Contract n° SSPI-2004-006538

BRIDGE

Background cRiteria for the IDentification of Groundwater thrEsholds

Research for Policy Support

WP3

D13: Summary report on groundwater quality monitoring network designs for groundwater bodies

Due date of deliverable: 31 August 2005
Actual submission date: 18 October 2005

The deliverable authors are responsible for the content

Start date of the project : 1 January 2005 **Duration : 2 years**

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Revision [3]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	

Content

1 Summary

Information assembled through several surveys show, that groundwater monitoring in Europe up to now is quite divers. Monitoring is usually depending on objectives and should cover the questions What, Where, How and When. So far monitoring objectives and the implementation have been individual and very different throughout Europe. The WFD now requires monitoring throughout Europe towards common objectives. An enhanced common understanding on the objectives of the WFD was identified within CIS working groups and guidance documents were elaborated aiming to support harmonised development of monitoring in Europe as a prerequisite to generate comparable data and status assessments.

Implementation: Due to the diversity of possible human pressures, topography, geo-hydrology, climate etc. monitoring guidance documents reflect on principles and rather general enumerate issues which should be taken into regard. The translation of such guidance to the local situation still depends on the interpretation of the guidance(s) and to the assumptions made upon the status of the groundwater system and the pressure situation. In many areas the knowledge of groundwater is currently rather scarce and the confidence in such assessments is rather vague.

Pressures: Groundwater monitoring should consider diffuse sources of pollution in a way reflecting their overall influence on the status of the whole groundwater body and in parallel reflect point sources of pollution in an equivalent way. It should furthermore take regard of seasonalities in the pressures and in the hydro-meteorological setting.

Aquifer types: The geo-hydrological landscape in Europe is manifold and partly incomparable. The monitoring network (sampling sites, frequency) has to consider that properties when reflecting the overall situation of the whole water body appropriately. Highly dynamic aquifers reacting immediately on changes of pressures must be treated differently to well protected, stagnant, old water bodies where the majority of ingredients in the water originate from the direct contact with the lithology.

Receptors / Location of monitoring sites: A further major issue is the consideration of receptors being affected by groundwater and in this connection the compliance regime on how and where to check the compliance with the environmental objectives. Where are thresholds to be met, at the receptors or at everywhere in the groundwater body? When looking at groundwater surface water interaction, the groundwater quality has to fulfil certain objectives at the interface groundwater to aquatic ecosystem. But, do the same objectives have to be fulfilled at regions where no aquatic ecosystem exists? The meeting of compliance at the aquatic and terrestrial ecosystem is checked by the aquatic and terrestrial ecosystem monitoring and no groundwater monitoring at that points of interaction would be needed.

If there are different receptors which need to be protected, than the protection of the most sensitive receptor is the determining factor and the minimum objective which has to be achieved. If there are individual threshold values for different receptors than the most sensitive threshold value is the limiting factor.

Number of monitoring sites: The philosophies and approaches within Europe differ from the installation of very few representative monitoring stations per groundwater body mainly in areas where a new network has to be implemented, to very sophisticated networks which already exist and need only slight adaptation. A major driver to (re-)design networks is not to pose an unaffordable burden to the monitoring budget.

Nevertheless the number of monitoring sites within a groundwater body is dependent on the assessment methodology and the level of confidence which is required in order to fulfil the

objectives of the Directive. This implies also the consideration of aquifer properties, pressure situation and the probability that a groundwater body may fail to meet environmental objectives and being assigned at 'poor' status.

Vertical stratification: A further major issue of monitoring is where the vertical focus is put on. It makes a difference if a vertically stratified groundwater body is treated as a 3-dimensional body and monitored in its whole expansion than looking at the upper layer only. Of course, the upper layer is in general the most vulnerable and first (most) affected by human activities but on the other hand it is the part which is interacting with aquatic and terrestrial ecosystems. The threshold value should take regard of this difference in the expressiveness of an average value between these monitoring approaches.

Types of networks: In many countries the existing networks have well defined objectives e.g. background monitoring, monitoring of polluted areas, compliance monitoring etc. The WFD monitoring is going to be designed upon existing wells/springs. It is recommended to base the network on a broad mixture of types of sampling stations in order to avoid biased results. E.g. as drinking water abstractions are usually very commonly available there might be a tendency to select the WFD monitoring sites mainly from that inventory. Such a focus on drinking water abstractions deliver very biased results as drinking water abstractions are usually situated in cleaner areas and might reflect a too optimistic overall status of the whole groundwater body. Such a broad variety of biases due to unbalanced mixtures of sampling sites is of high relevance when establishing threshold values.

Frequency: The minimum frequency of monitoring is given by the WFD. But a comparable answer to the questions implied in the monitoring objectives must take regard of the huge variability of dynamics of different aquifer types and the probability of exceeding the threshold value. A very dynamic aquifer needs at the beginning more investigation to gather a representative picture than a confined aquifer with an average renewal rate of decades. But if the dynamic aquifer is identified as being rather pristine, the continued monitoring could be reduced considerably as the probability to exceed a threshold value is then rather low.

Level of confidence: The number of sampling sites and the frequency of sampling (in connection with the variability of concentrations) is responsible for the level of confidence of the assessment. The higher the number of samples is and the lower the variation in concentrations, the lower the uncertainty in the assessment. Either the assessment methodology or the threshold value has to consider the variable level of confidence in order to guarantee the meeting of the Directives objectives to a certain and comparable level of probability.

Aggregation methodology: The aggregation methodology foreseen for the assessment has a strong influence on the monitoring. The methodology is posing several minimum requirements towards the design of the monitoring as the minimum number of sites, the minimum frequency, the selection of sites, the distribution of sites, quality assurance issues etc. The network design could be different if the overall quality of a groundwater body should be assessed based on aggregated data or if the status of a groundwater body is assessed based on the concentration level at the most sensitive part of the groundwater body. The aggregation methodology includes the confidence of the assessment and has to be appropriately robust to allow for pragmatic monitoring approaches and a certain level of confidence.

Threshold values: Considering all the variables mentioned above it can be concluded that the groundwater monitoring networks in Europe will be quite divers even after the implementation of the WFD requirements.

The monitoring network, the assessment methodology and the thresholds are tightly connected to each other. It seems that the methodology of establishing threshold values has to bring several variables under one hat. The key issue is the tight connection of the threshold value to the aggregation and assessment of data. That will else pose minimum requirements to the monitoring. Threshold values should furthermore consider the natural occurrence of substances in order to tackle the human impacts on the groundwater and also the different properties of substances. Finally, different receptors need different levels of protection which should be considered by the establishment of threshold values as well.

2 Introduction

The report presents as first part of activity 3.3 of WP 3 a review of literature and national strategies on groundwater monitoring, on the design of monitoring networks representative for groundwater bodies in correlation with sampling strategies. Capabilities for surveillance or operational monitoring of groundwater in line with the WFD are evaluated.

The application of the developed procedures of BRIDGE will take place at those WFD compliant monitoring networks which are currently under development by Member States.

At December 22, 2006 monitoring networks have to be established and currently the majority of Member States is in a phase of considering, designing and re-designing their WFD monitoring activities. Therefore the report is reflecting a status which might partly change considerably in the near future.

As the developed procedures in BRIDGE should be applicable to all types of GW-bodies (different hydrogeological characteristics, size, number of sampling sites, pressures, network design etc) the test and discussion of the proposed procedure on the basis of test data sets was regarded to be of vital importance.

Therefore it is inevitable to take regard of the monitoring which influences the aggregation of data and later on the compliance checking.

The following sources of information were considered most relevant and have been reviewed:

- the WG C Technical Workshop Report ‘Groundwater Monitoring’ (workshop held on 25th June 2004)
- WG C Drafting Group ‘Monitoring’
- WG 2.7 and WG 2.8 Guidance Documents
- a WP3.1 questionnaire distributed throughout BRIDGE consortium partners
- Groundwater bodies part of EIONET-Water of the European Environment Agency (EEA)
- Report on the implementation of the Nitrate Directive
- BRIDGE WP4 case studies
- UN/ECE Inventory of transboundary groundwaters

The single information sources are described in chapter 4 in more detail.

3 General principles of monitoring – GW bodies vs. point sources

In principle the monitoring network design depends on the objectives of monitoring. Designing a monitoring should cover the questions: What, Where, How and When.

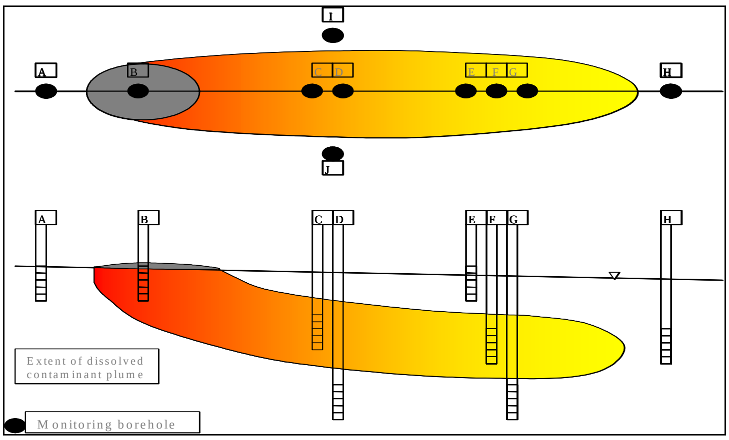
Regarding the WFD the monitoring tasks are defined by the environmental objectives. The WFD requires to control the input of pollutants into the groundwater locally (point sources) and to control the status ('overall health') of all bodies of groundwater.

The monitoring approaches for point sources and for groundwater bodies consider the same factors (e.g. geology, hydrogeology, contaminant(s), known impacts, receptor(s), system dynamics & travel times, size of plume or monitoring areas, regulatory requirements). But the monitoring approaches differ in intensity and detail e.g.: how many boreholes and location of boreholes, borehole construction/depth, which parameters e.g.: contaminant, breakdown products, indicators, duration and frequency of monitoring, environmental standards.

Monitoring design considerations relevant to point source are:

- Does the network allow a plume to be defined (3-D), as well as background conditions?
- Are sufficient monitoring data available to define seasonal and mid-term trends?

Figure 1: Monitoring design - point sources

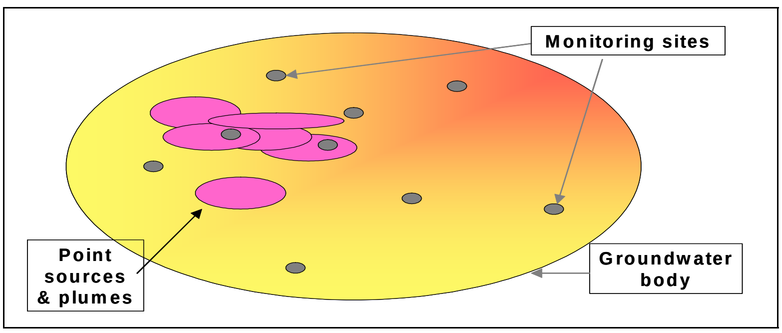


- Background (A)
- Source (B)
- Plume (C-G)
- Migration (H-J)
- Design considers
  - receptor location
  - travel times
  - stratigraphy & hydrogeology
  - NO minimum number

Monitoring design considerations relevant to the groundwater body are:

- Does the monitoring network provide a coherent and comprehensive overview of the groundwater status within a river basin / groundwater body?
- Are sufficient monitoring data available to define seasonal and mid- to long-term trends?

Figure 2: Monitoring design - groundwater body



4 Sources of information

The following sources of information were considered most relevant and have been reviewed:

- the WG C Technical Workshop Report 'Groundwater Monitoring' (workshop held on 25th June 2004)
- a WP3.1 questionnaire distributed throughout BRIDGE consortium partners
- WG C Drafting Group 'Monitoring'
- WG 2.7 and WG 2.8 Guidance Documents
- Report on the implementation of the Nitrate Directive
- Groundwater bodies part of EIONET Water of the European Environment Agency (EEA)
- WP4 case studies
- UN/ECE Inventory of transboundary groundwaters (1999)

The single information sources are described in the following chapters in more detail

4.1 WG C Technical Workshop Report 'Groundwater Monitoring' and BRIDGE WP 3.1 questionnaire

The aim of the WG C workshop on groundwater monitoring in June 2004 was to share national and regional experiences on groundwater monitoring, taking into account the CIS guidance. The *Technical workshop report 'Groundwater Monitoring'* summarises key elements, best practice and tools for the design of groundwater monitoring programmes as they are summarised in the *Monitoring Guidance Document*[1] of CIS WG 2.7 and the main findings regarding monitoring of the *Technical Report on groundwater statistics*[2] of CIS WG 2.8. The report was completed by some general features of groundwater monitoring also with regard to point sources of pollution, reports on the research and technological developments in support of groundwater monitoring and reports on monitoring approaches in the light of the WFD, either at the national and/or regional level (Germany, France, Austria, the United Kingdom, the Nordic Countries, Lithuania, Malta, Spain, Italy, Romania, Denmark and the Netherlands). This report represented the most up to date and most relevant compilation on the state of the WFD implementation regarding groundwater monitoring in Member States and Accession Countries.

In spring 2005 an internal BRIDGE questionnaire on *National Methods for Groundwater Protection* was distributed by Kim Dahlstrøm within activity 3.1 of WP 3 to the partners of WP 3. One part of the questionnaire dealt with the description of monitoring approaches for diffuse and point sources of pollution, for groundwater bodies and data aggregation.

The compiled country reports are attached in the Annex and comprise the information given in the Technical Workshop Report *Monitoring* which was supplemented and updated by information which was gathered recently via the BRIDGE questionnaire.

[1] Guidance Document No. 7. Monitoring under the Water Framework Directive. ISBN 92-894-5127-0

[2] Technical Report No. 1. The EU Water Framework Directive: statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results. ISBN: 92-894-5639-6

4.2 WG C Drafting Group 'Monitoring'

Objective of WG C is the clarification of GW issues covered by the WFD and the preparation of technical guidance documents in the light of the future GWD. These guidance documents are elaborated by drafting groups. Drafting group GW 1 deals with monitoring; it is based on existing CIS guidance papers and shall put its focus primarily on the issues covered by the WFD and secondly on issues with direct impact on GWD compliance.

The groundwater monitoring programmes meeting the requirements of the WFD include both quantitative and chemical (quality) monitoring for status and trend assessment, monitoring to support (ground)water body characterisation and protected area objectives. The establishment of high quality long-term monitoring programmes is essential if the implementation of the WFD is to be effective. Inadequate investment in monitoring, including network infrastructure and data quality and management will result in a significant risk of failure to meet the WFD's environmental objectives.

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

The current draft is under discussion within the drafting group members. A final version should be available at the end of 2005. This final guidance paper will provide a major input to the recommendations on monitoring which will be given in a separate deliverable (D16).

4.3 CIS WG 2.8 - Groundwater statistics (aggregation, trend, trend reversal)

The main goal of CIS WG 2.8 was to establish methods for the calculation of representative mean concentrations, for data aggregation and trend (reversal) assessment (Annex V 2.4.4) at the groundwater body level respectively for groups of groundwater bodies. The methods had to be suitable for Europe-wide application and implementation based on the provisions of the Water Framework Directive taking into account influences originating from diffuse and/or point sources.

Test GW-bodies

As the developed procedures should be applicable to all types of GW-bodies (different hydrogeological characteristics, size, number of sampling sites, pressures etc) the test and discussion of the proposed procedure on the basis of test data sets was regarded to be of vital importance. In total information on 21 GW-bodies in 9 countries was provided by the partners in the project (www.wfdgw.net). It comprises GW-body characterisation, quality data and network design. The assessment of the monitoring network was an essential part in the project as it biases the results of the proposed procedures considerably.

An overview of the distribution of the test GW-bodies in Europe and a summary of the groundwater body characteristics (size, hydrogeology) is given in the Annex 1. For each test groundwater body the design of the monitoring network (nitrate) is attached.

Requirements on the monitoring network

The working group agreed that the monitoring network should fulfil some minimum requirements. It was agreed that homogeneity (reflecting spatial representativity) of the network was a prerequisite and should be ensured to allow for sound statistical assessment in accordance with the requirements of the WFD. Homogeneity implies furthermore that there is no local accumulation of sites. For the assessment of the homogeneity of a monitoring network, a representativity index was developed. The representativity index assesses the deviations of the actual sampling site distribution to an ideal monitoring network. If the GW-body is hydrogeologically heterogeneous and if a spatially homogeneous monitoring network is not feasible or sensible the monitoring network has to be developed to be hydrogeologically representative. Representativity with regard to anthropogenic and natural factors was also regarded as important.

The importance of continuity with regard to the monitored sampling sites was required as well. The replacement of sampling sites should be kept as low as possible. In case of changes of monitoring stations it should be assured that these changes do not the affect the outcome of the assessment.

Requirements on the monitoring

Sampling techniques were regarded as important since considerable bias can be avoided by applying a sound sampling strategy. Consequently the quality of data can be improved. The following particular aspects were highlighted:

- In a time series some observations may be missing, but the missing of two or more subsequent values should be avoided, as this would cause a risk of bias due to extrapolation.
- Samples should be taken within a certain period of a year to avoid bias by seasonal effects. In particular for yearly measurements it should be guaranteed that the measurements are taken in one and the same quarter or within a certain time period of the year. This is required to avoid a high random variation which reduces the power of the trend analysis.
- The sampling frequency should reflect the natural conditions and dynamics of the GW-body.

4.4 Report on the implementation of the Nitrate Directive

In 2002 the European Commission published a synthesis report (COM(2002) 407 final) from year 2000 Member States reports. The Nitrate Directive (91/676/EEC) requires Member States to report every 4 years. These reports should include information pertaining to codes of good farm practice, designated nitrate vulnerable zones (NVZs), results of water monitoring and a summary of relevant aspects of actions programmes for vulnerable zones.

Within this synthesis report water monitoring networks have been assessed according to the requirements of the Directive. Regarding groundwater the Nitrate Directive (Art 6) requires networks of sampling stations to cover all main groundwaters, even if not used for drinking water. Criteria to monitor are nitrogen (ammonia, total N, nitrates). It was stated that generally Member States have established networks of hundreds or thousands of sampling stations, which give a good overview of water status (1996–98) and trends, by comparison with 1992–94, when the first survey was effectively made.

According to the Nitrate Directive the network has generally to be completed by an **"operational"** network allowing **assessment of action programmes** (cf. Art. 5.6 of the Directive), dealing with monitoring of N in soil or at root zone level, in pilot fields, farms or small watersheds, and inside vulnerable zones.

Regarding the groundwater monitoring networks the EC pointed out that (*abridged*):
- No formal report was transmitted by UK before July 2001.
- In Germany the network is unbalanced and incomplete, focusing only on areas of polluted groundwaters, and limited to only 10 stations for surface waters.

- In Greece and Portugal the groundwater network is limited to designated vulnerable zones, hampering a periodical evaluation of designation.
- These networks are also geographically unbalanced in Italy, where they don't cover the South and in Luxembourg.
- For groundwaters, drinking water catchments were often over represented (FR, GR, IE, BE,…). Deep sampling with natural chemical denitrification (NL, BE/Flanders…), or in captive waters (south-west FR, BE…) sometimes biased results.
- 12 countries succeeded in reporting geo-referenced data in a format compatible with EC Geographic Information System (GIS), using harmonised codes and classifications as developed by the "reporting guidelines".

4.5 BRIDGE WP 4 case studies

BRIDGE partners provided basic information on selected groundwater bodies respectively river basins subject of future testing of the proposed methodologies and algorithms within the project. The following table summarises the main characteristics of the case studies with regard to the existence of protected areas and available monitoring for groundwater, for aquatic ecosystems as well as for terrestrial ecosystems.

Table 1: Candidate case studies subject of testing in BRIDGE WP 4

no.	Country	Name	Size	GW-body River Basin	depth interval	Protected areas: Natur 2000	Protected areas: habitat sites	Protected areas: birds	Protected areas: water protection area	Protected areas: additional national sites	Monitoring available: GW	Monitoring available: a-E	Monitoring available: t-E
1	AT	Tullnerfeld	587	GWB	0-26				4		y	y	n
2	AT	Seewinkel	443	GWB	-	1					y	n	n
3	AT	Südl. Wr. Becken	1228	GWB	0-220	5			12		y	y	n
4	AT	Lafnitztal	96	GWB	-	4					y	y	n
5	AT	Glantal	77	GWB	0-65				1		y	y	n
6	BE	Central Campine System	2300	RB	0-400		18	11		yes	y	y	p
7	BG	Sofia Kettle	1090	GWB	0-20	1 draft				yes	y	y	n
8	DK	Odense PRB	1046	RB	0-80		7	3		yes	y	y	y
9	EE	East Estonia	5475	GWB	50-350	161				yes	y	n	n
10	FI	ISS - group of gwb's	145	GWB-Group	5-20						y		n
11	FR	Upper Rhine			0-220						y	y	
12	DE	Upper Rhine	21695 (13494 DE)	RB	0-50		97	56	900	yes	y	y	y
13	GR	Pinios PRB	10550	RB	0-400						y	y	
14	IT	Tevere PRB	17156	RB	-					yes	y	y	p
15	LT	Joniskis	516	GWB	180-250				1		y		
16	NL	Rhine West	7600		0-500		15	15		yes	y	y	p
17	NL	Sand Meuse	7700		0-400		40	16		yes	y	y	y
18	PL	Kedzierzyn	1350		0-120	1 draft					y	y	n
19	PL	Raba river	1565		0-100					yes	p	y	
20	PT	Vouga River Basin	66800 (11580 PT)		0-400		2	5		yes	y	y	y
21	PT	Guadiana PRB	66800 (11580 PT)		0-200		5	5		yes	y	y	y

a-E … aquatic ecosystem, t-E … terrestrial ecosystem, y…yes, n…no, p…partly

4.6 EEA - GW bodies provided via EIONET-Water

The European Environment Agency (EEA) is collecting data on groundwater quality via EIONET (European Environment Information and Observation Network) on an annual basis.

Data and information obtained are primarily used to compile indicator factsheets, associated with the EEA's Core Set Indicators, upon which EEA assessment reports are based. Data are also published in Waterbase, a series of water topic-specific databases and web pages, publicly accessible via the EEA Data Service's web site. Data on the status and quantity of Europe's water resources can be viewed, analysed and downloaded from Waterbase at:

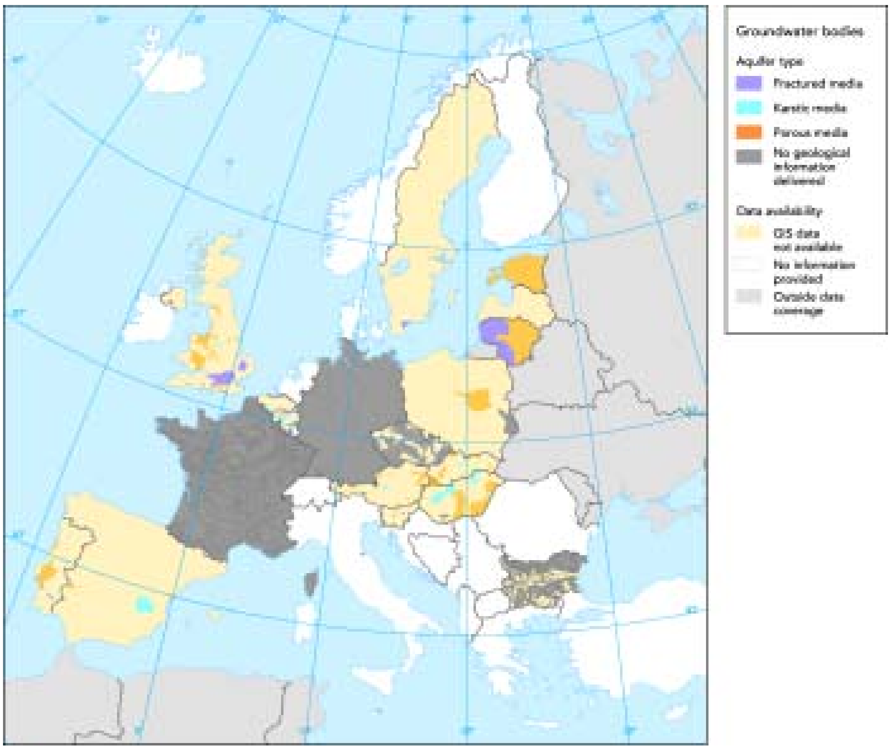
http://dataservice.eea.eu.int/dataservice/available2.asp?type=findkeyword&theme=waterbase

The data requested through the EIONET-Water process should be derived from existing national and/or regional monitoring networks within each EEA Member Country. Member Countries are asked to select groundwater bodies according to criteria described in technical guidelines (EEA Technical Report No. 7). Groundwater bodies should be at least 300 km² in area, or be of regional, socio-economic or environmental importance in terms of quantity and quality, or may be exposed to severe or major impacts. It is expected that these groundwater bodies should provide a general overview, based on truly comparable data, of water quality at a European level.

Collected data on groundwater comprise physical characteristics of the groundwater bodies, proxy pressures on the groundwater area, as well as chemical quality data on nutrients and organic matter, and hazardous substances in groundwater.

The figure below illustrates the geographical distribution of groundwater bodies reported via the EIONET-Water data collection. The attached summary (Table 4) gives an impression on the bandwidth of sizes of groundwater bodies, of the number of sampling sites per body, of site densities etc.

Figure 3: EIONET-Water groundwater bodies



Within the EIONET-Water data collection process information on 1934 groundwater bodies were reported from 31 European countries.

Groundwater bodies per country: The number of reported important groundwater bodies per country varies between 1 and 1244 with an average number of 62 and a median number of 9 groundwater bodies per country.

Aquifer type: About 80 % of the 439 groundwater bodies where information of the aquifer type is available are situated in porous media, 14 % are lying in karst and 7 % are fractured media.

Size of groundwater body: The average reported groundwater body has an area of 677 km² but the 1773 reported sizes of groundwater bodies varies between 0.2 and 63000 km².

Number of sampling sites: Information on the number of sampling sites is available for 766 bodies. In average around 10 sampling sites are situated in each groundwater body varying from 1 to 302 sites per body.

Sampling site density: The average sampling site density is about 337 km²/site, the median density is about 92 km²/site in a range of 0.2 to 15000 km²/sampling site.

Time series: Currently 201 groundwater bodies comprise time series of more than 8 years (and not more than 1 data gap) which are suitable for trend and trend reversal assessment.

Next page:

Table 2: EIONET-Water groundwater bodies. Summary overview (status: 2003)

	reported bodies	fractured media	Karstic media	Porous media	no info	bodies with size info	Average body area	Range of body size	bodies with sites info	average number of sites per body	Range of sites	bodies with density	mean site density	range of site density
AL	10			10		0			0			0		
AT	14		1	13		14	389	(40-1020)	14	49.5	(6-116)	14	13.5	(2.9-96.7)
BA	1			1		1	370	(370-370)	0			0		
BE	10	5	3	2		5	951	(490-1290)	2	37.0	(26-48)	2	21.7	(18.8-24.5)
BG	76				76	76	886	(10-18530)	72	3.5	(1-42)	72	226.0	(14.5-2068)
CS	9				9	0			9	1.8	(1-3)	0		
CZ	43				43	42	1116	(100-5930)	39	7.5	(1-24)	38	271.1	(22.2-2472)
DE	10				10	0			10	84.4	(10-252)	0		
DK	3	2		1		3	286	(80-400)	3	23.7	(16-37)	3	13.2	(4.3-25)
EE	5		1	4		5	20985	(670-38240)	5	113.4	(33-302)	5	358.2	(5.8-1012.7)
ES	3		1	2		3	1613	(550-3570)	3	7.3	(1-15)	3	302.1	(119.2-549)
FI	41			41		41	1		41	1.0	(1-1)	41	0.9	(0.2-4.2)
FR	1244				1244	1210	391	(0-13610)	330	4.5	(1-69)	296	418.5	(2-6688)
GB	37	13	2	21	1	35	774	(20-5540)	37	16.8	(1-78)	35	83.5	(11.4-827)
GR	130	3	38	89		84	189	(0-1000)	80	1.4	(1-8)	47	173.8	(5-1000)
HU	17		6	11		17	1894	(230-6250)	17	28.9	(2-144)	17	112.2	(9.4-311.2)
IE	3		1		2	3	452	(220-720)	3	1.7	(1-2)	3	261.7	(209.5-360.5)
IT	43				43	0			43	18.9	(1-107)	0		
LI	1			1		1	23	(20-20)	1	8.0	(8-8)	1	2.9	(2.9-2.9)
LT	5	3		2		5	16040	(13500-19100)	5	3.0	(1-7)	5	7762.9	(2514.3-15000)
LU	5				5	4	3	(0-10)	5	1.0	(1-1)	4	2.5	(1-7)
LV	4	1		2	1	4	24270	(80-63000)	4	33.5	(8-78)	4	558.6	(10-1083.3)
MK	7				7	7	397	(120-1210)	0			0		
MT	2	2				2	142	(60-220)	2	4.5	(2-7)	2	31.7	(31.4-32)
NL	9				9	9	3762	(530-8820)	9	43.1	(3-56)	9	92.7	(26.5-177.3)
NO	1			1		1	73	(70-70)	1	1.0	(1-1)	1	73.0	(73-73)
PL	173	1		127	45	173	1037	(20-51000)	3	9.0	(3-12)	3	825.4	(266.7-1458.3)
PT	10	1	4	5		10	1241	(10-6880)	10	26.6	(3-75)	10	38.8	(2.6-91.7)
SE	3	1		2		3	218	(50-530)	3	2.3	(1-3)	3	90.6	(16.7-175)
SI	5		1	4		5	234	(100-520)	5	8.6	(2-13)	5	39.9	(10.6-94.5)
SK	10		2	8		10	733	(120-1900)	10	18.0	(3-79)	10	73.7	(8.3-266)
Total	**1934**	**32**	**60**	**347**	**1495**	**1773**	**677**	**(0.2-63000)**	**766**	**9.8**	**(1-302)**	**633**	**337.0**	**(0.2-15000)**

4.7 UN/ECE Inventory of transboundary groundwaters

The main purpose of this report was to highlight:

- the location, extension and type of transboundary groundwaters;
- the monitoring activities, pollution sources and contamination of transboundary groundwaters;
- the uses, problems and trends in the state of groundwater according to the observations up till now and
- the institutional- and international aspects in their management in the ECE region.

The inventory is based on a questionnaire which was circulated by the UN/ECE in 1996 and 25 countries responded.

The inventory shows the inhomogeneity among the monitoring systems, if they are developed on both sides of the border when the same aquifer is being monitored and the lack of cooperation when the groundwater is monitored on one side of the border only.

Monitoring of groundwater quantity

23 countries reported quantity monitoring of transboundary groundwaters for 78 aquifers. In 18 of the countries, this kind of monitoring is organised on national level and in 8 countries institutions are responsible. 4 countries, (7 aquifers) explicitly indicated that there is no quantity monitoring of the relevant transboundary groundwaters at all. The sampling frequency varies between once per year up to continuous recording (in 36 bodies).

Monitoring of groundwater quality

22 countries reported quality monitoring of transboundary groundwaters for 71 aquifers. In 4 countries (8 aquifers) no quality monitoring is performed. The sampling frequency varies between once per year up to 186 times per year. In 23 aquifers (in Austria, Germany, Slovakia, Croatia, Czech Republic, Slovakia and The Ukraine), the majority of the parameters major ions, heavy metals, pesticides, nitrogen compounds, industrial organic compounds and others is being monitored.

The main characteristics of quality monitoring (specific distribution of monitoring sites, frequency of sampling and the coinciding monitored parameters) are the nearest on two sides of the border in the case of one aquifer. There are 40 aquifers in which the quality characteristics of transboundary groundwater are monitored on one side of the border only. There are 28 aquifers being monitored on both sides of the border.

4.8 Discussion of information sources

In 2004 and 2005 several technical workshops of WG C Groundwater took place in order to share national and regional experiences on groundwater monitoring, taking into account the CIS guidance. The *Technical workshop report 'Groundwater Monitoring'* summarises key elements, best practice and tools for the design of groundwater monitoring programmes as they are summarised in the WG 2.7 Guidance Document *Monitoring* and the main findings regarding monitoring of the Technical Report of WG 2.8 on *Groundwater Statistics*.

The report was completed by some general features of groundwater monitoring also with regard to point sources of pollution, reports on the research and technological developments in support of groundwater monitoring and reports on monitoring approaches in the light of the WFD, either at the national and/or regional level.

This report reflects the most up to date and most relevant compilation of country reports on the state of the WFD implementation regarding groundwater monitoring.

The country reports attached to the Technical Workshop Report *Monitoring* were supplemented and updated by information which was gathered recently by Kim Dahlstrøm via an internal BRIDGE questionnaire on *National Methods for Groundwater Protection* distributed within activity 3.1 of WP 3 to the partners of WP 3.

The EC report on the implementation of the Nitrate Directive includes an assessment of the groundwater monitoring activities according to the requirements of the Directive. The information was reported to the EC by the Member States in 2000.

WG 2.8 *Groundwater Statistics* gathered information on selected representative groundwater monitoring networks from the WG 2.8 project partners. These selected networks were subject of testing of the proposed algorithms, as a main task of the project. The available information not only comprises a description of the groundwater bodies and the quality data but also the network design (distribution of sampling sites within each body).

The European Environment Agency (EEA) is collecting information on Groundwater quality since 10 years in order to give European overviews of the groundwater quality situation focusing on nutrients and pesticides. The available information comprises quality data, groundwater body characterisations GIS maps of selected, important groundwater bodies and information on the number of sampling sites and the sampling frequency. The inventory reflects the current groundwater monitoring activities in Europe by figures and facts.

BRIDGE WP 4 is going to evaluate the elaborated approaches on threshold setting at selected representative case studies. Currently partners provided a selection of potential case studies giving a brief description of the test groundwater bodies or river basins also with regard to the available monitoring.

Some transboundary aspects were found in the UN/ECE inventory of transboundary groundwaters which throw light on the rather patchy and inhomogeneous monitoring situation.

5 National strategies of groundwater monitoring

5.1 Monitoring philosophies

The available information shows that groundwater monitoring is performed in nearly all European countries in a systematic way. In many countries quantity monitoring has a longer tradition than quality monitoring. In few countries the monitoring of groundwaters is performed occasionally on case to case investigations.

National groundwater monitoring follows mainly the following objectives and is designed accordingly:

1. to investigate the natural background quality (e.g. BE, FI, SE)
2. to investigate zones potentially influenced by anthropogenic pollution (e.g. BE, FR, ES)
3. to investigate the overall status of groundwater (quantity and quality) and to detect adverse developments (e.g. AT, DK, FR, PL, RO)
4. to document the efficiency of measures set (e.g. DK)
5. to fulfil reporting obligations (e.g. DE, FR, ES, UK)

This national monitoring is often divided into different networks according to different purposes, different obligations, different administrative responsibilities and/or regions.

In principle, the monitoring of diffuse pollution and the overall status is performed on a national level and the monitoring of point sources of pollution is the duty of the land owner or the requester of a permit. In the latter case the data are mostly not automatically forwarded to the national level.

The following monitoring is mainly performed on a local level by land owners, water companies, permit holders, investigators etc. and the data are mainly not reported automatically but available on request:

- The observation of raw water quality at drinking water abstractions is mainly done by the drinking water providers and the data are usually kept at the providers. In BE, FR, MT, data are collected at the national level.
- Monitoring to control permits, as a prerequisite of permitting and licensing of activities, is mainly done as self-monitoring of the licence holder.
- The observation of already impacted zones (around dump sites, contaminated land, plume investigation etc.) is mainly done in connection with remediation and focuses usually on very specific parameters.

5.2 Network organisation

The organisation of the groundwater monitoring networks is very diverse and differs from country to country which is demonstrated by some examples below (details see Annex 2):

- AT, BG (?), DK, LT, UK run a multipurpose national groundwater monitoring network covering several objectives.
- BE, ES run different monitoring sub-networks focusing on different topics (e.g. nitrate, pesticides, nature reserves, saltwater intrusion,…).
- FR distinguishes the national networks according to purposes and reporting obligations.

- DE distinguishes the national networks according to reporting obligations (Nitrate Directive, EEA data request)
- FI and PL distinguishes according to purposes and responsibilities
- NL distinguishes the networks according to topics, responsibilities and vertical levels

These differences probably derive from a different definition of a “monitoring network”. In France, for example, a network corresponds to an objective and to a manager (health services, water agencies,…). But as a monitoring point (and even a sample) can belong to several networks, it would be possible to consider a national and multidisciplinary network. This is a question of definition.

5.3 Consideration of vertical stratification, depth of monitoring, zones of interest

The majority of countries mention the understanding of the influence of anthropogenic activities on groundwater quality to be a main objective of groundwater monitoring. This suggests that the focus of monitoring seems to lie on shallow groundwater and deep groundwater is usually monitored to a less degree.

The focus on the upper groundwater horizon is explicitly mentioned in AT, DK, DE, LT and RO. In several countries the focus on groundwater quality and quantity also lies on the deep groundwater horizons as they are the main source of drinking water supply like in LT, PL and RO. In NL the groundwater is monitored in 4 different vertical levels (upper, shallow, intermediate and deep groundwater).

The country reports as well as the monitoring data for the test groundwater bodies within WG 2.8 let assume that mixed sampling is the preferred sampling beside NL which explicitly mentions vertical stratified sampling.

5.4 Network design – site density, areal distribution, sampling frequency

The EEA inventory of groundwater bodies collected via EIONET-Water gives a comprehensive overview of the number of sampling sites, the size of groundwater bodies and sampling site densities within Europe. Information on nearly 2,000 important groundwater bodies has been reported. Size and site information is available for about 630 groundwater bodies distributed all over Europe (25 countries). The average number of sampling sites within a groundwater body is 10 with a range of 1 to 302. The average size of groundwater bodies is about 670 km² with a range of 0.2 to 63,000 km². The mean density of sites is 337 km²/sampling site with a huge range of 0.2–15,000 km² per site.

It has to be taken into regard that in contrary to the WFD which covers all groundwater bodies, the groundwater bodies reported to the EEA via EIONET-Water comprise important groundwater bodies according to the selection criteria laid down in the Eurowaternet guidelines.

The areal distribution of monitoring sites highly depends on the compliance regime and the aggregation algorithms applied. The distribution was intensively discussed during the elaboration of statistical tools for the aggregation of data and the assessment of trends and trend reversal within WG 2.8. Annex I illustrates the spatial distribution of sampling sites within the test groundwater bodies. A first assessment whether the site distribution is adequate was performed by calculating the Representativity Index. The final assessment lies with the local expert who judges the representativity of the network from the hydrogeological expertise.

Nevertheless, at some groundwater bodies a need of network redesign under the given statistical assessment was identified.

According to the country reports the frequency of quality monitoring lies mainly around 1–4 times per year. It varies between once every 6 years to 12 times per year. The monitoring frequency usually depends on the monitoring objective (surveillance/operational) and the type of groundwater body (confined/unconfined). In DK the frequency depends on the age of GW and the type of parameter.

5.5 Consideration of dependent ecosystems

The WFD requires the prevention of deterioration of aquatic ecosystems and of terrestrial ecosystems and wetlands directly depending on the aquatic ecosystem. Regarding the monitoring of protected areas Art 8 requires the consideration of monitoring specifications laid down in Community legislation under which the individual protected areas have been established

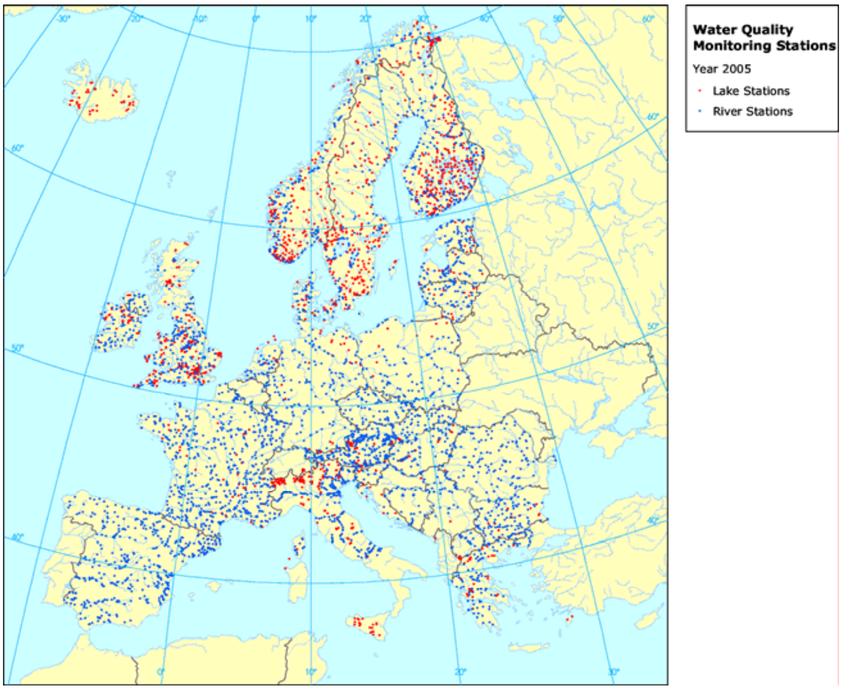
The consideration of dependent aquatic and terrestrial ecosystems in connection with groundwater monitoring is rather not that obvious within Europe.

Aquatic ecosystems

Monitoring of aquatic ecosystems is established nearly all over Europe as about 30 countries contributed to the data request for rivers data of the EEA and quality data on lakes is available for about 23 countries (http://dataservice.eea.eu.int). The following figure illustrates the distribution of sampling sites for river and lake monitoring where quality data have been provided within EIONET water. It can be seen that accessibility to data of lakes monitoring stations is partly not that developed whereas the river monitoring stations cover the whole of Europe in a more or less comprehensive way. It has to be taken into regard that the presented monitoring stations are subject to a prior selection process.

It can be assumed that up to now monitoring of groundwater and monitoring of aquatic ecosystems is usually performed very separately within Europe as the Water Framework Directive is the first attempt on a European level to consider the connection between groundwater quality and quantity and the status of aquatic ecosystems.

Figure 4: River and lake monitoring stations part of EIONET water.



Terrestrial ecosystems

In the context of groundwater and dependent terrestrial ecosystems the protected areas mentioned in the WFD include Natura 2000 sites established under the Habitats Directive (92/43/EEC) or the Birds Directive (79/409/EEC).

In May 2002 about 14 % of the territory of the EU 15 (more than 15,000 sites) has been proposed or included in Natura 2000. (Report from the Commission on the implementation of the Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora [Art 17 report]). A map of sites is not publicly available.

Regarding the implementation of the WFD groundwater monitoring the WG C groundwater and its drafting groups on *monitoring* and *protected areas* agreed that monitoring of the status of the dependent ecosystems has to be performed under the respective Directives (e.g. Art 11 of the Habitats Directive requires surveillance of the conservation status of the natural habitats and species). Only if dependent ecosystems are affected by groundwater a monitoring needs to be installed for the purpose of compliance with the WFD.

Regarding terrestrial ecosystems national reports on groundwater monitoring hardly mention the consideration of such ecosystems within the network design. Appropriate information on monitoring within such ecosystems would have to be gathered from different administrations responsible for nature protection. Only BE mentions explicitly the existence of a monitoring network for observing nature reserves when describing existing networks measuring the influence of certain pollutants on the groundwater quality (see Annex).

The summary of GW-bodies subject to testing within WP4 of BRIDGE gives a brief overview of other monitoring beside groundwater focusing on aquatic ecosystems and terrestrial ecosystems. Within 18 of the 21 proposed GW-bodies protected ecosystems have been reported. In 8 GW-bodies monitoring of terrestrial ecosystems was reported to be at least partially implemented.

5.6 Quality assurance procedures

The confidence in any assessment of groundwater will depend on the confidence in the conceptual model/understanding of how pressures are interacting with the groundwater system. The confidence in any model needs to be evaluated by testing its predictions with monitoring data. However, errors in the monitoring data could lead to errors in the evaluation of the reliability of the conceptual model/understanding. It is important that the probability and magnitude of errors in the monitoring data are estimated so that the confidence in the conceptual model/understanding can be properly understood. For the surveillance and operational monitoring programmes, estimates of the level of confidence and precision in the results of monitoring must be given in the river basin management plans.

Evaluation of existing networks – Network redesign

An appropriate quality assurance procedure should reduce errors in monitoring data. Such a procedure should review the location and design of monitoring points to ensure that the data they provide are relevant to the aspects of the conceptual model/understanding being tested.

Regular reviews of monitoring programmes contribute to a targeted answering of questions and an efficient use of resources. E.g. in AT the monitoring programmes are reviewed every 6 years. But it has to be taken into regard that in the light of long term trend assessments the stability of sampling sites over decades is quite important. In several countries the monitoring networks seem to be implemented recently therefore revision programmes might not have been performed.

Sampling, analytics, assessment

Errors can also occur in sampling and in the analysis of water samples. Quality assurance procedures may take the form of standardisation of sampling and analytical methods (e.g. ISO standards), replicate analyses, ionic balance checks on samples and laboratory accreditation schemes.

In 2003 the EEA tested a quality index assessing national data delivered via Eionet. The index comprises 8 questions targeted towards the assessment of sampling, analysis and data screening and is based on answers from 5 volunteer countries. The overview shows that in DK, ES, FR, HU and NO the efforts on quality assurance are already quite high.

Table 3: EEA Data Quality Index in selected countries

		Score	DK	ES	FR	HU	NO	PL	UK (E & W)
Questions	Question/waterbody type (R = rivers; L = lakes; GW = groundwater; ALL = inland, transitional, coastal and marine waters)		ALL	R, L, GW	R, L, GW	R, L, GW	ALL	R, L	R
1	Is sampling (and are any field measurements) carried out to a documented protocol by staff who have undergone specific training?	1	0	1	1	1	1	1	1
2	Are the analytical laboratories accredited by a national accreditation body — to ISO 9000 or EN45000 series standards?	1	1	1	1	1	1	1	1
3	Are the laboratories subject to external audit?	1	1	1	1	1	1	1	1
4	Have numerical accuracy requirements been defined for all relevant determinands?	2	0	2	2	2	2	0	2
5	Do laboratories have performance test data for their own analytical systems — indicating the precision of analysis, spiking recovery and limits of detection?	1	1	1	1	1	1	1	1
6	Can the laboratories produce routine quality control charts for all relevant determinands?	3	3	3	3	3	3	3	3
7	Is the monitoring programme linked to a series of routine and regular interlaboratory tests — for all relevant determinands either on a national or international basis?	2	2	2	2	2	2	0	2
8	Are the monitoring data automatically (i.e. using specific software) screened for statistical outliers or checked for unusual results before being stored on a national or regional database?	1	1	0	0	1	1	1	1
	Quality index score	12	9	11	11	12	12	8	12

Within the country reports AT highlights that every 6 years an extended investigation programme identifies the parameters being monitored in the remaining period. Various elements of QA procedures were introduced e.g. laboratories have to fulfil very stringent provisions. DE highlights the checking of results against formal criteria and against plausible concentration ranges.

5.7 Adaptations to WFD requirements

In many countries the groundwater bodies were delineated recently (according to the WFD) or the already existing groundwater bodies were amended accordingly. The monitoring is now designed or adapted based on the new groundwater bodies and the Art 5 analyses. Some country reports (attached in Annex 2) give a summary on the adjustments to the monitoring requirements laid down by the WFD.

As far as monitoring programmes are available they are going to be the basis for the implementation of the WFD groundwater monitoring. AT, FI, FR, DE, MT, NL, NO and UK explicitly mention that existing national monitoring networks are going to be amended according to the WFD requirements, ES intends to merge the existing programmes. Sampling sites will be selected from existing programmes and new sites will be established if necessary. In FI, NO and SE the grouping of groundwater bodies for monitoring purposes is essential.

Difference between surveillance and operational monitoring

The differentiation between surveillance and operational monitoring is not that far developed and decided at this stage.

In AT the surveillance and the operational monitoring network are intended to be identical.

FR intends the Patrimonial network to represent surveillance purposes and the Impact Networks (nitrate, pesticides, IPPC) to represent operational monitoring.

In NO the surveillance monitoring is covered by the reference stations and the operational monitoring by sites run by the water works.

Transboundary aspects

Transboundary aspects with regard to monitoring are not mentioned at all in the country reports. The only source of such information is the UN/ECE inventory of transboundary groundwaters which is based on information collected in 1996.

The main conclusion was that there is lack of cooperation in monitoring. In only one third of transboundary groundwater bodies where quality monitoring is performed, it is performed on both sides and the monitoring systems are inhomogeneous.

5.8 References

Technical Report No. 1. The EU Water Framework Directive: statistical aspects of the identification of groundwater pollution trends, and aggregation of monitoring results. ISBN: 92-894-5639-6

Guidance Document No. 2: Identification of Water Bodies. ISBN 92-894-5122-X

Guidance Document No. 3. Analysis of Pressures and Impacts. ISBN 92-894-5123-8

Guidance Document No. 7. Monitoring under the Water Framework Directive. ISBN 92-894-5127-0

Technical report on groundwater monitoring as discussed at the workshop of 25th June 2004.

EEA (2005): Waterbase Groundwater. EEA data service. http://dataservice.eea.eu.int/dataservice/metadetails.asp?id=757

Report COM(2002) 407. The implementation of Council Directive 91/676/EEC concerning the Protection of Waters against Pollution caused by Nitrates from Agricultural Sources.

UN/ECE (1999): Inventory of Transboundary Groundwaters.

6 Annex 1 - WG 2.8 test GW-bodies

Figure 5: Partners and observers in WG 2.8 and test GW-bodies

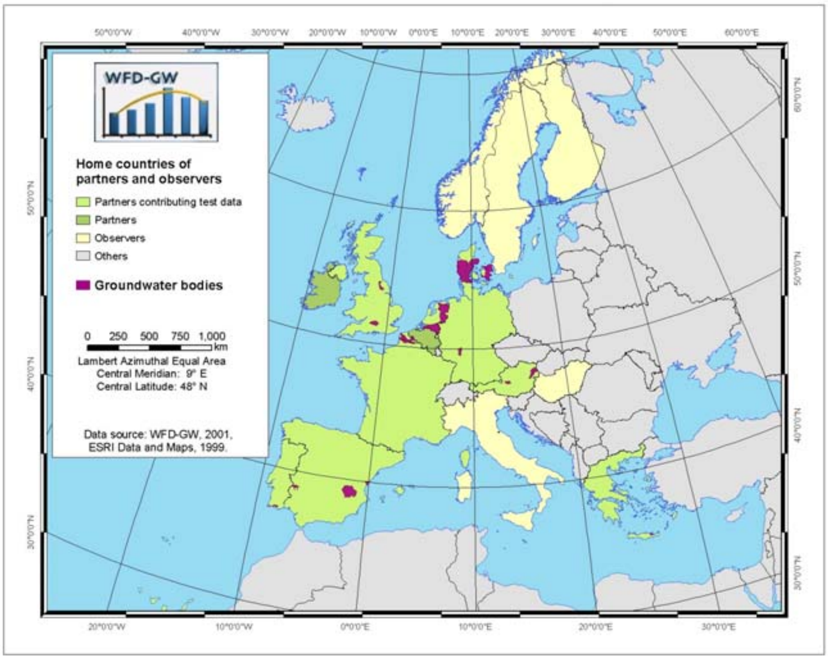


Table 4: WG 2.8 Test groundwater bodies, location and size information

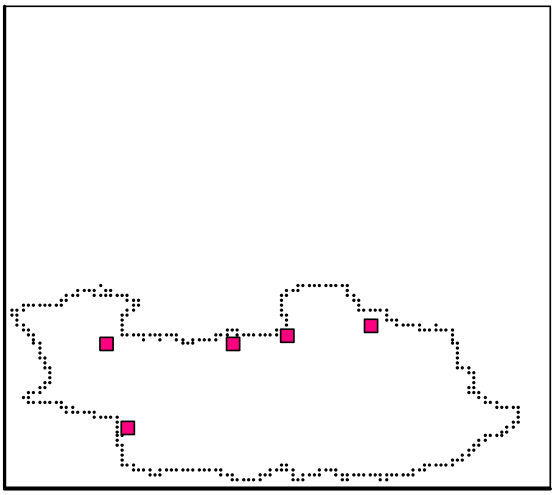
Code	GW-body name	Region	Area [km²]	Length/Width
AT154	Dachstein	Eastern Alps, Upper Austria	580	1.8
AT224	Marchfeld	Lower Austria	1 018	1.5
AT250	Südliches Wiener Becken	Lower Austria	1 198	2.0
DE001	Hessisches Ried	Hessian Ried	1 240	1.7
DK100	West Jutland		10 626	2.6
DK200	East Jutland		9 223	3.2
DK300	Zealand		5 821	2.2
ES0409	Vegas Bajas	Extremadura	715	1.5
ES0812	Plana de Castellón	Comunidad Valenciana	549	1.6
ES0829	Mancha Oriental	Castilla-La Mancha	3 574	1.3
FR001	Artois	Nord Pas de Calais	3 861	3.1
FR202	Calcaire carbonifère	Nord Pas de Calais	585	1.6
GR100	Agios Nikolaos	Crete island, Greece	150	2.0
NL002	Southern sand area	Noord-Brabant	5 452	0.7
NL004	Eastern sand area	Achterhoek/Twente/Salland	3 491	1.1
NL005	Northern sand area	Drente/Zuid-Groningen/Zuid-Friesland	5 196	1.0
PTA2	Escusa	Alentejo	8	11.0
PTM2	Almádena - Odeáxere	Algarve	64	2.7
PTM5	Querença - Silves	Algarve	318	4.3
UK002	Chalk - Marlborough & Berkshire Downs and Kennet Valley	Thames	1 534	0.5
UK006	Sherwood Sandstone Group - North Yorkshire	North Yorkshire - North East Region	550	1.9

Table 5: WG 2.8. Hydrogeological characteristics – thickness of the aquifer and the layers above the aquifer with reference to the aquifer type

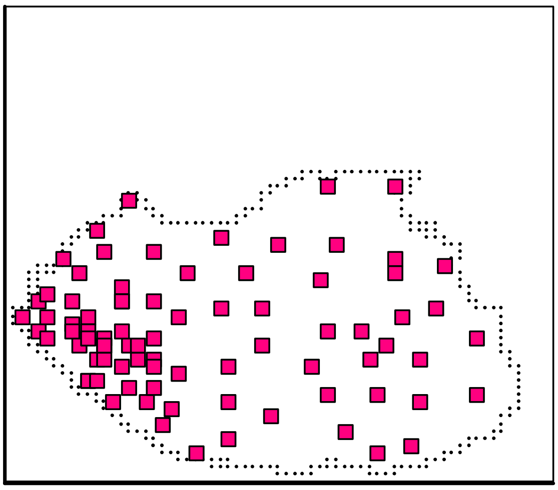
Code	**Thickness of top soil**	**Sum of thickness of low permeability layers (number of layers)**	**Mean depth to groundwater**		**Mean thickness of aquifer**	**Aquifer type**
			mean value	min-max	mean value	
	[m]	[m]	[m]		[m]	
AT154	0.1		600	1–1 000	1 000	karst-unconfined
AT224	1.2		5	1–30	15	porous-unconfined
AT250	0.5		5	1–60	30	porous-unconfined
DE001	1.75	20 (2)	3	1–35	100	porous-unconfined
DK100	1		4	1–10	20	porous-unconfined
DK200	5	10 (2)	10	1–25	10	porous-confined
DK300	5	20 (?)	8	0–20	30	karst-confined
ES0409	0.75		6	2–13	12	porous-unconfined
ES0812	0.75		20	0.5–100	80	porous-unconfined
ES0829	0.5		65	30–120	90	karst-unconfined
FR001			33	0–146	0	porous-unconfined
FR202			80	5–100	0	karst-confined
GR100	20	40 (2)	0	0–400	150	karst-unconfined
NL002	0.5		2	0–10	200	porous-unconfined
NL004	0.5		2	0–30	50	porous-unconfined
NL005	0.5		1	0–5	150	porous-unconfined
PTA2	1		10.6	0.19–20	0	karst-unconfined
PTM2	1		27.07	0.95–58.5	0	karst-unconfined
PTM5	1		41	0–81	200	karst-unconfined
UK002	1		15	0–140	110	fractured-unconfined
UK006		20 (?)	5	1–13	100	porous-unconfined

6.1 WG 2.8 Groundwater monitoring network designs

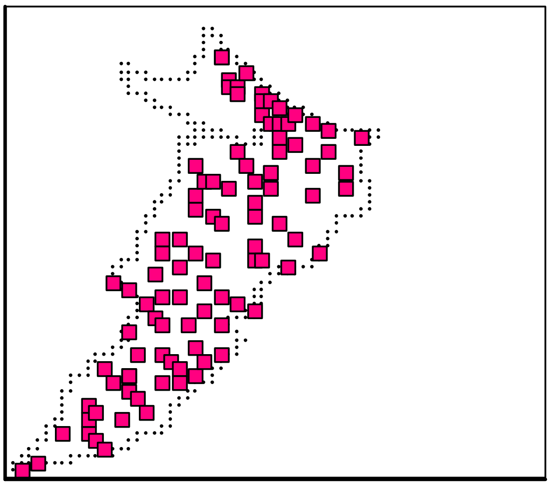
AT154
01.01.99 Ru: 63.5%



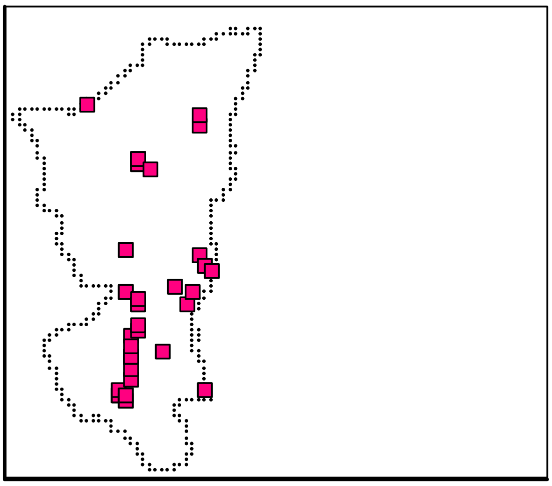
AT224
01.01.99 Ru: 74.9%



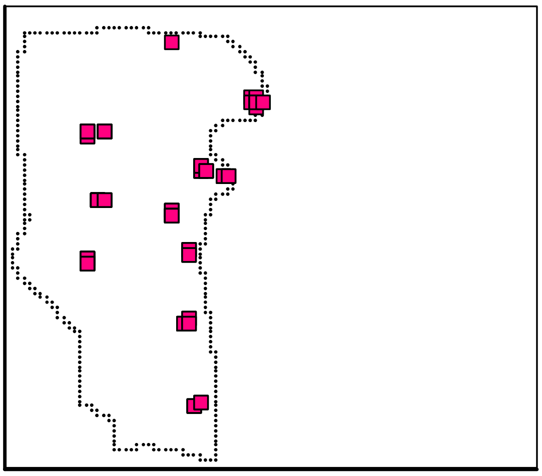
AT250
01.01.99 Ru: 65.3%



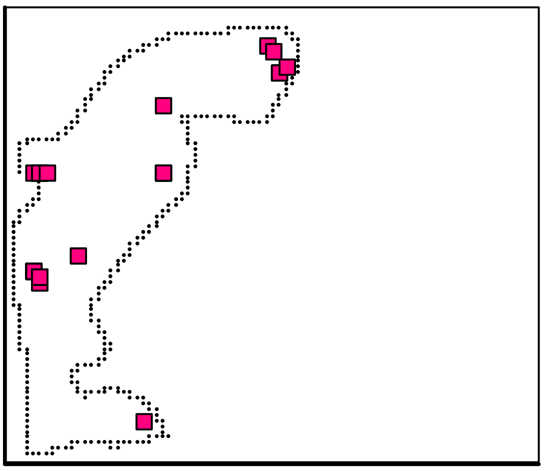
DE001
01.01.99 Ru: 39.1%



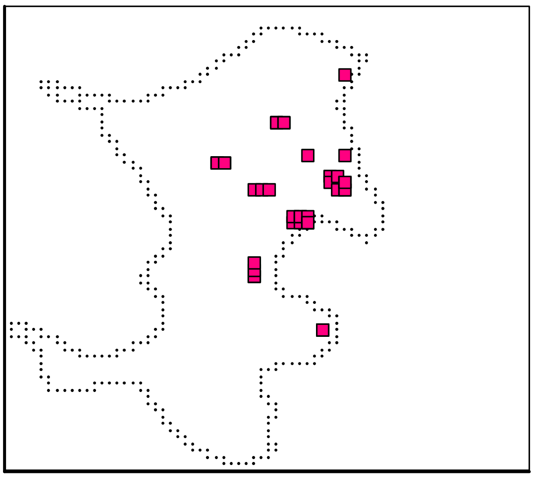
DK100
01.01.99 Ru: 26.8%



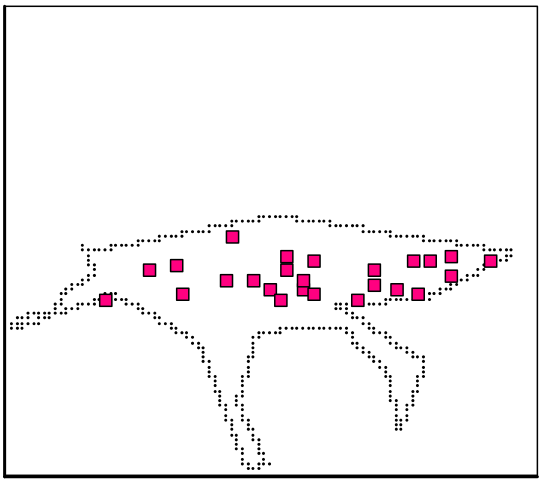
DK200
01.01.99 Ru: 42.4%



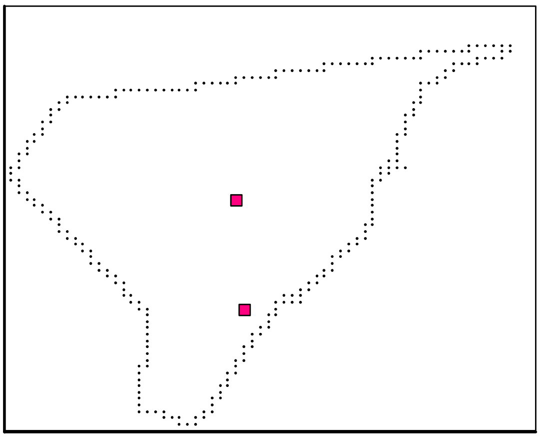
DK300
01.01.99 Ru: 23.4%



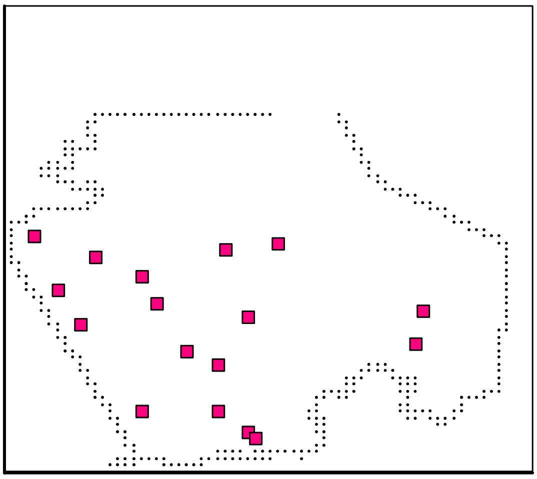
ES0409
01.01.99 Ru: 45.7%



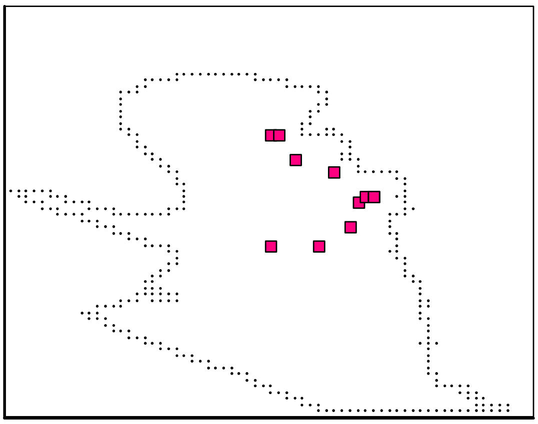
ES0812
01.01.99 Ru: 77.0%



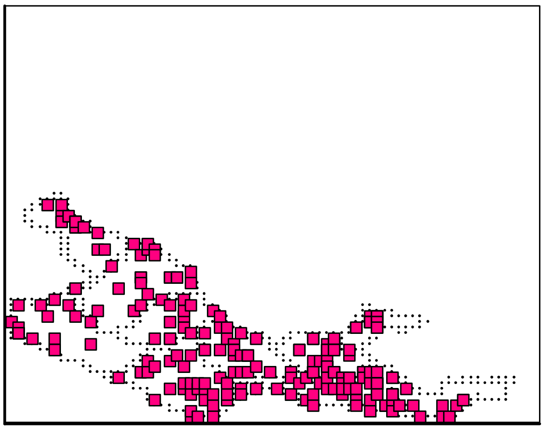
ES0829
01.01.99 Ru: 54.8%



FR202
01.01.99 Ru: 37.0%



FR001
01.01.99 Ru: 55.9%



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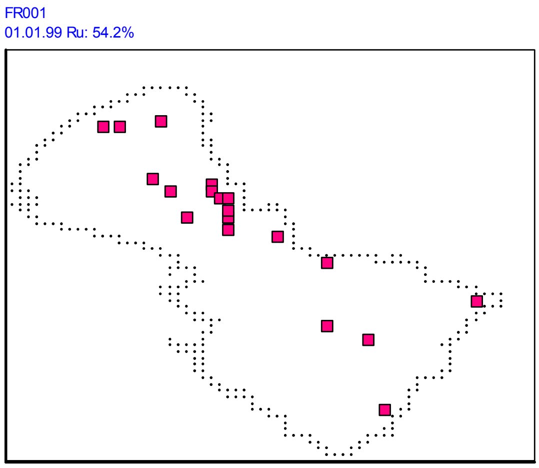

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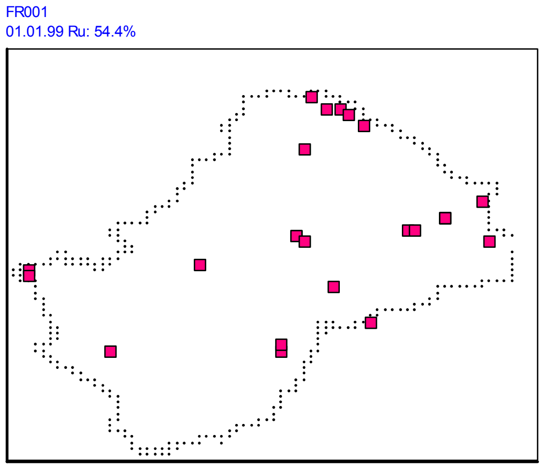

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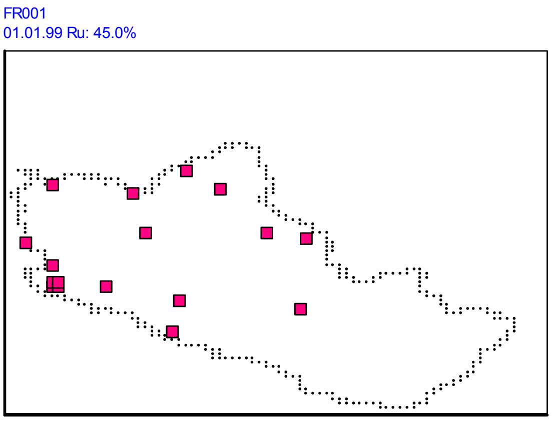

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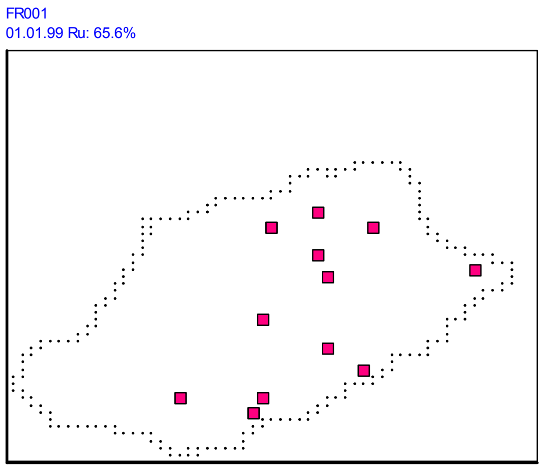
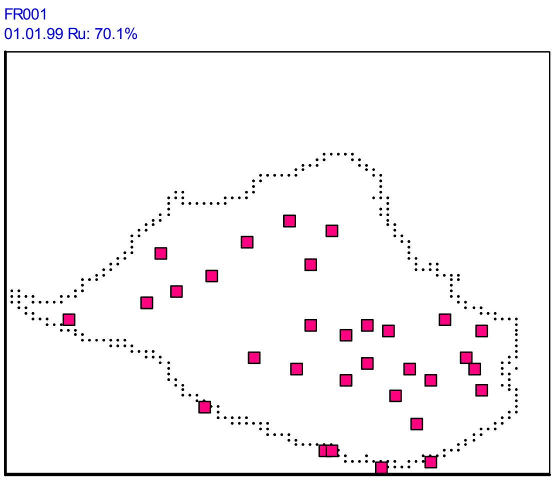
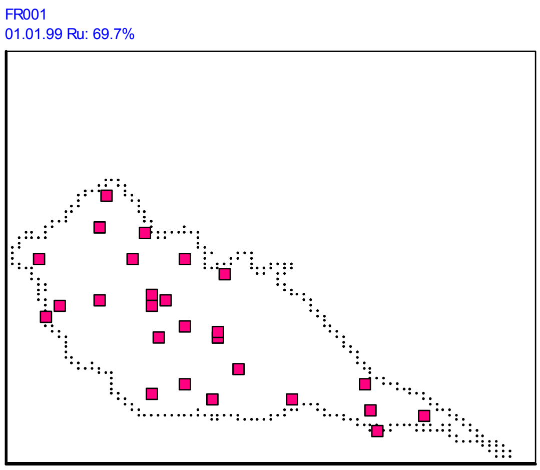


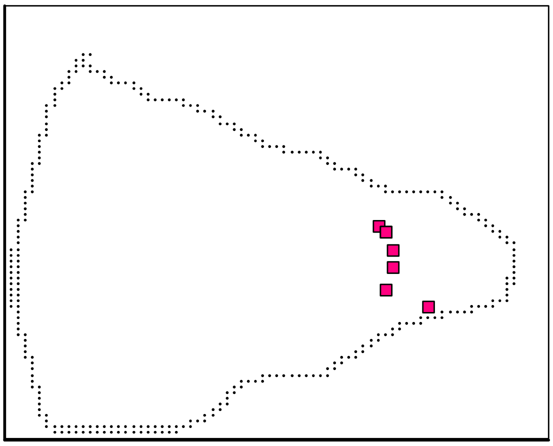
Subbody E



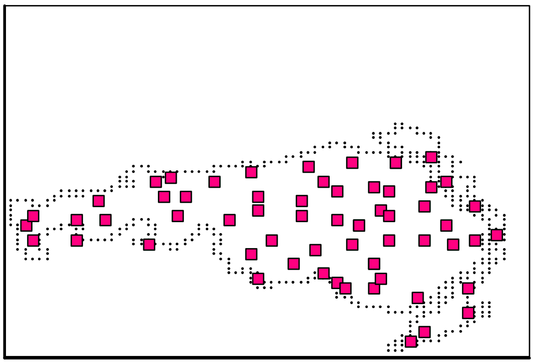
Subbody F



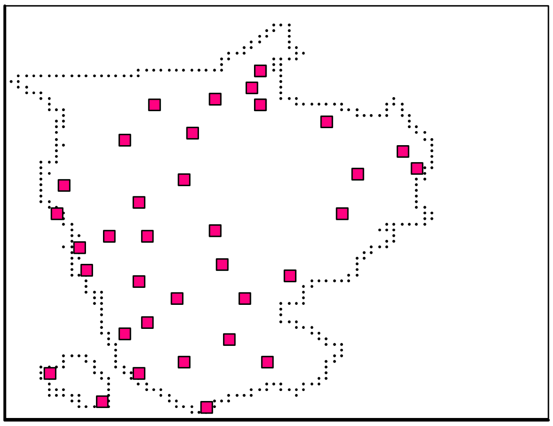
GR100
01.01.97 Ru: 28.5%



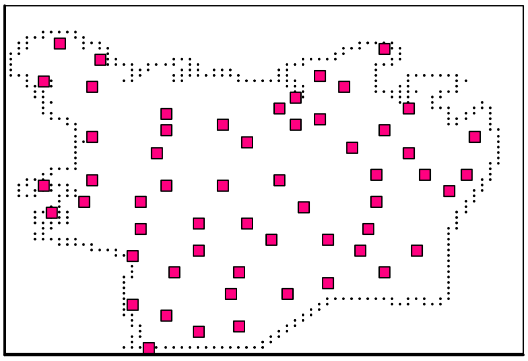
NL002
01.01.99 Ru: 81.9%



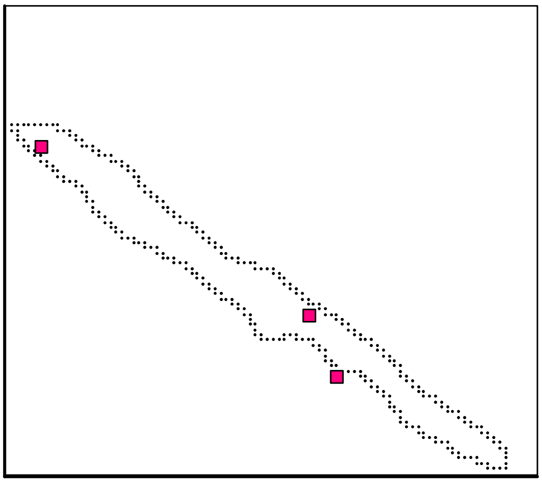
NL004
01.01.99 Ru: 74.1%



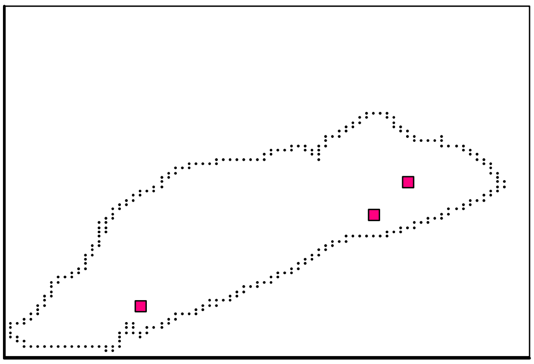
NL005
01.01.99 Ru: 84.8%



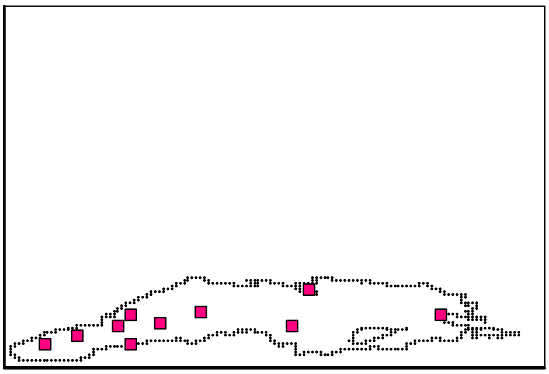
PTA2
01.01.99 Ru: 47.3%



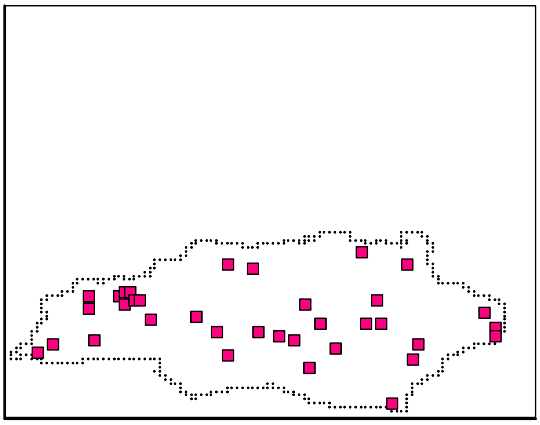
PTM2
01.01.95 Ru: 73.4%



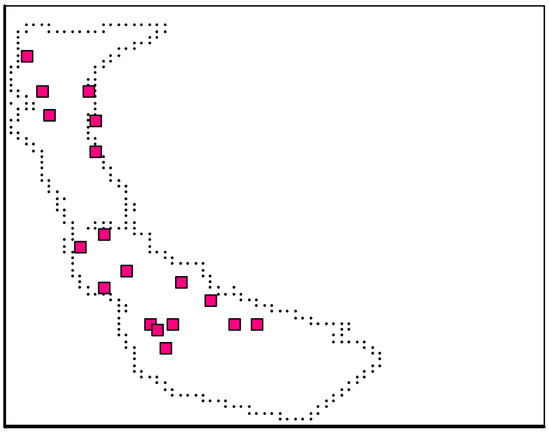
PTM5
01.01.99 Ru: 71.0%



UK002
01.01.99 Ru: 71.9%



UK006
01.01.99 Ru: 54.1%



7 Annex 2: Country reports – WG C and BRIDGE questionnaire

The overviews are based on the information provided for the technical workshop of WG C on groundwater monitoring and the accompanying technical workshop report. The overviews were supplemented by information gathered by a questionnaire which was distributed to the partners of the BRIDGE consortium.

7.1 Austria

Monitoring networks (general, introduction, philosophy)

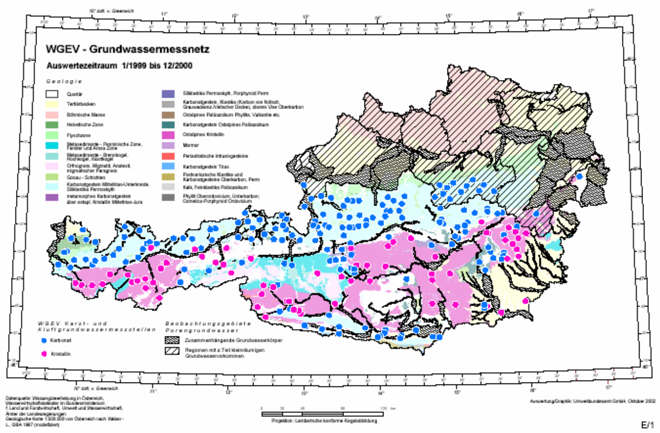
Standardised national water quality monitoring (groundwater and running waters) based on legal provisions started in 1991 and covers the whole of Austria. The groundwater monitoring programme covers groundwater in porous media, karst and fractured (fissured) rock.

Monitoring of groundwater chemical status

It is the objective to:

- monitor the overall groundwater quality
- detect negative developments at an early stage

Based on this monitoring, programmes of measures can be introduced to reverse a negative development. Current groundwater areas are very similar to the groundwater bodies or groups of groundwater bodies required by the WFD. The focus of the monitoring is on the upper groundwater horizon.



Number of monitoring sites

1759 monitoring sites for groundwater in porous media and 238 sites in karst and fractured rock were monitored (period 2001–2002).

Types of monitoring sites

Monitoring in porous media comprises investigation wells, private wells, industrial wells and partly water supply wells. Monitored springs (karst and fractured rock) comprise captured springs and springs.

Parameters

Block 1 - most important inorganic parameters: NO_3, NO_2, NH_4, P, B, Na, Ca, Mg,…

Block 2 – heavy metals and VHCs: As, Hg, Cd, Tetrachlorethylene,…

Block 3 – pesticides, PAHs: Triazine, Phenoxy alkane carbon acids,…

Frequency: 4/year

Organisation

At the Federal Level the Federal Ministry for Agriculture, Forestry, Environment and Water Management, Department Water Management Register, is responsible for the integrative assessment of data, the yearly publications of results, ensuring uniform procedures all over Austria and covering the main part of costs.

Based on an agreement the Umweltbundesamt (Federal Environment Agency) is responsible for IT-development and data management and technical co-operations regarding analytics and data assessment.

The provincial governor (Landeshauptmann) is responsible for operational management (call for tender, tendering, inspection of contractors during sampling and analyses, quality check of received data, data delivery to

the federal level), covering parts of the costs and co-operation regarding elaboration and amendment of guidance papers. In general, the costs of analyses and data transfer are met by federal (2/3) and provincial (1/3) authorities. The costs for selection and establishment of sampling sites are totally met by federal authorities. The total costs per year are about 2.2 to 2.9 mill. Euro. The legal background of the Groundwater Quality Monitoring Network are the Federal Water Act, the Hydrography Act, the Ordinance for Water quality Monitoring and the Ordinance for Groundwater Threshold Levels.
Quality assurance Since the beginning of the monitoring programme in 1991 importance was attached to take account of changes in the environmental conditions and to new experiences, which may result in an extension of the investigated chemical parameters in periodical intervals. For best quality assurance of analytical results, various elements of quality assurance were introduced in the monitoring programme. The overwhelming part of the operational activities (sampling and analysis) is contracted to private laboratories. To assure quality of sampling process and of monitoring results the laboratories have to fulfil stringent provisions. One of them is that only accredited laboratories (EN 4500) can attend. **Network review** The monitoring programme is based on a cyclic procedure of six years. An extended investigation is carried out in the first year covering an extended number of parameters. In the remaining five years the monitoring programme covers a minimum set of parameters plus parameters which appeared to be relevant based on experience from the initial investigation period. The quality data are publicly available via internet.
Adaptation to monitoring requirements by the WFD Until 2006 the existing Groundwater Quality Monitoring Network will be adapted according to the new Groundwater bodies and the WFD as far as required. The analysis for adaptation needs to new WFD groundwater bodies is mainly based on the information of the Art. 5 Analyses.

7.2 Belgium

Monitoring networks (general, introduction, philosophy) The monitoring network controlled by AMINAL consists of different sub-networks called primary, secondary and tertiary network.
Primary network This primary network consists of a restricted number of wells (approximately 240 wells) which are located in areas that are almost not influenced by anthropogenic activities. **Secondary network** The secondary network has to provide detailed information about restricted areas which can be influenced by anthropogenic activities. They are mostly located around water production areas and zones with high risks for groundwater pollution due to certain (industrial) activities. To measure the influence of certain pollutants on the groundwater quality different networks have been installed: - The *nitrate network*, which is also referred to as the phreatic observation network, is used to study the effect of agricultural activities and more specific the diffuse nitrate pollution. This network, composed of 2104 observation wells located in agricultural areas is monitored by AMINAL. - The *pesticide network,* also monitored by AMINAL is installed to study the effect of pesticides on the groundwater quality. - A network of observation wells *around drinking water production wells* or piezometers near specific industrial activities, where groundwater is used, necessary to obtain a production permit. Data collected

have to be reported to the Flemish government
- A network of wells in *nature reserves* to study the environmental conditions in these protected areas.
- A network of wells in *coastal areas* to follow possible salt water intrusion.

Tertiary network

The tertiary network focuses on anthropogenic impacts in very distinct zones e.g. around dump sites, polluting industries, nature reserves, or areas subjected to specific and temporary activities or structural changes. The number of wells depends on the type of activity present at the site. The monitoring is mainly carried out by the land owner or the owner of the facility. Data have to be reported to the Flemish government

Monitoring of point sources

The monitoring of groundwater point sources is regulated by the Flemish decree on soil remediation. Depending on the activity at a site soil and groundwater is investigated every 5, 10 or 20 years. The investigated parameters depend on the activities to be monitored.

Data are collected by the land owner or the responsible for the activities. The data are collected by OVAM. Data on groundwater quality is stored in a database. Till 2003 a total of 22.300 sites were investigated.

Organisation

Several groundwater monitoring networks focusing on water bodies and diffuse sources are maintained by the Flemish Administration for Environment, Nature, Land and Water Management (AMINAL). The collected data on quantity and quality provide an overall view on the changes in groundwater resources in Flanders.

Monitoring near point sources is laid down in a separate regulation which is organised and controlled by OVAM and currently implemented in Flanders.

7.3 Bulgaria

Monitoring of groundwater chemical status

The monitoring wells of the national groundwater monitoring network are linked to groundwater bodies. The national monitoring network is focusing on diffuse pollution and is currently modified.

Point sources of pollution are monitored by local monitoring. Data are not systematic and available at the Regional Inspectorates of Environment under the MoEW.

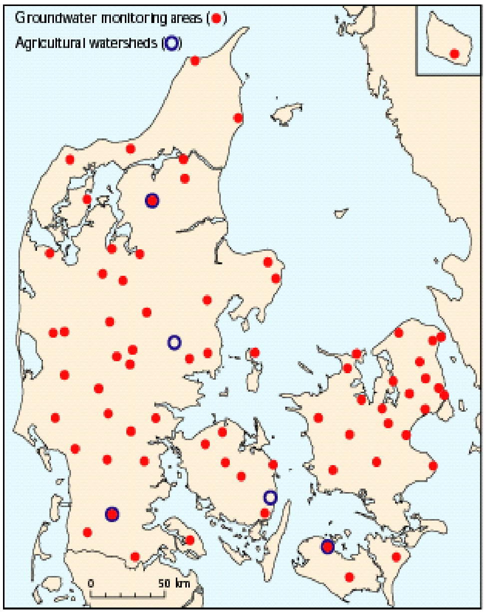
Data aggregation is in line with the principles laid down by the EEA (EIONET-Water

7.4 Denmark

Monitoring networks (general, introduction, objective)

The national monitoring programme was established in 1989. The objective of the monitoring programme is to:
- Monitor quality but also quantity in order to enable a description of status and follow trends, thus making it possible to explain the causes of the observed changes.
- Ensure sufficient amounts of groundwater with the right quality to cover the demand for drinking water, as well as to ensure the presence of sufficient water in nature to achieve standards set.
- Document effects of environmental measures and schemes regarding groundwater quality and quantity.
- Fulfil obligations under EU legislation as well as national legislation

Monitoring of groundwater chemical status



DK map showing the different monitoring areas

Network design, Sampling sites

Most important part of the monitoring programme is the 70 groundwater monitoring areas (> 1000 wells) called GRUMO that are distributed evenly throughout Denmark and representing the main aquifer types.

The national groundwater monitoring programme also includes approx. 85 intakes of groundwater from the shallow aquifers in 5 agricultural monitoring areas called LOOP. The LOOP catchment areas focus especially on describing the quality of the newly formed groundwater below cultivated fields.

In addition to GRUMO and LOOP groundwater analyses about 6000 abstraction wells connected to the waterworks are also available. The frequency of sampling and analysis is not the same as in GRUMO and LOOP but depends on the amount of groundwater abstracted and the type of parameter

Number of monitoring sites

Ca. 6084 wells/areas (70 GRUMO, 5 LOOP, ca. 6 000 water supply wells, 6 redox wells, 3 vadose zone wells)

Parameters

The monitoring programmes consist of 4 groups of compounds: main components (27 parameters), inorganic trace elements (23 parameters), pesticides (45 parameters) and other organic micro pollutants (24 parameters).

Frequency

In the national monitoring programme, the sampling and analysis frequency depends on the age of the groundwater and the type of parameter.

Monitoring of groundwater quantitative status

The Danish quantity monitoring programme focuses on water resource modelling. One modelling project concentrates on 12 main catchment areas. Another one is based on climate, precipitation, evaporation, piezometric network, water abstraction and water flow.

Number of monitoring sites

- GEUS piezometric network – 53 wells
- Counties network – unknown number
- Register of water abstraction
- Water resource modelling – 12 catchments

Network review

Since systematic monitoring started in 1989, minor adjustments have been incorporated in the programme. Some parameters and analysis frequencies have been changed.

7.5 Finland

Monitoring networks (general, introduction)

Nationwide groundwater monitoring networks are run by:

- Finnish Environment Administration (since 1975): The monitoring stations are located in areas without human impact to get background values as a basis for threshold values. The areas represent a range of geological and climatic conditions.
- The Geological Survey of Finland (since 1969): The aim is to measure the impact of geological factors and

anthropogenic activities on groundwater.
- The Finnish Road Administration (starts end of 2005): focusing on the impacts of road salting on groundwater.

Further monitoring networks are related to:
- Groundwater abstraction: Approximately 1500 water works monitor groundwater quality and quantity.
- Sand and gravel extraction: Based on licenses granted by municipal authorities about 1500 operators are obliged to monitor groundwater quantity and quality.
- Environmental permits:

Monitoring of groundwater chemical status

Finnish Environment Administration	The Geological Survey of Finland	The Finnish Road Administration
Number of monitoring sites		
53	50 groundwater basins	200 (50 more frequently)
Frequency		
4/year	1–4/year	

Monitoring of groundwater quantitative status

Number of monitoring sites	
53	50 groundwater basins
Frequency	
24/year	1-4/year

Adaptation to monitoring requirements by the WFD

The proposed surveillance monitoring network for groundwater will be based on the monitoring networks of the Finnish Environment Administration and The Geological Survey. About 180 sites in aquifers used for water abstraction will be added. The Finnish Environment Administration (POVET) will manage the database for groundwater quality and quantity data.

The existing monitoring networks will be used for groundwater monitoring programmes according to the WFD. Some additions will have to be made.

Due to the large number of groundwater bodies in Finland it is essential to group the groundwater bodies for monitoring purposes. The methodology is under development. To make use of all monitoring data more efficiently data management will have to be improved.

- Finnish Environment Administration
- Geological Survey of Finland

7.6 France

Current monitoring networks (general, introduction)

In France, many networks monitor groundwater chemical status at different scales. These networks are divided into three main types:

- Patrimonial network (since 1999): aims to give a general overview of groundwater status (quantitative + qualitative). It covers all groundwater bodies and is intended to be used as the WFD Surveillance Monitoring Network.
- Sanitary Network: is based on the Drinking Water Directive requirements and monitors untreated water. It is mainly composed of groundwater catchments (95% of the 35 000 catchments producing drinking water).
- Impact Networks: they aim to monitor the impact of a specific pollution on groundwater quality (e.g.: nitrates,

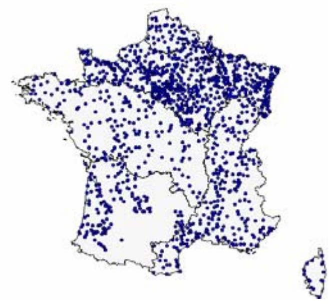
pesticides, point source pollution). They are intended to represent the WFD Operational Monitoring Network. The main networks of this type are:

- the *Nitrate Directive network*: designed to delineate vulnerable zones in accordance with the Nitrate Directive requirements.
- *Regional networks for the monitoring of pesticides contamination*: these networks aim to monitor water contamination caused by pesticides at a regional scale. The network differs from region to region depending on regional practices, crops or hydrogeological context.
- *Networks linked to the IPPC Directive*: local networks to monitor pollution caused by industrial installations. The specifications depend on the type of activity and the hydrogeological context

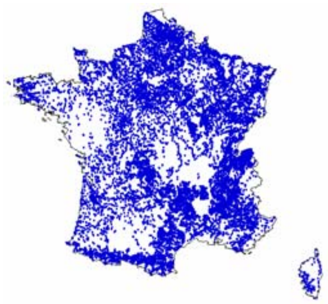
Network design

The networks design is based on the understanding of the hydrogeological system, the geological type of the groundwater body, on environmental objectives and on the type and level of pressures. In 2003 the French Guidance document on Groundwater Monitoring was published as well as the national groundwater database was made available (ADES: http://ades.rnde.tm.fr).

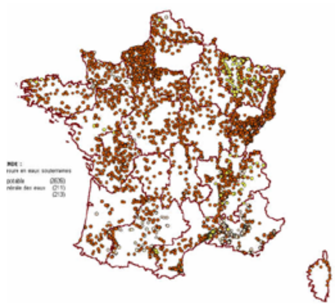
Surveillance Monitoring



Sanitary Network



Nitrate Network (Impact)



Surveillance Monitoring Network (Patrimonial)	Sanitary Network	Nitrate Network (Impact)
Number of monitoring sites		
1240 sites (about 1500 in 2006)	About 34 000	3052 (network is not representative)
Parameters		
parameters are linked to the frequency	parameters are different for GW and surface waters	Impact, one programme for 4 years
Frequency		
1/year in confined, 2/year in unconfined bodies	From 1/5 years to 12/year	every 4 years4/year

Monitoring of groundwater quantitative status

- Patrimonial Network
- Impact Network: is divided into the
  - Network for Water Policy: its objective is to share information on water abstraction within different users on the local scale
  - Warning Networks: concentrates on flooding and lowest water level

Number of monitoring sites

Patrimonial Network	Impact Network
1073 (about 1500 in 2006)	

Parameters

Water table level

Spring or river flow

Frequency

1/month (confined), 1/week (unconfined)

Organisation

The national patrimonial network aiming to monitor groundwater chemical status is called “RNES” (“Réseau National de connaissance des Eaux Souterraines”). It has been created in 1999 and is managed by the 6 Water Agencies.

Adaptation to monitoring requirements by the WFD

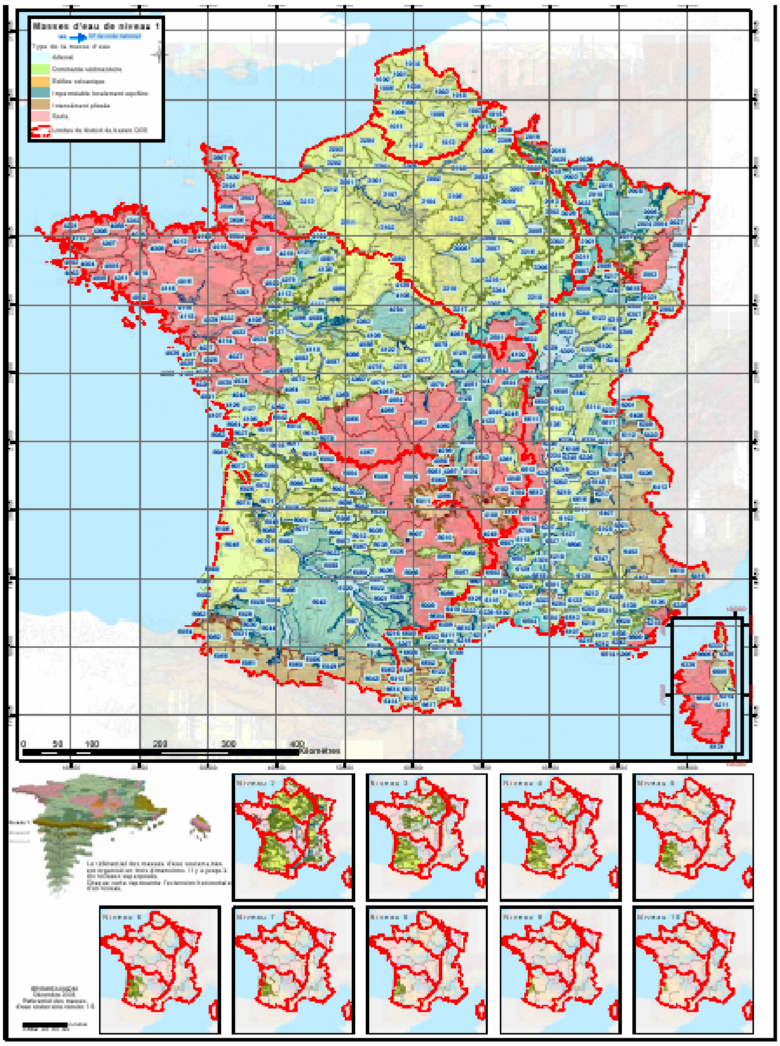
The networks mentioned above are providing very detailed information. To meet the WFD requirements, the national strategy consists of a rationalisation of existing networks. Monitoring sites or even measures can be used for different objectives e.g. surveillance monitoring + operational monitoring + sanitary control.

The Surveillance Monitoring network will mainly be based on the existing RNES and will be completed to take into account of the new delineation (groundwater bodies and not aquifers).

The Operational Monitoring network will be based on existing impact networks (i.e. for nitrates, pesticides and point source pollution linked to the IPPC Directive).

The sanitary network provides a lot of data that can be included in the surveillance monitoring network, although it is not representative of the general quality of groundwater (because catchments are preferentially situated in protected area to limit treatments).

French groundwater bodies



7.7 Germany

Monitoring networks (general, introduction)

In Germany the monitoring networks are in the responsibility of the Länder and each of the Länder runs its own monitoring network. Currently two transnational networks exist:

The EEA network and the EU Nitrate Network.

Types of monitoring sites

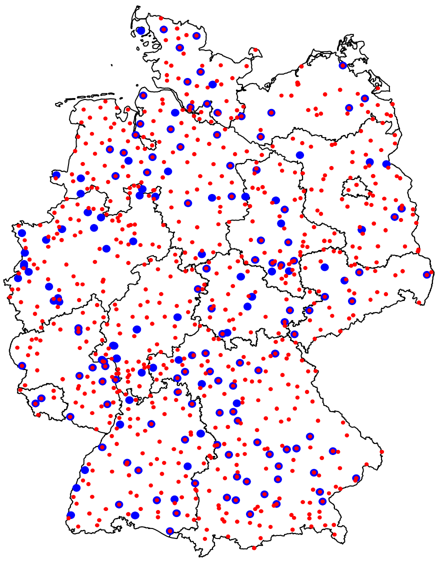
In general three types of sampling sites can be distinguished.

- Sites characterising groundwater “background conditions”, mainly situated in areas without any (significant) anthropogenic influence.
- Sites describing the influence of well known or expected anthropogenic influences, e.g. agricultural use, industries or settlements. Characterising the impact of diffuse inputs of substances in groundwater.
- Sites characterising point source contaminations, situated in the vicinity of waste disposal sites, contaminated sites, plants etc.

Monitoring networks - groundwater chemical status

The sites selected depend on the questions that have to be answered with these different networks. For reporting to the European Environment Agency (EEA) and for reporting on the implementation of the Nitrates Directive two nationwide monitoring networks have been set up in Germany.

Sampling sites were selected from existing monitoring networks operated by the Federal States. They reflect the known distribution of contaminated and uncontaminated groundwater bodies within each state. Sampling sites representing contaminated bodies of groundwater are located in regions in which groundwater contamination is more frequent.



EEA Network

Results have to be reported to the European Environment Agency (EEA)

- representative network
- about 800 sites
- distributed across the Federal States

Results are used for reporting under the EU Nitrates Directive

- worst case scenario
- about 180 sites
- influenced by agricultural use
- upper main aquifer

EEA network

The “EEA network” was established in 1990 in order to meet the data requests of the European Environment Agency. The network is designed to give a representative picture of the state of groundwater quality in Germany

The sampling sites are evenly distributed and focus on the upper main aquifer level.

Of major interest are the impacts of diffuse (non point source) anthropogenic inputs of contaminants on groundwater quality, e.g. nitrates, pesticides, acidifying components and other pollutants.

EU Nitrate Directive Network

The so-called “EU Nitrates Directive network” was established in 1995 and was specifically designed for reporting under the Nitrates Directive. The nitrate network was set up in order to depict the existing nitrate contamination and to evaluate the effectiveness of the measures taken. It focuses on regions with significant groundwater contamination by nitrates. The sampling sites are located in areas with high nitrate concentrations in groundwater. The sites were selected and are operated by the Federal States. The criteria for the selection of sites were:

- sites must be polluted by nitrate,
- the contamination source must be agriculture,
- site must be located in the upper aquifer

The EU Nitrates Directive network" is a "worst-case network" and describes the status of groundwater in polluted areas. It is not representative of the distribution of nitrogen in German groundwater.

Number of monitoring sites

EEA Network	EU Nitrate Network
About 800 sites (~1 per 450 km²)	About 180 sites

Parameters

General groundwater data: Temperature, pH, electrical conductivity, *Main components:* O2, NH_4, NO_2, NO3, o-PO_4, Cl, SO4, B, DOC, K, Na, Ca, Mg, Metals, Aliphatic halogenated hydrocarbons, Pesticides, Characterisation of site and catchment area

Frequency

2/year	2/year

Quality assurance

After checking for compliance with certain formal criteria, data validity is verified by drawing up the ion balance and by comparing the reported concentrations with known concentration ranges of similar types of groundwater and of the sites where they were measured.

Adaptation to monitoring requirements by the WFD

The EEA monitoring network as a starting point will be extended by the GWB approach in the near future. The number of sampling sites might increase or GWB will be grouped together.

The Federal States are planning to introduce corresponding changes over the next few years.

7.8 Italy

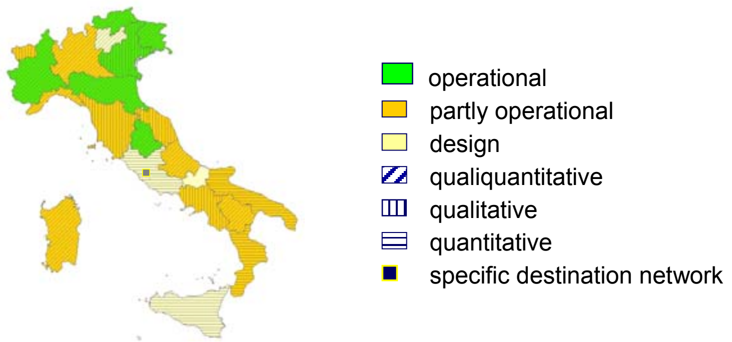
Monitoring networks (general, introduction)

Groundwater monitoring is based on the groundwater body characterisation. The implementation of the groundwater monitoring network is the first step in monitoring. The optimization of the groundwater monitoring network is the second monitoring step.

Existing monitoring networks cover different scales of areas. On the national level the monitoring programme focuses on national important groundwater resources, control of measurement programmes and on the functions of groundwater systems. The programme is a permanent one and will be operational in 2006.

On the regional level qualitative and quantitative monitoring as well as groundwater modelling are the main focuses. It's a permanent programme and already operational.

On the local level the monitoring programmes concentrate on specific occurrences and on risk warning. They are limited in time and operational when needed.



7.9 Lithuania

Monitoring networks (general, introduction, philosophy)

The first two levels (national and municipal network) are designed to observe and evaluate possible impacts of diffuse pollution.

The **National Monitoring Network** focuses on the overall status of groundwater quantity and quality taking regard of the natural background and human activities and is intended to tackle strategic questions of environmental protection. It represents the surveillance monitoring network. This network is supplemented by the **Municipal groundwater monitoring (**second level network) which started recently in municipalities of some larger cities. The strategic focus is more on daily business.

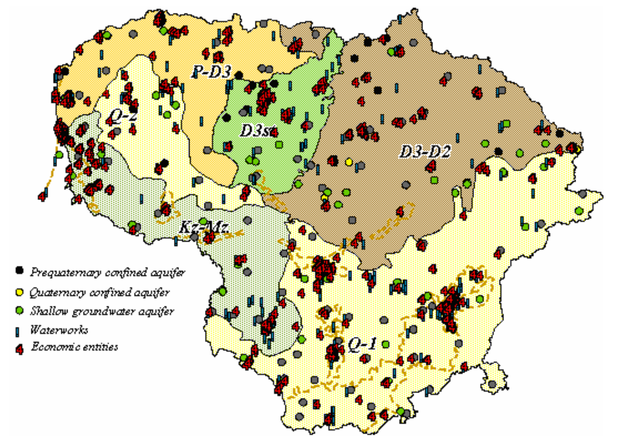
The **monitoring of economic entities** focuses on point sources of pollution and is intended to represent the operational monitoring network. Geological Survey approved an order on groundwater monitoring by economic entities and issued methodical recommendations. Monitoring specifications (frequency, parameters etc.) are laid down the individual permits/authorisations. The monitoring is approved by and the data are transferred to the Geological Survey.

Groundwater abstractions by water companies of more than 100 m³/day need at least one additional observation well - **well field monitoring**. The information obtained is a valuable supplement to the national monitoring programme.

National groundwater monitoring network

The Geological Survey prepared a National Groundwater Monitoring Programme for 2000–2005 which divides the monitoring network into two parts:

- Monitoring of shallow groundwater;
- Monitoring of deep aquifers. (Main sources of fresh water used for public water supply)



Monitoring of groundwater chemical status

Number of monitoring sites

Surveillance monitoring	Operational monitoring
284	1461/217 (potential polluters / water users)

Parameters

Basic parameters, Specific compounds

Frequency

basic parameters 1–2/year,

trace elements and organic pollutants every 2.5years

Monitoring of groundwater quantitative status

Number of monitoring sites

284	1461/217

Parameters

Water level	Water level, Water abstraction

Frequency

12-120/year water level	60-120/year water level users
4/year water abstraction	
1-4/year potential polluters	

Organisation

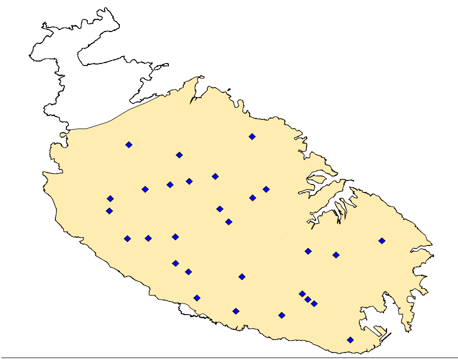
GW monitoring in Lithuania is performed at 3 administrative levels according to the Law on Environmental monitoring: national, municipal and economic entities level.

7.10 Malta

Monitoring networks (general, introduction)
For Malta including Gozo four main groundwater bodies are defined. The Malta Mean Sea Level groundwater body is by far the largest yielding about 66 % of the total Maltese GW abstraction.

Monitoring of groundwater chemical status
Currently the groundwater network is run and samples are analysed by the Water Services Corporation. Sampling sites are not monitored in that period where wells are not in use.
Number of monitoring sites: 92
Parameters: Temperature, pH, turbidity, conductivity, hardness, TDS, Nitrate, Chloride
Frequency: 12/year

Monitoring of groundwater quantitative status



The monitoring network (38 gauging boreholes) which was established in the late 1940s is managed by the Water Services Corporation. In vertical boreholes level recorders are used for the monitoring. As the network is not representative it will be redefined based on a 4x4 km grid. Additionally it is proposed to deepen the boreholes to include the Transition Zone.

Adaptation to monitoring requirements by the WFD
The groundwater monitoring strategy will be amended in order to be in line with the requirements of the WFD. A geometrically based network of abstraction sources has been proposed, where the quality of the extracted groundwater will be measured. Additionally the groundwater quality at the gauging stations will be measured, since this is expected to be more representative of the status of the groundwater body. The results obtained will be used to formulate the basic monitoring network.

7.11 The Netherlands

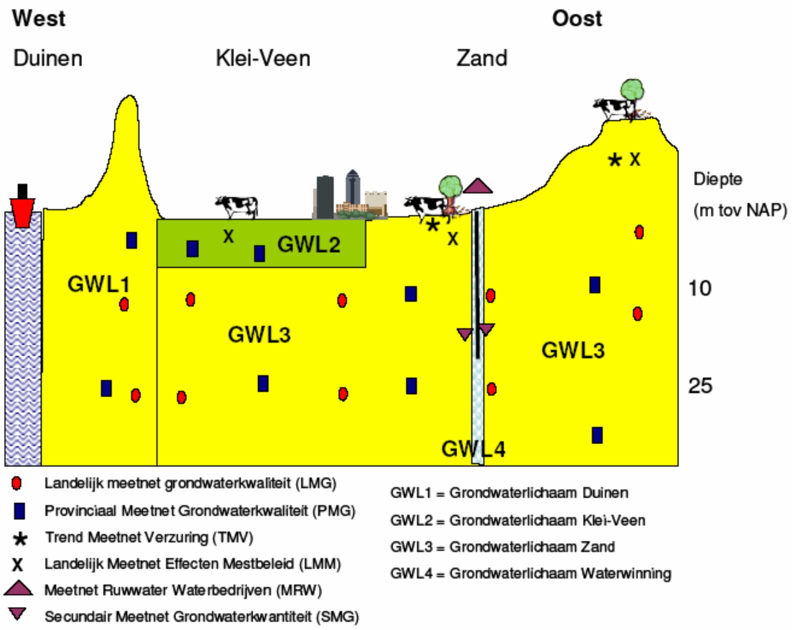
Monitoring networks (general, introduction)
In principle, the Netherlands consist of one single sandy aquifer. This aquifer was divided into 20 groundwater bodies based on the consideration of the hydrogeological situation, the status and the protection and finally water management aspects. Currently the various monitoring networks focus on 4 different vertical levels of groundwater: upper groundwater, shallow groundwater, intermediate groundwater and deep groundwater.

Monitoring of groundwater chemical status
Current networks
- *national GW quality network*: 340 wells, at 10 and 25 m below the surface, yearly, nutrients, metals
- *national soil quality network*: 200 wells, uppermost groundwater, yearly on 1/5 stations, nutrients and metals
- *provincial GW quality network*: 300 wells, 1–4/year, nutrients and metals, sometimes pesticides
- 246 water supply well fields
- additional networks: provincial soil quality network; National monitoring network for the management of manure, nutrients at farms; Designated monitoring networks around polluted locations; Monitoring systems of drinking water companies; Monitoring systems of towns

Adaptation to monitoring requirements by the WFD
In 2005 concept groundwater monitoring plans will be made for the 7 WFD river basin areas in the Netherlands. This will be done along the lines presented in the recently published “Draaiboek monitoring grondwater voor de Kaderrichtlijn Water”, Ministerie van VROM, March 2005. This cookbook is targeted to all involved groundwater

managers in the Netherlands and presents the basics to be followed when designing a network and monitoring groundwater for WFD purposes.
The design of existing monitoring systems and collection of data in the Netherlands are considered. The existing monitoring locations and data will be used in WFD monitoring as much as possible. The monitoring locations will be selected from the existing networks. If necessary, new monitoring wells have to be installed and monitoring frequency has to be increased.
The WFD monitoring network will based on the national and provincial GW quality network and the Provincial primary monitoring networks for groundwater levels. Several other existing monitoring networks that can be included in the WFD monitoring.

Network design
The figure below (from the "Draaiboek") illustrates the most important existing monitoring networks and how they will be used for the WFD groundwater quality monitoring in the Netherlands, in a west-east transect through the country. Groundwater bodies 1, 2 and 3 are regional bodies. In the western part of the Netherlands there is a vertical subdivision in groundwater bodies, the upper 3 meters are a separate groundwater body. Groundwater body 4 presents a body around a groundwater abstraction for drinking water purposes (100 yrs zone). In these bodies around abstractions the groundwater monitoring for WFD will mainly be based on monitoring of water companies.



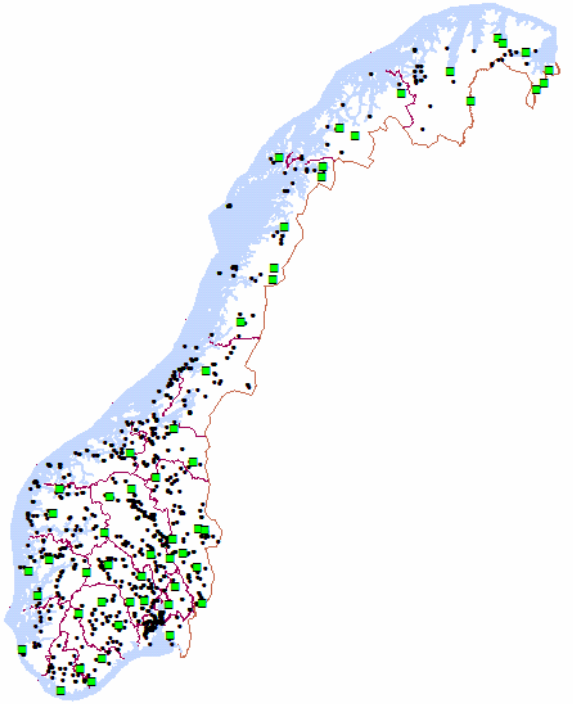
Network density, frequency, parameters
There will be about 1 monitoring station per 100 km^2, which means about 20 stations for large regional bodies. For status and trends, measurements are proposed to take place once every 6 years, for operational monitoring once every year. The proposal is to measure core parameters at all stations, pesticides only in agricultural areas, PO4 only in shallow groundwater bodies, and tri- and tetrachloroethene only in urban areas.

7.12 Norway

Monitoring networks (general, introduction)

The National Network with reference stations is operational since 1977. A national monitoring plan is under development. The total number of individual groundwater bodies is estimated to be about 8 000–10 000. Based on classification and grouping about 965 groundwater units will remain.

Monitoring of groundwater chemical status



Number of monitoring sites

Surveillance: 55 reference stations

Operational: 1500 waterworks

■ reference station

• waterworks

Adaptation to monitoring requirements by the WFD

Due to the large number of groundwater bodies a grouping of bodies is necessary. Especially in the northern part of the country few monitoring stations will represent a large number of groundwater bodies. The existing monitoring stations will be used for the surveillance monitoring. Monitoring sites run by water works will complete the network.

7.13 Poland

Monitoring networks (general, introduction)

The National Groundwater Monitoring in Poland is integrated in the Environmental Protection Programmes. The status of groundwater resources and groundwater quality are monitored in the framework monitoring networks operating on different levels (Kazimierski, Sadurski, 2002):

- national level (only for diffuse sources, for main GWBs);
- regional level (diffuse sources only, GWBs of regional importance) covering ca. 30% of the area of Poland;
- local level (early warning in wellhead protection areas and impact of point sources of pollution which is administratively imposed).

The national scale groundwater monitoring networks include monitoring of groundwater quantitative status and groundwater quality monitoring. Both types of groundwater monitoring are carried out by the Polish Geological Institute (PGI) and work within the framework of the environment quality monitoring programme of the State Environmental Monitoring System.

Monitoring of groundwater quantity status

The PGI set up the Stationary Groundwater Observation (SGO) network to monitor the quantity of primary and secondary usable aquifers within the entire country, excluding mineral, therapeutic and thermal waters.

The aim of this monitoring is

- to determine the freshwater dynamics,
- to protect groundwater resources from excessive exploitation, and
- to promote the public access to the results.

Number of monitoring sites: 600 (with a number of sites per aquifer system proportional to the estimated groundwater resources). For each observation point there is documentation concerning the geology, hydrogeological parameters and data regarding the environment (location, management method, land use, etc).

Frequency: The monitoring is made regularly observing the groundwater, assessing the groundwater quality changes and interpreting the obtained results. The aim of groundwater monitoring is to support the actions leading to limitation of negative influence of anthropogenic factors on the groundwater.

Monitoring of groundwater chemical status

Number of monitoring sites: 700 (exploitation wells, observation wells, dug wells and springs), monitoring various hydrological units. The proportion of sites monitoring shallow unconfined groundwater and deep groundwater are 54.6 and 45.4 %, respectively.

Frequency: The sampling of the monitoring network is carried out by the PGI once a year in the period of July-September.

Parameters: acidity, alkalinity, Al, NH4, As, Ba, CO3, HCO3, B, Br, Cd, Ca, carbonate hardness, Cl, Cr, Cu, dissolved organic carbon (DOC), specific electrical conductivity (SEC), F, hydrocarbons, Fe, Pb, Li, Mg, Mn, Mo, Ni, NO3, NO2, pH, PO4, K, SiO2, Sr, SO4, Ti, TDS, total hardness, V and Zn

Quality assurance

The Central Chemical Laboratory of the PGI in Warsaw, holding a quality certificate, carries out the measurement of the groundwater parameters.

Reporting

Annual report from the groundwater monitoring studies is presented to the Head Inspector of Environmental Protection. Each report contains the review of:

(1) groundwater quality (as well as changes relative to previous years);

(2) water quality in terms of quality indicators (physical and chemical parameters);

(3) water quality in terms of hydrogeological stages;

(4) water quality in areas of different land use;

(5) water quality as a function of depth of occurrence in the aquifer.

For the annual review of the groundwater quality, the ‘Classification of fresh groundwater fulfilling the needs for environmental monitoring’ is used (cf. Chapter 6). The results of the processed measurements along with short information about the monitoring system are periodically published in the series of the Environmental Monitoring Library (Hordejuk, 2002).

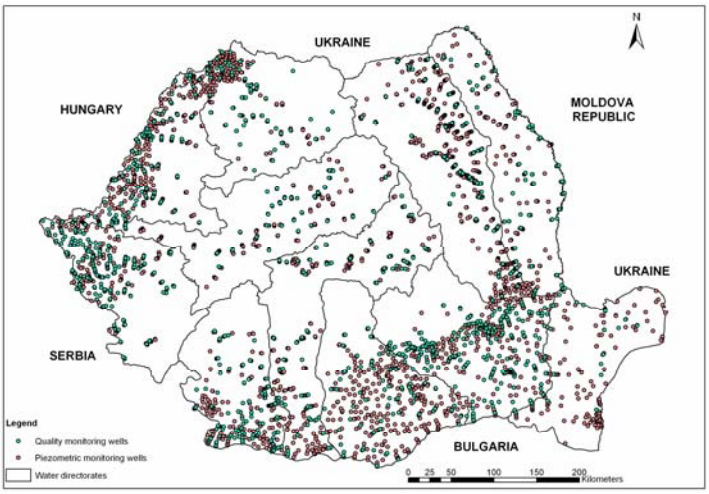
Groundwater quality is quantified through assessment of available data for individual monitoring sites and subsequent aggregation through simple statistics.

7.14 Romania

Monitoring networks (general, introduction)

In Romania two main monitoring programmes exist. The National Hydrogeological Network and Local Monitoring Networks.

- *National Hydrogeological Network*: The objectives are to improve the knowledge of the structure and the aquifer potential of phreatic and deep aquifers and to gain more information on the groundwater level regime and on the physical and chemical characteristics of the groundwater. The responsibility for the programme lies within the Romanian Waters National Administration where the data are stored in the hydrogeological database.
- *Local Monitoring Networks*: The objectives are to improve the information both on the development of the groundwater quality and on the groundwater quantity on local scale. The level of monitoring concentrates on certain pollutant sources or/and on important groundwater catchment areas.



Monitoring of groundwater chemical status - National Hydrogeological Network
Number of monitoring sites: Ca. 1200 phreatic aquifers, ca. 500 deep aquifers
Parameters: NO_3, NO_2, NH_4 etc. (22 at all)
Frequency: 2/year phreatic aquifers, every 2–3 years deep aquifers

Monitoring of groundwater quantitative status - National Hydrogeological Network
Number of monitoring sites: Ca. 4000 phreatic aquifers, ca. 500 deep aquifers
Parameters: Water level, Water temperature
Frequency: 120/year phreatic aquifers, 12/year deep aquifers

7.15 Spain

Monitoring networks (general, introduction, philosophy)

There are several groundwater monitoring networks in Spain.

- The automatic water quality information system (*SAICA*) for the control and monitoring of inland waters is based on a country wide network distributed in the nine hydrographic basins, and on a database keeping all relevant information (e.g. legislation, institutions, cartographic information of river beds, gauge stations, etc.). This automatic information system allows for almost real time decision making.
- The *piezometric monitoring networks* comprise more then 3,000 points and are managed by the Dirección General de Obras Hidráulicas and Instituto Geológico y Minero de España;
- The *hydrometric network* is controlled by the Drainage Basin Authorities to determine the flow of groundwater natural discharge;
- The groundwater quality observation control network (*ROCAS*) managed by IGME monitor major chemical components in about 1,800 points;
- The *Intrusion Observation Network*, to study the evolution of marine intrusion in coastal aquifers There are two additional networks:
- The *bathing waters quality control*, in accordance with Directive 76/160/CEE, and
- The *National Network for controlling Environmental Radioactivity* in surface waters, in operation since 1978 for controlling and monitoring several radioactive parameters.

Organisation

The Environmental Ministry by means of the Drainage Basin Authorities is responsible for the establishment of a National Monitoring Network. The Ministry is intending to merge the existing networks in order to create an Official Groundwater Network, managed by the Drainage Basin Authorities.

7.16 Sweden

Monitoring networks (general, introduction)

In Sweden three reference systems for groundwater monitoring exist.

- Reference stations for groundwater
- Groundwater network of the Geological Survey

Integrated Monitoring

Monitoring of groundwater chemical status

Number of monitoring sites

Reference Stations: 118

Groundwater Network: 34

Integrated Monitoring: 24

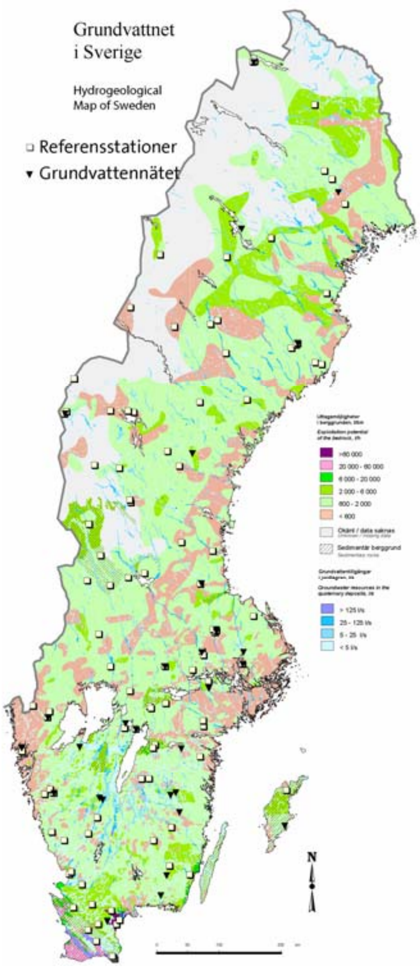
Monitoring of groundwater quantitative status

The Groundwater Network includes monitoring of the groundwater level.

Number of monitoring sites: 350 sites

Adaptation to monitoring requirements by the WFD

About 50 groundwater bodies are covered by the current monitoring network. Grouping of bodies in the northern part of Sweden will make it possible that stations represent a large number of groundwater bodies. At the moment the network is not designed to validate the impact assessment. Neither can the network serve as operational monitoring network. Background values will serve as basis for threshold values.



7.17 United Kingdom

Monitoring networks (general, introduction)

Obviously, many organisations (e.g. site owners) monitor groundwater at individual sites where there may be potential or known pollution or particularly sensitive receptors. In addition there is now a strategic monitoring network with over 2,700 boreholes.

Principles of network design

This network is designed to be risk based and to provide information focused on compliance with the Water Framework Directive. Boreholes are sampled to a nationally consistent frequency and determinand suite and used for reporting at local and national scales as well as international obligations such as contribution to the EEA (EIONET-Water)

Monitoring of groundwater quality

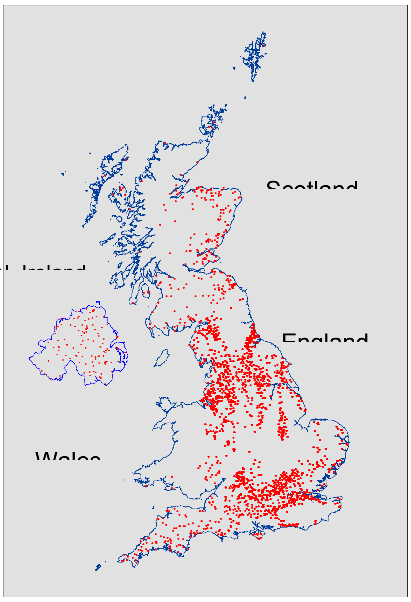
The groundwater Quality Monitoring Network is focussed on water supply aquifers but is being modified to take account of the WFD.

The groundwater levels in the groundwater quality monitoring network boreholes are monitored prior to the borehole being purged where possible. In addition there are also observation boreholes (not pumped) monitored for water level data. There are approximately 6400 observation boreholes in England and Wales that either contain data loggers or are regularly dipped.

Finally, the British Geological Survey maintains a record of all reported boreholes constructed across the country including stratigraphy, lithology and any water quality data available at the time

Number of monitoring sites

About 4000 are planned.



Parameters

Core parameters: WFD mandatory parameters, indicators and parameters for Quality Assurance

Selective parameters: parameters representative of land use/pressures, refined by output from risk assessment, local knowledge and regular review.

Surveillance monitoring will comprise core + occasional selective parameters for validation of risk assessments

Operational monitoring will consist of core + selective at sites in groundwater bodies "at risk"; for diffuse/widespread impacts at all monitoring sites; for point sources targeted monitoring.

Drinking Water Protected Areas as for surveillance and operational monitoring but focus on parameters that are driving any treatment of the water

Frequency

4/year – 1/6 years (surveillance)

1–4/year (operational)

Planned number of sites

Scotland: ~ 400 sites
England & Wales: ~ 3500 sites
N. Ireland: ~120

Monitoring of groundwater quantitative status

Parameters: Water levels, Spring and surface waters flow

Frequency: 12–4/year

STATUS, CONFIDENTIALITY AND ACCESSIBILITY									
Status				Confidentiality				Accessibility	
S0	Approved/Released	x		PU	public	x		Work-space	x
S1	Reviewed			PP	Restricted to other programme participants (including the Commission Services)			Internet	x
S2	Pending for review			RE	Restricted to a group specified by the consortium (including the Commission Services)			Paper	
S3	Draft for comments			CO	Confidential, only for members of the consortium (including the Commission Services)				
S4	Under preparation								