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Common Implementation Strategy for the

Water Framework Directive (2000/60/EC)

Technical Report No. 6

TECHNICAL REPORT ON GROUNDWATER DEPENDENT TERRESTRIAL ECOSYSTEMS

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FOREWORD

The EU Member States, Norway and the European Commission have jointly developed a common strategy for supporting the implementation of the Directive 2000/60/EC establishing a framework for Community action in the field of water policy (hereafter referred to as Common Implementation Strategy (CIS) for the Water Framework Directive (WFD)). The main aim of this strategy is to allow a coherent and harmonious implementation of this Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

This technical report is one of the outcomes of the CIS activity. Other documents related to this work can be found in the CIRCA website:
http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive&vm=detailed&sb=Title

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LIST OF USED ABBREVIATIONS

CIS – Common Implementation Strategy

EQS – Environmental Quality Standard

GWB – Groundwater body

GWDTE – Groundwater Dependent Terrestrial Ecosystems

RBMP – River Basin Management Plan

TV – Threshold Value

WFD – Water Framework Directive (2000/60/EC)

WG C – CIS Working Group on Groundwater

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1 INTRODUCTION

1.1 Background

The Water Framework Directive (WFD; 2000/60/EC) aims to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. For groundwater, there are five environmental objectives in Article 4. These objectives include good groundwater status, which is a combination of good groundwater quantitative status and good groundwater chemical status. Definitions of these two terms are given in the WFD (Annex V). Terrestrial ecosystems that are directly dependent on groundwater (GWDTE) can affect the status of a groundwater body, where the groundwater body is causing significant damage to the GWDTE.

1.2 Scope of this Technical Report

This Technical Report is prepared by WG C under the Common Implementation Strategy of the WFD (CIS).

Its purpose is to collate current available experience, contribute to clarification of terms, make use of already existing CIS documents and suggest pragmatic technical solutions for the implementation of the provisions regarding the interaction of GW-bodies with directly dependent terrestrial ecosystems but leaving flexibility for member states according to their specific needs.

This report is not a CIS guidance document. At the current stage it seemed more adequate to provide information in a technical report rather than developing a „guidance document“.

With respect to the availability of resources priority was give to groundwater dependent terrestrial ecosystems. Surface waters associated to groundwater are not the subject of this report.

1.3 Groundwater Dependent Terrestrial Ecosystems in the WFD

One of the objectives for groundwater in Article 4 of the WFD is to achieve good groundwater quantitative and good groundwater chemical status. The definition of chemical status is set out in WFD Annex V 2.3.2., which states that one of the elements in defining good groundwater **chemical status** is:

> *The chemical composition of the groundwater body is such that the concentrations of pollutants:*
>
> - *…. are not such as would result in failure to achieve the environmental objectives specified under Article 4 nor in any **significant damage** to terrestrial ecosystems which depend directly on the groundwater body…..*

It should be emphasised that poor chemical status does not relate to the impacts of high levels of naturally occurring substances but to impacts from human activities.

The definition of good **quantitative status** is set out in WFD Annex V 2.1.2., which states:

Accordingly, the level of groundwater is not subject to anthropogenic alterations such as would result in:

- *…. failure to achieve the environmental objectives specified under Article 4 for associated surface waters;*
- *any **significant damage** to terrestrial ecosystems which depend directly on the groundwater body…..*

2 KEY CONCEPTS

2.1 Groundwater dependent terrestrial ecosystems (GWDTEs)

In order for terrestrial ecosystems to be considered as part of the classification for groundwater bodies (GWBs), they need to be 'directly dependent' on the GWB (see also section 7.4). This means that the GWB should provide quantity (flow, level) or quality of water needed to sustain the ecosystems which are the reasons for the significance of the GWDTE. This critical dependence upon a GWB is most likely where groundwater supplies the GWDTE for a significant part or a significant time period of the year. For example, a fen in East Anglia (see situation type B in Figure 1) in the UK that is designated for its alkaline fen character under nature conservation i.e. Natura 2000, is directly dependent on a GWB as any significant reduction to groundwater input from the GWB giving rise to a shift in the dominant water source to rain would change the character of the fen and as a consequence cause it to fail its nature conservation objectives.

There are at least four types of situations, shown in Figure 1, where groundwater is essential to a terrestrial ecosystem and where GWDTEs can form. These four categories should be thought of as examples. A subset of these terrestrial ecosystems will be directly dependent on groundwater from a GWB and therefore considered during characterisation and classification:

A. A groundwater source directly irrigates the ecosystems and is visible as a spring or seepage. An example of this type would be a spring fed terrestrial ecosystem where high calcium content of the groundwater precipitates as tufa in the terrestrial ecosystems. In contrast, where springs feed a permanent lake or river system this would not be considered as a groundwater dependent **terrestrial** ecosystem, but an aquatic ecosystem. These aquatic ecosystems are not covered by this paper.

B. Groundwater collecting above impermeable strata, such as clay, in depressions in the landscape. These terrestrial ecosystems can be called fens, and their characteristic flora is directly influenced by the chemical composition of the groundwater it receives. This is in contrast to those terrestrial ecosystems where the ecology is substantially dependent on surface water (such as most swamps) or precipitation (such as some raised bogs).

C. High groundwater tables maintain a seasonally waterlogged condition. The groundwater in the dune sands discharges in so-called 'wet slacks.' The chemical composition of the water, resulting from its interaction with the dune sands, and the fluctuating nature of the water table are crucial in maintaining the ecological functioning of these terrestrial ecosystems.

D. A seasonally fluctuating groundwater table floods depressions intermittently. The resulting lakes, which are seasonal (ephemeral), have a characteristic flora which is directly related to their ecological or socio-economic significance (for example Turlochs, Ireland). The terrestrial component, which is the main reason for its significance, needs to be critically dependent upon the groundwater source to qualify as GWDTE.

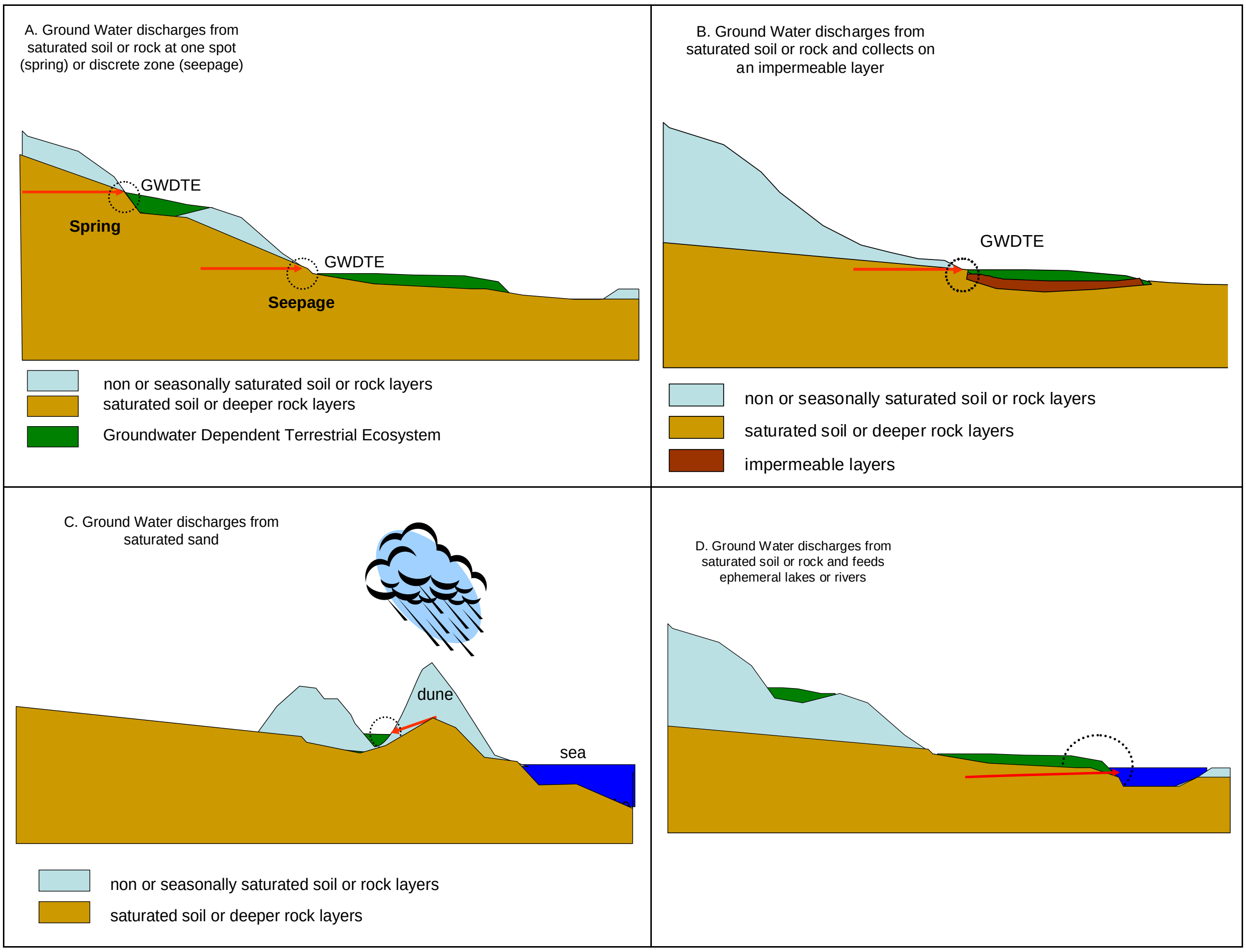

Figure 1: Conceptual diagrams indicative of different types of terrestrial ecosystems which depend on groundwater

2.2 How to determine whether a terrestrial ecosystem is directly dependent on a groundwater body

In practice, it is not easy to determine which terrestrial ecosystems are directly dependent on a GWB, and there will be a continuum of ecosystems between those that are dependent on groundwater from a GWB and those that are dependent on other water sources. In some cases, for example where a spring or seepage is clearly visible (Figure 1, type A), it may be obvious that these GWDTEs are directly dependent on groundwater. Member States may also have sufficient information about the groundwater dependency of a terrestrial ecosystem, such as through localised site assessments for the Habitats Directive, and therefore may not need to assess this further.

Where it is not clear whether a site is dependent on a GWB, a staged approach to screening some sites out using hydrogeological and ecological information, as well as expert judgement on the sites, mean they can be ranked in terms of likely GWB dependency.

Using this screening approach, the first step is to determine the likely dependency of the GWDTE on groundwater. This can be done by identifying features of significance, such as the ecological features. Member States may have lists of vegetation communities, list of habitat types under the Habitats Directive, drawn up by ecologists, which could indicate groundwater dependency for a range of terrestrial ecosystem types. This could be used as an initial tool to rule out any sites which do not have groundwater dependent vegetation.

Further screening could be undertaken using a conceptual model of the GWB, using groundwater level information to identify whether groundwater in the GWB is likely to be discharging to and supplying a GWDTE. These two sources of information should help to rule in or out whether a site may be a GWDTE, or help build up confidence as to whether the site is likely to be GWB dependent.

A conceptual model (as detailed in CIS Guidance No. 26) based on monitoring of the ecosystem itself and the GWB can also help to inform the groundwater dependency of the GWDTE. This model could include the habitat type, the ecosystem and the GWB and their linkages, or an approximated understanding of the linkages. It will also allow other water sources to be considered, such as rainfall and surface water, alongside the groundwater contribution. It may be impractical to develop individual conceptual models for all GWDTEs. If this is the case, then priority could be given to those GWDTEs that are known to be significantly damaged and in GWBs with significant pressures (see Chapter 3.2 for further information on prioritisation), as these models can be used for characterisation. The conceptual model may need to be refined, possibly several times, as more data become available. Where available, the model could include how the site functions in terms of both ecology and hydrology, as well as in terms of the hydro(geo)logical mechanisms.

When no monitoring and modelling results are available, expert judgement on a particular site or sites may be used. For instance, ecologists can often tell by the plants they see in a terrestrial ecosystem, whether the ecosystem is groundwater dependent, due to the distinctive natural chemistry of groundwater compared to surface waters. Such inventories might have already been established in EU Member States, like the list of National Vegetation Classification plant communities and their dependency on groundwater which was prepared by the WFD UK TAG[1] and annexed in the draft guidance on the identification of groundwater dependent terrestrial ecosystems (WFD UK TAG, 2004).

There may also be other indications that a site is groundwater dependent. For example, an orange-brown colour in the sediments, when combined with a blue layer of iron-oxidising bacteria, often indicates that precipitation of fresh iron oxide is occurring caused by anaerobic groundwater appearing on the surface. Such information is valuable in determining which ecosystems are directly dependent on groundwater.

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[1] United Kingdom Technical Advisory Group supporting the implementation of the WFD.

Frequently there is uncertainty about the proportion of groundwater influence on a GWDTE compared to other water sources. However, by combining all the types of evidence listed above, a weight-of-evidence approach can be used as a decision-making tool (CIS Guidance No. 26, section 2.5).

The disadvantage of this type of approach, including expert judgement, is that it only tells whether the ecosystem is *currently* groundwater dependent. If an ecosystem was groundwater dependent in the past but is not any longer due to anthropogenically induced groundwater table lowering or groundwater quality changes, it may not be possible to tell by on-site investigations.

If an ecosystem is currently not groundwater dependent (due to artificial lowering of groundwater tables) but was naturally, this should also be taken into account when identifying GWBs with dependent terrestrial ecosystems, because Art. 4 of WFD requires that 'Member States shall protect, enhance and *restore* all bodies of groundwater' (italicization added by authors). The objective of the Habitats Directive is to achieve favourable conservation status of habitats and species of Community interest. Additionally, the EU 2020 Biodiversity Strategy adopted 3 May 2011 established a target to restore at least 15% of degraded ecosystems and their services by 2020. However, priority could be given to preventing deterioration of sites which are currently groundwater dependent, restoration of recent damage and avoiding predicted future damage.

Note that GWDTEs can also be damaged due to *rising* groundwater tables, for example if a wetland becomes more inundated after construction of a dam that obstructs the discharge of groundwater, resulting in elevated groundwater levels upstream of this dam.

Approach for conceptual model development for specific habitats

Conceptual models will help both ecologists and hydrogeologists to combine their data and assess:

- the degree of dependence on the GWB;
- the risk of significant damage to GWDTEs, the impact on the ecology of different water supply mechanisms, and the significance of changes in both water quantity and chemistry. Many examples of general hydrogeological conceptual models for GWDTEs exist (Lloyd *et al.*, 1995; Winter, 1999; Dahl *et al.*, 2006; Acreman and Miller, 2007).

2.3 Significant damage to GWDTEs

If the quantity or quality of the groundwater of a GWB a GWDTE receives, or does not receive, causes a GWDTE to be significantly damaged this will result in a GWB to be classified at poor status.

CIS Guidance No. 12 explains that the expression 'significant damage' is based upon:

a) the magnitude of the damage and

b) the ecological or socio-economic significance of the terrestrial ecosystem.

The magnitude of the damage needs to be related to whether the GWDTE continues to have the capacity to continue to fulfil its ecological or socio-economic function. A GWDTE that is crucial to a regional tourist economy could be considered to have socio-economic significance. If pressures on the GWB cause changes to groundwater quality or quantity that, in turn, leads to damage to the ecosystem and reduced visitor numbers, this could be considered as significant damage.

For those terrestrial ecosystems that belong to the Natura 2000 network, the failure to meet conservation targets of the Natura 2000 area can be interpreted as significant damage (as far as groundwater status is concerned). (The relation between WFD and the Birds and Habitats Directives is further discussed in a draft document of the European Commission summarising several frequently asked questions [European Commission, 2010a][2]) This parallel approach would imply that if the conservation targets of the Natura 2000 area cannot be met as a result of *chemical or quantitative anthropogenic pressures on the GWB* and there is a groundwater hydraulic or pollutant linkage, the GWB should be considered 'at risk' (during characterisation) or at poor status (during status assessment), bearing in mind that the risk assessment looks forward to the end of the next RBMP cycle, and status assessment looks back at performance during the last RBMP cycle.

For terrestrial ecosystems that are *not* part of the Natura 2000 network, a similar approach could be developed by the Member States, i.e. formulation of targets, derivation of groundwater requirements (both quantitative and chemical), and then comparison of desired situation with actual situation. Then, if the targets are not met *because of quantitative or chemical anthropogenic pressures on the GWB*, the GWB should be considered 'at risk' or at poor status. This is likely to involve development of a simple conceptual model of the desired and actual situations. However, defining conservation or hydrogeological targets outside Natura 2000 is not straightforward.

LOOK OUT!

Defining significant damage includes both ecological and hydrogeological understanding, and it is recommended that work is carried out in multi-disciplinary teams. This will facilitate exchange of knowledge and concepts between the disciplines and allow understanding of each others' perspectives and 'language'.

2.4 Threshold values and 'Trigger values'

GWD Article 3 requires that "the threshold values (TVs) applicable to good chemical status shall be based on the protection of the body of groundwater in accordance with Part A, points 1, 2 and 3 of Annex II, having particular regard to its impact on, and interrelationship with…**directly dependent terrestrial ecosystems and wetlands** …".

GWD Annex I specifies that more stringent TVs for those pollutants with groundwater quality standards listed in Annex I are needed if the established groundwater quality standards could result in failure to achieve the Article 4 environmental objectives or in any **significant damage to terrestrial ecosystems**

[2] http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/implementation_conventio/-biodiversity_legislation/faq-wfd-bhd_june2010doc/_EN_1.0_&a=d

which depend directly on the body of groundwater. When establishing groundwater TVs (GWD Annex II), Member States will consider the extent of interactions between groundwater and associated dependent terrestrial ecosystems (for those GWDTE's that are significantly damaged; see also Figure 3). In order to determine threshold values for GWDTEs, we need to understand what different types of GWDTE can tolerate in terms of chemical inputs without resulting in the GWDTE becoming significantly damaged. This concept is similar to the use of environmental quality standards (EQS) in surface water bodies. For the purpose of this report, these will be called 'GWDTE trigger values' which, if exceeded **in** the GWDTE (not the GWB), **could** cause significant damage. Further work will be needed to determine whether damage has occurred or is likely to occur. Threshold values for the GWB will then be determined by taking into account dilution and attenuation between the GWB and the GWDTE through understanding the likely pollutant linkage.

This approach is in agreement with Annex III of the GWD. This Annex states that for the purposes of investigating whether the conditions for good groundwater chemical status are met, Member States will, where relevant and necessary, and on the basis of relevant monitoring results and of a suitable conceptual model of the body of groundwater, assess:

a) the amounts and the concentrations of the pollutants being, or likely to be, transferred from the body of groundwater to the associated surface waters or directly dependent terrestrial ecosystems;
b) the likely impact of the amounts and concentrations of the pollutants transferred to the associated surface waters and directly dependent terrestrial ecosystems;

3 CHARACTERISATION & RISK ASSESSMENT

As discussed in Chapter 1, GWDTEs are part of the status assessment for groundwater. Therefore, they are relevant in characterisation and risk assessment of GWBs.

3.1 Initial characterisation

The characterisation of GWBs is a two step risk assessment procedure. The aim of the initial characterisation is that an assessment is carried out to assess the uses of the GWBs and the degree to which they are at risk of failing to meet the objectives for each GWB under Article 4.' If the result of the initial characterisation is that a GWB is at risk of failing to meet the Article 4 objectives, then further characterisation is needed. The aim of the further characterisation is to establish a more precise assessment of the significance of such risk and the identification of any measures to be required under Article 11 WFD.' However, it may make practical sense to combine initial and further characterisation into one stage as long as the requirements of the Directive are fulfilled.

The initial characterisation (Annex II of WFD) may employ any available data covering diffuse and point sources of pollution, the character of overlying strata and abstraction and artificial recharge. One of the outcomes of the initial characterisation is that it should 'identify those GWBs for which there are directly dependent surface water ecosystems or terrestrial ecosystems.’ Identifying groundwater dependence of terrestrial ecosystems is covered in Chapter 2.2.

One approach for initial characterisation is to apply a spatial approach, for example using proximity tests for quantitative and chemical pressures and identifying possible linkages to GWDTEs. Screening can quickly be carried out using this method for both chemical and quantitative pressures on GWDTEs using automated GIS techniques. Another approach is to involve local experts to identify GWDTEs and screen for pressures in the GWB. This approach is practical only where there are few GWDTEs, or when used in conjunction with a simple screening method to reduce the numbers of sites. At the end of the initial characterisation, it should be clear which GWBs contain GWDTEs that cause the GWB to be at risk of failing to meet its objectives. Further characterisation is needed for those GWBs.

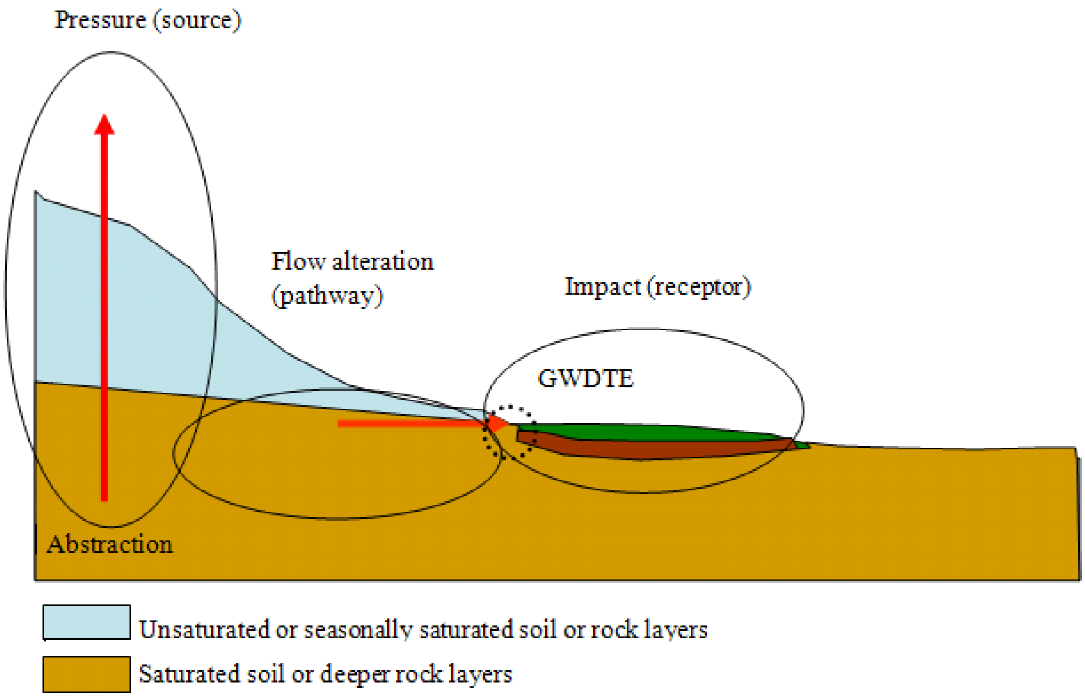
3.2 Further characterisation

For further characterisation, if a GWB is at risk due to effects of GWB pressures on dependent terrestrial ecosystems, ‘an inventory of ... terrestrial ecosystems …with which the GWB is dynamically linked,’ is needed. For those GWBs at risk, ‘estimates of the directions and rates of exchange of water between the GWB and associated surface systems’ are needed.

The WFD does not discriminate between different groundwater dependent ecosystems. However, in practice, it is likely to be necessary to prioritise ecosystems, e.g. when many ecosystems are connected to one GWB. CIS Guidance No. 12 gives practical guidelines for prioritising *terrestrial* ecosystems (section 3.3, pages 21 to 25), as: ‘*There are potentially very large numbers of terrestrial ecosystems that are directly dependent on groundwater within the Community. Whilst many support features of value (ecological or socioeconomic), a screening tool will be essential to focus action on the most important sites and areas, so that Member States do not face an impossible administrative burden. Member States may use their own, nationally developed criteria for identifying those dependent terrestrial systems which they believe are of sufficient importance that damage to them, as a result of anthropogenic groundwater alterations, could legitimately be described as 'significant'.*’

The step-wise approach recommends that the focus is on Natura 2000 sites and on those ecosystems which may experience significant damage (either ecological or socio-economic). These are then assessed, through characterisation and monitoring, as to whether significant damage has occurred or is likely to occur. Although prioritisation may be necessary in the initial planning cycles, ultimately all groundwater dependent ecosystems could be considered.

It should be kept in mind that it is necessary to determine whether or not a GWDTE is significantly damaged due to the impact from anthropogenically induced changes within a GWB. Inclusion of anthropogenic pressures can, therefore, focus the risk assessment. For example, for further characterisation, a source-pathway-receptor (SPR) approach could be used to conceptualise groundwater flows and anthropogenic pressures (Figure 2).



Note: The abstraction (**source**) lowers the groundwater table locally. This results in a reduced pressure head in the saturated rock (hydro-geological **pathway**) and subsequently less discharge at the GWDTE (**receptor**)

Figure 2: Source-pathway-receptor linkages for a GWDTE

Source

For quantitative pressures, it is worth considering the total amount of groundwater abstraction across the whole GWB, which may cause regional lowering of groundwater levels, in addition to those near to the GWDTE which exert a local effect. Local abstractions close to the GWDTE, even if they are of relatively small extent, are more likely to have a large impact on the flow, level and discharge to the GWDTE and so could be more damaging than abstractions some distance away in the GWB. Use can be made of 'equivalent recharge circles' to ascertain the spatial extent of the pressure in relation to the location of the GWDTE. These circles are generated by determining the area within the GWB needed to receive the recharge required to supply each abstraction around that point. Alternatively, zones of contribution (ZOCs) can be used to determine this spatial extent. The ZOCs may be calculated using the abstraction rate, hydraulic characteristics of the geological strata supplying the groundwater to the GWDTE, recharge rate, regional groundwater gradient and analytical flow equations or numerical models.

For chemical pressures, groundwater quality monitoring networks should provide sufficient data to estimate the average concentration of common pollutants that can adversely affect ecosystems, such as nitrates and phosphates. If such data are lacking, an estimate of chemical pressure may be obtained using chemical loading models. For example, where chemical pressures are from agriculture, agricultural information such as stocking densities, crop types and fertiliser loadings can be used.

Pathway

To understand the pathway and hydraulic connection between the GWB and GWDTE, hydrogeological maps and data on superficial geology and hydraulic properties may be used. However, these may not always provide a complete picture. For example, very local differences in hydraulic conductivity, such as at the bottom of a GWDTE where clay or silt layers might be present, can have major impacts on the overall hydraulic connectivity. In these cases, site-specific information on hydraulic properties and heterogeneities may be needed to better understand the pathway. This could be costly and so might only be undertaken if there is evidence that the receptor is sensitive to the identified source and that there is likely to be a good linkage.

Understanding the pathway is particularly important when considering the impact of chemical pressures. Some substances will be attenuated along the flowpath, and this needs to be factored into the assessment. For example, in some GWDTE's phosphate co-precipitates with calcium as the groundwater enters the GWDTE.

Receptor

It is understood that generic sensitivities of ecological receptors (GWDTEs) are being developed on a country by country basis, or are being collated from monitoring and literature sources. Comparison of this information and databases on GWDTE-communities between countries is recommended.

GWDTE trigger values are chemical values which if exceeded suggest that specific categories of GWDTE's may be at risk of damage (Chapter 2.3). These may also be used for risk screening and characterisation, where they are available. This will allow sites to be ruled in or out within the risk screening whether there is a known risk, or no risk. CIS Guidance No. 26 makes it clear that risk screening during characterisation '*is a precautionary risk screening exercise, which is quite distinct from the need to assess whether there is actual damage to a GWB from human activity (i.e. poor status) and therefore whether remedial action (measures) should be taken*.'

3.3 Importance of proper characterisation

CIS Guidance No. 26 stresses the importance of a correct evaluation in terms of 'at risk' or 'not at risk'. Eventually, in the last step of a tiered approach, a GWB should be characterised as 'at risk' in case of doubt. An important reason for this suggested approach is that, if a GWB is declared as 'not at risk', monitoring obligations are different (see chapter 5) and requirements for status assessment are different. The GWD requires that status assessment only needs to be carried out for GWBs identified as being at risk (Annex III 1 GWD). GWBs not at risk are automatically classified as being of good chemical status or good quantitative status. A GWB erroneously classified as 'not at risk' will automatically be classified as 'good status' which may lead, therefore, to not taking necessary measures. However, the WFD Article 4 objective to prevent inputs of hazardous substances and limit input of non hazardous pollutants to groundwater still needs to be met, irrespective of the chemical status of the GWB.

4 HOW TO DETERMINE THE GROUNDWATER QUANTITY AND QUALITY NEEDS OF GWDTES

4.1 Groundwater quantity requirements

The amount of water from all sources that a GWDTE needs to fulfil its ecological or socio-economic functioning will probably vary throughout the year. As a site has been identified as a GWDTE, there are key periods during a year when groundwater is critical to the functioning of the GWDTE. For example, groundwater discharge to a GWDTE on a slope may be particularly important during dry periods of the year, when evapotranspiration is not replenished by rainwater.

Key GWB dependencies can comprise:

- Discharge of groundwater to the site via springs and seepages – assessed by the relative volume of groundwater discharge to the GWDTE and water levels relative to the discharge point;
- Maintenance of an upward hydraulic **gradient** from the GWB to the near surface deposits – assessed by the relative elevations of groundwater **levels** within the GWB and the GWDTE;
- Maintenance of an upward **flow** of groundwater from the GWB to near surface deposits – assessed by the relative **volume** of flow to the GWDTE;
- Water saturation of the soil or influence on soil moisture characteristics as a result of inputs from groundwater – assessed by consideration of typical soil hydraulic properties related to groundwater level and flow.

Ecologists in Member States may understand the water quantity needs of specific GWDTEs, but there is little published guidance, as quantitative requirements are generally specific to individual GWDTEs. Examples of existing guidance are: Davy et al (2010); Huybrechts et al, 2009; Meuleman et al, 1996 and Whiteman et al, 2010.. In spite of this, there is a growing evidence base of general water quantity requirements of GWDTEs and an exchange of information across the EU Member States on the water quantity requirements of GWDTE categories would aid assessments and improve consistency. There will often be a need to derive GWDTE category-specific water quantities, which can be developed by an expert panel approach. General water requirements of GWDTE categories need to be evaluated for application to a particular site or location. The local variability of shallow and deeper soil and rock layers and topography (land level) are crucial to understand GWDTE hydrological functioning, and will inform how the general GWDTE requirements can be applied to a particular site. Where quantitative information is available, hydrogeological modelling can be used to link groundwater sources to a GWDTE. Modelling may range from a simple water balance right through to complex numerical analysis.

4.2 Groundwater quality requirements

Characterisation should determine what groundwater chemical pressures may be acting on the GWDTE, and information about anthropogenic pollutants present in the GWB should be obtained from the GWB chemical monitoring network. For example, in an intensive agricultural setting, it is likely that the most important substances affecting GWDTEs are nitrate and phosphate (note that all substances which are important should be considered). The substances which are identified as important should be considered as the starting point of the risk assessment.

When determining the impact of substances, different GWDTE categories can have large tolerance ranges. For example, some GWDTE vegetation types only grow in certain locations due to the unique chemistry of the water supply in that area. Some vegetation types are more or less tolerant of elevated concentrations of certain substances such as nutrients. Further investigation is needed to understand the effect of elevated pollutant concentrations on different GWDTE-categories.

Once established, the general effects of the concentration of substances on GWDTE categories will need to be evaluated before it can be applied to particular sites or locations. In addition, site specific conditions, such as the local variability of shallow and deeper soil and rock layers and topography, and the transformation of substances within the GWDTE, will modify the general effects and how they can be applied to a particular site.

The general information on the effects of different substances on GWDTEs can also be used to develop GWDTE trigger values and thus help establish GWB TVs (Chapter 6).

LOOK OUT!

Developing common categories of GWDTEs might help exchange of information and enable better comparison of methods between Member States. An example of simple categories of GWDTEs is given by SNIFFER (2009). Member States are encouraged to establish a common categorisation and co-operate on information and database sharing on the environmental requirements of GWDTE ecological features (such as plant communities).

LOOK OUT!

Co-operation is recommended between Member States to contrast and compare knowledge on the water quantity and effects of anthropogenic substances on different categories of GWDTE. This may be used by Member States to help develop trigger values in the GWDTE to help establish TVs (Chapter 6) in the GWB.

5 MONITORING

Considerable information is already available on monitoring, including monitoring of interactions between groundwater and ecosystems, e.g. CIS Guidance No. 7 (Monitoring) and No. 15 (Groundwater Monitoring), Technical Report No. 3 (Groundwater Monitoring) and CIS Guidance No. 26 (Risk Assessment and Conceptual Models).

The most relevant points for this Technical Report are that:

- the development of monitoring programs should go hand-in-hand with the development of a conceptual model of the GWB (see Figure 6 from the Technical Report No. 3 on Groundwater Monitoring);

- the WFD (Annex V) and GWD require that the monitoring network: 'shall be designed so as to provide a coherent and comprehensive overview of groundwater chemical status';
- monitoring should demonstrate that GWDTEs that were not previously classified as 'significantly damaged' do not become 'significantly damaged' as a result of GWB pressures, as this would cause deterioration in status of the GWB.

LOOK OUT!

The WFD requires monitoring of status and that monitoring should be representative, but does not make specific provisions for detailed 'site' monitoring i.e. investigative monitoring or ecological monitoring.

Site specific monitoring can be included as part of 'operational monitoring' as described in CIS Guidance No. 15 (GW Monitoring).

6 THRESHOLD VALUES (TVS) AND GWDTE TRIGGER VALUES

Article 3 of the GWD lays down criteria for assessing groundwater chemical status:

"1. For the purposes of the assessment of the chemical status of a GWB [….] Member States shall use the following criteria:

> *(a)* ***groundwater quality standards*** *as referred to in Annex I,*
>
> *(b)* ***threshold values*** *to be established by Member States in accordance with the procedure set out in Part A of Annex II […]".*

Where a groundwater quality standard is not sufficient to ensure that the environmental objectives set out in Article 4 of the WFD will be met, then a more stringent value is needed. This also considers any significant damage to GWDTEs. These more stringent values are defined as Threshold Values (TVs) and are to be established at an appropriate scale (national, river basin district or at GWB scale). They should be applied to the GWB (or relevant scale) during the relevant classification tests and if exceeded at relevant locations in the GWB, appropriate investigation need to be undertaken, including investigations for significant damage to GWDTEs, in order to confirm that the achievement of the WFD objectives is not compromised.

The criteria required for the establishment and application of TVs is set out in CIS Guidance No. 18: *Guidance on groundwater status and trends assessment*. One of the specific criteria is that TVs should 'aim to protect … **groundwater dependent terrestrial ecosystems'.**

TVs are used for classification purposes in each of the WFD tests. The derivation of TVs is based on the (use related and environmental) receptors present in a GWB. Groundwater TVs designed to protect surface waters are based upon surface water quality standards but there are no equivalents to these standards for GWDTEs. For the purposes of this report, these equivalent GWDTE quality standards that may be used to derive groundwater TVs, are referred to as trigger values. These trigger values can be developed from literature studies considering generic sensitivities of GWDTE categories, pre-existing on-site monitoring of GWDTEs and comparison between GWB chemistry and whether the site is meeting its ecological targets. This approach is currently being followed in the UK. Where possible, monitoring data can be included in the derivation of these trigger values.

Note that attenuation and dilution factors can be applied as described in CIS Guidance No. 18 (status & trends).

6.1 Naturally adapted ecosystems that are dependent upon concentrations of naturally occurring substances above default TVs

Some ecosystems are adapted to higher concentrations of naturally occurring substances. This is not pollution according to the WFD. For example in a region of the Netherlands, zinc naturally occurs in high concentrations. Local ecosystems are adapted to those conditions and therefore differ from ecosystems elsewhere. This should not be considered as pollution, because the origin is natural. If there was a region with naturally low concentrations of zinc in combination with high zinc emissions, the same type of ecosystem might develop. However, in such a case this should be considered as pollution and damage to the currently existing ecosystem and therefore measures might need to be implemented.

7 STATUS ASSESSMENT

Classification of the status of GWBs under the GWDTE test, for both quantitative and chemical status, is a decision based on the information and data from the monitoring networks, gathered in the previous 6 years.

There may be different levels of certainty in the risk assessment depending on the amount and type of evidence available about the site itself, linkages to the GWB and pressures acting on the GWB. Only those deemed to be 'at risk' of failing to meet the WFD objectives under the characterisation process are considered as potentially putting a GWB at poor status.

For those GWBs where there is significant risk of significant damage of a GWDTE after the characterisation process, the WFD and GWD recognises that additional investigation and monitoring is required to inform classification.

7.1 Stepwise approach

The assessment procedures (status tests) for identifying chemical and quantitative groundwater status in relation to terrestrial ecosystems dependent on groundwater bodies as outlined in Figure 3 and Figure 4 (from CIS Guidance No. 18) follow a stepwise approach. Both tests are very closely linked and both tests require that the environmental conditions needed to support and maintain conditions within a GWDTE (e.g. acceptable pollutants concentrations, GW flow or level needed to maintain dependent (plant) communities) are determined.

In a **first step** a screening exercise could identify terrestrial ecosystems which are (likely) interacting with a GWB, which are significantly damaged, and the damage is caused by the pressure exerted by the GWB.

Investigations could be used to provide the evidence base to understand whether a GWDTE is 'significantly damaged' and whether this is caused by pressures on the GWB and if so, which pressure (substance, groundwater level). This work needs to assess the magnitude of the damage, the hydrogeological linkage between the GWB and the GWDTE, and the relative importance of groundwater for that particular ecosystem.

Investigations may need to include a combination of ecological investigations to identify damage, and hydrogeological investigations to determine that the damage is caused by GWB pressures. Where there are many GWDTEs, it makes sense to use information readily available, undertake simple ecological walkover surveys of the site or use weight of evidence and expert judgment approaches with a panel of experts. Use of detailed site investigations is unlikely to be cost effective for all sites and should be reserved for sites where significant damage has occurred in order to investigate the reason for the damage and to design measures.

There may be terrestrial ecosystems with GWB interaction where the information is not sufficient to allow for clear distinction whether it is significantly damaged or not and/or the environmental supporting conditions are not quantifyable with a significant degree of confidence. Where this is the case, the GWDTEs will remain 'at risk' of being significantly damaged and could be prioritised for further investigation. Where there is insufficient information and knowledge the status assessment procedure can be stopped and the GWB is classified as of good status under this test but remains 'at risk'. The further steps of the status test might not contribute to an improved knowledge whether a terrestrial ecosystem is damaged or not which is a prerequisite of the full assessment procedure.

If the first step confirms that a GWDTE is significantly damaged and interacting with a groundwater body, then the **second step** identifies whether environmental supporting conditions are not being met due to anthropogenically induced changes in the associated groundwater body and if it is the case, which.

For groundwater quantitative status, the related status test (Figure 3) assesses the magnitude of the departure from the required environmental supporting conditions within the GWDTE. If the departure from the environmental conditions is the result of groundwater abstraction then the groundwater body is classified to be at poor status.

For groundwater chemical status the environmental supporting conditions needed to support and maintain conditions within a GWDTE can be represented by groundwater TVs which may be based on GWDTE trigger values (see Chapter 6). It is likely that other lines of evidence collected as part of the 'appropriate investigation' may be needed to add sufficient confidence in the status assessment (see 7.3).

7.2 Consideration of groundwater threshold values

As part of the second step, when ecosystems of different sensitivities for a certain substance fall in one GWB, the TV used is proposed to be based on the most sensitive GWDTE (see CIS Guidance No. 18, page 24). That ensures that, in the first step of classification, one can be sure that if all monitoring results are below the TV, all GWDTEs in a GWB are protected. There may be instances where the TV is exceeded at some monitoring points. This does not automatically lead to poor status. Appropriate investigations (see Chapter 7.3) can confirm that the objectives of the

WFD are still being met and the GWB is assigned as of good status. The suggested procedure in such a case is as follows:

- derive the TV based on the most sensitive GWDTE based on GWDTE trigger values and dilution and attenuation along the flow path.
- compare monitoring results from points where the GWDTE is linked to this TV (based on conceptual understanding).
- if the average of concentrations in each of these monitoring points is *lower* than the TV, the GWB is of good chemical status for that particular substance in relation to the GWDTE test.
- if average of concentrations in these monitoring points is *higher* than the TV, an 'appropriate investigation' is needed. Depending on the result of the appropriate investigation, assign either good or poor chemical status for this substance for the GWDTE test.
- If a single GWB contains ecosystems with *high* sensitivity for a substance as well as ecosystems with *low* sensitivity for the same substance, the 'appropriate investigation' should focus on the high sensitivity GWDTE (i.e. the GWDTE that is the reason the specific TV has been assigned to that GWB)

When establishing threshold values it is particularly important to consider the pathway. Some substances may be attenuated along the pathway. For example on some GWDTE's phosphate may co-precipitate with calcium as the groundwater enters the GWDTE or reducing conditions may remove nitrate. If this is the case then it is essential that attenuation is considered.

7.3 Appropriate investigation

For GWBs where a TV is exceeded, but significant uncertainty exists, this may trigger a more detailed site-specific assessment as part of the classification of the GWB or alternatively may rely on a weight-of-evidence approach and expert judgement, where information is available. The appropriate investigations are specified in Annex III of the GWD and need to find out the 'contribution' of the groundwater body to the significant damage of a GWDTE by assessing whether there might be pollutant transfer from the GWB to the GWDTE and if so, then by assessing the amounts and concentrations of pollutions being transferred and their impacts on the GWDTE:

It is important to carry out any form of detailed on site investigation that is needed in a cost-effective way. The investigation should always be guided by the conceptual model (CIS Guidance No. 26, Annex II). It is recommended that a 'site-works plan' is prepared in collaboration with partner organisations and shared between technical specialists to scope the work. Methods that may be cost-effective and help to reduce uncertainty in source-pathway-receptor links for GWDTEs include:

- Targeted ecological surveys (e.g. vegetation surveys to detect changes in abundance of species indicative of chemical damage such as nutrient enrichment);
- Walkover hydro-ecological surveys to determine the location of springs and seepages in relation to critical groundwater-dependent ecological features, and ascertain hydraulic relationships between groundwater and surface water features such as ditches, ponds and other watercourses;

- Establishment of shallow dipwells to measure water levels in the near-surface deposits and their hydraulic relationships with the underlying GWB.
- Remote sensing data to predict water levels in GWDTE's.

Other techniques that may be used include:

- Geophysical surveys e.g. resistivity, ground-penetrating radar to confirm stratigraphic relationships and location of water-bearing/conductive strata;
- Drilling of deeper piezometers into the underlying GWB;
- Measurement of other sources of chemical pressure e.g. atmospheric nitrogen deposition that may cause a critical loading to be exceeded.

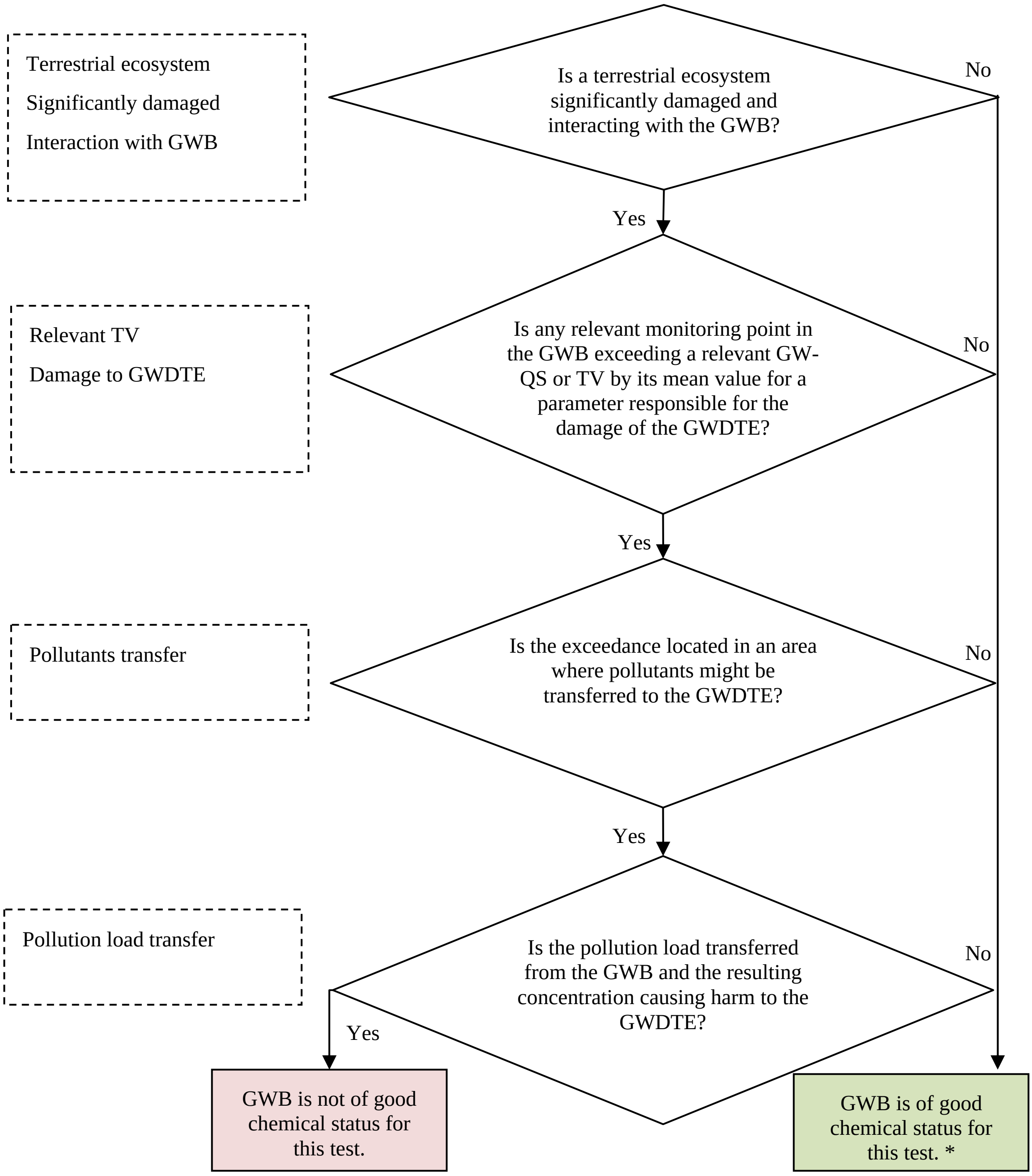
LOOK OUT!

'In-combination' effects may be important in causing actual ecological damage to GWDTEs. For example, even if the chemical loading of nitrates from groundwater does not exceed a concentration which causes ecological damage, aerial deposition of nitrates (from atmospheric pollution or incineration for example) may cause a critical loading for the catchment to be exceeded (see for example, the case of Merthyr Mawr, reported by Jones *et al*. 2006). This may need to be investigated if a site is failing to meet the function for which it was deemed significant. It should be noted that in order for it to cause poor groundwater status, the majority or a significant proportion of the impact should be coming from pressures in the GWB.

Correlation between the status of the GWB and that of the GWDTEs as well as relevant Natura 2000 habitats should be further investigated in order to better understand the interlinkages building on which the monitoring and assessment can be further improved in the future.

7.4 Status assessment and size of GW body versus GWDTE

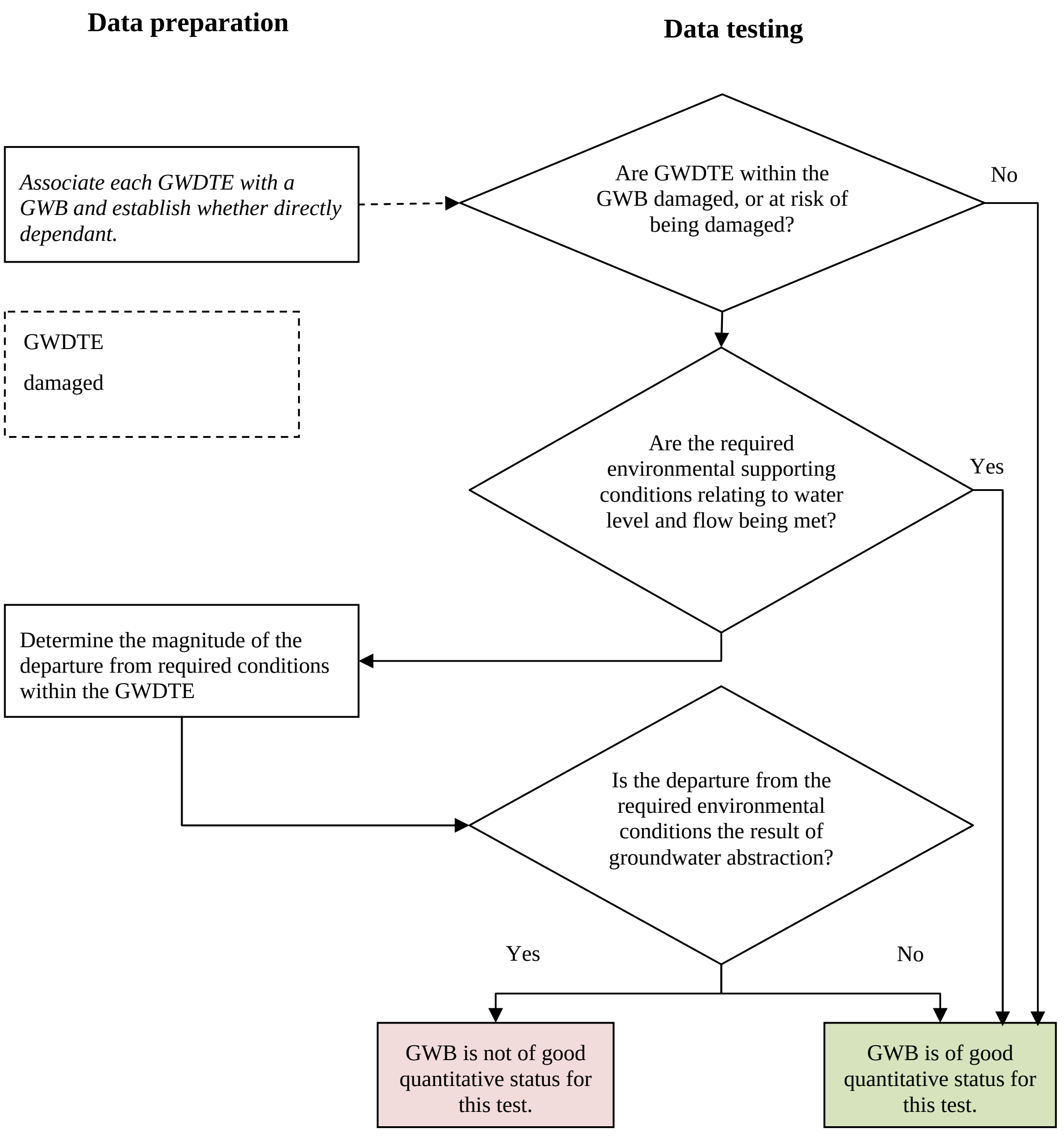
When assessing a GWDTE, it is not specifically the scale (i.e. the size) of that GWDTE that is important in relation to the GWB. If a GWDTE has been identified as significant (and is therefore important) and is significantly damaged from groundwater pressures such that it can no longer perform the function for which it was identified as significant, the GWB should be at poor status.



Consider the conceptual understanding (e.g. pressure, vulnerability, impact situation) of the GWB at each step within the assessment.

* Proceed according to Article 4(5) GWD

Figure 3: Proposed procedure for test of significant damage of terrestrial ecosystems directly dependent on the GWB caused by the chemical pressure of the GWB (from CIS Guidance No.18).



Note:
If the proportion of failure due to anthropogenically impacted groundwater is significant, and a dependent community is not damaged, the GWB is deemed to be of good status for his test, but is at risk of failing the relevant good status requirements in the future.

Figure 4: Outline of procedure for the GWDTE element of quantitative status assessment (from CIS Guidance No.18).

8 RECOMMENDATIONS

1. It is advisable that multi-disciplinary teams (hydrogeologists and ecologists) work together in determining the risk to the GWDTE and the level of damage to the GWDTE caused by the GWB pressures.
2. It is advisable that ground and surface water organisations work together when dealing with GWDTEs
3. It is advisable to make use of an interdisciplinary network (e.g. via the SPI initiative, EU-funded projects) to further develop GWDTE-issues and share knowledge and pragmatic and practical solutions.

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10 CASE STUDY – AUSTRIA

The Austrian case study describes the selection procedure of WFD relevant (ground)water dependent terrestrial ecosystems and wetlands.

10.1 Characterisation

10.1.1 Terrestrial ecosystems - Solutions chosen

To identify WFD relevant (ground)water dependent terrestrial ecosystems and wetlands in Austria, the following 3-step strategy has been developed:

1. Definition of (ground)water dependent habitats according to the Flora-Fauna-Habitats-Directive (FFH-D) and the Birds-Directive
2. Selection of Natura 2000 sites with (ground)water dependent habitats
3. Plausibility checks, verification and final selection of WFD relevant sites.

In a first step, hydrological criteria have been developed and applied to identify (ground)water dependent habitats according to the FFH-D. Explicit 'threshold values' for these criteria were not laid down in order to allow for certain site specific flexibility. The hydrological criteria are:

- Groundwater table
  - Frequent (at least annual) raise of GW into the fine soil (covering layer),
  - Groundwater table is permanently in fine soil
- Surface water table
  - The particular time and duration of floods,
  - Frequency and amplitude of surface water tables
- Precipitation
  - Amount and distribution over the year
- Special sites
  - Indirectly influenced by water or located close to water.

In a second step criteria have been developed for identifying those Natura 2000 sites which are WFD relevant and (ground)water dependent. The selection has been performed according to the following criteria:

- Degree of representativity of FFH-D habitat in the Natura 2000 site
  - The representativity of a habitat needs to be at least excellent or good (top two levels out of a 4-level scale)
- Area-criterion
  - The total area of a habitat within a Natura 2000 site is larger than 5 ha (with two exceptions);
- Species-criteria (FFH-species and/or bird-species)
  - There is at least one water related species with a population value larger than 2% of the whole national species population; or
  - There are at least 10 species present.

In a third step, the results of the pre-selection procedures were checked for plausibility considering Austrian Red Lists, the estimation of the ecological status of ecosystems, special protection needs, etc.

Finally, the application of the hydrological criteria lead to the identification of 19 FFH-D habitats to be groundwater dependent and 8 FFH-D habitats to be surface water dependent. The application of the selection procedure (second step) to the 204 Natura 2000 sites in Austria finally lead to the identification of 104 sites which are groundwater dependent and WFD relevant.

10.2 Status assessment

10.2.1 Terrestrial ecosystems - Difficulties encountered

Main shortcoming in the status assessment procedure is the lack of identifying cause-effect-relationships. What are the effects on groundwater dependent terrestrial ecosystems caused by changes of quality/quantity of groundwater and what is the contribution of human activity to such changes?

A further open issue is the definition of the baseline of the assessment and hence a target for remediation.

A definition of ‘significant damage’ according to the WFD needs to be set in relation to the ‘favourable status’ in FFH-Directive.

10.3 Conclusions from this case study

The elaborated selection procedure and the defined criteria were an excellent basis for the final identification of WFD relevant Natura 2000 sites. This strategy could easily be applied to further (ground)water dependent non-Natura 2000 sites.

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