# UK Technical Advisory Group
# on the Water Framework Directive
## Groundwater Trend Assessment

**This Guidance Paper is a <u>working draft</u> defined by the UKTAG. It documents the principles to be adopted by agencies responsible for implementing the Water Framework Directive (WFD) and the Groundwater Directive in the UK. The methods will evolve as they are tested and further clarification on the requirements for trend assessment is provided by the European Commission through its Common Implementation Strategy Guidance. This draft will be amended accordingly.**

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**Contents**



## 1 Purpose

1.1 This document provides guidance on the requirements and methods for identifying and assessing statistically and environmentally significant trends in pollutant concentrations and natural parameters in groundwater.

1.2 The identification and characterisation of trends is a specific requirement of the Water Framework Directive (WFD) and the Groundwater Directive (GWD). It is also needed as part of groundwater body chemical status assessment.

## 2 Background and WFD/GWD requirements

2.1 The WFD and GWD requires us to identify and assess significant and sustained upward trends in concentrations of pollutants in Groundwater Bodies (GWBs) identified as being at risk (Article 5(1)–GWD). The identification of upward trends has to be made in sufficient time to allow programmes of measures to be implemented to reduce pollution, avoid deterioration of groundwater quality or avoid failure of any other relevant WFD objective, e.g. good status.

2.2 The GWD requires that the results from the trend assessments should be reported in the River Basin Management Plan (RBMP) i.e. once every six years. The results

from trend assessments undertaken to verify that contamination plumes are not expanding should also be included in the RBMP.

2.3 A significant trend is one that can be demonstrated statistically and is also environmentally significant. On the basis of GWD Article 2 (3) and Article 5 (2), and WFD Annex V (2.4.4) and Annex V (2.4.5), a significant trend at an individual monitoring point is one that:

- can be demonstrated with statistical confidence using a recognised statistical method; and
- presents a significant risk of harm to the quality of aquatic or terrestrial ecosystems, to human health, or to actual or potential legitimate uses of the water environment.

2.4 The results of trend assessment at individual monitoring points should be used to identify whether the groundwater body is subject to a significant and sustained upward trend in pollutant concentrations (see Section 6).

2.5 The trend assessment method(s) adopted should also be suitable for verifying, where necessary, that plumes of pollutants from contaminated sites do not expand to such an extent that they put a groundwater body at poor status. Our interpretation of the GWD (Article 5 (5)) and (Article 5 (1)) is that any assessment of trends carried out on specific pollutant plumes does not have a specific WFD reporting requirement, unless:

- the plume has been identified during risk characterisation as presenting a risk of failing an environmental objective of the WFD in the future and is therefore associated with WFD operational monitoring points[1]; or
- trends indicate that the plume is expanding and is impacting on a significant portion of the groundwater body. A "significant proportion" is defined in the EC CIS Guidance Document No. 18 (on Groundwater Status and Trend Assessments) as at least 20% of the minimum size of a groundwater body.

2.6 Expanding plumes are defined in the EC CIS Guidance Document No. 18 as plumes where the overall mass of contaminants within the plume is increasing, i.e. there is an ongoing source term. The assessment of plumes should focus on the relevant parameters within the plume.

2.7 The methods adopted for trend assessment must be reported in the RBMP and in particular how trends at individual monitoring points are being used to indicate trends across a groundwater body.

2.8 Where environmentally and statistically significant upward trends have been identified these must be reversed. This is to be achieved by the Programmes of Measures. The starting point for trend reversal must be stated in the RBMP. It should be expressed as a percentage of the level (or concentration) of the relevant

[1] Formal reporting from investigative monitoring, e.g. monitoring of plumes at a contaminated land site, is not required under the WFD. Reporting is only required if monitoring sites are representative of the groundwater body, i.e. operational or surveillance monitoring. Therefore, monitoring of trends at contaminated land sites only require formal reporting if the plume presents a risk of failing an environmental objective of the WFD and are representative of the groundwater body, i.e. the monitoring sites may then be included in the operational or surveillance monitoring networks.

groundwater quality standard or threshold value. The starting point should be based on the significance of the trend and the environmental risk associated with it. By default the starting point is 75% of a standard or threshold value but an earlier or later starting point can be chosen to meet environmental objectives cost-effectively.

2.9 In addition to the specified WFD/GWD requirements, trend assessment is needed to support two of the tests established for assessing good chemical status for groundwater bodies. These tests are the Saline Intrusion test and the Drinking Water Protected Area (DWPA) test (see UKTAG Groundwater Task Team paper 11b(i)).

## 3 Monitoring and information requirements for trend assessment

3.1 Monitoring networks need to be designed to allow long term trends to be detected (Annex V(2.4.1) – WFD) in both natural parameters and pollutants. UKTAG guidance on monitoring sets out the criteria for establishing monitoring programmes that include the requirements for trend assessment (UKTAG Groundwater Monitoring Guidance paper 12a).

3.2 Data from both Surveillance Monitoring (SM) and Operational Monitoring (OM) should be used to identify the presence of anthropogenically upward trends and the reversal of such trends (Annex V(2.4.4) - WFD). The data from SM should also be used to assess natural trends in groundwater.

3.3 Monitoring should be sufficient (spatially and temporally) to ensure that trends in pollutants can be distinguished from natural variation with an adequate level of confidence and precision. The assessment should be able to take into account natural physical and chemical temporal characteristics including groundwater flow conditions. The WFD monitoring guidance provides recommendations for minimum frequencies in different types of groundwater body (WFD Common Implementation Strategy Guidance Document No. 15 (2007)).

3.4 It is assumed that during the period for which the analysis of trends is taking place, the procedures adopted for sampling, analysis and data QA have conformed to relevant international quality standards, e.g. ISO 5667 parts 11 and 18, and complied with the requirements of the EC QA/QC Directive[2]. This will ensure that the data represent a continuous record of groundwater chemistry at each site and these data are directly comparable.

3.5 Monitoring networks and sampling frequencies should be sufficient to allow trends to be identified in sufficient time for the effective implementation of programmes of measures to achieve trend reversal. The WFD requires that a minimum frequency for operational monitoring is once per year. However this frequency will often be too low to adequately assess trends with any degree of confidence and so increased frequency will be required in some groundwater bodies.

3.6 Short-term temporal variability in pollutant (and natural) concentrations within the groundwater body should also be taken into account when identifying sustained trends. This may require additional data to be considered in addition to groundwater chemistry. For example, changes in groundwater level, recharge and flow conditions. Annex V (2.4.4) – WFD, indicates that the base year for trend assessment corresponds to the year(s) when baseline levels were measured. The

[2] EC Directive 2009/90/EC, laying down, pursuant to Directive 2000/60/EC of the European Parliament and of the Council, technical specifications for chemical analysis and monitoring of water status.

GWD (Article 2 and Annex IV (3)) require 'baseline levels' to be established by monitoring in 2007 and 2008, or as soon as possible thereafter for newly detected substances (also see Figure 14 of CIS Guidance Document No.18).

## 4 Trend assessment at individual points

4.1 Trend assessment at individual monitoring points will be carried out to determine one or more of the following:

- Trends (upwards or downwards) in concentrations (or values) of natural parameters resulting from natural processes,
- Upward trends in pollutant concentrations,
- Downward trends in pollutant concentrations following confirmed presence of an upward trend in pollutant concentrations and implementation of programmes of measures to reverse the trend.

4.2 Trend assessment should be carried out on data from individual monitoring sites for individual parameters and for total pesticides. Where individual parameter concentrations (or values) are reported as below the level of quantification (LOQ) care should be taken to ensure that substitute values do not unreasonably influence the trend assessment. The recommended approach in Annex IV (2) (d) of the GWD and in the QA/QC Directive is to replace these values with half of the reported LOQ, except for total pesticides[3]. For example a value reported as <0.1 μg/l would become 0.05 μg/l. However, if a statistically significant trend is found it is suggested that the assessment is rerun firstly substituting the below LOQ value with the LOQ (i.e. <0.1 becomes 0.1) and secondly replacing the below LOQ value with zero. By using this approach we will ensure that we don't identify statistically significant trends that are an artefact of our approach to dealing with values less than the LOQ. It is also recommended that we do not carry out trend assessment on datasets that comprise more than 80% of values below the LOQ.

4.3 When considering natural trends, data should be considered from as long a time period as possible. As a minimum this should be at least 6 years with at least one measurement per year. Where gaps in data exist the length of time series should be increased beyond 6 years.

4.4 For assessment of anthropogenically induced upward trends in pollutant concentrations, monitoring data for a period of between 6 and 10 years leading up to the date at which assessment is being made should be used for identifying trends. A longer period may be used if reliable data are available and where the conceptual model indicates that the changes induced by pressures have been consistent. Where data are inadequate, then no trend assessment should be carried out and an explanation recorded.

4.5 Identification of trend reversal will only be necessary where an environmentally and statistically significant upward pollutant trend has been previously confirmed and measures put in place to reverse the trend. For assessing trend reversal at least 6 years data will be required. In most cases it is expected that a longer period of data will be required to demonstrate the reversal with the required statistical confidence.

[3] In the case of total pesticides the substitution rule, above, cannot be used as this would potentially introduce bias. Therefore when considering total pesticides only those pesticides which have measurable concentrations, i.e. greater than LOQ should be included when calculating totals and trends.

4.6 When identifying trend reversal, the trend should be both an environmentally and statistically significant downward trend. The test of environmental significance will be made by examining whether the trend at the monitoring point will lead to the body passing one or more of its environmental objectives within the period covered by two river basin cycles. If upward and downward trends are identified for a groundwater body (e.g. an upward trend for the surface water test and a downward trend for the general chemical assessment test) then an upward trend will be reported in the River Basin Plans.

4.7 Recognised statistical methods must be used for trend analysis. Further information on appropriate statistical methods are provided in the EU Technical Report 1[4]. The methods must be appropriate for undertaking the trend assessment and be applicable to the available data. For example, conventional parametric statistical methods that are based on normally distributed data, such as linear regression, may present difficulties if the available groundwater data:

a. Are all positive concentrations,
b. Contain censored (LOQ) data, and
c. Have multiple detection limits and missing values.

Groundwater quality data possess unique characteristics that require specialist approaches to statistical testing. Groundwater data often have asymmetric or non-normal distributions. These 'skewed' data sets may therefore require use of alternative non-parametric statistical methods where no assumptions are required about the underlying data distribution. Non-parametric tests are very powerful for identifying trends in non-normally distributed data and are almost as powerful as parametric tests when applied to normally distributed data. The recommendation is therefore to apply non-parametric tests for identifying trends in time series data for individual parameters from individual monitoring sites.

4.8 In many groundwater systems there will be considerable seasonal variability in parameter concentrations. This variability may introduce problems in the trend analysis unless it can be corrected for. Where there are sufficient data within a given year, the best way to do this is to fit a seasonal model to the data and then use this to de-seasonalise the data. The recommended method for this is the non-parametric Seasonal Kendall trend test (Hirsch and Slack, 1984)[5]. The alternative, where there are variable or insufficient within year measurements is to remove seasonality by calculating the annual means, and then to perform the trend analysis on the annual means. In this case the recommended method is Sen's Method (Sen, 1968)[6]. Both the Seasonal Kendall test and Sen's Method are robust methods that allow for some missing data in the time series and are not badly affected by gross errors or outliers in the data series.

4.9 The data requirements for trend assessment at individual monitoring points need to take account of the objectives of trend assessment and the statistical methods being used. There will be method specific minimum data requirements and these must be met before the trend assessment is carried out. At the minimum level it is unlikely that there will be strong statistical confidence in any trend identified by the test(s).

[4] Technical Report No. 1 (2001): Statistical aspects of the identification of groundwater pollution trends and aggregation of monitoring results – WG 2.8 Statistics

[5] Hirsch R.M. and Slack J.R. 1984. A non-parametric trend test for seasonal data with serial dependence. Water Resources Research 20, 727-732.

[6] Sen P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association. 63, 1379-1389.

As data availability improves confidence in the assessment should also improve. It is recommended that for a trend to be statistically significant there should be at least 80% confidence. The level of confidence in the trend assessment should also be reported with the results of the assessment in the RBMP.

4.10 The test of environmental significance will be made by examining whether the trend(s) at the monitoring point will lead to the body failing one or more of its environmental objectives within the period covered by two river basin cycles. This will be assessed by comparing predicted concentrations at the end of the two river basin cycles with the threshold value(s) and status assessment criteria relevant to the monitoring point, see UKTAG paper 11b(i). Note: For each trend assessment this will mean predicting forward two RBMP cycles.

## 5 Trend assessment - Groundwater Body

5.1 The WFD requires that groundwater bodies subject to significant and sustained upward/downward trends are to be identified in the RBMP. The GWD additionally requires that an explanation be provided for how the results of trend assessment at individual monitoring points have contributed to identifying bodies with trends.

5.2 To determine whether a GWB has a significant and sustained upward/downward trend, the results from the analysis of trends at individual monitoring sites will be assessed. Where a statistically significant trend is identified across a groundwater body, this trend must be tested for environmental significance (see Section 4.9). Depending on the test(s) for environmental significance being applied (i.e. which status assessment criteria are applied); the number of monitoring points may vary. For example, for the DWPA test, an individual monitoring point (drinking water abstraction) that indicates an environmentally significant upward trend would lead to the GWB being reported as having environmentally significant upward trend. For the general chemical test an aggregation of the results of trend assessment from all relevant monitoring sites is required to test for environmental significance. If environmentally and statistically significant upward trends are identified for one or more parameters, the GWB will reported as having a significant and sustained upward trend. **Note**: the presence of a statistically significant trend at an individual monitoring point will not on its own lead to a requirement to report that the GWB has an upward trend because the trend also needs to be environmentally significant

## 6 Starting Point for trend reversal

6.1 The starting point for trend reversal is the pollutant concentration at which measures must be implemented to reverse environmentally significant upward trends (see Section 4.9). It must be defined and reported in the RBMP.

6.2 By default the starting point for trend reversal will be when pollutants concentrations reach 75% of any relevant threshold value[7]. Alternative earlier or later starting points can be set if it can be demonstrated they are needed to avoid a future failure of

[7] Threshold values are groundwater quality standards that are to be established by Member States and can be set nationally, or on a local groundwater body scale, for the purpose of assessing groundwater chemical status. Threshold values are triggers, such that their exceedance prompts further investigation to determine whether the conditions for good status have been met, rather than representing the boundary between good and poor status. See UKTAG Groundwater Task Team paper 11b(i).

WFD objectives or can be justified in terms of cost-effectiveness and technical feasibility. Reasons for selecting starting points have to be reported in the RBMP. Once a starting point has been reported in the RBMP it cannot be changed until the next river basin cycle.

6.3 The results of trend assessment should be taken into account when determining the starting point for trend reversal. Where a trend indicates that there is likely to be a failure of one or more environmental objectives, before the end of the river basin cycle then this failure should be taken into account when defining a starting point. A starting point must be chosen to allow measures to be put in place to reverse trends in sufficient time to avoid failure of WFD environmental objectives.

## 7 Trend assessment – supporting chemical classification (Status Tests)

7.1 Trend assessment plays a part in two of the groundwater chemical status classification tests (see UKTAG paper 11b(i)). These are the Saline Intrusion Test and the DWPA Test.

7.2 The statistical tests applicable to individual monitoring points outlined in this document are also suitable for assessing trends to support the status assessment. In many cases the trend assessment will be carried out once and the data used for both assessing trend objectives and relevant status objectives.

## 8 Reporting of trends

8.1 The WFD and GWD require us to report elements of trend assessment in the River Basin Management Plan. We must summarise the methodology used for identifying environmentally significant trends (and trend reversal) and the reasons for selecting the starting point for trend reversal [GWD Article 5(4)]. In addition, maps must be produced that identify GWBs with environmentally and statistically significant upward trends and those where trends have been reversed. GWBs with a significant upward trend will be identified on the maps with a black dot and where the trends have been reversed with a blue dot [WFD Annex (2.4.5)].