

COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE (2000/60/EC)



Guidance Document No. 16

Guidance on Groundwater in Drinking Water Protected Areas

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This technical document has been developed through a collaborative programme involving the European Commission, all the Member States, the Accession Countries, Norway and other stakeholders and Non-Governmental Organisations. The document should be regarded as presenting an informal consensus position on best practice agreed by all partners. However, the document does not necessarily represent the official, formal position of any of the partners. Hence, the views expressed in the document do not necessarily represent the views of the European Commission.

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FOREWORD

The Water Directors of the European Union (EU), Acceding Countries, Candidate Countries and EFTA Countries 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” (the Water Framework Directive). The main aim of this strategy is to allow a coherent and harmonious implementation of the Directive. Focus is on methodological questions related to a common understanding of the technical and scientific implications of the Water Framework Directive.

In particular, one of the objectives of the strategy is the development of non-legally binding and practical Guidance Documents on various technical issues of the Directive. These Guidance Documents are targeted to those experts who are directly or indirectly implementing the Water Framework Directive in river basins. The structure, presentation and terminology are therefore adapted to the needs of these experts and formal, legalistic language is avoided wherever possible.

In this context, a guidance document "Identification of Water Bodies" has been developed and endorsed by the Water Directors in November 2002 (CIS Guidance Document Nr. 2). This document provides Member States with a common understanding of the definition of water bodies and specific practical suggestions for their identification under the Water Framework Directive.

As a follow-up, and in the context of the development of the new Groundwater Directive under Article 17 of the Water Framework Directive, Member States have expressed the need to clarify issues of groundwater in protected areas, in particular Drinking Water Protected Areas (DWPAs). A project to develop a guidance document complementing the CIS Guidance Document Nr. 2 has, therefore, been designed in 2004, and an informal drafting group has been established under the umbrella of the CIS Working Group on Groundwater (WG C). This drafting group has been coordinated by the United Kingdom and EUREAU, and involved a range of experts from other Member States and from stakeholder organisations.

The present Guidance Document is the outcome of this drafting group. It contains the synthesis of the output of discussions that have taken place since December 2004. It builds on the input and feedback from a wide range of experts and stakeholders that have been involved throughout the procedure of Guidance development through meetings, workshops, conferences and electronic media, without binding them in any way to this content.

“We, the water directors of the European Union, Norway, Switzerland and the countries applying for accession to the European Union, have examined and endorsed this Guidance during our informal meeting under the German Presidency in Dresden (18-19 June 2007). We would like to thank the participants of the Working Group C and, in particular, the leaders of the monitoring drafting group, the United Kingdom and EUREAU, for preparing this high quality document. We strongly believe that this and other Guidance Documents developed under the Common Implementation Strategy will play a key role in the process of implementing the Water Framework Directive and the newly adopted Groundwater Directive.

This Guidance Document is a living document that will need continuous input and improvements as application and experience build up in all countries of the European Union and beyond. We agree, however, that this document will be made publicly available in its current form in order to present it to a wider public as a basis for carrying forward ongoing implementation work. We also commit ourselves to assess and decide upon the necessity for reviewing this document in the light of scientific and technical progress and the experiences gained in implementing the Water Framework Directive and the new Groundwater Directive”.

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TABLE OF CONTENTS

Members of the Drafting Group

1. Purpose and Scope of guidance	5
1.1 Introduction.....	5
1.2 Purpose of this document.....	5
2. The Water Framework Directive's general requirements for Protected Areas.....	6
2.1 Areas defined under the WFD	6
2.2 Timescales for meeting objectives.....	7
2.3 Relationship of protected area to other WFD objectives	8
2.4 Registers of Protected Areas	8
3. Groundwater Drinking Water Protected Areas	9
3.1 Terminology.....	9
3.2 Identification and Delineation of DWPA's	9
3.3 Meeting the requirements of the Drinking Water Directive (DWD).....	10
3.4 Necessary protection and avoiding deterioration.....	13
3.5 Timescales for compliance.....	16
3.6 Monitoring and assessment.....	17
3.7 Assessment of the need for and level of purification treatment.....	18
3.8 Safeguard Zones.....	19
References.....	20
Annex 1 : Case studies.....	22
CASE STUDY – ITALY (Emilia Romagna Region).....	22
CASE STUDY : PORTUGAL Source Protection Zones and measures around a public water-supply in Golegã,	26
CASE STUDY – HUNGARY/ROUMANIA Maros/Mureş transboundary groundwater bodies - a multi-layered aquifer system.....	28
CASE STUDY – GERMANY (Lingen area) Delineation and use of safeguard zones	31

1. Purpose and Scope of guidance

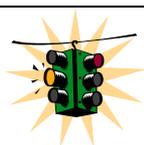
1.1 Introduction

This guidance explains the obligations for Protected Areas that apply to groundwater, in particular the requirements for Drinking Water Protected Areas (DWPAs) that are introduced under Article 7 of the Water Framework Directive (WFD). It does not cover the requirements of the source Directives under which individual Protected Areas are designated. The guidance explains the relationship between the objectives for protected areas and other WFD objectives. In particular it clarifies the requirements for DWPAs.

This guidance should be read in conjunction with existing CIS guidance, such as the horizontal guidance on the delineation of water bodies¹ and the companion guidance documents developed by the CIS Working Group C – Groundwater, in particular on groundwater monitoring².

1.2 Purpose of this document

- To provide a common understanding of the technical and scientific implications of the WFD regarding protected areas;
- Provide this in terms that can be understood by both regulators and those affected by the Directive's implementation;
- Clarify the groundwater aspects of the WFD's requirements for Protected Areas, where this is not already dealt with elsewhere, with a particular focus on the requirements for Drinking Water Protected Areas (DWPAs) and their associated safeguard zones;
- Highlight issues that may affect the management of cross-boundary aquifers and water bodies.



Look out! The methodology from this Guidance Document must be adapted to regional and national circumstances

The Guidance Document proposes an overall pragmatic approach. Because of the diversity of circumstances within the European Union, Member States may apply guidance in a flexible way in answer to problems that will vary from one river basin to the next. This guidance will therefore need to be tailored to specific circumstances.

¹ CIS Guidance Document No. 2 on identification of water bodies, European Commission, 2003

² CIS Guidance Document No. 15 on groundwater monitoring, European Commission, 2006

2. The Water Framework Directive's general requirements for Protected Areas

2.1 Areas defined under the WFD

Under Article 4 the environmental objectives of the Water Framework Directive (WFD) are divided into those for surface waters, groundwater and protected areas. For protected areas the objectives are those noted in the Community legislation under which these areas are designated, with the additional objective that "*Member States shall achieve compliance with the existing standards and objectives*" at the latest by December 2015, unless otherwise stated in the source legislation.

Annex IV of the WFD defines protected areas as areas designated:

1. For the abstraction of water intended for human consumption under Article 7 of the WFD – Drinking Water Protected Areas (DWPAs);
2. For the protection of economically significant aquatic species;
3. As recreational waters, including bathing waters under Directive 76/160/EEC;
4. As nutrient sensitive areas, including areas designated as vulnerable zones under Directive 91/676 and areas designated as sensitive areas under Directive 91/271/EEC; and
5. For the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection, including relevant Natura 2000 sites designated under Directive 92/43/EEC and directive 79/409/EEC.

For groundwater protected areas except DWPAs:

At the discretion of Member States¹, these may:

- be part of a groundwater body;
- extend over parts of two or more groundwater bodies;
- include areas that do not themselves comprise groundwater or surface water but contain habitats or species that depend directly on such water (e.g. some Natura Protected Areas); or
- coincide with the boundaries of groundwater bodies.

These areas must be reported in River Basin Management Plans.

The designation of **DWPAs** in accordance with WFD Article 6.2 and Article 7.1 has been prone to different interpretations discussed during the drafting of this guidance document. A first interpretation is that DWPAs may be delineated as "areas", while the second interpretation is that they are to be delineated as whole water bodies as noted under Article 7.1. This divergence of opinions mainly stems from terminologies used at national level in the Member States, which may have perceived consequences in term of protection measures. They may be summarised as follows:

- In the first interpretation, a DWPA may be an area which is part of a groundwater body, extend over parts of two or more bodies, or correspond to groundwater body boundaries. In this context, safeguard zones defined under Article 7.3 may not be needed in addition to the DWPA. Effectively the DWPAs become safeguard zones where measures are focused.
- In the second interpretation, DPWAs are whole groundwater bodies. The necessary protection measures may be focused (but not necessarily restricted) to zones around

actual of planned abstractions, i.e. safeguard zones, which are hence similar to DWPAAs defined in the first interpretation.

Regardless of which interpretation is used, the Article 7.3 objective to avoid deterioration in quality applies and the necessary protection is needed for those areas at risk of deterioration.

The second interpretation is adopted as a working basis in this guidance document. This implies, in summary, that:

1. DWPAAs are whole water bodies;
2. DWPAAs cover actual abstraction zones (safeguard zones) and other zones of potential abstraction;
3. Protection measures are focused on safeguard zones, normally linked to existing drinking water abstractions that are at risk of deterioration. This does not rule out wider measures over the entire DPWA, if a Member State wishes to provide protection, for example, to an area that is identified for future abstractions.
4. As noted in the new Groundwater Directive, safeguard zones may be part of a groundwater body (i.e. DWPA), may cover parts of two or more bodies, or cover the whole territory of a Member State.

The delineation of groundwater bodies (including bodies designated as DWPAAs), which are management units that are created to facilitate the achievement of WFD objectives, is entirely at the discretion of Member States. The requirements associated with DWPAAs may be a consideration in the delineation of a groundwater body. As stressed above, **safeguard zones** may also be delineated to focus protection measures in order to meet the objectives of Article 7 and in accordance with Article 4.2.

	<p>Look out! The existing terminology used in Member States for areas or zones used for drinking water protection may not be consistent with that in Article 7. In some Member States such areas are equivalent to “safeguard zones”. There is no need to alter existing designations provided that the relationship with WFD terminology is clear and the WFD objectives and measures are implemented.</p>
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2.2 Timescales for meeting objectives

Article 4(1)c of the WFD states that, for protected areas:

“Member States shall achieve compliance with any standards and objectives at the latest 15 years after the date of entry into force of this Directive, unless otherwise specified in the Community legislation under which the individual protected areas have been established.”

The objectives and standards of other Community legislation are thereby integrated into the WFD’s river basin planning system.

Unless an alternative date is given in the Community legislation under which a protected area has been established, the WFD introduces a date of 22 December 2015 for achieving the standards and objectives for that protected area.

2.3 Relationship of protected area to other WFD and GWD objectives

The objectives to implement the measures necessary to prevent or limit the input of pollutants to groundwater in Article 4.1(b)(i) and to reverse significant and sustained upward trends in 4.1(b)(iii) apply to all groundwater. The status objectives specified in Article 4.1(b)(i) and (ii) of the WFD apply to groundwater bodies. The objectives for protected areas specified in Article 4.1(c) of Article 4 apply to the areas designated under the source Directives (that is, those noted in section 2.1 above).

The standards and objectives for protected areas are distinct from status objectives. Measures to meet protected area objectives may be focused within, but not necessarily restricted to, those protected areas. Measures to meet the status objectives are applied, as necessary, over the whole groundwater body.

Article 4(2) of the WFD, states that where more than one objective applies to a water body, the most stringent objective shall apply. Within a protected area the most stringent of the protected area and, for example, the status objective would apply. Even if it were more stringent, a protected area objective should not apply outside the designated protected area.

Exemptions and derogations that apply to each of the WFD's environmental objectives, including protected areas objectives, will be discussed in the CIS drafting group on Exemptions and Environmental Objectives, and clear recommendations will be formulated in this respect in a separate CIS Guidance document.

Article 11 of the WFD requires Member States to establish a programme of measures in order to achieve all the Article 4 objectives, including the objectives for protected areas.

Finally, it should be mentioned that the new Groundwater Directive mentions the need to undertake research in order to provide better criteria for ensuring groundwater ecosystem quality and protection. This highlights awareness for considering groundwater as an ecosystem, while recognising that present knowledge is not sufficient to establish clear protection measures. According to Recital 20 of the directive, relevant findings will have to be considered in the context of the implementation or revision of the directive, meaning that related guidance documents will also have to be updated.

2.4 Registers of Protected Areas

Article 6 of the WFD requires Member States to establish a register of protected areas. The register (or registers) is limited to:

- *Areas lying within river basin districts....*
- *designated as requiring special protection under specific Community legislation....*
- *for the protection of their surface water and groundwater or...*
- *for the conservation of habitats and species directly depending on water.*

These registers should have been completed by 22 December 2004 and must be kept up to date. In the case of DWPAs, which have not previously been identified under other legislation, this implies that they should have been identified by this date.

3. Groundwater Drinking Water Protected Areas

3.1 Terminology

Article 7 of the WFD introduces but does not define certain terms. Guidance on these is given below:

- **abstraction of water intended for human consumption**

for the purposes of this guidance, groundwater taken from the groundwater body and intended for drinking, cooking, food preparation or other domestic purposes. In addition, water used in any food-production undertaking for the manufacture, processing, preservation or marketing of products or substances intended for human consumption, unless the competent national authorities are satisfied that the quality of the water cannot affect the wholesomeness of the foodstuff in its finished form.

Note: This definition is taken from the Drinking Water Directive (98/83/EC). It includes water abstracted for public or private drinking water supplies, direct inclusion within food (e.g. brewing and canning), but not water intended for indirect uses such as spray irrigation.

- **safeguard zone**

normally, an area within a groundwater body (designated as DWPA) that may be significantly smaller than this body, where measures can be focused to protect groundwater that is abstracted for human consumption from deterioration in groundwater quality (see section 3.4). In some circumstances, for example in karstic aquifers, safeguard zones may be as large as or may extend beyond the boundary of a groundwater body (see further discussion of safeguard zones in section 3.7). Safeguard zones may also cover the whole territory of a Member State (Recital 15 of Directive 2006/118/EC).

3.2 Identification and Delineation of DWPA's

Article 7.1 states that Member States shall identify, within each river basin district:

“all bodies of water used for the abstraction of groundwater intended for human consumption providing more than 10 m³ a day as an average or serving more than 50 persons, and

those bodies of water intended for such future use”

Whole groundwater bodies must be so designated under this provision and this is confirmed by section 4 of Reference 1.

Note: As highlighted in section 2.1, this does not mean that the objective under Article 7.3 of the WFD must be met at all points over a groundwater body or that measures must be applied equally over the whole body (see sections 3.4- 3.8 of this guidance).

The wording “10m³ a day as an average” suggests that the whole of the water body should be able to supply 10m³/day. The alternative qualification, to supply more than 50 persons, confirms this interpretation (Note: although this wording is similar to that used in the DWD, it is used in a different context). Allowing for variations in water usage and size of households across the Community, these limits approximate to the supply of water for potable purposes to between 10 and 20 households within a groundwater body.

There are no constraints on the size of groundwater bodies in the WFD - they are management units that are delineated at the discretion of Member States, as noted in Ref.1. However, the

administrative requirements under the WFD, including reporting, encourage the creation of quite large groundwater bodies or groups of groundwater bodies. Typically these are many tens to many hundreds of square kilometres in size. The need to protect drinking water is only one of many potentially competing factors that may be considered in the delineation of groundwater bodies.

	<p>Look out! Many groundwater bodies in a Member State may need to be designated as WFD - DWPAs. This does not mean that it is necessary to apply protection measures to meet Article 7 objectives equally over the entire land area of these WFD – DWPAs. Safeguard zones may be used to focus measures to protect groundwater abstracted for human consumption and thereby meet the requirements of Article 7.3 and Article 4.1(c).</p> <p>Existing (pre-WFD) protection areas that have been identified under Member States legislation or guidance may be similar to safeguard zones and could be used to meet Article 7 objectives.</p>
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The requirements to identify groundwater bodies that are “intended for such future use” under Article 7.1 and to compile a register of such areas under Annex IV of the WFD, indicate that Member States should designate such bodies as a resource of water intended for human consumption in the future. At present there may be no such use or the total existing abstraction may be less than the limits noted above. If, within the planning horizons of the WFD, such use may reasonably be anticipated (based on both the hydrogeological properties of the aquifer and the potential use), then the groundwater bodies should be identified as intended for such future use.

3.3 Meeting the requirements of the Drinking Water Directive (DWD)³

Article 7.2 of the WFD states that “*in addition to meeting the objectives of Article 4.....Member States shall ensure that under the water treatment regime applied, and in accordance with Community legislation, the resulting water will meet the requirements of directive 80/778/EEC as amended by Directive 98/83/EC.*”

(Note: in practice Directive 98/83/EC replaces Directive 80/778/EEC).

This confirms that:

- the Article 4 objectives (that is, status, prevent or limit, implementation of trend reversal and other protected area objectives) must be met independently of meeting the Article 7.2 objective; and
- the requirements of the Drinking Water Directive (DWD) must be met. This includes a general requirement to ensure water is free from contamination that could constitute a danger to human health **and** the requirement to comply with formal DWD standards at the point of delivery to consumers (i.e. the tap).

Note: *references to meeting DWD standards in the remainder of this guidance should be taken to mean compliance with both of these requirements.*

Not all abstractions of water intended for human consumption may be subject to the DWD. As permitted under the DWD, a number of Member States have chosen to exempt **individual**

³ Council Directive 98/83/EC on the quality of water intended for human consumption.

sources that provide less than 10m³ a day as an average or serving less than 50 persons from this Directive. On this basis, not all abstractions within a DWPA will be required to meet the DWD and therefore Article 7.2 of the WFD.

Note: this exemption of individual sources is quite different in effect from the application of similar wording in Article 7.1, described above, which defines which water bodies are DWPA's).

The point of compliance for Article 7.2 is the same as that noted in the DWD, that is, the point at which the drinking water is used for human consumption. Under Community legislation the quality standards noted in the DWD do not apply to the raw (untreated) water abstracted from the groundwater body. However, Member States may have their own legislation that applies quality standards to raw groundwater in such circumstances and in practice there are many supplies within the EU where groundwater is abstracted and used as water intended for human consumption without purification treatment.

The requirements of Article 7.2 do not introduce any new objectives for Member States and the timetable for meeting the requirements is set out in the Drinking Water Directive.

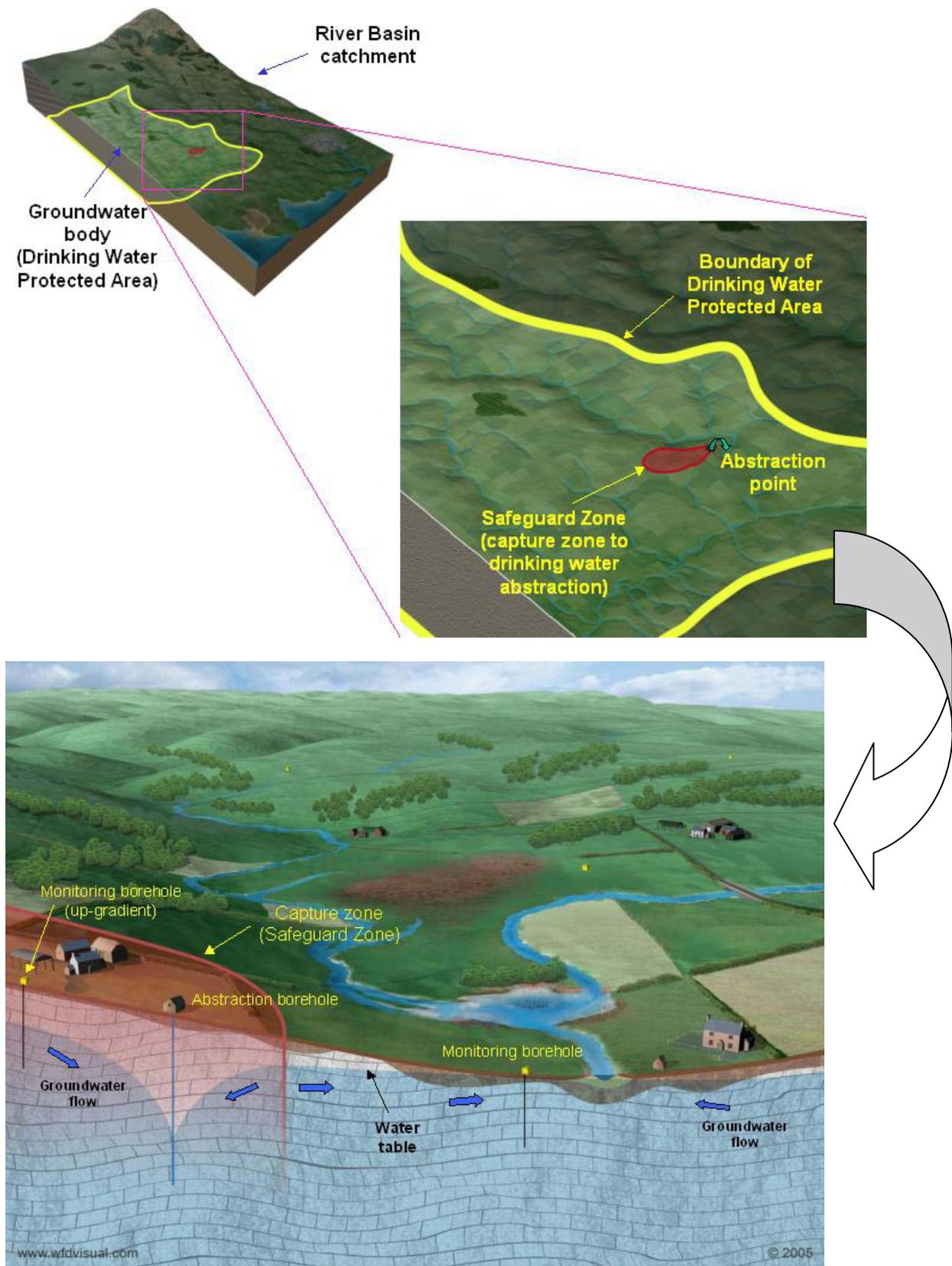


Figure 1 : Potential relationship between a groundwater Drinking Water Protected Area and a Safeguard Zone.

3.4 Necessary protection and avoiding deterioration

Under **Article 7.3** of the WFD, Member States shall ensure the necessary protection for groundwater bodies identified as DWPAs “with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water. Member States may establish safeguard zones for those bodies of water.”

In practice, avoiding deterioration in the quality of a groundwater body would not in itself necessarily result in the reduction in the level of purification treatment that may be required to produce drinking water. An improvement in quality would be needed to reduce treatment. However, it is clear that there is an intention to avoid deterioration in groundwater quality, as a minimum. Ideally, the protection should be sufficient that, through time, purification treatment can be reduced. The second sentence in Article 7.3 allows Member States, at their discretion, to establish safeguard zones within which the necessary protection may be focused. In a number of Member States these are what are commonly understood to be “drinking water protection zones”. They are discussed in more detail in section 3.8 and Annex 1.

When is deterioration significant?

Benchmark data on existing groundwater quality are needed against which deterioration may be assessed. These may be derived from existing data and from the monitoring programmes set up under the WFD, as described in section 3.6 below. As exceedence of a drinking water standard for a single contaminant may trigger the need for purification treatment it follows that the assessment of deterioration should be conducted for individual parameters. A benchmark is needed for those contaminants that could be at risk of deterioration, against which future trends can be assessed. The aim is to prevent deterioration arising from anthropogenic pressures in any contaminant that could require additional treatment in order to meet drinking water standards.

Fig. 2 illustrates a case where treatment is already installed to deal with an existing water quality problem (which may arise from natural or anthropogenic contamination), so that the drinking water standard can be met for contaminant 1. This treatment could also deal with a future deterioration in contaminant 2. However, this disguises the fact that there has been a significant deterioration in raw water quality. The aim of preventing deterioration has not been met.

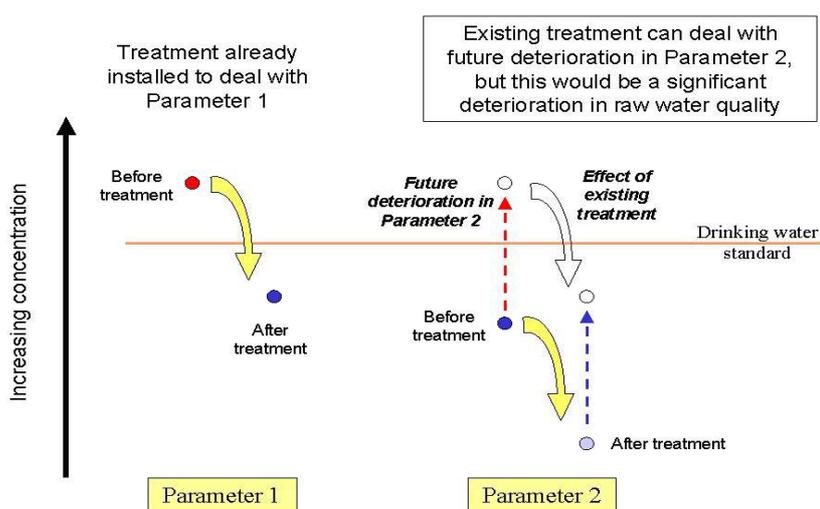


Figure 2: Significant deterioration in groundwater quality at an abstraction source when purification treatment is already installed.

Improvements in quality

The consequences of failure to supply wholesome and clean water are serious for both the supplier and the consumer of drinking water. In practice, a small improvement in untreated water quality would not necessarily reduce the level of treatment. Once purification treatment has been installed, a sustained improvement in quality is likely to be necessary to give sufficient confidence to the supplier (and the consumer) that such treatment is no longer necessary and can be decommissioned.

In Article 11(3)(d) of the WFD it is noted that basic measures in a programme of measures for a River Basin District should include:

“measures to meet the requirements of Article 7, including measures to safeguard water quality in order to reduce the level of purification treatment required for the production of drinking water”

Whilst this clearly indicates an aspiration to reduce the level of treatment, it is not in itself an absolute obligation to do so.

The term “aim of avoiding” in Article 7.3 of the WFD indicates that Member States should use their best endeavours to ensure the necessary protection to groundwater. However, best endeavours may have been taken and yet deterioration in quality due to anthropogenic influences cannot be avoided. This may arise where there is a long time lag between the source of pollution and any impact at a receptor, as a consequence of slow flow within the subsurface environment. The source of pollution may predate the WFD or other legislation requiring its control and this source may now have been removed, but there is still residual groundwater pollution. In addition, it may not be technically feasible or it may be disproportionately expensive to remove the pollution in the groundwater.

In such circumstances it would not be reasonable to expect Member States to undertake further measures to protect the drinking water abstraction if all measures that were feasible have been taken. The installation of treatment or an additional level of treatment may still be needed to ensure the continued supply of drinking water and to meet the requirements of the DWD.

A further option - closure of the drinking water source – should in itself be considered as an indicator that the aims of Article 7.3 may not have been met, but only where there is deterioration in quality due to anthropogenic effects. In many cases closure of a drinking water supply may not be feasible as an alternative supply may not be available; purification treatment may be unavoidable.

Necessary protection

Protective measures may not need to be applied equally over the whole of a groundwater body in order to meet the requirements of Article 7.3. The WFD envisages the use of safeguard zones within which measures may be focused for these purposes (section 3.8).

Member States have total flexibility in terms of how they delineate and apply safeguard zones but in principle these zones should be risk-based so that any necessary measures are most effective in reducing the impact of human activities on the quality of the abstracted groundwater. Vulnerability mapping and/or travel-time methods are already used in many Member States as methods of delineating zones with different levels of risk, where specific protection measures may be focused.

Note: there are proposals under discussion to introduce Water Safety Plans under the DWD which would include integrated quality assurance procedures from catchment to consumer. In terms of effect, the proposals are similar to the requirements of Article 7 of the WFD, but the links should be clarified.

	<p>Look out! There is a potential link between the identification of DWPAs and in particular the delineation of safeguard zones and necessary protection measures with the proposed Water Safety Plans under the Drinking Water Directive.</p>
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Compliance points

A compliance point is needed in order to assess whether the necessary protection has been provided. If this point was at the consumer point of use (the tap) then it would be possible for multiple water sources over a wide area to be blended prior to supply, thus masking any deterioration in groundwater quality and any inadequate protection measures.

Equally, it would be impractical to monitor and assess compliance at all points within the groundwater body. As the aim is to assess deterioration in the quality of abstracted water, the compliance point should be close to where groundwater is abstracted and before any purification treatment has taken place. A certain amount of blending to even out raw water quality within a well field may be acceptable, or unavoidable given the nature of the infrastructure used for abstraction. However, the mixing of water from different well fields/production sites could obscure significant and sustained changes in groundwater quality.

	<p>Look out! Member States should ensure that raw water quality monitoring is representative and sufficient to ensure that significant and sustained changes in groundwater quality due to anthropogenic influences can be detected and acted upon. Compliance points should be set at appropriate locations to detect such changes.</p>
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Application to future abstractions

Where there is no existing use of the groundwater for drinking water supply but future use is planned, it is impractical to assess whether or what level of purification treatment is required until testing has been undertaken at the proposed point of abstraction. Therefore, it is advised that a baseline quality and level of treatment needed to deal with anthropogenic influences should be determined at the time that the proposed drinking water supply is being developed and initially tested. Compliance with the objective in Article 7.3 should be assessed against this baseline.

Summary interpretation of Article 7.3 requirements

By taking groundwater protection measures that are technically feasible and proportionate, Member States shall use their best endeavours to ensure that groundwater quality does not deteriorate at the point of abstraction for drinking water supply, so that there is no need to increase the level of purification treatment.

The risk of deterioration should be assessed for all individual parameters. If treatment has been installed for one parameter, other parameters that can also be dealt with by that treatment should not deteriorate to the point where treatment for these is also necessary.

Purification treatment may be in place to deal with poor natural quality and quality changes brought about by human activities. Member States should provide protection to groundwater with the aim of giving sufficient confidence to suppliers (and consumers) of drinking water that the level of purification treatment needed to deal with anthropogenically induced changes in groundwater quality can be reduced through time and ideally eliminated altogether. This may be achieved by groundwater protection measures (which may be focused using safeguard zones) and the monitoring of raw groundwater quality to demonstrate significant and sustained improvements (trends).

3.5 Timescales for compliance

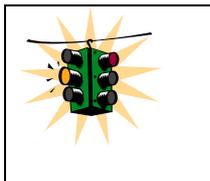
As noted earlier, DWPAs should have been identified and placed on a register by 22 December 2004.

There are no explicit timescales in Article 7.3 of the WFD to indicate the starting point at which any deterioration in groundwater quality should be assessed and by when the necessary protection should be in place.

Where sufficient existing groundwater quality monitoring data are available to define a baseline quality from which deterioration may be assessed, it is recommended that the starting point should be based on these data, with the aim of preventing any further deterioration in quality from this baseline. However, where existing data are not sufficient then assessment may wait until sufficient data from the WFD monitoring programmes are available.

In practice, it may take some time to collect sufficient data to establish both a coherent picture of the natural background water quality over the groundwater body and the trends in quality at the points where water is abstracted for human consumption. To reliably determine a deterioration in untreated water quality from the established starting point (in effect a significant and sustained adverse trend) may take several years.

The above does not imply that the necessary protection for DWPAs and safeguard zones should not be in place at an early stage. In most instances protective measures will take the form of measures to prevent or limit the inputs of contaminants to groundwater. The existing Groundwater Directive (80/68/EEC) along with the new Groundwater Directive (2006/118/EC) and other Community legislation that contributes to groundwater protection are in force. Member States should already have substantial groundwater protection programmes in place to meet these requirements; these should be maintained and extended to meet the requirements of the WFD and of the GWD. Any necessary additional measures should be drawn up and incorporated in the draft River Basin District plans by December 2008 and fully implemented by December 2012, in accordance with Articles 11 and 13 of the WFD.



Look out! Existing groundwater protection programmes should be maintained with the aim of preventing deterioration in groundwater quality whilst the collection of sufficient monitoring data and the assessments of baseline quality and trends are being conducted.

3.6 Monitoring and assessment

It is essential that the monitoring for DWPAs is integrated with the operational and surveillance groundwater monitoring programmes that are required under Annex V of the WFD. Details of the monitoring requirements for DWPAs are given in the Groundwater Monitoring Guidance². However, some key issues are noted below.

Article 7.1 of the WFD states that:

“Member States shall monitor, in accordance with Annex V, those bodies of water which according to Annex V, provide more than 100 m³ a day as an average.”

The 100 m³ a day threshold should be interpreted as the sum of all the abstractions for human consumption over the entire groundwater body.

Article 7.2 states that the DWD objectives must be met for abstracted water to be used for human consumption. To do this the range of parameters that are assessed under this Directive may need to be taken into account, to assess whether there is a risk of deterioration in these parameters.

Via references to and the definitions of “pollutants” and “pollution”, most of the WFD’s objectives apply only to substances, which excludes biological parameters. However, **Article 7.3** does not make reference to pollutants and instead refers to “quality” (Note: for this reason “contaminants” is used in this text, rather than “pollutants”, and this includes microbiological parameters and both chemical and radioactive substances).

Member States may need to consider whether the additional parameters noted in the DWD need to be monitored in untreated water, taking into account any risk of deterioration in these parameters.

New contaminants may be present that have no formal drinking water standard, but may affect the use of the groundwater for human consumption. Additional monitoring and assessment may then be needed, where a risk has been identified.

Where there is a risk from anthropogenic sources of contamination, the parameters that are monitored in treated water should also be monitored in the untreated groundwater at the abstraction point. In principle, this may include those chemical, radiological and microbiological parameters monitored under the DWD.

The monitoring programme for DWPAs does not necessarily require the same intensity of monitoring that is required by the DWD. It is recommended that, for those abstractions that are subject to the DWD, there should be monitoring of untreated groundwater for all the parameters noted in the DWD at least once every six years (the planning cycle of the WFD). For parameters where there is a risk of deterioration, monitoring should be more frequent and in accordance with

recommendations expresses in the Groundwater Monitoring Guidance². Abstractions may be grouped for these purposes, provided that the monitoring is representative.

In determining the scope and frequency of any necessary monitoring, consideration should be given to the likely risks of contamination, any actual impacts on groundwater and surface waters from human activity, and the hydrogeological characteristics of the groundwater body². For example, for a group of abstractions it may be appropriate to monitor one abstraction that is representative of the whole group and also the abstraction that is most at risk.

3.7 Assessment of the need for and level of purification treatment

Purification treatment to meet the DWD or any other requirements for human consumption may be installed at a drinking water source to deal with both contamination by naturally occurring substances and anthropogenic impacts.

In practice it may be difficult to attribute a current level of treatment to a particular contaminant and then assess whether the level of treatment has increased due solely to the anthropogenic component of this contaminant. This will be particularly the case where the substance is commonplace in the natural environment (e.g. chloride, sulphate, arsenic). Treatment systems are also complex to assess.

Given the above and the emphasis in Article 7.3 on avoiding deterioration in groundwater quality, Member States are advised that they should focus on whether there have been significant and sustained changes in untreated groundwater quality at the abstraction point, as determined from monitoring programmes. If there are no such changes it is a reasonable assumption that no changes in treatment level are needed.

If there are significant and sustained trends and treatment is already installed, in most cases any further deterioration will have implications through time for the level of treatment (see below). Where drinking water standards are not yet exceeded and treatment is not yet installed, the potential future deterioration and its implications for treatment should be assessed.

Note: in this context a significant change in untreated groundwater quality would be a change in an individual parameter that would, now or in the foreseeable future (e.g. one or two WFD planning cycles) result in the need for purification treatment in order to meet drinking water standards.

Only if there is evidence of significant changes in the untreated water quality that can be attributed to an anthropogenic impact should the impact on the level of treatment at the abstraction need to be assessed. In this way the collection and assessment of additional data can be minimised.

In assessing changes in the “level” of purification treatment, knowledge of the treatment process would be required (this may include which parameters it was installed to treat, to what extent, and the use of consumable materials such as chemicals).

It is difficult to give firm guidance on the issue of what constitutes a change in the level of treatment, but Member States are encouraged to take into account the following factors, on a case-by-case basis:

- The timescale over which the potential increased treatment is necessary – is it a temporary or long- term increase?
- What is the overall trend in the use of treatment at the site?

- Is new equipment required?
- Are any changes in equipment or chemicals aimed at increased or simply more efficient treatment? A change in treatment process may reflect changes in technology and not an increased level of treatment as such.
- If blending of different sources takes place, what is the purpose? Is this an indicator that there is a significant and sustained change in raw water quality within the DWPA?

Information on the disruption to, closure and abandonment of existing drinking water supplies due to anthropogenic contamination should be collected so that such evidence can be used to provide a back up to the monitoring system, which despite best endeavours, may not always detect contamination incidents. These data may also be used to assess whether any necessary protection measures are being effective.

It should be noted that changes in groundwater quality may be induced not only directly by the release of pollutants but also by the effects of abstraction. These effects should also be taken into account.

3.8 Safeguard Zones

As noted above, Article 7.3 indicates that Member States may establish safeguard zones to assist in meeting the requirement to ensure the necessary protection of DWPAs. The establishment of such zones is thus at the discretion of Member States.

Safeguard zones can be used as a practical means of focusing protection measures for the abstraction of water for human consumption. Given the size and extent of most groundwater bodies this option is recommended so that, where appropriate, specific protection measures can be directed to give the greatest effect – in this case to protect the groundwater catchments (capture zones) for those points (sources) where groundwater is abstracted for human consumption.

It follows therefore that safeguard zones could in many cases be significantly smaller than groundwater bodies and that there could be a number of such zones within a groundwater body. However, in some circumstances, such as karstic aquifers, safeguard zones may need to be quite large, reflecting rapid flow and extreme groundwater vulnerability. Safeguard zones may even need to be extended beyond the boundaries of the groundwater body and also include associated “upstream” surface water bodies, reflecting the capture zones of the drinking water abstractions. Finally, Member States may decide to establish safeguard zones covering the whole of their territory in order to protect drinking water supplies (Recital 15 of Directive 2006/118/EC).

The size of a safeguard zone could therefore vary according to:

- hydrogeological properties of the aquifer. For example, within a highly porous aquifer the capture zone for an abstraction may be relatively small. Within a low porosity aquifer the capture zone may be extensive;
- the size of the abstraction for human consumption;
- the type of pollutant and the sources of contamination for which protection measures are necessary. In principle, larger safeguard zones may be needed for persistent contaminants arising from extensive diffuse sources, in comparison with readily attenuated contaminants arising from small point sources;

- whether the safeguard zone was based on a time of travel to the abstraction or the extent of the capture zone. In principle, capture zones are more appropriate for focusing measures to deal with persistent contaminants, whereas time of travel zones are more appropriate for readily attenuated contaminants.
- the vulnerability of aquifers. For example, where there is a low permeability cover close to the abstraction, the capture zone may be extensive and the highest risk areas may be some distance from the abstraction, where the vulnerability to contamination from the surface is higher.

Many Member States already use groundwater protection zones for a variety of purposes, based on the above principles. Case studies that illustrate their delineation and use are given in Annex 1. Most schemes focus on abstraction points that are used for drinking water and in particular those sources where the water supplied to consumers is subject to the DWD. They could be readily adapted for the purposes of delineating safeguard zones for the purposes of Article 7.3 of the WFD. Highly fissured or karst areas may need additional consideration and special methods when delineating safeguard zones.

Particularly where abstractions are very small (for example, for supply to isolated dwellings/single properties), the location and maintenance of records of all such supplies may be difficult and site-specific protection measures may not be practical. Equally, the provision of groundwater protection measures over a whole groundwater body may be unnecessarily restrictive. For example, the imposition of precautionary measures for a readily attenuated contaminant over the entire groundwater body may prevent many commonplace human activities. This may be unnecessary to maintain the quality of water abstracted for human consumption.

A risk-based approach to the delineation of safeguard zones is suggested for use by Member States to give the most cost-effective protection to abstractions for human consumption and to highlight to stakeholders that groundwater protection is particularly important in areas where groundwater is exploited for such use. An example of such a scheme is given in Table 1. The aim is to relate safeguard zone delineation to both the presence and type of abstractions for human consumption and the risk to these abstractions from human activities.

References

1. Common Implementation Strategy for the WFD – Identification of water bodies: horizontal guidance, CIS Guidance Document No. 2, January 2003.
2. Common Implementation Strategy for the WFD – Guidance on Groundwater Monitoring, CIS Guidance Document No. 15, December 2006.
3. Protecting Groundwater for Health. Managing the Quality of Drinking Water Sources. WHO/IWA publication. 2006.

Table 1: Example of a scheme to delineate safeguard zones around individual or groups of abstractions for the purposes of Article 7.3 of the WFD

	Anthropogenic Pressures	Monitoring	Zones and measures
Type 1 Low Risk General protection	Insignificant e.g. designated not at risk during characterisation, low density of population and human activity in general.	No additional strategic monitoring. (WFD operational and surveillance monitoring only).	Minimum arbitrary zones. e.g. precautionary measures such as codes of practice applied within 50m radius around abstraction.
Type 2 Moderate Risk Precautionary Protection	Moderate e.g. WFD characterisation has identified risks but no evidence of declining groundwater quality	Monitoring of abstraction sources and possible additional precautionary monitoring targeted on identified risks.	Consider establishing time of travel and/or capture zones. Appropriate precautionary measures focused on identified risks.
Type 3 High Risk Specific protection	High e.g. evidence of deteriorating water quality	Specific monitoring in safeguard zone (both abstraction and groundwater within zone). Monitoring to be designed to determine effectiveness of measures.	Site-specific time of travel and/or capture zones recommended. Measures within these specifically to address sources of contamination.

Note: in all cases the size of the abstraction and the risks within the capture/time of travel zone to this abstraction should be taken into account. This should include a consideration of the vulnerability of the aquifer within the zone.

Annex 1: Case studies

CASE STUDY – ITALY (Emilia Romagna Region)

Groundwater protected areas identification and measures enforcement

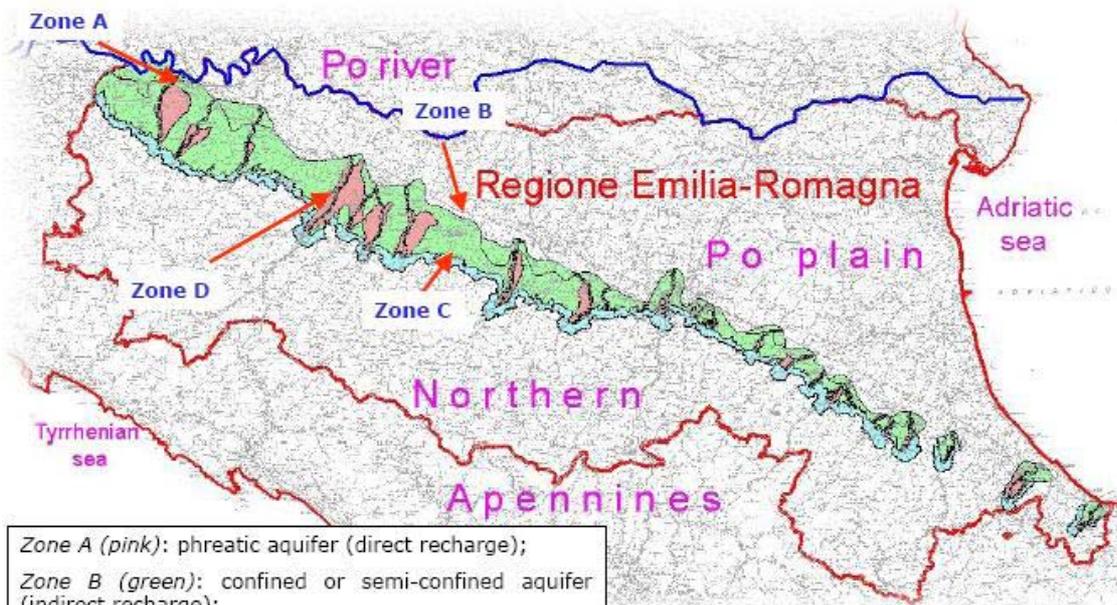
Type of case study: Implementation of existing regulations in Italy
Web-Links: http://www.camera.it/parlam/leggi/deleghe/testi/99152dl.htm http://www.sogesid.it/allegati/accordo_conferenza_permanente_12_12_2002.pdf
Objective of case study: drinking water quality protection and improvement
WFD focus: Protection of groundwater for human consumption.
Specific contributions: Safeguard zone and protected area definition
<p>Characterisation</p> <p>Italian law (D.Lgs. 152/99, Art.21, paragraph 1) states that, in order to protect and improve the quality of groundwater resources intended for human consumption, Regions (Italian administrative units) must identify safeguard zones, within which measures and restrictions can be enforced in order to assure the protection of groundwaters.</p> <p>Safeguard zones are divided into: 1. “absolute guardianship zone” (an area of at least 10 m radius immediately surrounding the abstraction point); 2. “respect zone” (the territory surrounding the absolute guardianship zone, identified by a travel time of 180 to 365 days, depending on vulnerability and hazard conditions, or at least with a radius of 200 m from the abstraction point); and 3. “protection zones”, identified within the groundwater recharge areas. The protection zone is based on hydrogeological, hydrochemical and hydrological analysis. Vulnerability to pollution is also taken into account. Specifically, spring protection zones correspond to the entire recharge area.</p> <p>The “absolute guardianship zone” and the “respect zone” have already been delineated in most cases, while Regions are establishing protected areas. In a few cases protected areas have been already identified and protection measures are in force. Emilia Romagna Region has identified the main groundwater protected areas consisting of over 2850 km² out of the 22,000 km² (13%) of the entire administrative territory, subdivided into 4 sub-zones with different characteristics (Fig.1).</p>  <p>Zone A (pink): phreatic aquifer (direct recharge); Zone B (green): confined or semi-confined aquifer (indirect recharge); Zone C (light blue): watersheds recharging the zone A; Zone D (dashed): riverbed.</p>

Figure 1: Drinking water protected areas in Emilia Romagna.

The Po river alluvial plain extends in the northern part of the Emilia Romagna region over 12,000 km². Three different groundwater bodies have been recognised in this plain, among which the “Apennine river alluvial fans” could be considered as the priority groundwater bodies for chemical and quantitative features. Recharge areas are located along the southern margin, where the aquifers are unconfined; towards the north they become multilayered and confined (Fig.2).

Drinking water protected areas have been identified in the recharge areas as shown in Fig.1 and in the schematic cross section in Fig. 2. Protection areas extend beyond the boundaries of the groundwater body in order to include the impervious basins upstream of the fans that can indirectly contribute to the recharge of the aquifers (zone C in Fig.1).

Protection measures applied

The protection measures, organised in a Regional Plan, vary depending on the characteristics of the zones of the protected areas (A, B, C, D in Fig.1). They concern agriculture and cattle breeding activities (manure spreading, fertilisers and pesticides use), quarrying activities, urbanisation (sewage networks, waterproofing), industrial activities (also in relation to quantitative aspects) and landfill location. Hazardous activities in relation to water quality must be specifically authorised. Measures and rules have been discussed and modified through a participatory process in which public and private stakeholders (water companies, agriculture associations, industry representatives, environmental organisations and others) have been involved.

Pollution indicators (e.g. NO₃) have been selected and monitoring activities have been undertaken in the protected areas in order to check the effectiveness of the adopted measures. The possibility of introducing corrective actions during the implementation of the Plan has been foreseen. Additional drinking water protected areas are being identified in the Region by other administrative boards for minor groundwater bodies.

Experiences gained – Conclusions - Recommendations

The large involvement of stakeholders in the definition of measures and restrictions to be adopted has been a fundamental part in the implementation of protected areas, leading to the general acceptance of the plan.

Outlook - Accessibility of results

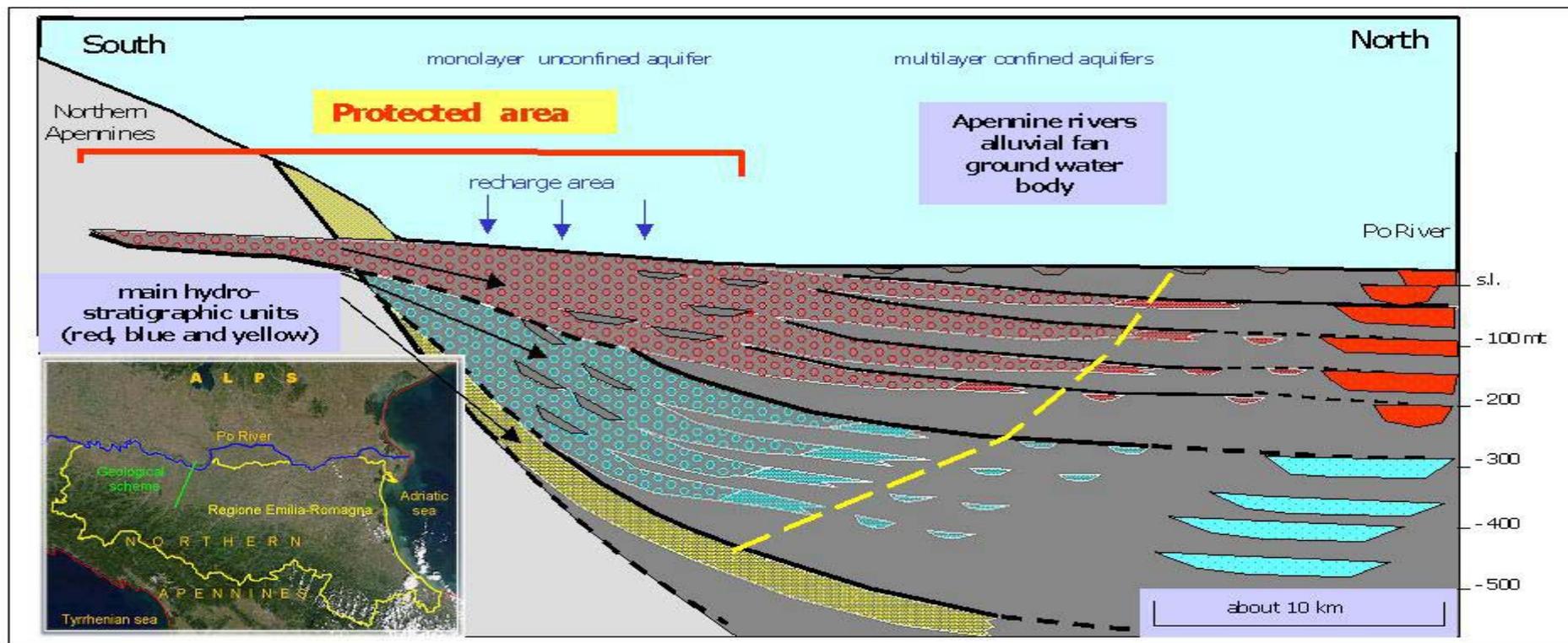
<http://www.regione.emilia-romagna.it/geologia/> (Italian and English language)

<http://www.ermesambiente.it/PianoTutelaAcque/> (Italian language)

Next steps:

Other Regions in Italy are currently implementing the national regulations and are delineating areas for the protection of groundwater for human consumption. Measures to be applied and delineation procedures are in fact entrusted to Regions, whereas the general criteria and the objectives are established by the national legislation.

Figure 2: Location map and schematic cross section of the aquifers showing the protected areas for the “Apennine river alluvial fan” groundwater body.



CASE STUDY : PORTUGAL Source Protection Zones and measures around a public water-supply in Golegã,

Type of study: Groundwater protection zone identification and enforcement of measures.

Web-Link: http://snirh.inag.pt/snirh.php?main_id=1&item=3.4&objlink=&objrede=

Objective of case study - to indicate how comply the Portuguese legislation is used in drinking water quality protection and groundwater supply management at two wells in Golegã

WFD focus : Protection of groundwater for human consumption, groundwater monitoring

Specific contributions : groundwater quality assurance, protection zones

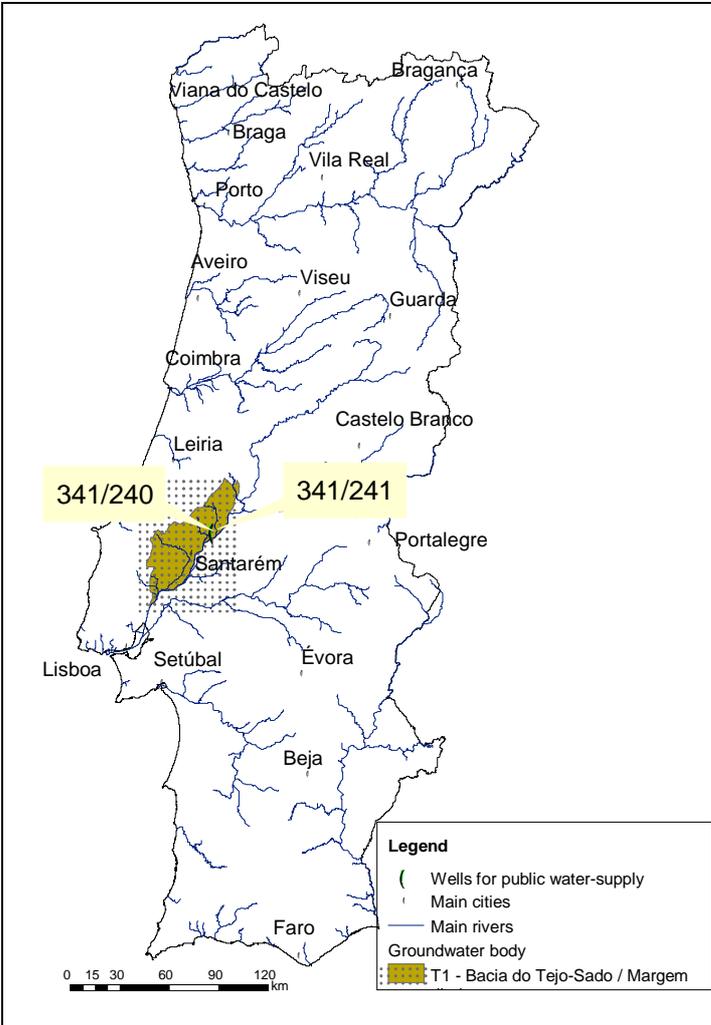
Characterisation

Two wells, with the national code 341/240 (JK1) and 341/241 (JK2), are in a porous aquifer system called “Bacia do Tejo-Sado / Margem Direita”. This aquifer system is confined and composed of alternating sandstones and clays. The JK1 well is 226.5 m in depth and the JK2 well is 230.5 m in depth.

The local groundwater flow direction is from NNW to SSE. This means that, to account for possible plume spread, the intermediate and outer protection zones will have an elliptic shape developed along the opposite direction to the groundwater flow. The inner zone has a polygonal shape.

In this case, a simple method (Jacobs and Bear) was used to define the source protection areas, mainly the intermediate and outer areas. It is necessary to know the transmissivity (T), pumping rate (Q), residence time (t) (t=50 days for the intermediate zone and t=3500 days for the outer zone), saturated thickness (b), effective porosity (m_e) and hydraulic gradient (i). The travel time(t_R) is calculated by the formula:

$$t_R = \frac{2T^2 i^2}{m_e Q b} t$$



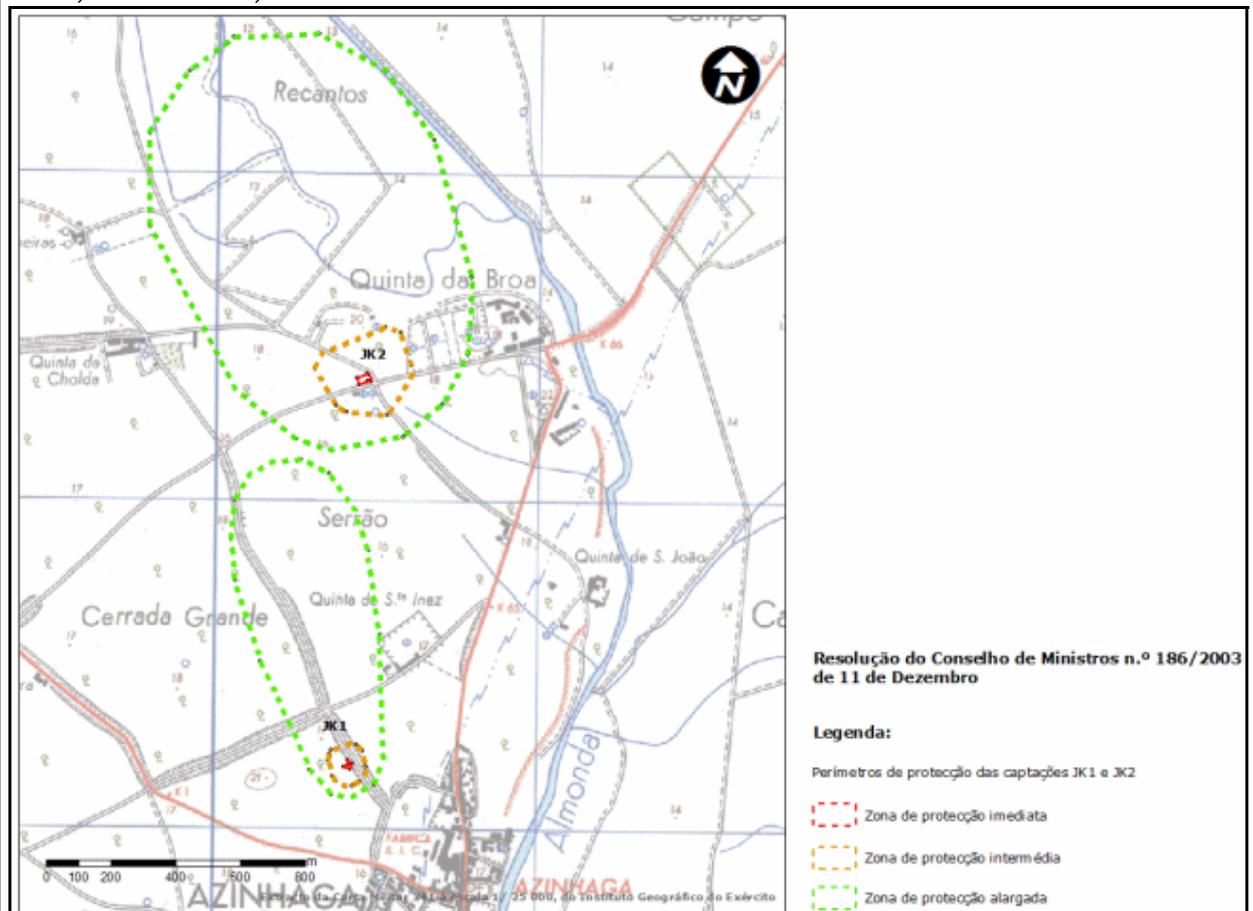
The inner zone was already defined by the groundwater supply management authority, with a polygonal shape. It was decided to maintain this because it was proven that the area is sufficient to protect the wells.

The three source protection zones are defined as shown by the sketch below: The red line is the inner protection zone; in orange the intermediate zone and the green line, the outer

zone. The areas are, for JK1, the inner zone: 263 m², intermediate zone: 0,01 km², outer zone: 0,34 km²; JK2, the inner zone: 780 m², intermediate zone: 0,06 km², outer zone: 0,95 km².

After the zones were defined, it was necessary to establish which activities or facilities, within the different protection zones, were to be restricted, in order to avoid pollution.

For each protection zone, the Portuguese legislation states in its 6th article which activities or facilities are forbidden or restricted. Accordingly, in the inner zone all the activities or facilities are forbidden except those meant to preserve the well. A fence must be installed. In the intermediate zone, for example, septic tanks, waste scrapyards and aeronautic installations are forbidden. The use of persistent and mobile pesticides, roads, railways, wastewater treatment plants (WWTPs), cemeteries, may occur within this protection zone only if its proven that they consist of no threat of pollution to groundwater. For the outer zone, septic tanks, landfills and chemical industries are forbidden. The lakes and the new wells, for instance, are conditioned.



These two wells belong to the national surveillance monitoring programme. Samples of raw water are taken twice per year. 48 different parameters are monitored.

Experiences gained - Conclusions - Recommendations

Groundwater is a very important natural resource in Portugal, accounting for nearly 60% of drinking water supplies. Protection of both quality and quantity is a priority. One of the strategies used in groundwater protection for public water supply is the definition of source protection zones. This framework is very important and needs to be integrated with monitoring programmes and other preventive practices to maintain good groundwater quality.

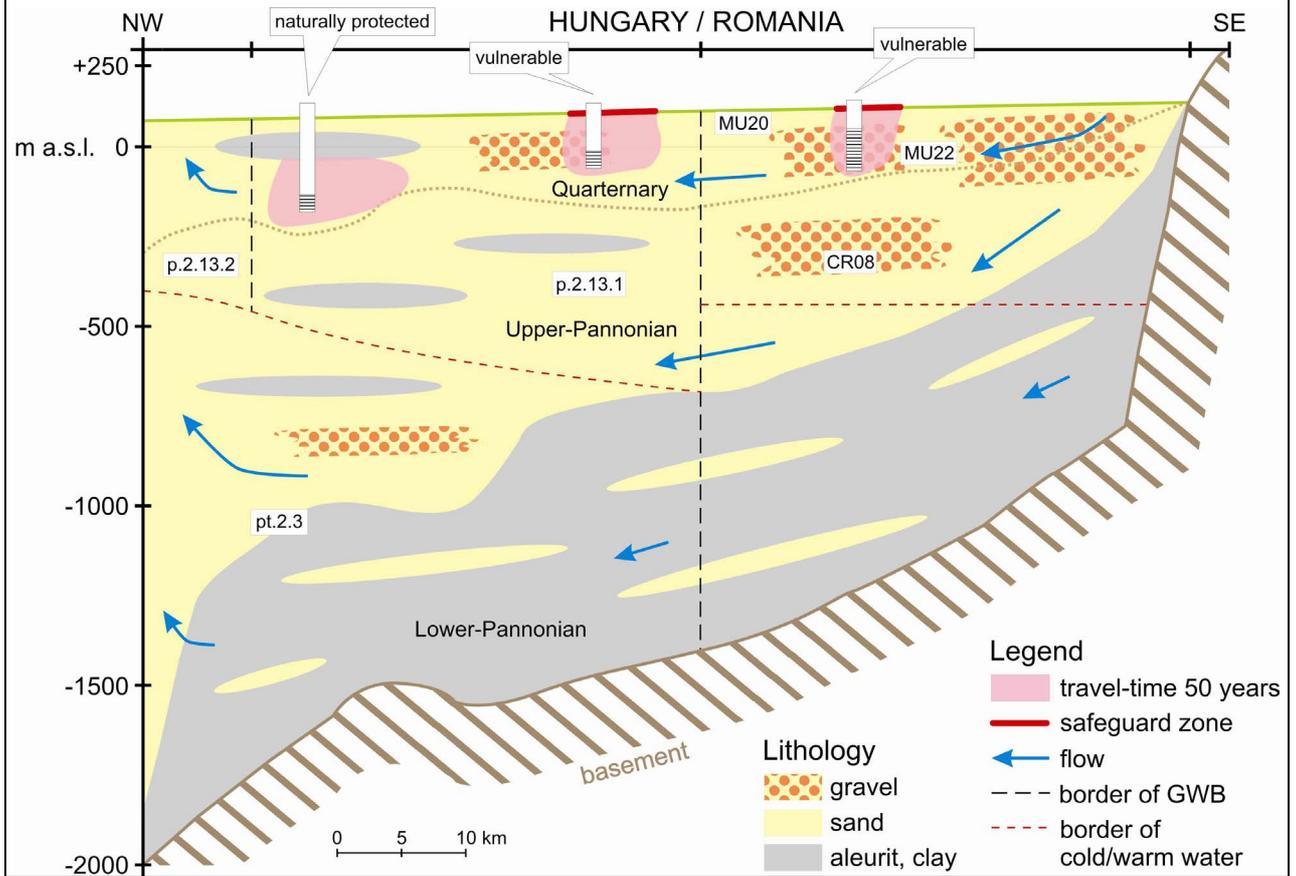
Outlook - Next steps - Accessibility of results

Data are available at http://snirh.inag.pt/snirh.php?main_id=2&item=1.1&objlink=&objrede= (Portuguese language)

CASE STUDY – HUNGARY/ROUMANIA Maros/Mureş transboundary groundwater bodies - a multi-layered aquifer system

Background information
Title/Name of case study: Maros/Mureş alluvial fan group of transboundary groundwater bodies - a multi-layered porous aquifer system
Type of case study: Example of groundwater protection in transboundary groundwater bodies between Hungary and Romania (sub-region – Maros/Mures alluvial plain : central part of the Western Plain in Romania and south-eastern part of the Great Hungarian Plain).
Web-Link: www.euvki.hu , www.inhga.ro , www.icpdr.org
<p>Background information:</p> <p>The Mureş/Maros alluvial fan group of groundwater bodies is designated as important transboundary groundwater body in the Danube River Basin. The alluvial fan of the Maros/Mures River, that has been depositing since the Miocene age, lies along both sides of the Hungarian-Romanian border.</p> <p>It is an important drinking water resource in both countries. Some of the drinking water supplies are facing considerable quality problems due to the naturally high arsenic, iron, manganese and ammonium content of the water, especially on the Hungarian side. The upper water body in Romania and the shallow groundwater in Hungary are vulnerable to pollutants originating at the surface.</p>
WFD focus: Drinking water safeguard zones, protected areas, transboundary water body.
Specific contributions: Safeguard zone delineation, protection of drinking water sources.
<p>Characterisation:</p> <p>The basin encompassing the south-eastern part of the Great Hungarian Plain is in-filled with more than 2000 m of sedimentary deposits of different ages. The Hungarian approach for delineating water bodies separates the multi-layered aquifer system vertically based on temperature differences (HU 30 °C, RO 23 30 °C isotherm). Thus the cold part of the Upper-Pannonian and the Pleistocene layers are vertically unified in Hungary, but divided horizontally with the characteristic downward and transitional flow system (Figure 1 - p.2.13.1) separated from the upward one (p.2.13.2).</p> <p>On the Romanian side, three water bodies are delineated based on the dividing horizon of Upper-Pleistocene - Holocene (MU20) and Lower-Pleistocene - Middle Pleistocene (MU22) age of the strata. The MU20 groundwater body is developed to 30 m depth, while the MU22 lies between 30 - 150 m depth with the maximum thickness at the border. Beneath the MU22 groundwater body, the Arad-Oradea-Satu Mare groundwater body (CR08) is of Upper Pannonian age, with cold water, developed between 150-400 m depth. This GWB is a confined, porous-permeable type and consists of clays and marls, with thin interlayers of sands, argillaceous sands, rarely pebbles or sandstones. This body has the most development in the Crişuri River Basin and was assigned for management to the Crişuri Water Directorate.</p> <p>The water bodies can be lithologically characterised by pebbles, sands and clayey interlayers, but the upper and eastern part is significantly coarser with higher permeability. The covering layer consists mainly of 3-5 m of sandy silt and clay.</p> <p>The upper aquifer is unconfined, while the lower ones are confined. The water table is only 2-4 m below the surface in Hungary. The main direction of the groundwater flow is from the recharge area to the discharge areas, thus generally from the East-South-East to the West-North-West. Under natural conditions (without groundwater abstraction) the main recharge area is in Romania, thus an important element of the water regime of the Hungarian part is the lateral flow across the border.</p>

Figure 1 : Cross section through Maros/Mureş alluvial fan group

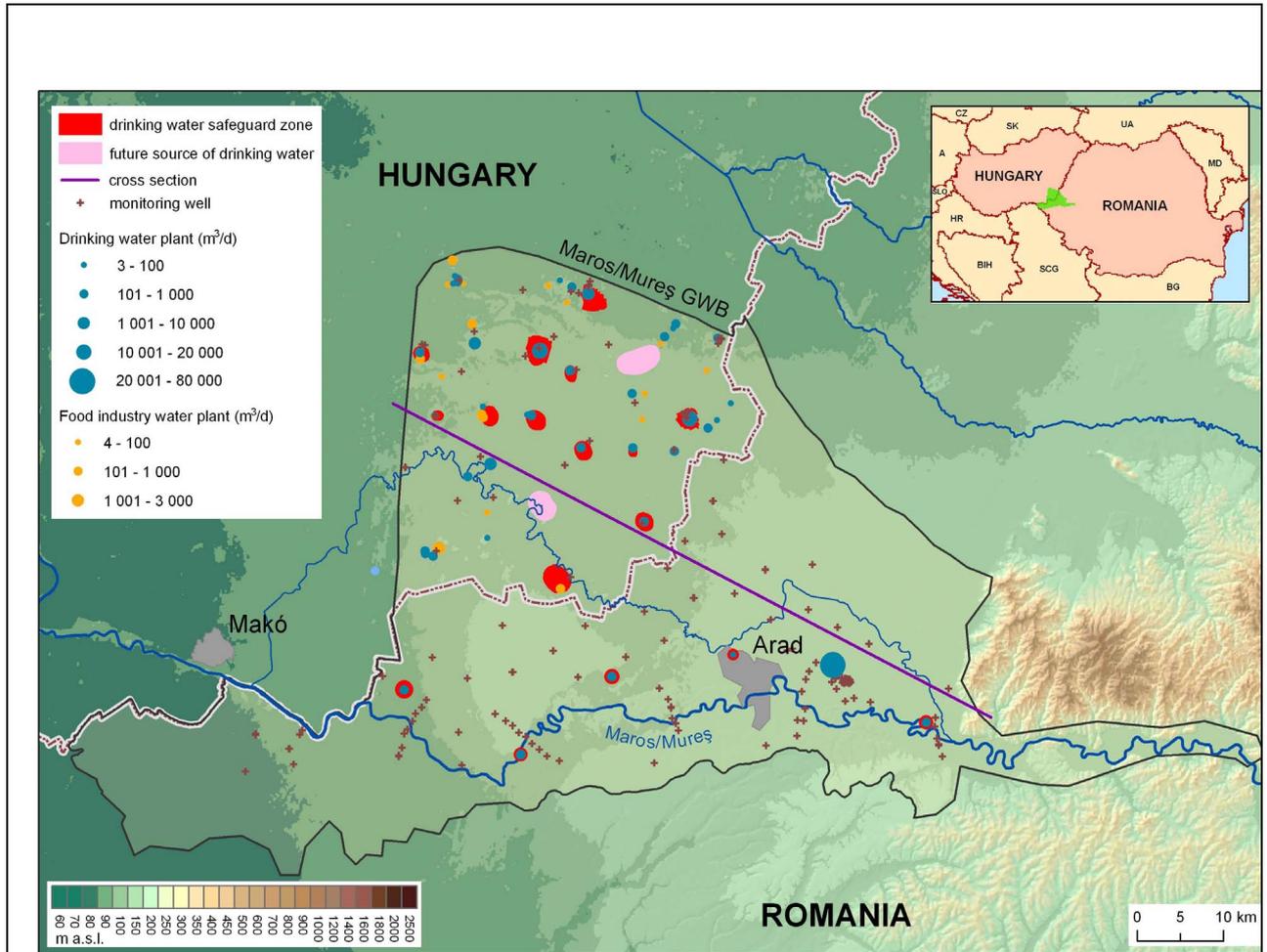


Experiences gained - Conclusions - Recommendations

In Hungary, the vast majority of drinking water supply (96%) relies on subsurface water resources. The law requires protection of all drinking water sources, regardless of whether they are actually exploited or designated for future use. The safeguard zone delineation methodology is based on the Governmental Decree 123/1997. (VII.18.). The boundaries of the safeguard zones have to be determined by the hydrological and hydrogeological conditions, with the dimensions of the protective zones based on the travel time concept. The travel times used areas follows: 20 days for the inner zone, half year for the outer zone, and 5 and 50 years for hydrogeological protective zones. These safeguard zone are established where the zones intersect the terrain.

The aim of water management is to delineate safeguard zones and evaluate a tailor-made plan of land use restriction and other necessary measures for each vulnerable drinking water source. As a result of a countrywide investigation, all drinking water sources were categorised into naturally protected and vulnerable groups. A source is considered vulnerable when pollution could reach it in less than 50 years. The hydrogeological model is checked by the chemical survey of the groundwater especially from pollutants of human origin, e.g. nitrate, pesticides, chlorinated hydrocarbons, etc. In addition the tritium (³H) content is measured. If tritium is detected, the age of water is younger than 50 years, thus the groundwater is vulnerable.

In Romania, the delineation of sanitary protection areas and hydrogeological protection zones are made according to the Governmental Decision nr. 930/2005. The sanitary protection areas take into account a 20 days travel time of a supposed polluted water particle from the area limit up to the water catchment point, in case of severe regime area, and a 50 days travel time, in the case of a restriction regime area. The hydrogeological protection zone delineation takes into account geological and geomorphological criteria.



These methods meet the requirements of Article 6 and 7 of WFD. For vulnerable sources, safeguard zones have to be established to ensure the necessary protection of drinking water sources. The drinking water protected area is the entire territory of all the different safeguard zones. Measures are not necessary to safeguard the naturally protected resources (deep aquifers), thus there is no protected area.

The monitoring of drinking water protected area is based on wells (abstraction and monitoring).

In this region, about 63 million m³ of drinking water is abstracted yearly from groundwater. Half of the drinking water resources are vulnerable. Drinking water protection areas cover about 2% of the entire (4038 km²) territory of the Maros/Mureş alluvial fan.

Outlook - Accessibility of results

The results of the investigations of each individual water works are accessible at the regional environmental and water directorates (in Hungarian only). In Romania these data are accessible at the National Institute of Hydrology and Water Management and at the Mureş Water Directorate.

Next steps

In both counties a national drinking water source protection program is under implementation. The delineation process will be finished in 2009.

According to the new bilateral agreement signed in 2005, the Maros/Mureş alluvial cone will be the subject of joint hydrogeological modelling to evaluate the water regime to provide a sound basis for integrated groundwater management. Bilateral monitoring activity is under negotiation.

CASE STUDY – GERMANY (Lingen area) Delineation and use of safeguard zones

Type of case study: Redefinition of safeguard zones around an abstraction well field
Objective of case study: Drinking water quality protection and improvement
WFD focus: Protection of groundwater for human consumption.
Specific contributions: Safeguard zone and protected area definition
<p>Description</p> <p>The city of Lingen (population 57,000) is located on the river Ems, 30 km from the Dutch border, between 20 and 65 m above sea level. A substantial part of the city's drinking water requirements comes from two of its own water works. These have a legal water extraction right of 2.5 Mm³ per year. The older is relatively close to the city centre and is surrounded by residential housing. Despite the land use and the relatively high vulnerability of the aquifer, abstracted groundwater quality is very good. Except for the removal of iron no further purification treatment is required to guarantee the quality of the drinking water. The main reason for this is that the catchment area has been protected for over 30 years through the establishment of drinking water safeguard zones.</p> <p>In 2003, extensive hydrogeological investigations were initiated to review and adjust the existing safeguard zones. The investigations resulted in the establishment and calibration of a three-dimensional transient groundwater flow and transport model. Utilizing the model as a management tool, the objective was to establish new safeguard zones based on the guideline DVGW W101 used by the German authorities. According to these guidelines three safeguard zones have to be established:</p> <ul style="list-style-type: none"> • Zone I: within direct vicinity of the extraction wells (10 m in diameter) • Zone II: Closer Safeguard Zone (50 days travel time) • Zone III: Wider Safeguard Zone <p>The geology of Lingen consists of Quaternary sands up to 30m thick, intercalated with layers of silt and clay. This leads to a separation into two aquifers which are more or less independent, though there are local hydraulic windows that allow limited connections between them. The lower aquifer is used as the source for the drinking water wells.</p> <p>South-east of Lingen the catchment area is delineated by a ridge of glacial deposits, typical of the lowlands of northern Germany (Fig. 2). Groundwater flows from this ridge in a north-westerly direction towards the extraction wells (Fig. 1). A detailed 3D finite element groundwater flow model was established for the wider catchment.</p> <p>Surface water flow measurements indicate a degree of interaction between the surface water bodies and the underlying aquifer. The model therefore also incorporates leakage from the smaller brooks and creeks into the aquifer.</p> <p>After successful calibration of the model, the hydrogeological delineation of the catchment area could be determined through various simulations (Fig. 3). This was easily undertaken through a visualization of the simulated flow pattern (Fig. 4).</p> <p>The demarcation line for the Closer Safeguard Zone II was determined utilizing an inverse numerical transport model approach (Fig. 5). Here the migration of a virtual tracer is simulated against the flow direction over a time period of 50 days. The outer boundary, from which – with a 95% probability – the tracer can reach the abstraction wells within the given time interval, serves as an indication for the definition of the Closer Safeguard Zone II.</p> <p>Protection measures applied</p> <p>The entire protected area is finally mapped out based on the hydrologic catchment area utilizing landmarks, roads and property boundaries (Fig. 6). The individually defined usage restrictions in relation to e.g. building work, commercial and agricultural usage are based on the local conditions and are captured as part of the management guidelines for the specific water protection area.</p>

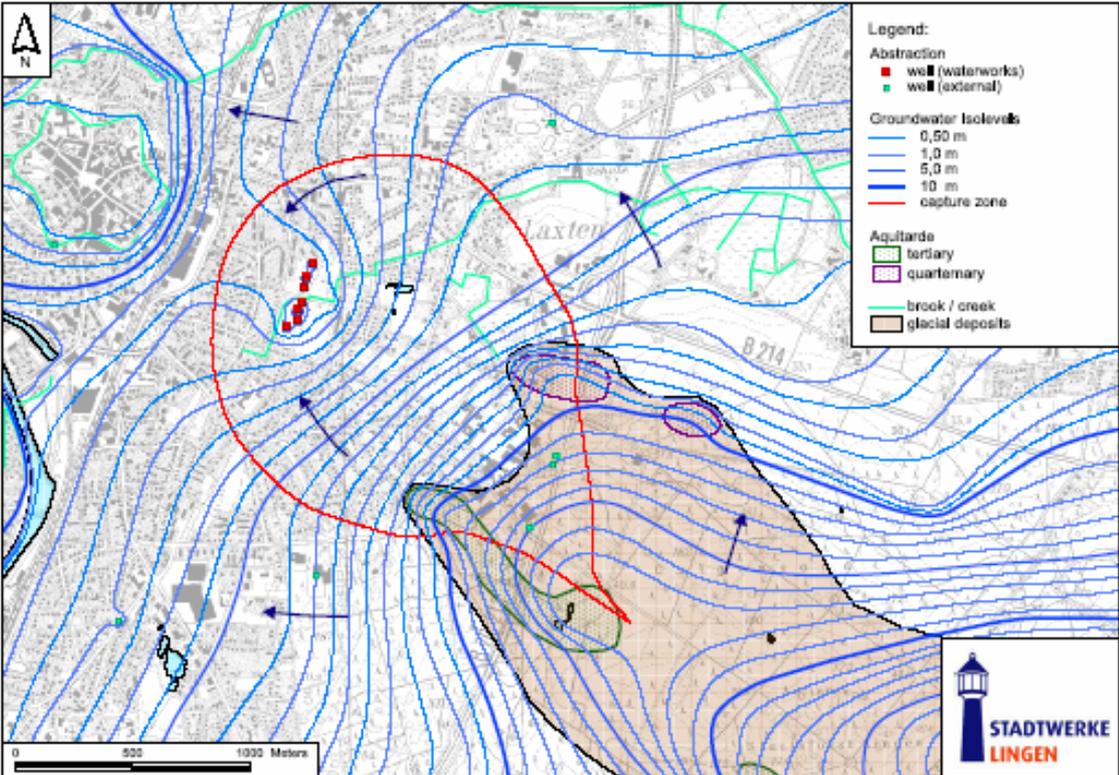


Figure 1 : Observed water table with hydrological delineation of the catchment area

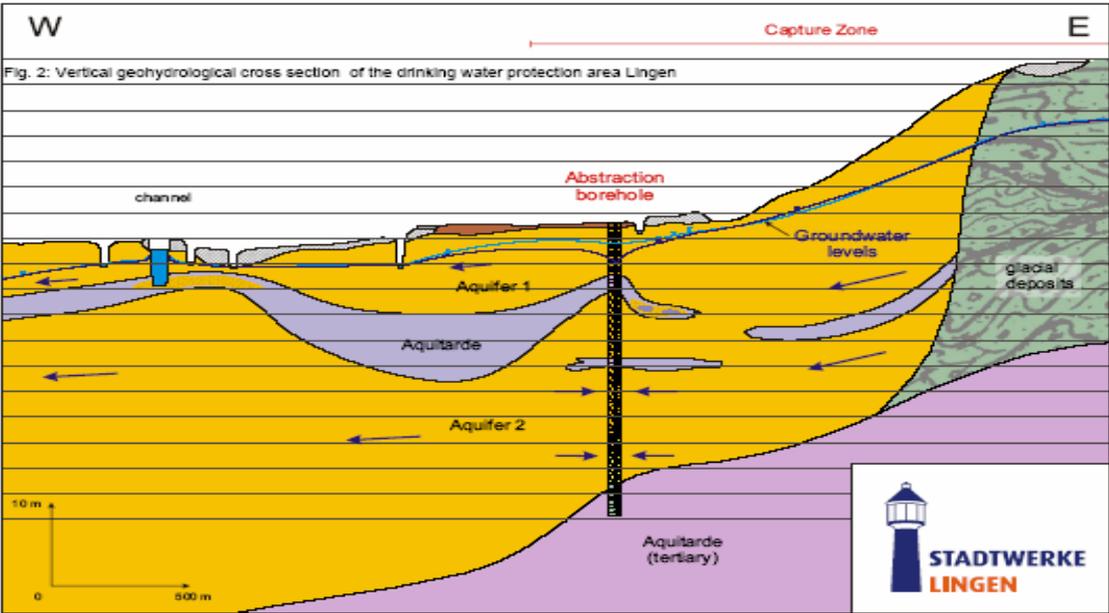


Figure 2 : Hydrogeological cross-section of the Lingen area

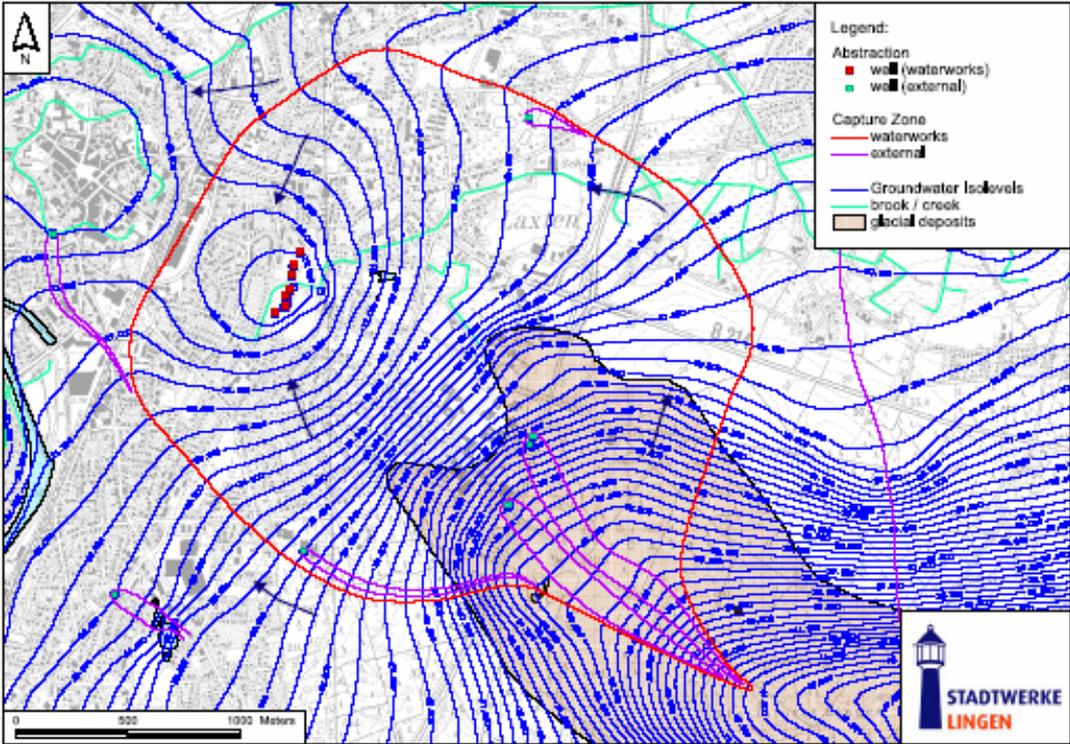


Figure 3 : Simulated piezometric heads based upon an abstraction of 1.5Mm3 per year

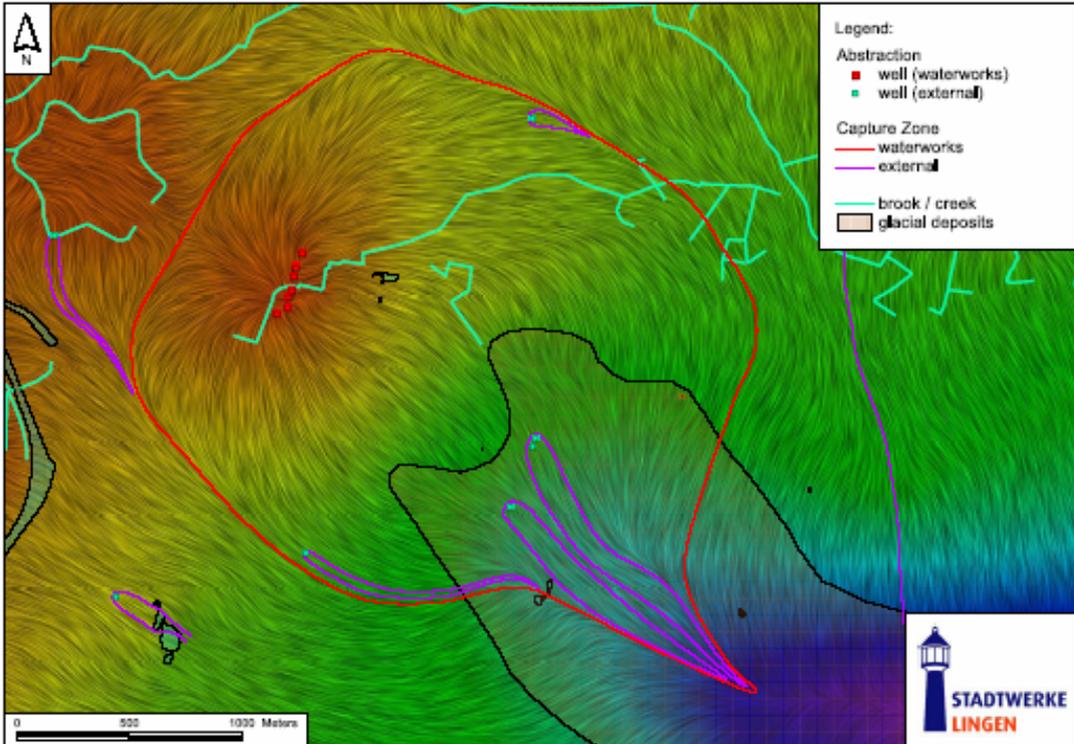


Figure 4 : Visualisation of the simulated flow pattern

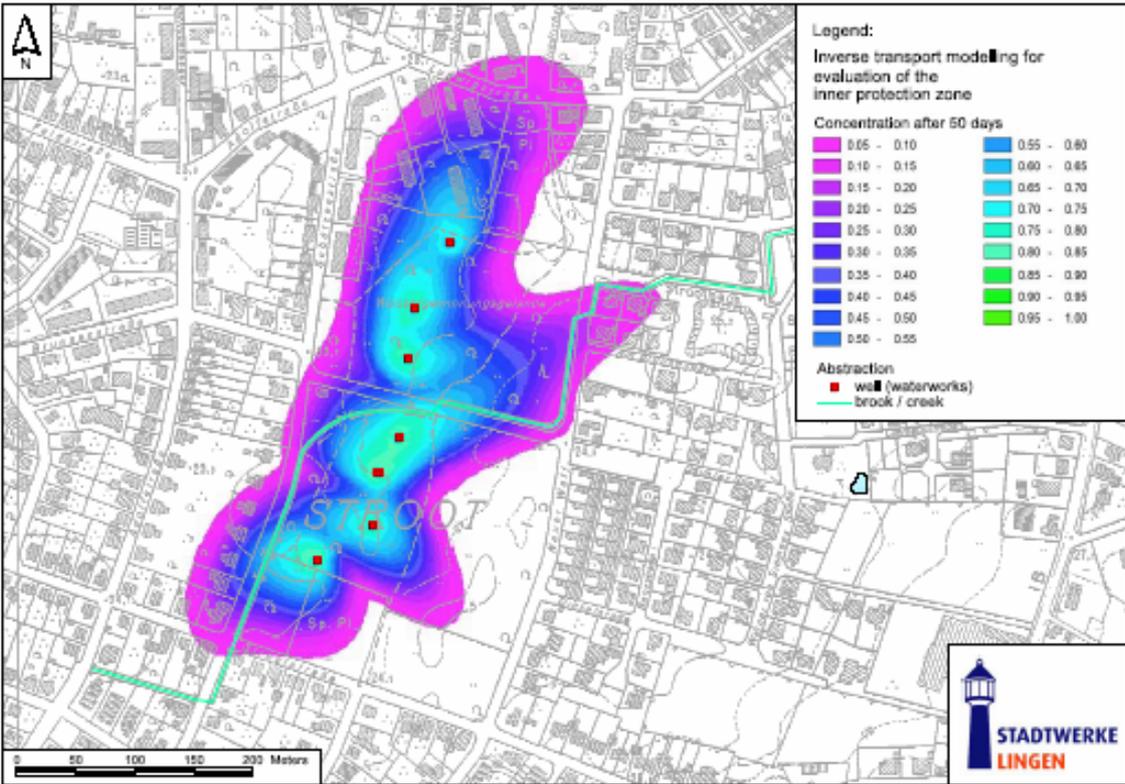


Figure 5 : Inverse transport modelling for evaluation of Safeguard Zone II (50 days)

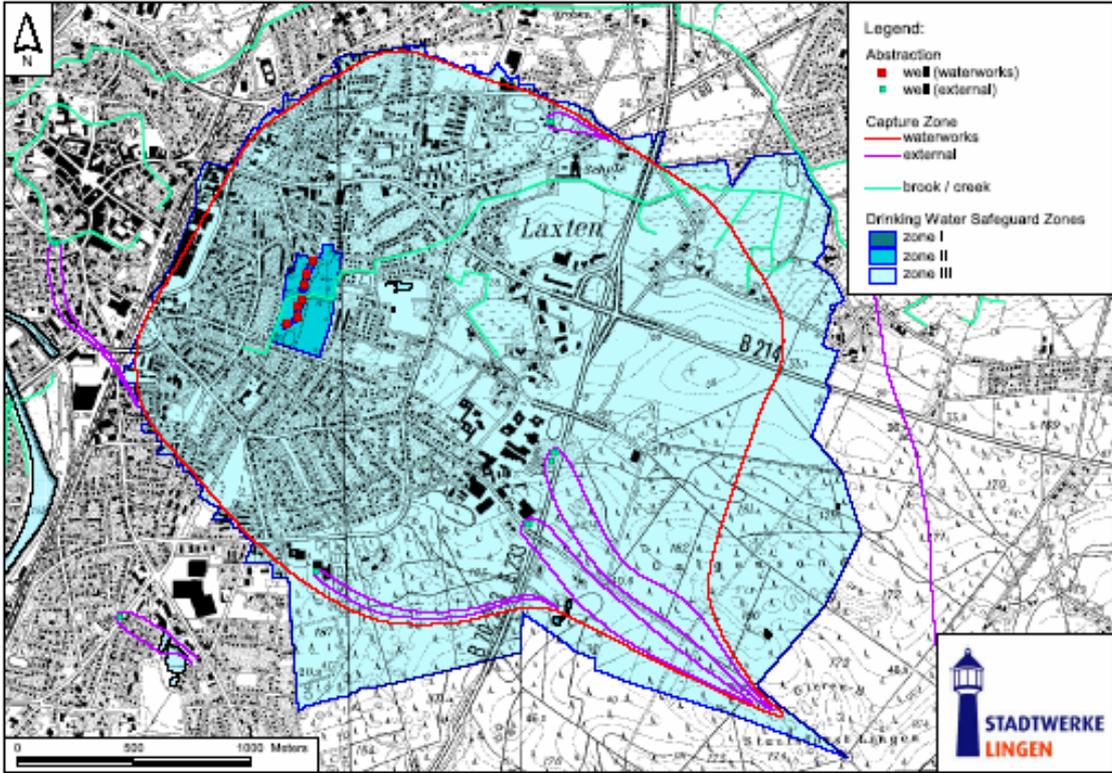


Figure 6 : Final safeguard zones for the Lingen waterworks

