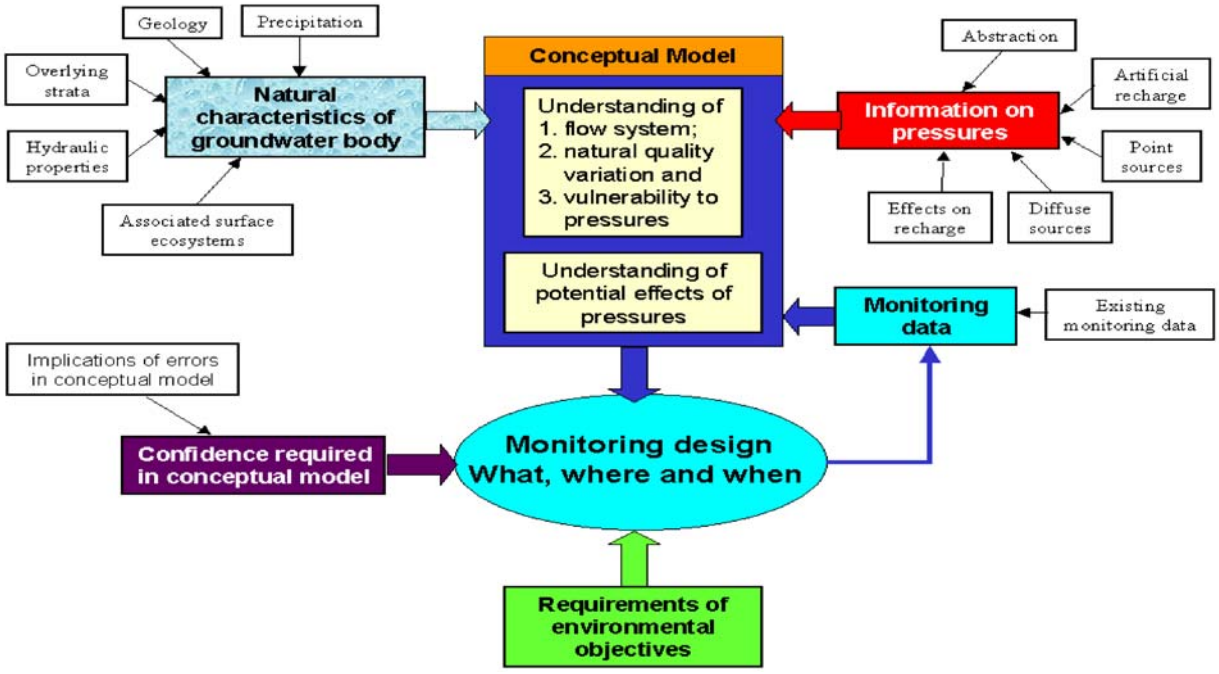
3.1.3. The design and operation of monitoring programmes should be informed by:

- 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;
- 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.

3.1.4. 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 5. 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



3.1.5. 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.

3.1.6. 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. This conceptual understanding is vital for the effective operation of the monitoring programme.

3.1.7. 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 [9](ZOC)
- Abstraction impacts
- Approximate size of ZOC;
- Land use and pressures within ZOC.

3.1.8. 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 2. 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. Integrated Monitoring

3.2.1. 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 Groundwater Dependant Terrestrial Ecosystems (GWDTES).

3.2.2. 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 GWDTES (groundwater body dependant terrestrial wetlands).

3.2.3. 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.

3.3. Grouping of Groundwater Bodies

3.3.1. 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.

3.3.2. In grouping groundwater bodies, the monitoring programmes must be designed and operated to ensure that the environmental and monitoring objectives for each

[9] 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.

of the component bodies making up the group can be achieved with adequate confidence.

3.3.3. 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.

3.3.4. 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 must be adjacent to each other except in exceptional circumstances (e.g. islands);
- Each component body must have at least one monitoring point to determine the relationship between the bodies;

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.

3.4. 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 assist in characterisation, to determine the quantitative "status of groundwater bodies, and to support the design and evaluation of the programme 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. 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

4.1.4. 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.

4.2. 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 will 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. Article 4 objectives. Firstly, where possible, groundwater levels and flows across a groundwater body must be assessed. These may be related to the water balance assessment for the body as a whole. 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 needed. 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", the monitoring can be minimised. Indeed, monitoring need not be located in each body within a group, provided that the groups are hydrogeologically comparable (Chapter 2, Section 5.).

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 the hydrogeological conditions that relate to the receptors identified as being "at risk" and to their perceived importance.

4.4. Frequency of Monitoring

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

4.4.2. In general, daily monitoring would be preferred (particularly when measuring flows) while monthly monitoring would generally 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.
It is probable that the detailed interpretation of these requirements will be adjusted by the proposed Groundwater Daughter Directive, but this is unlikely to be agreed before the end of 2005.

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 16 and 17.

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 groups 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. Selection of Representative Surveillance Monitoring Sites
The selection process will be based on 3 main factors:

- Body grouping (Chapter 2, Section 3.3), characterisation and conceptual model(s) including an assessment of aquifer, pathway susceptibility and receptor sensitivity;
- Assessment of risk and the level of confidence in the assessment; including the distribution of key pressures and;
- Practical considerations relating to suitability of individual sampling points. Sites need to be easily accessed, secure and be able to provide long-term access agreements. Further information is provided in Appendix 1.

5.2.5. Site selection factors must be assessed on site by site basis, but key principles are as follows:

- *Suitable types of site:* Selection should be based on the conceptual model of the groundwater bodies (or group) and a review of existing and candidate monitoring sites. 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.

5.2.6. Monitoring frequency selection will generally be based on the characteristics of the aquifer and the conceptual model. Table 9 provides suggested surveillance monitoring frequencies for different aquifer types.

Table 9. 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. Operational programmes are required only in bodies "at risk" of failing to meet WFD objectives. For groundwater bodies this includes:

- 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. 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.

5.3.3. The selection process will be based on 3 main factors: Body grouping (Chapter 2, Section 3.3), characterisation and conceptual model(s) including an assessment of aquifer, pathway susceptibility and receptor sensitivity.

- Assessment of risk and the level of confidence in the assessment; including the distribution of key pressures identified in the characterisation process and which may cause the body to be classified at poor status.

Practical considerations relating to suitability of individual sampling points. Sites need to be easily accessed, secure and be able to provide long-term access agreements. Further information is given in Appendix 1.

5.3.4. Where risk issues relate to specific receptors 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, determine contaminant fate and transport between the pressure and the receptor and assess the effectiveness of Programmes of Measures.

5.3.5. 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.

5.3.6. Where pressures and risk issues relate to the water body 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.

5.3.7. 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).

5.3.8. 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 10 provides suggested minimum frequencies for different aquifer types.

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 10 provides suggested minimum frequencies for different aquifer types.

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.

Table 10. 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

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 Chapter 2, Section 11) 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[10]) to confirm the risk assessment. 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

[10] 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;

- 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.

minimum 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 relevant to the quality of abstracted water. 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 S7.5 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.

Appendix 1. Overlapping drivers for monitoring concurrent with the Water Framework Directive

Drivers	Start	End	Data Collected
EU Directives			
Urban Waste Water Treatment Directive (91/271/EEC)	1991	Ongoing	Chemistry, microbiology, biology
Bathing Waters Directive (76/160/EEC)	1975	Ongoing	Chemistry microbiology, water resources for abnormal weather
Dangerous Substances Directive (76/464/EEC)	1976	2013	Chemistry
Dangerous Substances (List 1) Daughter Directives	1976	tbc	Chemistry
Freshwater Fish Directive (78/659/EEC)	1978	2013	Chemistry, microbiology, biology
Groundwater Directive (80/68/EEC)	1979	2013	Chemistry
Nitrates Directive (91/676/EEC)	1991	Ongoing	Chemistry, biology
Shellfish Waters Directive (79/440/EEC)	1979	2013	Chemistry, microbiology
Surface Waters for Drinking Directive (75/440/EEC)	1975	2007	Chemistry, microbiology
Drinking Water Directive (98/;83/EEC)	1998	Ongoing	Chemistry, microbiology
Exchange of Information Directive (77/795/EEC)	1977	Ongoing	Report chemistry and biology
Environmental Impact Assessment (85/337/EEC)	1985	Ongoing	May inform investigative monitoring
Strategic Environmental Assessment (2001/42/EEC)	2001	Ongoing	May inform investigative monitoring
Habitats Directive (92/43/EEC)	1992	Ongoing	Chemistry and biology as appropriate
Birds Directive (79/409/EEC)	1979	Ongoing	Chemistry and biology as appropriate
Integrated Pollution Prevention and Control (IPPC) (96/61/EEC)	1999	Ongoing	Chemistry
Other legislation and drivers			
Control of Pollution Act (COPA) 1974	1974	2005	Chemistry, water resources for Q95 flows, Microbiology
Pollution Prevention and Control (PPC) Act 1999	1999	tbc	Chemistry, water resources for ground water level
Water Resources Act, 1991 (E+W)	1991	ongoing	Chemistry, water resources
Countryside and Rights of Way Act Nature Conservation Act [Scotland]	2000 2004	tbc	tbc – Biodiversity information
Electricity Act 1989	1989	Ongoing	Water resources
Water Fittings (Water Supply) Regulations 1999 [England and Wales] Water Act [Scotland] 1980	1999 1980	tbc	Water resources
Radioactive Substances Act (RSA)	1993	Ongoing	Tbc
Water Environment and Water Services Act (WEWS)	2006	Ongoing	Chemistry, water resources, biology, habitat
WEWS regulations	2005	Ongoing	Chemistry, water resources, biology, habitat

Drivers	Start	End	Data Collected
Environment Act 1995	1995	tbc	All
OSPAR – including North Sea Conventions	1998		Chemistry, water resources for loadings, discharges
Harmonised Monitoring Scheme			Chemistry, water resources
National Marine Monitoring Plans			Biology, chemistry
Acid Waters			Biology, chemistry
Environmental Change Network (ECN)			Chemistry, biology, water resources
Natural Heritage (Scotland) Act	1991		Water resources

Appendix 2. 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 3. Initial Guidance on the Selection of Determinand Suites

A2.1 Surveillance monitoring

The following core determinands are mandatory:

- oxygen content (DO);
- pH;
- nitrate;
- conductivity (EC);
- 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 4. 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