COMMON IMPLEMENTATION STRATEGY FOR THE WATER FRAMEWORK DIRECTIVE AND THE FLOODS DIRECTIVE

ANNEX

Compilation of indicative case studies in relation to WFD Article 4(4) exemptions on grounds of 'natural conditions'

Document endorsed by EU Water Directors at their meeting in Tallinn on 4-5 December 2017

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1 Background

This document compiles case studies provided by Member States and Participating Countries describing situations where “natural conditions” have been cited or are considered as a reason for the use of exemptions from meeting the environmental objectives according to Article 4(4) of the Water Framework Directive (WFD). **The document is an Annex to the main document on "Natural conditions in relation to WFD Exemptions",** which was elaborated in the context of discussions on the WFD 2027 deadline, identified by the Water Directors during discussions in 2016 as needing early attention, specifically in relation to the application of exemptions in the third River Basin Management Plans (RBMPs) which are due in 2021.

For the elaboration of the main document and this Annex, case studies on the concept on 'natural conditions' in relation to WFD exemptions were provided by Member State and Participating Country representatives in the WFD Common Implementation Strategy (CIS) working groups for Chemicals, Ecological Status and Groundwater. In addition several countries provided further thoughts and discussion points on the concept of "natural conditions" and potential issues that may justify this type of exemption. Discussions on the topic were also held at the meetings of these respective working groups during 2017.

All the case studies and input provided have been reviewed and used for drafting the main document “Natural Conditions in relation to WFD Exemptions” to which this Annex is attached. Note that **the main document focuses on Article 4(4) time extensions on grounds of 'natural conditions'. Therefore, also this Annex focuses on case studies in relation to the application of this type of exemption.** The case studies in this Annex are therefore a sub-set of the full complement of case studies which were provided, aiming to offer a particular focus on practical considerations and indicative information on issues pointed out in the main document. **In this context it needs to be clarified that the inclusion of case studies in this Annex does not automatically qualify them for Article 4(4) time extensions on grounds of 'natural conditions' or pre-empt any necessary justification required to be undertaken by the respective Member State.**

The case studies are presented in the following chapters by subject area in relation to Surface Water Ecological Status, Surface Water Chemical Status, Groundwater Quantitative Status and Groundwater Chemical Status. Some of the case studies may be relevant for more than one of these subject areas.

2 Compilation of Case studies

2.1 Surface Water - Ecological Status

Case study title: **Recovering from eutrophication after load reduction: the shallow Lake Balaton case study**	
Country: Hungary	Lake (real case)

Outline and general description: The case study represents an overview about recovery of shallow Lake Balaton. Lake Balaton is the largest (596 km²) shallow (average depth is 3.2 m), freshwater lake in the Central European region. It has a narrow and elongated shape. The largest inflow is the Zala River at the Western end, while there is a single outflow at the East where a sluice is regulating the water level. The mean depth and surface area of the lake's geographical basins increase from west to east, while the area of the contributing sub-watersheds decreases. The River Zala supplies almost 50% of the lake's total water and load input. The watershed area is approximately 5180 km².

Nutrient loads have been reduced by 45–50% since mid-1980s. While a delayed, but still surprisingly fast recovery was observed in the hypertrophic western areas of the lake, eutrophication followed sewage diversion from the mesotrophic eastern basins. The likely reason was the fast renewal of the sediment and hence the reduction of the internal P loads. Simultaneously, the structure of phytoplankton also changed: now blue-green algae has only a small fraction in the total biomass. Considering known patterns of recovery, it has been unexpected that formerly mesotrophic eastern basins Lake Balaton became more eutrophic after a 45–50% reduction in their external load and its trophic state did not changed until 2004 when a sudden improvement happened (Istvánovics et al., 2002).

Pressures: From pressure screening it became evident that the main problem of Lake Balaton is formed by excess amount of nutrients.

The accelerated anthropogenic activity in the catchment (waste water production, use of fertilizers), resulted in a significant increase of the external nutrient load and a deterioration of Lake Balaton's water quality, leading to occasional considerable economic losses in the tourism sector (Istvánovics et al., 2007). The first signs of man-made eutrophication were recognized at the 1940s. Heavy eutrophication were observed during the 1970s, at first only in Keszthely Bay, followed by the other basins, producing a significant trophic state gradient from West to East (Somlyódy and van Straten, 1986). The morphometry of the lake gave rise to environmental gradients along the longitudinal axis, due to the increasing water depth and retention time and decreasing area specific nutrient loads (Istvánovics et al., 2007). The highest algae blooms were recorded in 1982 in Keszthely Bay, exceeding 60 mg m^{-3} as an annual mean, and 200 mg m^{-3} Chl-a as a maximum value. Blooms of N_2-fixing cyanobacteria developed regularly during summers in the western basins and invasive *Cylindrospermopsis raciborskii* became the dominant summer species in each basin (Istvánovics et al., 2007).

The worst trophic conditions along the longitudinal section of the lake, however, were observed in 1994. In the following years, algal biomass was driven by the decreasing external loads and the then current hydrometeorological conditions. Nevertheless after 2000 although the external loads decreased, Chl-a content remained somewhat elevated, mostly because of the internal loads during dry years (Hatvani et al., 2014).

Trophic status changes were detected in every Bay and can be viewed on map: http://www.ktm.hu/balaton/lang_en/balweb.htm

Measures: By the end of the 1980s the P load carried by river Zala had doubled compared to the beginning of the 1970s. For this reason a regional nutrient load control strategy was worked out for Lake Balaton in the early 1980s and approved by the government in 1983 (Somlyódy and van Straten, 1986). The most important management measures included:

i. sewage diversion from the eastern and southern shoreline settlements,
ii. construction of a new WWTP with tertiary treatment and introduction of P removal (chemical P precipitation) at the Zalaegerszeg and Keszthely WWTPs in the western part of watershed,
iii. the downsizing of several large livestock farms, and
iv. the construction of a pre-reservoir (mitigation wetland, the Kis–Balaton Water Protection System) in the Zala River.

In the meantime, Hungarian agriculture has collapsed following the political changes in 1989. From the perspective of eutrophication, the most important consequence was a 90% drop in fertilizer application.

Monitoring shows that the total load carried by the Zala River has changed dramatically in the past 30 years as a result of the load reduction measures implemented on the watershed (Fig. 1.). There was an unambiguous increase between the 1960s and 1980s both from diffuse and point sources. The initiation of the Upper Kis–Balaton reservoir, the improvement of WWTPs and the restructuring of the agricultural sector have resulted in a load reduction of more than 50% in TP compared to the 1980s. Two periods of drought during 1990–1993 and 2000–2003 further decreased diffuse load of nutrients (Istvánovics et al., 2007, Hatvani et al., 2014).

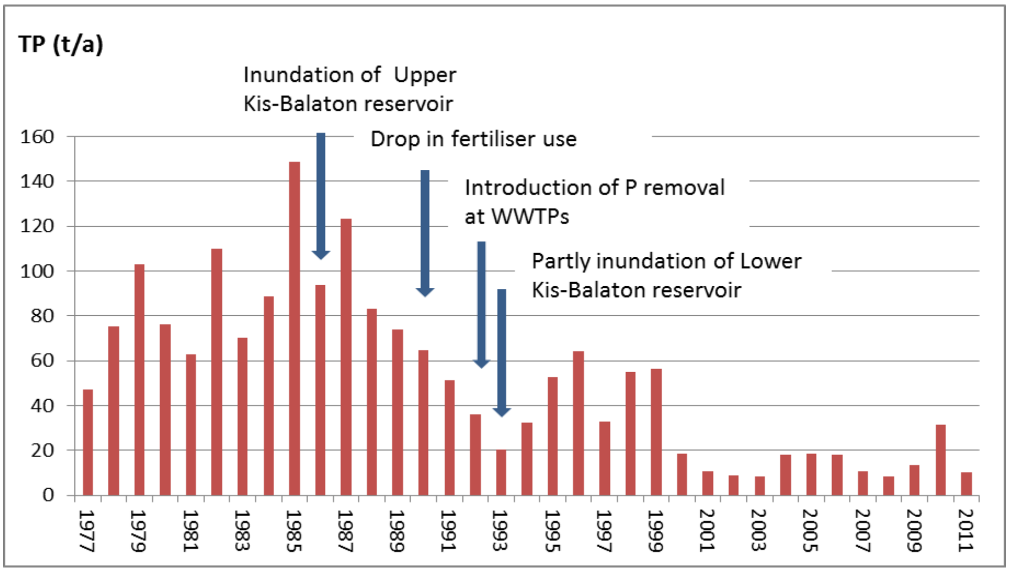

Figure 1: Total P load at the mouth section of the Zala River

Arrows indicate timing of load reduction measures.

Justification for application of exemption: Similar reduction in the external load of TP to the various basins resulted in basically different trophic responses (Istvánovics et al., 2002).

In the western basins (Basins 1 and 2), maximum biomass of the phytoplankton decreased steeply after a few years of delay, although inter-annual fluctuations remained substantial (Fig 3.). Most of this variability was associated with the blooms of a single cyanobacterium (*Cylindrospermopsis raciborskii).* The reason behind the delay was the internal phosphorus loads originating from the sediment. These were enough to maintain a high algal biomass, and the regeneration of the sediment took several years (Istvánovics and Somlyódy, 2001). The long term behaviour of the highly calcareous sediment of Lake Balaton determined the potential maximum of internal P load. In the years when internal load approached its maximum, there was strong correlation between the biomass of phytoplankton and the estimated concentration of mobile P, which is influenced by the carbonate content of the sediment. In other years, physical constraints which depend on hydrometeorological conditions might have played a role in keeping the biomass of phytoplankton below the highest possible level.

In contrast to this, a lasting increase occurred in the summer maximum biomass of phytoplankton, including N2-fixing cyanobacteria and particularly *C. raciborskii* in the eastern basins from the mid-1980s. Trophic state did not change until 2004 when a sudden improvement happened (see Fig. 2).

By differential enhancement of internal load, invasion of a mighty cyanobacterium (*C. raciborskii*) led to eutrophication in the mesotrophic eastern basins and partly contributed to delayed recovery in the hypertrophic western basins of Lake Balaton during the restoration period. Mesoclimatic changes and inoculation promoted by high wind-induced dispersion might be the two prerequisites for successfully invading formerly mesotrophic areas of the lake. Such incidental events should be considered during eutrophication management (Istvánovics et al., 2002).

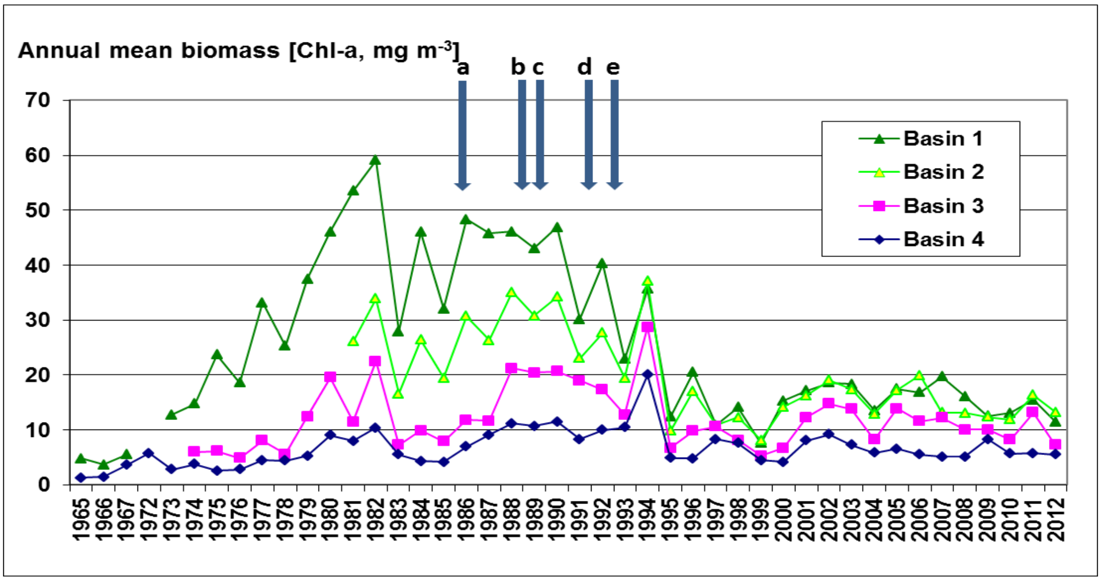

Figure 2: Annual mean biomass of phytoplankton in the four basins of Lake Balaton

Arrows indicate timing of load reduction (Fig. 1) as follows: a—inundation of the Upper Kis-Balaton reservoir; b—sewage diversion from the eastern basins; c—sudden drop in fertilizer application due to the collapse of agriculture; d—introduction of chemical P removal at the sewage treatment plant of Zalaegerszeg, e—inundation of the Lower Kis-Balaton reservoir.

Conclusions: The experience of a number of eutrophication management projects has been published (e.g. Sas, 1989). These studies agree that the most frequent outcome of a statistically significant reduction in nutrient loads is a delayed recovery of our shallow lakes. Since, however, general relationships between nutrient loads and functioning of aquatic ecosystems are poorly known, prediction of the response of individual lakes remains uncertain. Delayed recovery is typically attributed to enhanced internal P load during the transition to a new steady state between the reduced input concentration and in-lake concentration of P and/or to the resilience of the ecosystem (Istvánovics et al., 2002, Istvánovics et al., 2007).

Links to more information:

Somlyódy, L., and van Straten, G., eds. 1986. Modeling and Managing Shallow Lake Eutrophication. With application to Lake Balaton. Springer Verlag, Berlin, 1986.

Istvánovics V, Somlyódy L. 2001. Factors influencing lake recovery from eutrophication—the case of Basin 1 of Lake Balaton. Water Res 35:729–35.

Istvánovics, V., Somlyódy, L., Clement, A., 2002. Cyanobacteria-mediated internal eutrophication in shallow Lake Balaton after load reduction. Water Res. 36: 3314–3322.

Istvánovics, V., Clement, A., Somlyódy, L., Specziár, A., Tóth, G.-L., Padisák, J., 2007. Updating water quality targets for shallow Lake Balaton (Hungary), recovering from eutrophication. Hydrobiologia 581: 305–318.

Hatvani, I.G., A. Clement, J. Kovács, I.Sz. Kovács, J.Korponai, 2014. Assessing water-quality data: The relationship between the water quality amelioration of Lake Balaton and the construction of its mitigation wetland. Journal of Great Lakes Research 40: 115 – 125.

Sas H. 1989. Lake restoration and reduction of nutrient loading: expectations, experiences, and extrapolations. St Augustin: Academia Verlag Richarz.

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Case study title: **Reversing eutrophication in a slowly-responsive lake: issues and perspectives. The case of Viverone Lake (Po River Basin District Management Plan**	
Country: Italy	Lake (real case)

Outline and general description: Lake Viverone (WISE-code ID: IT01AL-6_204PI, sometimes called also “Lake Azeglio”) is a natural lake located at an altitude of 230 m. a.s.l. near Biella and Ivrea Towns, not far (about 50 km) from Turin, capital city of the Piedmont Region in the PO River Basin District. The Lake origin dates back to the Quaternary Period as a relic of the ancient Great Baltean Glacier and its morainic barrages (Serra, Bollengo-Strambino, S.Michele Borgo), actually occupied by the Dora Baltea river valley (Aosta Valley) and the Piedmont floodplain.

The Lake and some riparian and retro-riparian zones are Sites of Community Importance (SCI), according EU 92/43/EEC “Habitat” Directive and Special Protection Area (SPA) according 2009/147/CE “Birds” Directive, included in Natura 2000 Network.

A Neolithic UNESCO site is located in a small portion of the North-Western littoral zone; it is part of the World Heritage List of “Prehistoric Pile-Dwellings around the Alps, Switzerland, Austria, France, Germany, Italy, Slovenia“ (UNESCO Decision35 COM 8B.35 - 35th World Heritage Committee, Paris - 2011).

Lake Viverone is characterized by significant water volumes (129 Mm3) and occupies the end of a very scenic morainic amphitheatre, named Ivrea’s Serra, that borders the lacustrine hydrographic catchment, a small basin if compared to the lake’s surface (approximately 21,4 Km2 versus 5,7 Km2).

The catchment is characterized, from a topographic point of view, by a significant mean slope (about 5%) despite a completely plain area in the Northern part of the basin, arising from the so called "Ivrea Plain"(the upper portion of Dora Baltea river floodplain) and is cultivated with intensive crops(mainly semi-natives: maize, wheat…). The Lake is deep (maximum depth 50 m., average depth 22,5 m.) and presents a typical holomictic-warm monomictic thermal behaviour, with complete water circulation in late Winter-Spring and stratification in the Summer season. The maximum Euphotic zone is -18 m deep. No winter large ice-covering was recently observed. Lake Viverone is a closed reservoir, without significant effluents (the only one, named Roggia Fola, has mild and discontinue flows, e.g. 0,1-0,15 m3/s - average annual value -) and small tributaries (mainly Roggia di Roppolo and Roggia di Piverone). Furthermore, according to a scientific study by CNR-ISE and ARPA Piemonte[1] carried out in 2005, groundwater flows (prevalent direction from N-NE to SW) seem to contribute to the lake hydraulic balance (30-40% at least), but mainly through inflows. However, overall inflows-outflows are very scarce and the lacustrine hydraulic renewal time is estimated to be around 30-35 years.

Physical-chemical conditions of the lake water truly reflect the eutrophic condition of a temperate, deep, and anthropomorphised lake: Total Phosphorous average levels, far from "natural" estimated value (14 µg/L)[2], are around 100-110 µg/L varying from 200-400 µg/L (bottom) to 10-20µg/L (surface) in stratification period. The lake bottom suffers from severe anoxia conditions (O2 saturation varies from 0% to 10% in hypolimnion during stratification period) and negative redox potential values (from -100 to -500 mV).This implies a mild-to-appreciable NH3 presence (from 0,02 to 0,80 mg/L Ammoniacal N) on the bottom of the lake.

Lake Viverone is not usually subject to algal blooms but is periodically monitored to detect risk of cyanobacterial proliferation: despite being eutrophic, water transparency is generally not a critical parameter. The chemical conditions of the lake are good: at present no pollution due to heavy metals and organic dangerous substances was registered. Very low SQA exceedances were registered episodically by the monitoring campaigns according WFD (Operational monitoring) exclusively for a few pesticides (terbuthylazine, metholaclor), but they didn't influence the overall quality status.

SCI Area identifies 10 Habitats listed in 92/43/CEE directive (Annex I: 91E0 - 9160 - 3150 - 3130 - 3260 - 7150 - 7210 - 6410 - 6430 - 6510); besides hygrophylic terrestrial species, among hydrophytes and helophytes we can mention a great number of species of particular interest, such as *Carex appropinquata*, *Carex lasiocarpa*, *Hottonia palustris*, *Ludwigia palustris*, *Menyanthes trifoliata*, *Nuphar luteum*, *Nymphaea alba*, *Potentilla palustris*, *Ranunculus flammula*, *Ranunculus lingua*, *Salvinia natans*, *Thalictrum lucidum*, *Trapa natans*. In the SCI area at least 19 alien plant species have been reported, among which some invasive or health threatening species (*Ambrosia artemisifolia L., Nelumbo nucifera Gaertner, Solidago gigantea Aiton, Phytolacca americana L, Eleocharis obtusa (Willd.) Schultes, Nymphaea mexicana Zuccarini*); many other IAS species were recently indicated in or around this SCI (e.g. *Ailantus altissima*).

Moreover, the lake is one of the most important Piedmont sites for Odonata (36 species, including *Erythromma najas* and *Sympecma paedisca*, the last listed in Annex IV) Lepidoptera (50 species, one of which is *Lycaena dispar* (Annex II) and *Coleoptera Carabidae* (30 species). Among Vertebrates it's worth mentioning 14 Chiroptera species (some in Annex II) and two amphibian species listed in Annex II of Habitat directive (*Triturus carnifex* and *Rana latastei*). Fish fauna is represented by 16 identified species (3 autochthonous key-species: *Esox lucius, Scardinius sp. Tinca tinca*); on the other hand 4 species are invasive alien species (*Carassius spp., Misgurnus anguillicaudatus, Ameiurus melas,*

[1] ARPA Piemonte & CNR-ISE, 2006. Progetto di recupero del lago di Viverone. Regione Piemonte, Provincia di Biella, Provincia di Torino

[2] Vighi, M. & G. Chiaudani. 1986. Una nuova metodologia per la valutazione della capacità recettiva degli ambienti lacustri: il modello MEI e sua applicazione nei piani di risanamento. Ingegneria ambientale, 15: 239-246

Lepomis gibbosus). Moreover, in the Special Protection Area (the same of SCI) more than 90 species of birds were identified (resident, breeding and overwintering migratory species) among which 21 are listed in Annex I of the Birds Directive.

The ecological status of the Viverone Lake is moderate while chemical status is good.

Pressures: According to the Pressures and Impacts analysis (2015-2021 Programme - Elaborate 2 and its annexes ("Synthesis and analysis of significant pressures and impacts" as provided by CIS Guidance Doc. n.3), carried out on the basis of the methodology adopted in Po River Basin Management Plan – RBMP - in accordance with Art. 5 of WFD, no significant codified pressures, apart from Pressure 5.1 "Introduced species and diseases" (see below), were detected, despite a wide anthropomorphised coast and a plethora of human activities which impact the lake. The lake's Eastern and South-eastern coasts are, in fact, partially infrastructure and artificialized. Many tourism structures and services (water sport activities e.g. sailing, water-skiing, wake-boarding, fishing stations, restaurants, bars, hotels, fun attractions…) are located on the lake. The riparian and retro-riparian areas of these coasts are urbanised (mostly Viverone village). In the 80's, through a sewerage pipeline system, the whole urban wastewater load was diverted out of the lake and redirected to a Treatment Plant sited in the Azeglio municipal territory. Therefore, in the last two decades the lake has not been affected by urban waste water untreated discharges (impacts which have been affecting the lake for many decades) since in the early year 2000 the last - illegal - private wastewater discharges were discovered and banned. On the other hand, the sewerage and the WWTP built in the 80's became gradually inadequate due to the riparian increased urbanization; the sewerage system, which collects mixed wastewater and run-off white water loads, especially during storm events, is at risk of overflows and spillages into the lake. These issues are now being solved, by an overall (10.5 M Euros cost) upgrading project divided in 4 tranches, which concerns both the sewerage system and the WWTP. At present, the project is in its 3rd phase and some partial results have already been achieved. In fact, the last bathing-water quality profile of the lake carried according to Directive 2006/7/EC, was "excellent" and in the last three years (2014-2016) no one of the 7 official Viverone's beaches whose waters are classified "bathing waters" were affected by temporary or permanent bathing bans. Agriculture in the catchment is not extensive and is characterized by mixed crops; hills slopes are cultivated by vineyards and orchards (mainly actinidia - kiwi - and, less, other fruits). There are no significant breeding farms and manure-spreading areas in the catchment. Water abstractions for irrigation purposes are limited to one permanent medium-sized water supply service (Cossano's Consortium 0,6 Mm/y) and to some temporary, negligible withdrawal permissions. Lake level fluctuations (varying from a few cm. to 70-80 cm.) seem to be influenced by meteoric and evaporation processes. The major agriculture nutrient load source is probably to be found in the Ivrea Plain, a NW 30x10 km strip, which is located almost completely outside of the lake hydrographic catchment but is connected to the lake through groundwater flows. This area is already designated Nitrate Vulnerable Zone in accordance with the Nitrates Directive.

No untreated discharges actually flow into the lake. No significant industries or productive sites are situated in the catchment area. The Lake is affected by many small or very small tourist services like restaurants, bars, hotels, water-sport clubs. Tourism is strongly intermittent and of the touch-and-go typology. Motorboat navigation, water-skiing and wakeboarding activities are limited, due to a specific regulation, only to the eastern part of the lake and are not continuous. Another potential impact is fishing. In particular, a special no-kill fishing technique named "carp-fishing" is practised in 15 specific sites placed all around the lake. Some limitations to reduce the impact of this technique are on the agenda. However, the potential impact of fishing activities is still unclear and needs to be further investigated.

The only pressure indicated as significant in the Po River Basin Management Plan (2015-2021 is pressure 5.1 (“Introduction of species and diseases”). Alien species data, at the present time, are principally qualitative and well-documented evidences of impacts, due to the IAS presence, lack. Notwithstanding this pressure 5.1 was identified due to the wide number of IAS species identified in lacustrine environment and surroundings.

The depicted scarcity of relevant pressures that directly relate to impacts and to unsatisfactory ecological conditions is not be considered a paradox in the case of a closed lentic water-body .

In fact:

1) the effects of old or recent pressures and impacts caused by no longer existing anthropic activities, structures or behaviours are still acting and will continue to have effects in the future (e.g. as internal load in the lake);
2) multiple and various pressures and impacts insist on this water body. These cannot, however, be considered individually as “significant”.

Measures: The recently adopted Po River Basin Management Plan (2nd planning period 2015-2021) includes a coordinate set of safeguard and recovery measures strongly grounded on territorial organizations and initiatives. Such measures are described below:

a) Measure code KTM01-P1-b006 “Interventi di sistemazione delle reti esistenti (separazione delle reti, eliminazione delle acque parassite, ecc.) al fine di migliorare le prestazioni degli impianti di trattamento” Description: “Intervento 500: F-D/034: Interventi di riorganizzazione funzionale del sistema di smaltimento dei reflui degli abitati di Roppolo, Viverone, Piverone e Azeglio - 3° lotto”

This measure aims at improving the WWTP and Sewerage systems, to prevent any risk of accidental spillages into the lake. It will be completed in five years.

b) Measure code KTM03-P2-b015 (Azioni per la mitigazione dell'impatto agricolo da correlare alla misura prevista dai PSR per "indennità direttiva acque" e "indennità direttiva habitat" 2 measures - Description: “Rinaturazione di superfici perilacuali incidenti sull'area in Rete Natura 2000” and “Definizione e applicazione, previa formazione e consulenza specifica, di un Codice sito-specifico di buone pratiche nel bacino drenante, per riduzione apporti di nutrienti e contaminanti”

These are two measures aimed at increasing the “buffer capacity” of the catchment area against exogenous nutrient loads, by naturalization of farmlands near the lake, with the collateral positive effect of connecting ecological corridors and ecosystem services (experimental afforestation of public areas and a demonstrative plant buffer strip were already successfully performed in the past);

c) Measure code KTM26-P5-a105 “Tutela dei paesaggi fluviali attraverso azioni specifiche di integrazione con i Piani paesaggistici regionali e altri strumenti di pianificazione che concorrono a tutelare il paesaggio” Description: “Azioni per l'attuazione delle norme del PPR - Ambito 28 Eporediese - Obiettivo 1.7.1 - Linea di azione: Salvaguardia e difesa delle zone lacuali e delle zone umide minori”

This measure is aimed at defining a local landscape policy focused on environmental protection according Regional Landscape Plan. It is strictly connected with the Lake Contract’s actions.

d) Measure code KTM26-P5-a107 “Attivazione e attuazione dei contratti di fiume, lago e delta” Description: “Attivazione Piano d'Azione Contratto lago Viverone - Azioni: A.3.1 - A.3.2 - A.3.3; A.4.2; A.5.2; A.5.3; A.5.4; A.5.5; A.6; A.8; B.3.2 ; C.1.1; C.1.5; C.1.6; C.1.8; C.2.2; C.3.2; C.3.3.”

The process that brought to sign the River contract started in 2008 among Piedmont Region, Biella and Torino Provinces, the basin’s municipalities together with Regional Environment protection

Agency (ARPA), WWT and Drinking water public utilities and local private and public citizen associations. The Lake contract was signed in February 2016. It activated measures like afforestation areas, buffer strips, improvement of sewerage system, information and education projects to reduce nutrient input into the lake in order to counteract eutrophication processes.

It builds upon a strong participated process involving all institutional actors and stakeholders which led to address almost all the issues synthesized in the“2b Pressures” paragraph of this template. In particular, Actions, referred to the three Strategies (A “Safeguard and Recovery”, B “sustainable development”, C “Knowledge and monitoring”) respectively regard:

- (A.3.1) the promotion and implementation of buffer areas and buffer strips in the catchment agricultural lands;
- (A.3.2) diffusion and promotion of eco-sustainable irrigation and fertilization best practices also extended to the whole hydrogeological basin;
- (A.3.3) promotion of agricultural conversion of the most impacting crops, also extended to the hydrogeological basin;
- (A.4.2) feasibility analysis for a Forest Business Plan;
- (A.5.2) a stricter regulation and control of the carp-fishing activity;
- (A.5.3) a stricter regulation about navigation and motorboat activities and sports, even by reduction of boat horsepower and lake zoning by uses;
- (A.5.4) a stricter control on to the existing buoy-line respect;
- (A.5.5) adequacy test of wells for water abstraction;
- (A.6) better organization in waste collecting and control of illegal waste dumping around the lake;
- (A.8) activities aimed to control and to contain IAS populations, particularly regarding species *Procambarus clarkii*, *Myocastor coypus, Nelumbo nucifera* and *Nymphaea mexicana*;
- (B.3.2) enhancement and promotion of eco-sustainable sports and tourism activities such as canoeing, kayak, sailing, cycling and pedestrian trails;
- (C.1.1) measures to improve water balance knowledge, water abstraction and uses, with the aim of regulating abstractions with special attention to lake critical levels;
- (C.1.5) carp-fishing impact assessment;
- (C.1.6) overall navigation impact assessment;
- (C.1.8) technical insights about some punctual critical issues in SW peat-bog area;
- (C.2.2) punctual insights about state-owned areas delimitations;
- (C.3.2) school involvement and environmental education activities;
- (C.3.3) prevention, information awareness campaigns to stakeholders and citizen groups.

e) Measure code KTMyy-P2-a112 “Applicazione delle misure nell'ambito dei Programmi di Sviluppo Rurale (PSR 2014-2020)” Description: “Rinaturazione di superfici perilacuali incidenti sull'area in Rete Natura 2000”

This is a set of measures complementary and specular to the above described actions concerning the reduction of agricultural impacts and it takes into account the possible implementation of the voluntary measures included in the Piedmont region Rural Development Plan.

Justification for application of exemption: Viverone is a deep, closed lake characterized by a very long hydraulic Renewal Time. The lack of relevant and continuative surface outflows is associated with seasonal and modest inflows (a few semi-natural canalizations named “rogge”) in comparison with the lake surface evaporation rates and soil transpiration losses; piezometric levels show a partial groundwater drainage towards the lake, but groundwater outflows, due the complex moraine hydrogeology, are more difficult to quantify but are anyhow not relevant. Despite this ecological characteristics, the lacustrine environment still appears to be an efficient ecosystem which shows a good level of biodiversity and biomass abundance which reveal an elevated overall resilience capacity of the water-body.

The Lake and some riparian and retro-riparian portions of its catchment are included in the Natura 2000 Network as SCI according 92/43/CEE “Habitat” Directive, and SPA in accordance with 2009/147/EC “Birds” Directive. A wide portion of its shoreline and riparian zones (North, Western and South-western) are characterized by natural forests, wetlands or peat-bogs that could be depicted as the “resilience reserve” of this area. But the lacustrine reservoir, placed at a low altitude in a geological Cul-de-sac at the end of a sloped moraine basin, is also a really sensitive ecosystem just because of its natural conditions. The lake was affected, mainly in the past decades, by massive and multiple anthropogenic impacts that strongly contributed to the actual nutrient internal load accumulation (the self-sustaining Phosphorus and Nitrogen pools contained in the bottom sediment and subject to seasonal cyclic re-suspension and precipitation processes facilitated by bottom anoxia and reduction conditions). Many relevant impacts like wastewater discharges and exogenous nutrient loads from agricultural activities were long ago reduced, in accordance with 91/271/EEC and 91/676/EEC Directives. At present these impacts are being further mitigated.

However, the accumulation of exogenous, multiple and various impacts due to the sum of diversified anthropic pressures and of self-sustaining internal loads in a water body characterized by a very long renewal time, make it very difficult to achieve the good status objective by 2027.

Conclusions: Direct experience has clearly shown that Lake Viverone is a highly resilient water body that needs time to achieve good status and recover its natural conditions. In the last decade, a series of important structural measures were planned and implemented, some of which are still ongoing. Monitoring data confirm the effectiveness of measures. Indicators of the lake’s eutrophication status and ecological degradation processes are substantially stabilized and, at present, lake conditions do not show deterioration.

Furthermore, in both Natura 2000 protected areas and UNESCO sites specific environmental principles and limitations shall be taken: some worldwide applied “hard” invasive structural recovery techniques (such as, e.g. capping, washing, dredging, chemical precipitation, certain bio-manipulations, others), besides their costs, are here simply unsuitable. The River Basin Management Plan implementation process, has led to better understand that even modest multiple impacts can act as significant ones and that cooperation among institutions and involved stakeholders is essential on such a closed and slowly-responsive lake. Taking into consideration the wide range and variety of pressures insisting on this water-body, a clear strategy had to be adopted to achieve environmental objectives based on complementarity and coordination of basic and supplementary measures (structural measures like wastewater management, good practices adoption in farmlands, regulation measures on lake uses and territorial careful control measures, awareness raising and education) .In this context the Lake Contract is a powerful instrument to influence local behaviours, ensure active involvement of local authorities, stakeholders’ and citizens’ participation and environmental awareness raising. It consists of a balanced set of complementary and coordinate tangible and intangible actions that involve institutional authorities, private stakeholders and citizens which will allow, within the necessary timeframe, to achieve the environmental objectives of Lake Viverone.

Links to more information: More information, photos and a short documentary film (language: Italian) about Viverone Lake are available on-line, in the websites realized to promote and to disseminate Lake Contract initiative and the lake and landscape highlights and beauties.

http://pianoacque.adbpo.it/

http://www.provincia.biella.it/on-line/Home/Sezioni/Ambiente/IlcontrattodiLagodiViverone.html http://www.cittametropolitana.torino.it/cms/ambiente/risorse-idriche/progetti-ris-idriche/contratti/viverone

http://www.lagodiviverone.org

http://www.regione.piemonte.it/ambiente/acqua/pianoTAcque.htm

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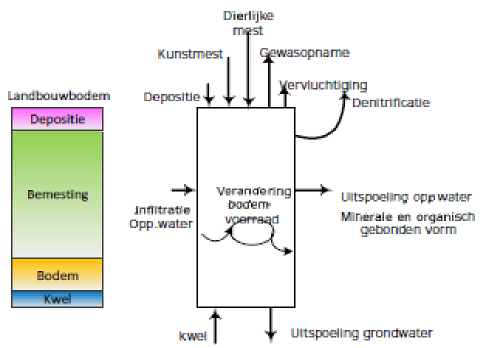
Case study title: **Fertilisation running off from agricultural soils**	
Country: The Netherlands	Lake (real case)

Outline and general description: This case is based on real national data and estimations, but with focus on general issues. The case study is meant to provoke discussion on application of 4.4 natural condition.

Input of nutrients from waste water treatment and agricultural runoff have been reduced since the 1970s. However, concentrations of nutrients and ecological response show a long response time (rather decades than years). Quality elements related to eutrophication is in about 50% of the Dutch waters still a problem, although the number is decreasing and especially the large public waters are approaching natural background levels for nutrients. Agriculture is the main driver causing the largest source of nutrients in surface waters on the scale of river basins.

To unravel the source of the nutrient pressure within agriculture, process based model studies are applied which accounts for many steps between the nutrient load on the field itself (pressure) and the concentration in the water (status, see figure 1). This model results show that only a small part of the nutrients can be influenced on the level of input or pressure level (e.g. the amount of P m-2 y-1 allowed to bring on the fields).



Figuur 8 *Schematische voorstelling van een nutriëntenbalans van een landbouwbodem met links het bodemdeel van Figuur 5 en rechts in- en uitgaande termen van de balans.*

Figure 1: Schematic nutrient balance in an agricultural soil with left the estimated soil fractions (depositie =deposition, bemesting=fertilisation, bodem=soil, kwel=seepage) and on the right the in and out causing processes of nutrients (kunstmest= artificial fe

Pressures: Estimation of the quantitative origin of nutrients both between and within ''drivers'', is necessary to take cost-effective measures. On average, the main source of phosphorus which is emitted to the Dutch regional surface waters, originates from the uploaded agricultural soils (brown area, 33%, figure 2). About 70 % of the nutrient pressure is related directly or indirectly with agricultural activities. Because the model accounts for soil type and water type, large differences can occur from place to place. Figure 2 shows the averaged situation in the regional Dutch waters.

Waste water treatment complies with the Urban Waste water Directive and the average purification levels is around 85% for Phosphorus.

Figure 2: Modelled and estimated proportion of different sources of nutrients (P) averaged in NL watersheds (soil output= brown, , waste water treatment plants=red, Actual fertilization= grey, inlet water=light blue, historical fertilization=black)

Measures: Since 2012 it is policy to allow P fertilisation (kg m-2 y-1) which is in equilibrium with the amount of P (kg m-2 y-1) harvested by crops. And even less if the phosphorus status of the soil is above average. This means that problems with nutrients related with manure will cease. The nutrient source analysis shows however that actual fertilisation is still contributing with on average 10% to the present concentration of P in the waters. This means that the present fertilisation is partly running off easy, but also means that the agricultural soil will get lower nutrient contents. Models show that this effect may take up to 100 years before objectives are met completely.

Locally additional measures are taken to reduce the load and/or concentration in waterbodies with a relatively high proportion of waste water, or if waters are relatively sensitive for eutrophication.

Justification for application of exemption: On the precondition that an effective policy is present ensuring no surplus fertilisation on the agricultural fields, we advocate that 4.4 should be used for both 'historical' and 'present' fertilisation. The measures to reduce the present pressure are taken to a sufficient extent. It only takes time before the effects of the measure can be expected.

In some cases additional measures may be considered to reduce the effect of the pressure. This means that not the pressures itself is reduced, but the e.g. the extent of run off is reduced, or that soil process are steered in a way that run off reduces. However, this is not always possible or cost-effective. It is necessary to cover this example with 4.4, otherwise the possibilities of 4.5 should be explored. However, it is more comfortable to apply 4.4 if the wording becomes wider than only "natural conditions".

Drivers -->Pressure-->Status--->Impact

In the DSPIR model measures can be taken in or between these steps. The fertilisation can be reduced to a certain level (measure to reduce the Pressure), other crops or other use can be applied (measure to reduce the Driver), measure to increase the retention of nutrients in soils can be applied (measure to reduce the step between pressure and status), measures to change the ecology by introduction plants or biomanipulation of fish communities (measure to change the impact). We advocate that measures which aim to change status and impact are typically valid for time extension based on natural conditions.

Conclusions: The time extension based on natural conditions of article 4.4 can be applied when measures are taken to reduce the pressure to sufficient low level. When status and or impact are still present –despite measures are taken- we advocate that natural conditions is a valid argumentation for delaying the objectives.

Case study title: **Lower Part of River Narpionjoki (LPRN) located in an area with multiple pressures, and acid sulphate soils (AS soils)**	
Country: Finland	River (real case)

Outline and general description: This case study describes an example and the challenges of river basin management in the area with multiple pressures, and also reconciliation of the needs between WFD and profitable livelihood.

Background: During the Holocene Epoch large areas of sulphide-bearing sediments were deposited under reducing conditions on the bottom of the Baltic Sea between Finland and Sweden. Because of the rapid postglacial land uplift (today up to 8 mm/a) in the area, a large portion of these sediments have been raised up to 100 m above current sea level. Due to reclamation, the upper 1-2 m have generally been oxidized into acid sulphate soils (AS soils, minimum pH 3-4), giving Finland the largest known occurrence of AS soils in Europe, roughly 1000 km2 using Soil Taxonomy criteria. It is well documented that these soils leach huge amounts of metals into watercourses, and for several heavy metals the amounts exceed the total metal discharge in effluents from the entire Finnish industry causing severe damage on the ecology. Systematic mapping of AS soils in Finland has started in 2009. It was initiated after massive fish kills in 2006 and in order to meet the WFD, aiming at good chemical and ecological status of surface waters till 2015. A national strategy aiming at the elimination or reduction of damages caused by AS soils was published in 2011. (source: Finnish Geological Survey (GTK), http://projects.gtk.fi/7iassc/infinland/).

Case study area: The case study area ‘Lower Parts of River Narpionjoki (‘Narpionjoki alaosa’ in Finnish, referred later as ‘LPRN’) locates in Ostrobotnia in western Finland. The water body LPRN belongs to River Narpionjoki which is a medium-sized, naturally humic river that flows through the cities of Kurikka and Narpio. The drainage area of R. Narpionjoki is 1000 km2 and the total length is 75 km. 23 % of the catchment area is agricultural land (fields) and 70 % forests. Human population in the catchment is 12 000 inhabitants. The largest lakes of R. Narpionjoki are Kivi- ja Levalampi and Salaisjarvi that are both reservoirs and under water level regulation. In the mouth of the R. Narpionjoki is a dammed bay (Vasterfjarden), which is a raw water source for the Kaskinen woodworking industry. The water body LPRN belongs to the Finnish river type Kt (a medium-sized humic river). LPRN is 42.05 km long and has the catchment area of 991.92 km2.

Ecological status of LPRN is ‘poor’: (i) BQE’s/sub-BQE’s: periphyton (‘moderate’), benthic macroinvertebrates (‘poor’), fish (‘poor’), (ii) physical-chemical elements, nutrients (TP 88 µg/l, TN

2190 µg/l; 2006-2012) -> 'poor', (iii) HyMo status -> 'good'. Poor status results from loading of acid waters and metals (LPRN locates in the AS soils area; log-transferred mean pH minimum 4.8; 2006-2012) and its impacts to ecology, but also from strong diffuse loading of nutrients. Chemical status of LPRN is 'worse than good' as a result of exceeding concentrations of cadmium (Cd) and nickel (Ni) due to both natural reasons (AS soils) and draining of AS soils (acid peaks). Acid peaks are seasonal and occur during flood periods in spring and autumn. During other times of the year pH is 6-7 which is typical for eutrophic humic rivers of Finland.

During the 1st circle until 2015, the regional Centres for Economic Development, Transport and the Environment (ELY) in Finland estimated exemptions and time schedules to reach environmental targets of water bodies. The same was also done for the water bodies that were included for the first time in the 2nd circle. It was concluded by the regional EPO-ELY that to reach or maintain good status in R. Narpionjoki will require both basic and supplementary measures.

The reason for exemption of LPRN as well as for the other water bodies of R. Narpionjoki with exemption is natural conditions and technical feasibility. The most important pressure have been eutrophication (diffuse and point source loading), but acid conditions, and structural issues (e.g. fish migration barriers) also explain the need for time extension. In all water bodies of R. Narpionjoki, the justification for extension of time includes natural conditions because the recovery from perturbations takes time, in some cases even decades. Exemption based on technical feasibility is used because technical solutions are not ready or applicable or their operation is uncertain or there are administrational or other practical reasons that slow down their use. This will be discussed in more detail later in the text.

Pressures: Point source loading (municipalities), diffuse loading (fur animal production, agriculture, forestry, sewage waters from sparsely populated areas), and soil drainage of AS soils (by agriculture, forestry, peat production and construction) cause nutrient loading, chemical loading and acidification.

Eutrophication and abundance of AS soils areas are the main problems experienced by R. Narpionjoki. AS soils are abundant in the upper and lower parts of the river, including LPRN. AS soils cause problems to fishery in the whole river area and the Vasterfjarden bay. Constructions (e.g. embankments and dams) for flood prevention and water supply bias the river bed. Barrage, submerged weir and old mill dams partly restrict the movement of migratory fishes in the main river. Fish in the lakes Kivi- ja Levalampi and Salaisjarvi still have elevated concentrations of Hg which weakens the usability of fish for human consumption.

R. Narpionjoki water is humic and highly nutrient-rich. Water quality problems are acidic waters and eutrophication. High nutrient and organic loading mainly originates from agricultural and forestry areas. The role of agriculture is important due to high percentage of fields (21%) in the catchment. Estimated annual nutrient loading from the catchment is 29 000 kg P, and 738 000 kg N (SYKE-WSFS-VEMALA-models; years 2000-2011). Agriculture explains 66 % of P loading, while ca. 25% is background loading.

Industry has a minor role for the loading of R. Narpionjoki. Industry leads their sewage waters after pre-treatment to waste water treatment plants (WWTP's). The most important point source pollution has earlier been WWTP's of municipalities (covered on average 70 % of population), but since 2016 sewage water is directed to WWTP's outside the municipalities of the region and R. Narpionjoki.

LPRN belongs to AS soils area and surface waters with very low pH are recorded frequently. The proportion of AS soils in the catchment area of R. Narpionjoki is ca. 27 % (27 000 ha). It is estimated that at the present drainage situation, the risks to ecology are serious (acid-sensitive fish and organisms with calcareous crusts/shells) if the AS soils cover >1% of the catchment area (Sutela et al.

2012; Tolonen 2012). Intensification of drainage to new AS soils would increase leaching of sulphur (S) compounds and worsen the situation. However, weather conditions and precipitation have an important role for the oxidation of sulphide clays and the loading of sulphate to rivers. The situation is worst, when a rainy autumn follows a dry summer or there will be a strong spring flood in the following year. Climate change is likely to increase problems resulting from AS soils. AS soil areas are highly productive, but cultivation necessitates drainage and accordingly during the course of the time the level of groundwater decreases which leads to oxidation of S compounds and leaching of metals from the soils. Acid and metal containing waters end up into drainage systems and further to recipient waters. Underdrainage results in several-fold higher loading to waters. In addition to agricultural activities, other land-use in AS soils that increases the depth of drying soils also increase acid and metal loading (forestry, building, tillage of soils) if sulphide are present in the layers to be dried. In R. Narpionjoki average sulphate concentrations are highest in LPRN (maximum 77 mg/l). Average SO4-concentrations have been lower in 2007–2012 than in 1996–2006 due to more rainy summers that have better prevented oxidation of sulphide clays. Annual pH-minima at LPRN have mostly been higher than pH 4.5 since 2000.

Measures: To reach the environmental targets of surface waters at the R. Narpionjoki river area, the most important measures are those that aim at reducing nutrient loading from cultivated fields of the agricultural area, i.e. for instance increase of wintertime vegetation cover, buffer strips and wetlands. Concerning the forestry, it is essential to reduce loading of sediments by high-quality implementation of ditch maintenance and concentrating into areas with highest impact. To reach and maintain good status in R. Narpionjoki there is also a need to increase the efficiency of water protection measures in the peat production areas. Measures to reduce acidification are important especially in the lower parts of the river (LPRN). This means avoidance of intensification of soil drainage of all sectors (incl. construction) and activities (incl. also measures for water protection, e.g. building of wetlands or sedimentation basins) in the areas that are under risk. For many sectors a common measure to support environmental targets is to reduce hydraulic conductivity. These measures either reduce or balance positively loading of nutrients, sediments, acid waters and organics (humic substances) for organisms, and improve flood risk control. Further, the purpose is to conduct at the R. Narpionjoki area a set of remediation and restoration measures to reduce negative impacts of earlier water engineering and loading. The measures particularly aim at increase biodiversity and removal of migration barriers. The recommended measures for 2016-2021 are presented in detail in table 8.4.2 of Programme of Measures for R. Narpionjoki (Bonde et al. 2016). In total, the costs for planned measures are 5717200 euros (municipalities and sparsely populated areas 1114 k€, agriculture 1677 k€, AS soils/acidification 2791 k€, forestry 18.8 k€, and peat production 116.4 k€).

Justification for application of exemption: In the lower parts of the river, the LPRN water body, the exemption is justified both by natural conditions and technical feasibility, and the key reasons for this are eutrophication, acidification and HyMo. Applying the article 4(4) of WFD in Finland is done according to the national guidance (Guidance (2013): Planning of PoM's for RBM in 2016-2021 - setting of environmental targets (in Finnish).

The justification of time extension by the regional EPO-ELY due to natural conditions for ecological status of LPRN is as follows: The problems are eutrophication, acidic waters and structural changes. Good status cannot be reached by the year 2015, because a) the P-values of fields are high or precariously high, and there will be a lag of years or even decades in the decrease of P-status of fields, b) reduction of soil acidity first results in increases in P load which thus prolongs the achievement of good ecological status, c) the increase in winter precipitation and heavy rains increase the loading from the fields and forests of the LPRN catchment.

The respective justification of technical feasibility includes: The problems are eutrophication, acidity and structural changes. Good status cannot be reached by 2015. This is because a) the catchment area has high abundance of AS soils, and at present there are not available enough efficient means for controlling the negative effects caused by drainage of AS soils. At present, available measures allow improvement of water quality, but not their recovery into good status, b) reaching good ecological status requires technical solutions, whose design/planning, negotiations, and permitting is not possible by 2015 (improvement of free passage by organisms, fisheries remediation). Extension of time is needed also for HyMo pressure in the main river. For LPRN good ecological status is to be reached by 2027.

Thus, the reason for exemption of LPRN, as well as for the other water bodies of R. Narpionjoki with exemption, are natural conditions and technical feasibility. The most important pressure is eutrophication (diffuse and point source loading), but also acid conditions and structural issues (e.g. fish migration barriers) explain the need for time extension. In all water bodies of R. Narpionjoki, the justification for extension of time includes natural conditions because the recovery from perturbations takes time, in some cases even decades. Exemption based on technical feasibility is used because technical solutions are not ready or applicable or their operation is uncertain or there are administrational or other practical reasons that slow down their use.

Exemptions on chemical status are related to Hg, Cd and/or Ni concentrations and they are set to four water bodies of the R. Narpionjoki area due to AS soils, one of them being LPRN.

Conclusions: In the case of R. Narpionjoki river basin there are good grounds to justify the need for extension of time to reach good ecological status using natural conditions. R. Narpionjoki and its water bodies suffer multiple pressures which set challenges for efficient management of waters and selection of best measures which should also appreciate realistic costs for measures. This case study also highlights the importance of representative information and data on pressures and indicators. It also demonstrates challenges that arise / intermingle between remediation/mitigation of acidic and metal-rich waters and the use of catchment area for profitable agriculture.

Low pH of soils and release of acidic waters and metals due to land-use are a problem that is technically difficult to manage in particular if at the same time there is a need to conduct profitable agriculture (and other livelihood). In this case, acidity (pH) and metals are more challenging than eutrophication, the problem for the area is evident, serious and long-lasting. In this kind of case, extension due to natural conditions and extension due to technical feasibility intermingle and overlap. Natural conditions are largely connected to agriculture and nutrient loading, but “acidification” situation in more challenging. AS soils include high storage of acidity that can leach after a lag of several years. This and the seasonality of acid peaks mean that the recovery of acid-sensitive biological elements (e.g. taxa) will take a long time despite all efforts. In this respect, there is a certain kind of analogy to P-value of fields that will also take long time to reach lower P levels.

Links to more information:

Bonde, A. (eds.), Bredgard, E.-S., Teppo, A. & Westberg, V. 2016. Närpiönjoen vesistöalueen vesienhoidon toimenpideohjelma 2016 – 2021 (Programme of measures for the Narpionjoki 2016-2021; in Finnish). Report no. 43. Ostrobothnia Centre of Economic Development, Transport, and the Environment. 125 pp. http://www.doria.fi/handle/10024/124448

Guidance, 2013. Vesienhoiden toimenpiteet 2016-2021 - suunnittelun vaiheet (Planning of PoM’s for RBM in 2016-2021 - setting of environmental targets), in Finnish. 10 pp. http://www.ymparisto.fi/vesienhoito/opas

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Case study title: **Recolonization of Eelgrass (Zostera marina) in Danish coastal waters**	
Country: Denmark	Coastal waters (hypothetical case)

Outline and general description: Most Danish coastal waters are in not good ecological status due to one or more of the three biological quality elements (phytoplankton, benthic invertebrate fauna and Macroalgae and Angiosperms) not achieving the specific boundaries (good-moderate) set in accordance with the WFD. The Danish indicator Eelgrass depth limit (Commission decision 2013) describes the depth distribution of eelgrass beds in coastal waters.

Pressures: Nutrient load from land leading to eutrophication in coastal waters have caused a decreased in Eelgrass depth distribution in general. Reduction in emissions of phosphorous (mainly sewage treatment and partly from agriculture) and nitrogen (mainly in agriculture) have improved the water quality in general i.e. reduced nutrient concentrations, lower phytoplankton levels (chlorophyll) and positive trends in the Eelgrass depth distribution in response to improving water clarity.

Measures: Earlier nutrient management plans and now the Danish River Basin Management Plans (RBMP) include programmes of measures related to the reduction of nitrogen (coastal waters) and phosphorous (lakes).

Justification for application of exemption: Natural recolonization of Eelgrass beds is a slow process and may take decades after measures have been taken. Direct biological factors as vegetative growth (rhizomes) or spreading of seeds play an important role but several indirect factors can influence the recolonization process like sediment character (e.g. reduces anchoring capacity due to organic enrichment of the sediment, oxygen depletion and sediment chemistry (hydrogen sulphide), loss of suitable substrate, light absorbance in the water column by dissolved organic matter).

Due to the slow but positive trends observed in the depth distribution of Eelgrass in Danish coastal waters it might take long time after measures of nutrient reduction have been implemented. The timeframe of this natural recolonization is difficult to predict but in some cases it could be expected to reach beyond 2027. Applying Article 4(4) due to natural conditions (recolonization processes) is suggested to be appropriate to postpone the deadline for achieving good ecological status of angiosperms in some cases.

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Case study title: **Recovery from lake acidification and extension of deadlines to achieve environmental objectives**	
Country: Norway	Lake (real case)

Outline and general description: Several Norwegian water bodies, lakes and rivers, have moderate or lower ecological status due to acidification caused by long-range transported air-borne sulphates and nitrates and watersheds with low neutralizing capacity. Most of these water bodies have extended deadlines for achieving the environmental objectives in 2027 (some even in 2033). There is a concern that for a large part of these waterbodies, the recovery from acidification is too slow to make this scenario realistic. Prognoses for the future, based on modelling, indicate that for many acidified waterbodies in Norway, the environmental objectives are achievable towards the end of the century.

Pressures: The typical Norwegian waterbody, which has been acidified and for this reason is in need of extended deadlines for achieving environmental objectives, is a low-alkalinity clear-water small lake in Southern or South-western Norway. These waterbodies have been acidified since the early or middle 1900's, and are located in watersheds with calcium-poor bedrock and often with thin deposits. Acid-sensitive species, invertebrates as well as fish, have been wiped out or are largely reduced in numbers. Since many of those sites are located in sparsely populated areas, deposition of air-transported acidifying compounds are often the only or the main anthropogenic pressure.

Measures: In the acidified areas, selected water bodies are being treated with limestone, with the goal to restore biodiversity and the fish community. The Environmental Authorities have planned and carried out a national liming program in Norway since the early 1990-ies, with yearly budgets of 10-15 mill. EUROs. Several trout-stocks and a number of salmon stocks have been re-established after lime-treatment. This kind of mitigation measure is however, for practical and economic reasons, not possible for the majority of the acidified waterbodies. For the acidification problem as such, the only measure which will work in the long term, is internationally agreed reductions in sulphur and nitrogen emissions to the atmosphere.

Justification for application of exemption: Slow recovery from acidification is caused by:

- watersheds with very low acid neutralizing capacity due to calcium-poor bedrocks and deposits, and
- continued deposition of long-range transported sulphur- and nitrate-compounds.

While the deposition scenario is an economic and political question, the natural recovery is dependent on natural characteristics of the watersheds, the weathering rate of neutralizing compounds. In the watersheds located at the Scandinavian shield, this can be a very slow process. More than hundred years of exposure to acidified precipitation have increased the weathering temporarily, and potentially even slowing down the recovery process when the acidic deposition decreases.

Conclusions: Using extended deadlines to 2027 and 2033 (Norway is an EEA member and one cycle behind the EU MS in implementation) will not give sufficient time for recovery from acidification, and would possibly result in application of less stringent environmental objectives for a large number of acidified waterbodies in Norway unless further time extension can be implemented.

To make a good basis for the negotiations on emissions reductions to the atmosphere in Europe, development of models has been a prioritized issue. These models make prognoses for the development of water chemistry in selected lakes based on the characteristics of the lake, future deposition scenarios and watershed characteristics. These models indicate a continued recovery from acidification well beyond 2033 and towards the end of this century for the most acidified and sensitive lakes. Extension of deadlines more than two WFD plan-cycles can have the result that more waterbodies can be given realistic objectives as an alternative to less stringent environmental objectives.

Links to more information:

A regional model of lake acidification in Southernmost Norway Ambio Vol 20 No 6 Wright, R.F. Cosby, B.J. Hornberger, G.M.,

Miljødirektoratet - Forside / Publikasjoner / 2014 / November 2014 / Critical limits for surface water acidification in Norwegian critical loads calculation and Water Framework Directive classification,

Miljødirektoratet - Forside / Publikasjoner / Publikasjoner fra klif / 2012 / Mai / Impacts of Air Pollution on Freshwater Acidification under Future Emission Reduction Scenarios; ICP Waters contribution to WGE report

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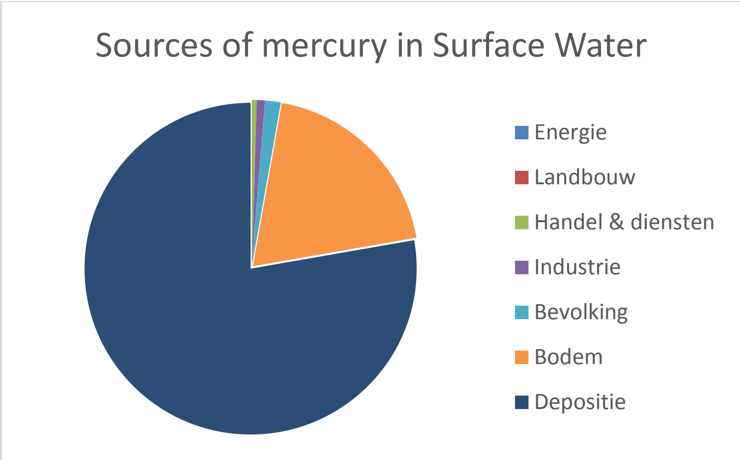
2.2 Surface Water - Chemical Status

Case study title: **Mercury pollution in Flanders**	
Country: Belgium (Flanders)	River (hypothetical case)

Outline and general description: The Flemish Environment Agency (VMM) has conducted 2 campaigns of biota monitoring in Flanders, one in 2013 (16 sites) and one 2015 (11 sites). The results of both campaigns indicate that mercury exceeds the EQS at all sites and for all sampled fish species. For now, Flanders has not made use of the possibility to derogate according to Article 4(4) for natural conditions and so this case study as hypothetical.

Pressures: The Flemish Inventory for priority substances (2008-2010) indicates atmospheric deposition and run-off from soil as the most important sources of mercury in surface water. Release from sediments is not included in the emission inventory, and this could (at least locally) play a role in the exceedance of the EQS.



Bodem = run-off soil, Depositie = atmospheric deposition. (From Flemish Inventory Priority Substances, reference years 2008-2010, Scheldt).

Measures: The restrictions for mercury use and production, according to Annex 17 in REACH and the EU-mercury strategy (2005), are applicable in Belgium. Overall, industrial emissions to water represent only a very small percentage although in the RBMP 2015-2021 relevant measures are taken to minimize mercury from dentists and industrial installations. Atmospheric deposition and run-off from soil remain two major emission sources in Flanders. Measures to tackle the run-off from soils are applicable in Flanders. Mercury in atmospheric deposition could be coming from long-range atmospheric transport and therefore require measures which go beyond the member state level.

Justification for application of exemption: We expect that mercury will still be found in the aquatic environment, even when all measures in RMBP, are taken to control this substance. Mercury is a substance which is subject to long range atmospheric transport, therefore, measures at the international level are crucial. This means that, after all measures are taken, we expect it will take a long time for the ecosystem to recover.

Conclusions: We expect that mercury will still be found in the aquatic environment, even when all measures are taken to control this substance. Mercury is a substance which is subject to long range atmospheric transport, therefore, measures on international level are crucial.

Case study title: **A headwater lake Hattujärvi, where chemical status is poor due to high mercury concentration in fish**	
Country: Finland	Lake (real case)

Outline and general description: This case study (Lake Hattujärvi) is an example of the 3427 Finnish water bodies classified as having poor chemical status due to high mercury concentrations in fish (the 2nd WFD classification). Hattujärvi is a shallow, humic rich headwater lake located in Eastern Finland (Water body code 04.983.1.004_001). There are no point sources within the catchment area of 58 km^2, over which the main land use is forest. The catchment is mainly lowland wet peat soil. The lake water area is 5.21 km^2 and mean and maximum depths are 3.3 m and 9.2 m, respectively.

The ecological status of Hattujärvi is classified as high according to biological measurements (phytoplankton, periphyton, benthic and littoral macroinvertebrates, fish and aquatic plants; the overall scaled ELS value was 0.91). The phosphorus content was on the limit of good. The pH of 5.4 was rather low, which is typical to this lake type. The chemical status was classified as poor because the mercury (Hg) concentration in 16 out of 19 sampled perches exceeded the sum of EQS and the Finnish background value.

Mercury is a ubiquitous compound and it is present in Finnish soils and lakes. In Finland, the mercury concentrations in fish are found to be highest in humic headwaters with moist conditions in catchment soils supporting microbial net methylation.

Pressures: There are no point sources in the catchment area.

Atmospheric Deposition**:** Mercury is released to the atmosphere both from natural sources like volcanoes, forest fires, soil weathering, but to a large extent it is released from the use of fossil fuels. Mercury is present in the atmosphere and has been transported to all continents, and has been deposited into areas where human activities are low. Measurements in Southern Fennoscandia show a weak declining trend in mercury deposition which can be attributed to reduction controls in EU countries (Berg et al. 2010). The current median calculated annual mercury deposition in the area was about 9 g km^2 (Holmberg 2013 in the Finnish/VHA1 loading inventory of priority substances). Due to the long depositional history, mercury has accumulated in soils.

Diffuse loading**:** High reserves of mercury have already accumulated into soil (including the Hattujärvi catchment). The organic forms of mercury (e.g. methylmercury) are formed from the inorganic mercury by microbes under wet conditions. These organic mercury compounds are more toxic than the inorganic, elemental mercury. Moreover, they do accumulate into biota.

The fraction of methylmercury to total mercury in runoff water has shown to be higher in peat soil catchment than in agricultural or pure mineral soils (Porvari and Verta, 2003). The Hattujärvi catchment area has high fraction of low-land peat soils with high groundwater-table and therefore conditions are favourable for this process.

The catchment land-use and forestry management after clear cutting may have some effect on mercury concentrations in lakes, but the processes are rather difficult to quantify without site specific research level data.

Measures: Mercury is a global pollutant. Therefore, the control measures should be carried out in global scale. The mercury emissions are already strongly restricted in EU and North America and they are expected to further decrease due to Minemata convention on mercury in 2013, which 35 nations/areas (including EU) have so far ratified in.

Local attempts could focus on preventing land-use change and silvicultural measures (e.g. clear cut), which increases the areas favourable for mercury-methylation. However, forestry management measures are not regulated by law in Finland and the exact effects of each measure is not known.

Justification for application of exemption: It takes long time before the effects of international conventions like Minemata convention can be observed through decreased mercury concentrations in fish. As an element, mercury does not dissipate from nature. However, the new loading of mercury can be minimized and the formation and run-off of methylmercury from catchment soils to lakes are likely to decrease with time.

Conclusions: The mercury concentration in perch of Hattujärvi Lake exceeded the sum of EQS and Finnish background concentration. There are over 3000 similar water bodies in Finland (and more in Europe). Mercury is a ubiquitous compound and a global pollutant and although global acts have been implemented in Europe and internationally to stop the loading to atmosphere, the “recovery times” are not known.

Other Issues:

Grouping model for mercury: In Finland, the mercury concentrations in fish are found to be at highest in humic headwaters with moist conditions in catchment soils supporting microbial net methylation. The catchment land-use and forest management after clear cut may have some effect on mercury concentrations in lakes, but the processes are rather difficult to quantify without site specific research level data. A simple grouping model was created and it was used to classify the mercury-status in those water bodies where no measured data existed. The model was based on measured data in known water body types. The mercury exceedances were estimated to occur in the most humic water types.

Background concentration for metals: In Finland the background concentrations of all metals (Cd, Pb, Ni, Hg) were taken into account in classification. The sum of the EU EQS-values (directive 2013) and the tabulated estimation of typical natural background in different water types were summed in the Finnish decree, which implements the EQS-directive to Finnish legislation. For mercury the background concentration values vary between 180 and 230 µg/kg depending on water body type, while the EU EQS of mercury in fish is 20 µg/kg. The typical natural background values are based on data and expert judgements (Verta et al. 2010). However, the use of even higher background concentrations would be possible if based on local geological conditions.

Further information:

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Case study title: **Implementation of the concept of natural condition under article 4.4 of the WFD due to persistent mercury pollution in lagoons**	
Country: Italy	Transitional waters (hypothetical case)

Outline and general description: The case study describes mercury (Hg) pollution in lagoons and linked coastal waters in Italy. In these lagoons several water bodies exceed the Hg EQS in biota and sediments, which are set out in national legislation that transposed Directive 2013/39/EU. The Hg concentration in sediments of the lagoon water bodies is strongly influenced by the transport of suspended solids from rivers. One of the main Hg sources was historical mining activity, including, in one case, mining activities located in another Member State. The other sources include discharge from past industrial activities and remediation sites. Monitoring programmes implemented since the year 2000 allowed mapping of the distribution of Hg contamination.

In one of these lagoons, for instance, the Hg concentration in sediments shows a decreasing concentration gradient from the east (> 11 mg kg^{-1}) to the west (0.7 mg kg^{-1}). Background levels, observed at depths of 50-100 cm, are of the order of 0.13 mg kg^{-1}. In the central sector of this lagoon a relatively high Hg concentration in sediments is linked to the former discharges from a chloro-alkali installation equipped with Hg cell technology.

Pressures: The main contamination sources are:

- Mining sites and mining waste and subsequent transportation by rivers flowing to the lagoons (point and diffuse sources);
- Chloro-alkali installations discharging directly or indirectly into the lagoons (IED plants producing point sources);
- Landfills and contaminated sites;
- Atmospheric fall-out;
- Historical pollution.

Measures: Measures aimed at preventing the Hg release from past mining activities:

- Hg mining ceased decades ago. Despite the fact that the mining activity ceased, river contamination is still an issue. Beside the historical Hg accumulation in the lagoon sediments due to the past mining activities, water bodies of the lagoons are also still impacted by the solid transport of the rivers flowing from the mining sites.
- Measurements undertaken in the sediments have not shown, yet, a significant decreasing trend in Hg concentration, which implies that the system is responding very slowly to the measures in place, and this is also due to the complexity of the lagoon ecosystem.

Measures aimed at preventing the Hg release from the chloro-alkali installations:

The chloro-alkali production of the industrial sites based on mercury cells ceased several years ago and new plants equipped with membrane technology (no Hg discharge) are under construction.

Other measures:

a) Remediation under the national or regional Programmes on remediation sites (including landfill remediation): designation of lagoons and discharging territories as remediation sites of national/regional interest. The remediation sites includes a terrestrial area with industrial installations and a portion of the lagoons. As a consequence of the designation as remediation sites, measures foreseen by national and regional regulations on remediation of contaminated sites are ongoing, including, where needed, those which address mercury pollution.

b) Other measures against mercury pollution set out by the relevant EU legislation and international Conventions, for instance:

- limit values on discharges from IED and non-IED plants and authorisations to control and prevent pollution from point sources;
- maximum Hg loads from the specific industrial cycles and implementation of IES Directive;
- monitoring mercury trends in biota and sediments.

Atmospheric deposition measures:

- restrictions on products containing Hg
- monitoring Mercury trends in biota and sediments

Justification for application of exemption: Notwithstanding the phasing out of the emissions and the measures already taken, mercury in sediments accumulated in the lagoons will not allow the achievement of good chemical status by 2027, due to the persistency of this pollutant in the environment and the complexity of the lagoon ecosystem.

Further difficulties may refer to the control of possible releases from mining waste still stored in the mines, including a mines located in other member states and, in this latter case, the challenge of managing mercury emissions coming from abroad.

Conclusions: Due to the persistency of mercury in the environment and despite the implementation of measures to control chemical pollution, it may be difficult to achieve good chemical status within 2 programming cycles, in particular in the case of confined environment such as lagoons (and connected coastal waters). This may be the case for several lagoons in Italy.

Other issues preventing the achievement of good status by 2027 in transitional waters with reference to mercury are linked to the difficulties in managing contamination from trans-boundary atmospheric transport and, in some cases, contamination coming from another Member State.

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Case study title: **Mercury in Coastal Waters and Lakes**	
Country: Denmark	Coastal waters & lakes (hypothetical case)

Outline and general description: Most Danish lakes and coastal water bodies which are in not good chemical status are in this condition due to mercury levels in fish exceeding the EQS biota (20 µg/kg wet weight).

Pressures: Mercury pollution of the aquatic environment happened mainly historically where waste water from industry and household and atmospheric deposition were some of the sources. Mercury has been highly regulated for many years in Denmark and only a limited emission to the environment remains from sewage and atmospheric deposition originating from power plants. The mercury present in the aquatic environment mainly persists from pollution in the past.

Measures: Existing national regulation and new international initiatives in the EU and the global agreement - the Minamata Convention.

Justification for application of exemption: Despite the intense regulation of mercury in Denmark and significant reduced emission to the environment mercury will persist in sediment, water and biota in lakes and coastal waters as well in the environment in general. Only a few signs of reduced concentrations in the freshwater and marine environment exist, but significantly lower concentrations have been documented in blue mussels in some coastal water locations. Hence the mercury level in the marine environment is expected to decrease slowly due to dilution, immobilisation in sediments and organisms brought to land through natural food chains and fishery. The timeframe of this natural lowering of mercury to a level below the EQS in fish is not known, but it could be expected to extend beyond 2027. Applying Article 4(4) due to natural conditions (dilution, immobilisation etc.) is suggested to be appropriate to postpone the deadline for achieving good chemical status of mercury.

Conclusions and lessons learned: The use of Article 4(4) in the case of mercury in lakes and coastal water (fish EQS) raise the question if the rate of the decrease in mercury level in the environment due to natural processes actually exceeds the low but still existing emission rates and thus leading to a net reduction of mercury concentration in lakes and coastal waters? Few significant trends of reduced mercury level in the aquatic environment exist. The development of methods/tools to predict the future levels of mercury in different types of lakes and coastal waters could support the use of exception 4(4) natural conditions.

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Case study title: **Brominated diphenyl ethers (PBDE)**	
Country: Austria	Rivers & lakes (real case)

Outline and general description: Due to the ubiquitous presence of PBDEs in the environment, their expected continuous release from environmental sinks, and their persistence against degradation and the very long half-life, it is likely that good chemical status will not be achieved by 2027 despite the use of PBDEs being widely restricted.

The EQS for PBDE is expressed as biota standard and is defined as 0.0085 µg/kg. The corresponding water concentration is provided in the EQS dossier at 0.000000049 µg/l. The EQS refers to the sum of six congeners. A biota monitoring program at surveillance monitoring stations in Austria, including remote areas, showed large exceedances of the EQS in all sampled fish. Several fish species were investigated with single fish samples as well as pooled samples. Beside methodological issues resulting in an overprotective EQS, environmental conditions will preclude compliance with the EQS for PBDE.

Historically PBDEs were mainly used as flame retardants, and usually mixtures of various congeners were used. The use of PBDEs is now widely restricted and the sale of penta-BDE or octa-BDE as substances, mixtures or in articles in concentrations > 0.1% by weight is not permitted. Under regulation (EU) 2017/227, after 9th February 2017 this restriction will also apply to deca-BDE.

However, PBDEs are still released to surface waters via different pathways. Beside diffuse and point source emissions, remobilisation in the environment for example from contaminated sediments also occurs. Deca-BDE especially is found in high concentrations in sediments, but lower chained congeners are also present in sediments due to their high affinity to sorb on particles. Measurement in remote alpine areas showed high concentrations of PBDEs reaching 4.1 µg/kg dry matter for BDE-209. Higher values are observed in areas influenced by anthropogenic activities. Anaerobic de-bromination these reservoirs of BDE-209 provides a further source for "smaller" congeners.

Pressures: Despite the stringent restrictions on the sale and use of PDBEs emissions to surface waters occur via different pathways from point and diffuse sources. The major contributions derive from diffuse sources (atmospheric deposition, erosion, run-off). Remobilisation as well as degradation of high molecular congeners results in a continuous release from environmental sinks as e.g. sediments.

Measures: As noted above the use and sale of PBDEs is widely restricted. In UWWTP fulfilling the requirements of the UWWTD (91/271/EEC) PBDEs are widely removed, mainly by adsorption to sewage sludge. Further measures at UWWTP presumably will not lead to an improvement in the water body status (Recital 25). Penta-BDE and octa-BDE are defined as persistent organic pollutants and regulated in the POP-regulation (regulation (EC) nr. 850/2004).

Justification for application of exemption: The use of PBDEs is widely restricted and further measures at point source discharges will not result in an improvement of the total burden of the water body as these emissions are not the major contributors.

Penta-BDE and octa-PBDE are defined POPs according to the POPs regulation. They are persistent in the environment, poorly degradable and have very long degradation half-lives. PBDEs are accumulated in environmental sinks (e.g. sediments) and continuously released to water bodies. Due to these properties and conditions it is to be expected that environmental concentrations will only decrease very slowly and concentrations at EQS-level will be reached in decades, although the presence of PBDEs in the environment is due to anthropogenic activities.

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Case study title: **Pollution by persistent chemicals in lagoons: hexachlorocyclohexane**	
Country: Italy	Transitional waters (real case)

Outline and general description: The case study refers to hexachlorocyclohexane (HCHs) pollution of ponds in coastal Mediterranean wetlands (brackish water bodies). In these ponds, the sediment EQS for HCHs, which is set to assess chemical status in transitional waters, is exceeded. The presence of these substances in the sediments of the pond is probably due to the historic use, of products (pesticides) based on HCHs, prior to the ban on the use of these substances entering into force.

Pressures: Diffuse urban and agricultural pressures are present. The main HCHs contamination sources were diffuse agricultural including:

- losses from agricultural soils surrounding the ponds areas, which were treated in the past with this substance, used as an insecticide; and
- atmospheric deposition.

Measures:

a) The use of hexachlorocyclohexane (HCHs) has been forbidden since 2002 in the European Union and since 2001 in Italy;

b) Since May 2009, HCHs were included in the list of the Stockholm Convention's banned substances (Annex A) with a specific exemption for use as a human health pharmaceutical for control of head lice and scabies as second line treatment (decision SC-4/15);

c) other measures on HCHs are set out by the Italian legislation, for example:

- limit values on HCHs in discharges;
- maximum HCHs loading from the specific industrial cycles;
- monitoring of the trends on HCHs in biota and sediments.

Justification for application of exemption: Even though emissions have been phased out and necessary measures already taken, the presence of HCHs in the sediment accumulated in the pond will not allow achievement of the good chemical status objective by 2027, due to the persistency of HCHs in the environment and the complexity of the pond ecosystem. In fact, due to their low polarity, upon release or atmospheric deposition to the water environment HCHs tend to associate with soils and sediments. HCHs biodegradation has been reported to be affected by a number of physical, chemical, and biological site specific factors, i.e. initial substance concentration and bioavailability, presence of oxygen, temperature, pH, biomass concentration, and composition of the medium. Further difficulties in lowering HCHs presence in the ponds may be caused by potential sediment run-off from surrounding polluted soils and of atmospheric deposition.

Conclusions: Due to the persistency in the environment of HCHs and despite the implementation of measures to control chemical pollution, it may be difficult to achieve good chemical status within 2 programming cycles, in particular in the case of closed systems such as ponds.

In the described case study other issues also contribute to preventing the achievement of good status by 2027 i.e. the difficulties in managing contamination from transboundary atmospheric transport.

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Case study title: **Pollution by persistent chemicals in coastal water, Tributyltin Compounds**	
Country: Italy	Coastal waters (real case)

Outline and general description: This case study refers to chemical pollution by Tributyltin (TBT) compounds of the coastal waters of the Tyrrhenian Sea, mainly through historic use of TBT compounds as components of antifouling agents to extend the life of ship antifouling coatings. TBT is adsorbed to the seabed sediments and may be released from the sediments back into the aquatic environment for many years after the enforcement of the ban on its use. The water bodies described in this case study which are polluted with TBT are characterised by shallow and sandy water, with limited dilution and mixing dynamic. However, similar TBT pollution problems are recorded elsewhere in Italy, in coastal and transitional waters with different dilution and mixing characteristics.

Pressures: The main pressure identified as linked to TBT pollution was diffuse – other.

Measures:

- TBT compounds are included in the Rotterdam Convention and are banned by other international conventions.
- Bans on TBT on small boats (less than 25 metres long) first started in the 1980s.
- In Italy the Ministerial Decree 29/7/1994 and Ministerial Decree 13/12/1999 transposed the Directive 89/677/EEC introducing a ban on the utilisation of TBT compounds.
- In 2008 the use of Organotin compounds as biocide in antifouling paintings was totally banned by the International Convention on the Control of Harmful Anti-fouling Systems on Ships of the International Maritime Organisation.
- Monitoring of the trends of TBT compounds to assess the results achieved with the implementation of the measures.

Justification: Notwithstanding the implementation of the necessary measures, it is very likely that the presence of TBT compounds in sediments will not allow achievement of the good chemical status objective by 2027 in shallow coastal water bodies of the Northern Tyrrhenian Sea. This is due to the long half-life of these compounds, in particular when they are trapped in the sediment, and to their persistency in the environment.

Conclusions: Due to the persistency in the environment of TBTs and despite the implementation of measures to control chemical pollution, it may be difficult to achieve good chemical status within 2 programming cycles, in particular in the case of shallow and sandy coastal waters.

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Case study title: **Natural base flow of man-made substances from groundwater to streams**	
Country: Denmark	Rivers (hypothetical case), also relevant for groundwater chemical status

Outline and general description: Groundwater can more or less flow naturally to surface water through base-flow to streams and thus lead to water quality objectives not being met. In this case a stream is supplied with significant quantities of groundwater which contains man- made substances. The substances use has been banned and they are therefore no longer used e.g, a pesticide. Because of the input of groundwater to surface water, including such substances the water quality requirements for the substance in streams cannot be met.

Pressures: Chemical substances (e.g. some pesticides) can stay in the groundwater for a long time (years) before it eventually flow from groundwater into the stream, producing a lag effect.

Measures: You can set requirements for environmental authorities to investigate the cause of the increased concentrations, to assess whether sources other than groundwater inputs could be causing non-compliance with water quality requirements.

Justification for application of exemption: Natural inflow of groundwater may make it impossible to comply with water quality requirement set for the stream. Depending on the substance chemistry, and the aquifer geochemical conditions, it may take years before the substance possibly reaches the stream. When it is judged that the input of pesticides to the stream will continue for some years due to a delay effect in the aquifer, this may justify applying Article 4.4.

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2.3 Groundwater - Quantitative Status

Case study title: **Groundwater bodies located in coastal Italian areas (e.g. Tuscany, Latium, Campania, Calabria, Puglia, Sicily, Sardinia, Adriatic coastal regions) affected by saline intrusion**	
Country: Italy	Groundwater (real case)

Outline and general description: Italian coastal groundwater bodies are often of a great environmental and socio-economic importance since they supply urban and tourist seaside areas. In general, these coastal water bodies are located in phreatic aquifers that consist of marine and aeolic sands or alluvial sandy-gravel. At the bottom, they are often delimited by an aquiclude such as clay, silt, or silty-clay layers. The coastal aquifers are fed by both (i) direct precipitation and/or (ii) groundwater coming from the nearby mountain aquifers (e.g. the Apennines) which are part of the same hydrogeological system.

These groundwater bodies are generally at poor quantitative status due to over-exploitation and saline intrusion, and are characterised by long groundwater renewal times due to low aquifer recharge rates and long residence time of groundwater.

The case presented here describes a frequent situation in Italy: coastal aquifers which are overexploited by abstraction for agricultural, industrial and drinking water uses. Due to historic over-exploitation, the aquifers are currently suffering from saltwater intrusion. In some cases, the hydrological situation is more complex because of the interactions between abstraction, groundwater circulation and surface water interaction (e.g. Versilia in Tuscany, Lago di Fondi in Latium, Chioggia, Laguna di Venezia, Gargano, etc.) where brackish water can directly percolate into the aquifers. In certain situations, the altered water table geometry, which was modified by historic abstraction, hinders the recharge of the coastal section of the aquifers by groundwater flowing from neighbouring mountain areas, worsening the quantitative status. The water imbalance between aquifer recharge and abstraction leads to constant lowering of the water table, and therefore the recovery of good quantitative status, taking into account the water needs of the tourist and urban areas, may take a long time. In several cases, the coastal GWBs have been classified in "poor" quantitative status because of both water imbalance and saline intrusion.

Pressures: The pressures identified included, abstraction of flow diversion, diffuse pollution from transport, urban run-off; and point sources of contaminated sites or abandoned industrial sites and urban waste water.

Measures: The following measures were implemented in the case of saline intrusion in coastal aquifers:

- Temporary restrictions for abstraction and diversion of both surface and groundwater;
- Establishment of Technical Committees to compare saline intrusion in coastal areas;
- Monitoring plans for groundwater needs and uses;
- Monitoring plans for groundwater uses in irrigated agriculture and industry;
- Promoting practices for sustainable use of groundwater resources;
- Regulation of water abstraction and diversion;
- Measures for installation of treatment of runoff including advanced filtration;
- Technical interventions on surface water-groundwater interaction;
- Restoration of natural areas and reclamation measures;

- Other measures included in the River basin Management Plans.

Justification for application of exemption: Groundwater bodies located in Italian coastal areas are often in poor quantitative status due to saline intrusion. Saline intrusion often lasts for years, due to historic overexploitation. In some cases, chemical status is classified as 'poor' because of groundwater pollution, in particular due to the agricultural irrigation of the land.

The natural aquifer recharge, especially in Southern Italian regions, is low because of the natural hydrogeological features of the aquifer and the low rates of water recharge. However, it is important to stress that the aquifers affected by saline intrusion usually supply coastal tourist areas, and so mitigation measures must take into account the water demand needs of these areas.

Once all measures are implemented, namely the reduction of water withdrawals and the technical interventions to limit the saline and brackish water intrusion, the achievement of the WFD environmental objectives may have to be postponed to after 2027 because of natural conditions in the aquifer.

This is mainly due to the natural features (namely the natural conditions under Article 4(4)) of coastal aquifers including: low rates of aquifer recharge in Southern Italy; and long times for groundwater recharge that mean that the recovery of groundwater levels (and hence the restoration of the natural balance between saltwater and freshwater interface). In addition, the implementation of the maximum acceptable reduction in abstraction, taking into account water demands, will also hinder the recovery of the aquifers.

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Case study title: **Poor quantitative status of Isokangas-Syrjänharju Groundwater body**	
Country: Finland	Groundwater (real case)

Outline and general description: The Kinnala Water works has operated since 1983 in Isokangas-Syrjänharju groundwater body. The permit for groundwater abstraction was given in 1978 for the amount of 1000 m3/d. The estimated groundwater resource for the formation is 3100 m3/d. At the time the amount of abstraction was around 400 m3/d, but at the start of the 1990's abstraction increased to an average rate of approximately 500 m3/d. Between 1983 and 1997 the water table dropped by 2 m. By 2007 total abstraction was already between 700 and 800 m3/d and the water table was 4 m lower than in 1983. The average abstraction rate remained close to 700 m3/d until 2012, at which time it decreased to 500 m3/d. Groundwater levels started rising and in 2014 to 1.5-2 m higher than in 2011, but good quantitative status was not reached by 2015.

Pressures: Water abstraction for public supply has exceeded the available groundwater resource.

Measures: The proposed measure was to re-evaluate the permit for abstraction. However, it was not necessary as it is forbidden by law to alter groundwater levels such that other uses of the groundwater body are prevented. Therefore the operator of the water works was legally obliged to decrease the abstraction to restore good quantitative status.

Justification for application of exemption: Measures have been taken to restore the quantitative status but the groundwater level will rise slowly since the abstraction cannot be completely stopped.

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2.4 Groundwater - Chemical Status

Case study title: **Low-Eastern Friulana Plain - A multi-layered confined aquifer with slow groundwater circulation where historic over-abstraction has led to the intrusion of pollutants**	
Country: Italy	Groundwater (real case)

Outline and general description: The Confined multi-layered aquifer of the Low-Eastern Friulana Plain (AQUIFER A and B) (ITAGW00010400FR) GWB is located in the Oriental Alps River Basin District, in the Friuli Venezia Giulia Region. It consists of a series of confined and multi-layered alluvial aquifers with low flow rates of water and long times for groundwater circulation. The over-exploitation of groundwater over time has caused pollution due to the intrusion of contaminants from upstream hydraulically connected GWBs. The natural conditions of slow circulation of groundwater within the aquifer and the low water flow rates imply long residence time in the reservoir. These characteristics of the GWB have led to the decision to apply exemptions under Articles 4(4) "Natural conditions" and 4(4) "Technical feasibility" of the WFD.

Pressures: The substances that cause failure to achieve the environmental objectives include Desethylatrazine which has been banned for a long time, and nitrate which is decreasing in concentration due to the implementation of basic measures. Other pressures include contaminated sites or abandoned industrial sites, waste disposal sites and diffuse urban run-off. Over-abstraction of groundwater has led to an imbalance in water resources in the aquifer, with the main effect of lowered water tables and flow direction alterations. These alterations in flow regime are linked to industry, hydropower and fish farms, and have led to an intrusion of contaminants into the GWB from neighbouring hydraulically connected aquifers.

Measures: The pollution pressures identified above have been dealt with through the following measures:

- Contaminated sites or abandoned industrial sites: operational safety measures (MISO: "Messa in sicurezza operativa") of "Chrome Friuli srl" site are applied.
- Waste disposal sites: improvement of the "Romanello Ambiente" waste water treatment plant, where leakage of leachate was found to occur.
- Diffuse urban runoff: control of stormwater runoff.
- Diffuse agricultural pollution from nitrates and pesticides:
    - Knowledge transfer, training and information actions related to the forest and rural areas. Training, courses and seminars on environmental issues and efficient use of natural resources.
    - Consulting services to farms related to the forest sector and rural areas.
    - Enforcement of the compliance regime (Decree of Ministry to be approved for 2014-2020 period) which requires the introduction and maintenance of buffer strips.
    - Enforcement of regulation on animal manure application to land and storage (Nitrates Directive); areas and prohibition periods for animal manure spreading; management of manure storage.

The abstraction or flow diversion related pressures of industrial abstraction, fish farming and other abstraction pressures have been addressed through:

- Setting restrictions on abstraction from artesian and private wells, taking into account present needs.

- Abstraction Licencing fees regulation (Art. 96 of Legislative Decree no. 152/2006). In case of aquifers used for drinking water, the user fee for non-drinking use has been tripled.
- Actions aimed at improving awareness and public responsibility regarding the effective use of renewable water resources, with particular attention to the issue of the artesian wells of the alluvial Friulana plain.

Justification for application of exemption: Groundwater status is caused by the intrusion of the pollutants Desethylatrazine and Nitrate from hydraulically connected GWBs neighbouring the Friulana Plain. The intrusion has been caused by over-abstraction in the GWB.

The measures included in the River Basin District Management Plan are mainly related to the reduction of over-abstraction, and aim to minimise groundwater flow alteration by intensive use of private and artesian wells. These measures are not immediately effective because of the time needed for all planned measures to have an impact.

Irrigation of agricultural areas has led to the presence of nitrate and desethylatrazine in groundwater at concentrations above the thresholds set by Ministerial Decree 260 of 2010. These substances which are leading to failure to achieve environmental objectives have been prohibited for a long time (desethylatrazine) or have decreasing trends (nitrate) due to basic measures. The long time for water circulation in the confined aquifer due to the hydrogeological features (or natural conditions) of the GWB mean that there is uncertainty around the timescale required to achieve good environmental status despite the removal of pressures.

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Case study title: **High-Eastern Friulana Plain – Southern Areas - An unconfined alluvial aquifer with low flow rates and long groundwater residence times**	
Country: Italy	Groundwater (real case)

Outline and general description: The Confined multi-layered aquifer of the High Friulana Eastern Plain – Southern Areas (ITAGW00010500FR) GWB is located in the Oriental Alps River Basin District, in the Friuli Venezia Giulia Region. It consists of an unconfined, undifferentiated alluvial aquifer whose hydrogeological features (silty sands, silt and clay) mean that there are low flow rates and long residence times for groundwater in the aquifer. These natural conditions in the aquifer have led to exemptions under Article 4(4) for “Natural conditions” and “Technical feasibility” being applied.

Pressures: The groundwater body is affected by a contaminant plume (Chromium VI) generated by the polluted abandoned industrial site "Chrome Friuli" (Friuli Venezia Giulia Region). Urban run-off has led to diffuse pollution from Tetrachlorethylene (PCE) and Trichlorethylene in the GWB. The substances produced by agricultural pressures that cause poor chemical status in the GWB have either been banned for a long time (desethylatrazine) or have decreasing concentrations values due to the effect of the basic measures that have been put in place (nitrate and metolachor).

Pressures from abstraction for agricultural or other purposes also act on the GWB, and there is point source pollution from waste disposal sites.

Measures: The pollution pressures identified above have been dealt with through the following measures:

- Contaminated sites or abandoned industrial sites: operational safety measures (MISO: "Messa in sicurezza operativa") of "Chrome Friuli srl" site are applied.
- Waste disposal sites: improvement of the "Romanello Ambiente" waste water treatment plant, where leakage of leachate was found to occur.
- Diffuse urban runoff: control of stormwater runoff.
- Diffuse agricultural pollution from nitrates and pesticides:
  - Knowledge transfer, training and information actions related to the forest and rural areas. Training, courses and seminars on environmental issues and efficient use of natural resources.
  - Consulting services to farms related to the forest sector and rural areas.
  - Enforcement of the compliance regime (Decree of Ministry to be approved for 2014-2020 period) which requires the introduction and maintenance of buffer strips.
  - Enforcement of regulation on animal manure application to land and storage (Nitrates Directive); areas and prohibition periods for animal manure spreading; management of manure storage.

The abstraction or flow diversion related pressures of agricultural abstraction have been addressed through:

- Abstraction Licencing fees regulation (Art. 96 of Legislative Decree no. 152/2006). In case of aquifers used for drinking water, the user fee for non-drinking use has been tripled.
- Awareness and dissemination activities aimed at water saving in irrigated agriculture.

Justification for application of exemption: Agricultural pressures: Failure to achieve environmental objectives is caused by terbuthylazine, metolachor and nitrates, for which basic measures to reduce pollution loads have been implemented. However, because of the inertia of circulation in the GWB, it is not possible to improve status by the set deadlines.

Contaminated land pressure: The GWB is affected by a chromium VI plume caused by the contaminated site called "Chrome Friuli." The procedures required by the Italian regulations on the remediation of contaminated sites has started. In particular the project on operational safety measures, with the aim of reducing the risk due to the contamination of the site to acceptable level has been approved. The possibility of removing the unsaturated contaminated soil from the site was also evaluated, in order to remove the source term and solve the problem. However, the extent of the contamination means that such an intervention to completely remove contaminants from the aquifer is not technically feasible.

Urban run-off pressures: The diffuse urban run-off and presence in the GWB of tetrachlorethylene (PCE) and tricloroetilenenel and the time required for the measures to take effect means that there is an expected delay and environmental objectives will not be achieved by 2027.

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Case study title: **IT0911AR012 "Water body of the Florence-Prato-Pistoia plain – Zona Prato" - An unconfined alluvial aquifer located in the Northern Apennines River Basin District in the Florence-Prato-Pistoia plain polluted by nitrate and organohalides**	
Country: Italy	Groundwater (real case)

Outline and general description: The groundwater body IT0911AR012 "Water body of the Florence-Prato-Pistoia plain – Zona Prato" is located in the Northern Apennines River Basin District -Tuscany Region within the wider alluvial plain of Florence - Prato – Pistoia. It is characterised by coarse gravel in a silty-sandy matrix, with clay-silty intercalations, more frequent towards the edges of the alluvial fan. The thickness of the unconfined aquifer varies from 10 to about 50 m and is free draining due to the absence of impermeable lithotypes which could isolate the gravels layers. The underlying confined aquifer is characterized by intercalations of silty-clay and sandy-silty horizons. The permeable horizons (sandy, sandy-gravel) are partially in contact with each other, in particular in the upper part of the alluvial fan.

In the past, the GWB has been affected by intensive over-exploitation and very deep piezometric depressions. Nevertheless, the groundwater body is at present in good quantitative status because of the progressive reduction of abstractions, in particular those for industrial use (textile industry), while the abstraction for drinking water purposes remains rather high.

The chemical status is, however, classified as poor, because of the presence of nitrate and organohalogen compounds linked to the industrialisation of the area in the 1980s. These chemicals are accumulated in the higher unsaturated layers of the aquifer, thus groundwater pollution is mainly caused by the rain filtration into the soil (the unsaturated layer of the aquifer). Water table fluctuations also control pollutant concentrations, as demonstrated by the correlation of groundwater fluctuations and changes of the pollutant concentrations in groundwater.

In the case of GWB IT0911AR012, the deadline extension under WFD Article 4(4) “Technical feasibility” has been applied. Nevertheless, as a result of the implementation of the KTM ITC0900091 “Memorandum of Understanding for the hydrogeological study of the Prato aquifer” implemented in the 2016 RBD Management Plan, Article 4(4) natural conditions may be applied appropriately because of the aquifer’s slow recharge timescales and flow rates.

Pressures: Pressures on the GWB include contaminated sites or abandoned industrial sites, urban runoff (diffuse) related to nitrate, organohalogen compounds (tetrachloroethylene and trichloroethylene); diffuse pollution from industrial areas. Abstraction for industrial and drinking water purposes are also pressures on the GWB.

Measures: The significant pressures acting on the GWB are addressed by the following measures:

Contaminated or abandoned industrial sites:

- KTM “CONTAM” - [ITC0900040] Remediation Actions contained in the Regional Remediation Plan
- KTM “POINT”- [ITC0900004] Sewer network maintenance and completion works. Supplementary agreement for water resources protection of the lower and middle Arno Valley and the Prato - Pistoia aquifers
- [ITC0900005] Improvement of wastewater treatment. Supplementary agreement for the protection of water resources of the lower and middle Arno Valley and the Prato - Pistoia aquifers.

- [ITC0900006] Improvement of industrial wastewater treatments. Supplementary Agreement for the water resources protection of the Lower and middle Arno Valley and the Prato - Pistoia aquifers

Diffuse pollution: MISURA: KTM "KNOW" - [ITC0900091] Memorandum of understanding for the hydrogeological study of the Prato aquifer, signed by the Northern Apennines River Basin District Authority, Prato Water Utility, Water Authority and the Province of Prato.

Abstraction or flow diversion:

- MISURA: [ITC0900014] Water Balance management plan measures for the Arno river basin
- MISURA: [ITC0900031] Improvement of water resources management. Regulations on Water abstraction reduction for non-drinking water purposes; Regional Decree n. 50, April 21, 2015

Justification for application of exemption: Because of the diffuse chemical pollution caused by nitrates and organohalogens the reclamation of the whole GWB is difficult because of both technical feasibility and disproportionate costs. In this situation, a site-specific remediation, using pump and treat processes, with interventions at those sites where contamination is well characterised seems to be more feasible. Moreover, the measure [ITC0900091] "KNOW" has identified the actual extent of the GWB contamination as well as the mechanisms of pollutant transport in groundwater. This knowledge measure highlighted that the Prato aquifer will be very difficult to restore as a whole.

After removing the point source pollution by means of site-specific measures, the diffuse sources will be removed by the natural flushing of the groundwater systems (natural conditions). The time for this natural removal will depend on water flow rates and the timescales of the natural hydrological cycle (i.e. several years). Therefore, there may be a need to extend the deadline to achieve the good chemical status for this GWB to beyond 2027 because the hydrogeological conditions of this water body are difficult to predict using hydrogeological modelling.

Conclusions: This case study is a frequent case in the Northern Apennines District. In general, once all mitigation measures will be implemented, in particular those on point sources, it may take a long time to remove diffuse sources of pollution (which are often historical sources related to chemicals currently out of market). These timescales mainly depend from the natural conditions of water bodies, such as the hydrogeological features of aquifers as well as the hydrological cycles required for the aquifer recharge and groundwater seepage. Hydrological modeling may, in these cases, not provide correct predictions.

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Case study title: **Nitrate in Groundwater**	
Country: Austria	Groundwater (real case)

Outline and general description: A groundwater body in the eastern part of Austria has poor chemical status due to nitrate, with the pressure resulting mainly from agricultural land use. The aquifer is mainly composed of gravel and is highly permeable. Protective superficial deposits (silt and loess) cover less than 25 % of the aquifer surface. The region has a negative average climatic water balance and precipitation surplus is restricted to winter months when groundwater recharge mainly occurs. There is also some in-flow from surface water and groundwater, and to a small extent by artificial recharge. The calculated groundwater recharge rate is about 50 mm/yr.

The low recharge and negative water balance in the GWB, where combined with highly permeable soils, lead to a high risk of nitrate leaching from agricultural fields, and subsequent groundwater pollution. The nitrogen uptake of plants is strongly triggered by rainfall, and the gross nitrogen balance of the GWB strongly varies with seasonal weather conditions. A year with optimal conditions results in small nitrogen surpluses, whereas a year with unfavourable weather conditions results in higher nitrogen surplus. As the groundwater recharge rate of the GWB is very low a small nitrogen surplus results in high nitrate concentrations in water seeping to the underlying aquifer.

Various investigations have been carried out to improve the conceptual understanding of the GWB including comprehensive studies of mean residence time (MRT) of groundwater. Values of MRT of < 5 to > 50 years, with a significant proportion up to and beyond 50 years, indicate that the GWB responds very slowly to reductions in nitrogen inputs. Consequently the effectiveness of measures taken to reduce nitrate leaching to groundwater is not yet entirely apparent.

Although various measures have been applied, and trend reversal recently occurred in the GWB, the overall picture shows that: (i) Concentrations at most stations in 1997 were considerably higher than the quality standard (45 mg/l) and very large reductions are required to meet this standard; and (ii) concentrations decrease slowly. The concentration gradient is clearly not only related to measures and present day cultivation, but also to a combination of natural conditions controlling the leaching of nitrate to groundwater. Even though all feasible measures have been implemented, and are assessed and regularly adapted, natural conditions will stop the GWB from attaining good chemical status until 2027.

Pressures: Agriculture is the dominant land use of the GWB, with predominantly arable farming (grain, field vegetables, sugar beet). Fertiliser application and irrigation as required is common practice to enhance plant growth and increase harvested yield.

Measures: The nitrates action program provides a set of compulsory measures. These are supported by voluntary measures put in place through the agri-environmental program. These voluntary measures are tailored to the region-specific needs to minimise the risk of nitrate leaching to groundwater.

Justification for application of exemption: The land use of the GWB is dominated by arable farming and the livestock density is generally very low. For about two thirds of groundwater stations nitrate trends have reversed between 1997 and 2015. However the rate of nitrate reduction is slow and the majority of groundwater stations still show nitrate concentrations above the quality standard (45 mg/l).

Conclusions: Experiences gained from an Austrian GWB with short MRT (stations with MRTs of < 5 years or 5-10 years, respectively) demonstrated that the implementation of measures lead to a significant and lasting reduction of nitrate concentration throughout the GWB within a few years.

Obviously the natural conditions also prevented a substantial accumulation of nitrate in the vadose zone.

With regard to the described GWB, it has to be concluded that adverse natural conditions contribute considerably to the observed slow decrease of nitrate concentration in groundwater. A further adverse impact on timely implementation of good chemical status might arise from the remobilisation of historic nitrate load stored in the vadose zone.

Further information can be found at:

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Case study title: **The GWB BE-Meuse-RWM040 “Chalk of the Geer basin”: delayed effect for nitrate in deep, old groundwater**	
Country: Belgium (Wallonia)	Groundwater (real case)

Outline and general description: GWB BERWM040 corresponds to a chalk aquifer located to the north-west of Liège, in eastern Belgium and sits within the Geer River Basin, a tributary of the Meuse River (Figure 1). Also known as the Hesbaye Chalk aquifer, the GWB is a very important groundwater resource supplying approximately 30 million m^3 drinking water per year, abstracted through galleries and pumped wells, to around 600 000 people in the city of Liège and its suburbs. The GWB is comprised of fractured, dual-porosity chalk formations overlain by loess deposits (Figure 2). The large porosity of the chalk (30 to 50%) provides important water storage capacity with a dense fissure network draining groundwater stored in the chalk. Piezometric measurements indicate a north-oriented hydraulic gradient (Dassargues and Monjoie, 1993). Most of the aquifer is unconfined except in the north, where semi-unconfined conditions prevail close to the Geer River, and locally under Cenozoic clayey sediments, where the aquifer is confined. To the north, in the Flemish region, the chalk aquifer (GWB BEVG_BLKS_1100_GWL_1M) is totally confined by overlying Cenozoic sediments. The loess formations overlying the majority of the chalk produce soils favourable to agricultural practices, leading to the majority of the Geer Catchment being intensively cultivated.

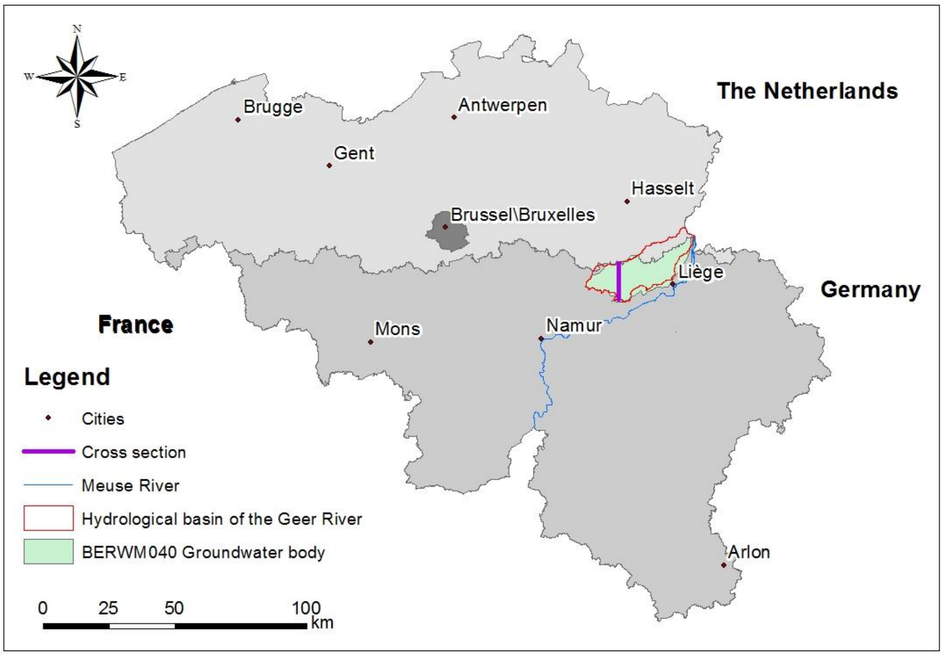

Figure 1: Location of the 'Chalk of the Geer basin' groundwater body BERWM040

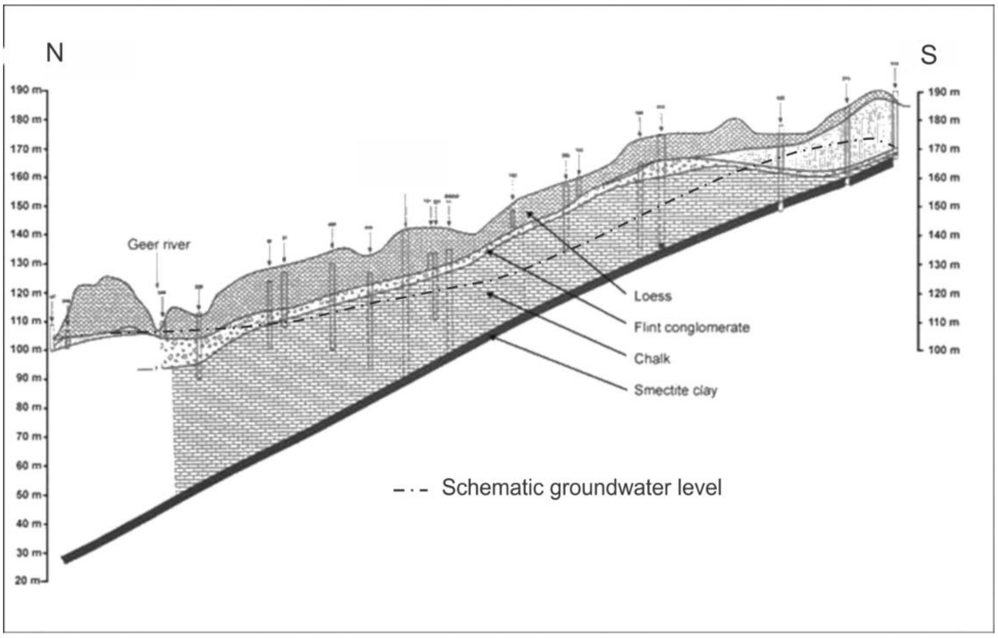

Figure 2: North-South schematic cross-section of the 'Chalk of the Geer basin' groundwater body BERWM040 (modified from Dassargues et al., 1989 and Brouyère et al., 2004)

Pressures: The most relevant pressure on the Geer Basin chalk GWB is agricultural land management. Crops and pastures cover 83% of the Geer Basin, including food and industrial crops (sugar beet, flax, chicory etc.). In the south-eastern area of the GWB urban and industrial areas dominate. Modelled estimates of nitrate loading Dautrebande and Sohier (2004) indicated that agricultural sources contributed 88% and domestic sources (urban waste water) 12 % of the total nitrate load. Consequently there has been a slow but constant increase in nitrate, resulting in the present day critical concentrations in the groundwater of the chalk aquifer. A statistical approach was applied to nitrate time series for trend detection and quantification in the Geer Basin chalk (Batlle et al., 2007; Visser et al., 2009) as part of the EU AQUATERRA project. The analysis confirmed a general upward trend in nitrate concentrations in the entire Geer Basin chalk with low trend gradients of 0.25 - 0.30 mg/l/yr at monitoring points in the east, and steeper trends (0.4 and 0.8 mg/l/yr) in the south of the Hesbaye Chalk aquifer (Batlle et al., 2007).

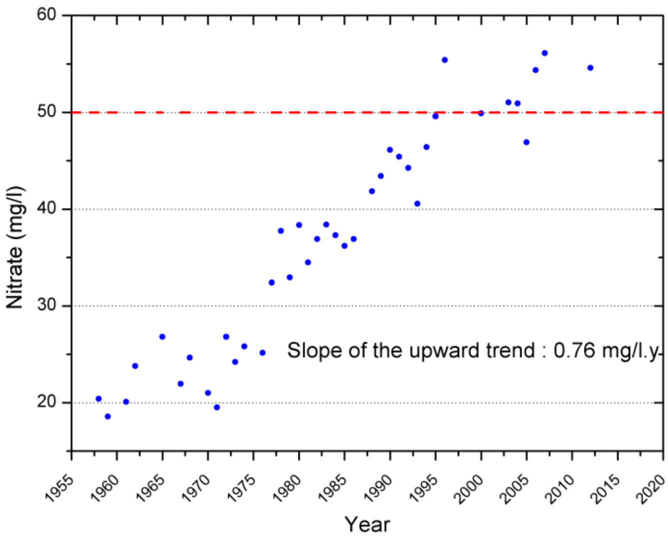

Figure 3: Example of temporal evolution of annual mean nitrate concentrations in one well located in the centre part of groundwater body BERWM040. An upward trend with a slope of 0.76 mg/l/yr is detected in the dataset using the Mann-Kendall test and the Sen slope analysis.

Measures: Different measures have been taken reduce the nitrate pressure and to better understand nitrate contamination in the basin:

(1) The Hesbaye Chalk aquifer was classified in 1994 as vulnerable to nitrate under the European Nitrates Directive (91/676/CEE) and an action program was set up following the Code of Good Agricultural Practice to reduce nitrate pressures on water resources. The action program includes regulation of: manure storage, the timing of manure spreading, and application rates of nitrogen fertilisers per hectare. It also requires the implementation of catch crops and control of potentially leachable nitrogen in the soil at the start of the lixiviation period. As a result of these controls the content of nitrate in soil pore water has been reduced to less than 50 mg/l over recent years.

(2) Studies have been performed in the chalk aquifer of the Geer Basin to understand the origin, spatial distribution, temporal evolution and mechanisms of propagation of nitrate contamination. For example, the 'Programme Action Hesbaye' study (Dautrebande et al., 1996) identified that the spatial distribution of nitrate concentrations is mainly controlled by hydrogeological conditions (Hallet, 1998) with higher and lower nitrate concentrations linked respectively to unconfined and semiconfined parts of the aquifer.

Despite these measures, nitrate concentrations in groundwater have been increasing continuously in most parts of the chalk aquifer. The water company abstracting groundwater for human consumption from the Hesbaye Chalk ('Compagnie Intercommunale Liégoise des Eaux' or CILE), has installed a treatment plant to reduce nitrate (and pesticide) concentrations prior to supply to the distribution network.

Justification for application of exemption: Article 4(4) should be applied in the case of the diffuse nitrate pollution of the Geer Basin chalk GWB due to the natural conditions in the aquifer. Good chemical status will not be reached rapidly due to the very long transit and residence time of groundwater in the unsaturated and saturated zones of the aquifer. The impact of measures taken at the current day to reduce nitrate pressures will only contribute to an improvement of groundwater quality in several decade's time. Long residence and transport times for groundwater, have been identified by various studies of the unsaturated and saturated zones of the Hesbaye Chalk aquifer, at local and regional scales.

Between 1998 and 2001 a pilot investigation was carried out looking at groundwater and nitrate recharge processes across the thick unsaturated zone of the Hesbaye Chalk (Brouyère 2001). Data was collected from: laboratory measurements of chalk core samples from exploratory boreholes at the site, field based data collation of well logging, infiltration tests of the unsaturated zone, pumped testing of the saturated zone, and tracer tests of both zones (Brouyère et al. 2004). The investigation found that recharge in the loess is dominated by gravitational flow, with no evidence of preferential flow, and an average downward solute migration of 1 m/yr. Solute transport is strongly influenced by the low hydraulic conductivity and large porosity of the matrix. In the Hesbaye aquifer the unsaturated zone thickness ranges between a few metres to many tens of metres, and due to the slow velocity of solute in the unsaturated zone (1 m/yr) the time for nitrate to reach the saturated zone can be of the order of several decades.

Subsequent studies of combined nitrate and tritium were undertaken in 2005 and 2007, as part of the EU AQUATERRA project, co-funded by the Administration of the Walloon Region. These studies were undertaken to identify whether the spatial distribution of nitrate concentrations observed in the aquifer can be explained by the age of groundwater (Broers et al., 2007; Orban et al., 2010). Three zones were identified based on nitrate and tritium concentrations:

- A zone in the confined aquifer to the north of the basin with very low tritium and nitrate concentrations are very low, characterized as non-contaminated water which infiltrated before 1960.
- A zone in the main recharge area of the aquifer in the south-west with high tritium and nitrate concentrations (5 to 14 TU and from 30 to 90 mg/l NO_3), characteristic of younger and more contaminated water which infiltrated after 1960.
- A zone located in discharge zone of the aquifer, in particular to the Geer River, in the east and north-east, with concentrations of tritium of 2 to 6 TU and nitrate close to 25 mg/l NO_3. Such concentrations reflect mixing between old/low nitrate groundwater and young/contaminated groundwater.

The spatial distribution of tritium and nitrate demonstrates that nitrate concentrations are directly related to the age of water, and that there is water in the aquifer that entered before the 1960s.

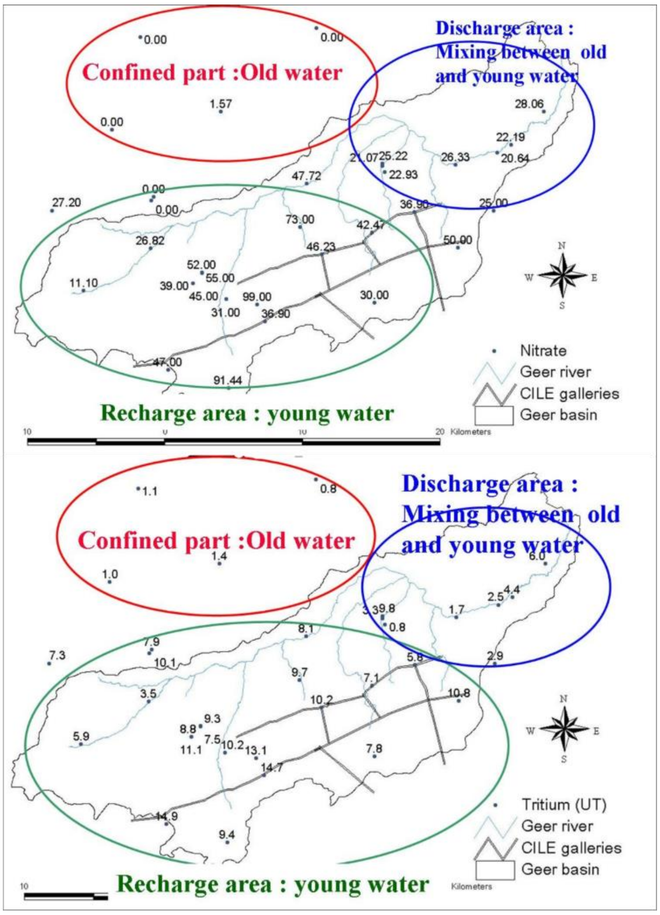

Figure 4: Comparison of the spatial distribution of nitrate and tritium concentrations in the Hesbaye chalky aquifer.

A 3D spatially distributed model was developed using the SUFT3D finite element numerical model package to simulate groundwater and solute transport in all zones of the aquifer (Orban & Brouyère, 2006). The objective was to predict mid and long-term trends in nitrate in the Geer Basin Chalk (Orban, 2009; Orban et al., 2010). The model was calibrated using groundwater levels and the tritium and nitrate data for the flow and transport model and then used to predict nitrate trends over the next 50 years under scenarios of reduced nitrate loading. Two specific scenarios were modelled to identify the point of trend reversal and when concentrations would fall below the drinking water standard: nitrate leaching at 50 mg/l (this should be the objective of agri-environmental programs), and an unrealistic 0 mg/l NO_3 in recharge water (although this should demonstrate the limitations of compliance with the WFD timescales due to natural conditions). At a leaching rate of 50 mg/l NO_3 trend reversal is predicted in the southern part of the basin (recharge area) between 2009 and 2058. In the north-east (discharge area) trend reversal is not predicted at all, and an upward trend is predicted over the same period with exceedance of the drinking water standard (Figure 5). This variation is due to difference in the thickness of the unsaturated zones and in travel times in the saturated zones in the two areas of the aquifer (Orban et al., 2010). A leaching rate of 0 mg/l shows expected faster trend reversals and decreases in nitrate than in the 50 mg/l scenario, but trend reversal will not occur rapidly everywhere.

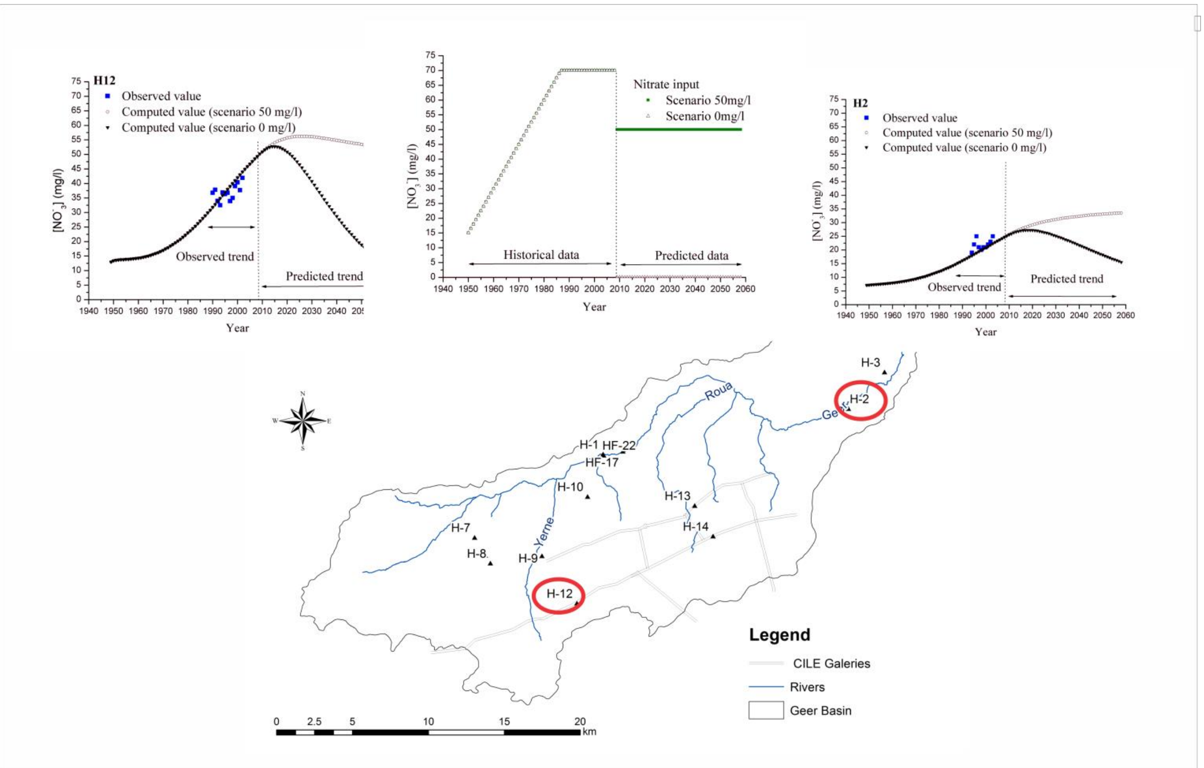

Figure 5: Computed nitrate concentrations for the wells H2and H12 located in the Geer basin (modified from Orban et al., 2010).

Conclusions: This case study shows that a good understanding of the inertia of the groundwater system, including the thick unsaturated zone, is essential for efficient and realistic management of diffuse groundwater pollution at regional scale. In the Geer Basin, the inertia of groundwater quality to change in nitrate loading is strong due to the slow transit time in the unsaturated zone and to the dual porosity of the chalk storing large amounts of pollutant. Measures taken today to reduce nitrate pressures will only be observed in groundwater in several decades time.

Different lessons can be drawn on what investigations are needed into diffuse pollution in similar GWBs:

1) A good understanding of the hydrodynamic conditions prevailing in the basin is essential. The spatial distribution of diffuse nitrate contamination in the Geer Basin is essentially linked to groundwater residence time and mixing, rather than the spatial distribution of land-use or local flow regime. The latter is more important for localised nitrate hotspots related to point sources of pollution.
2) Determination of the age of groundwater is essential in understanding regional nitrate pollution. This can be carried out through a combination of nitrate and environmental tracer concentrations (e.g. tritium). By correlating patterns in nitrate concentrations with the age of groundwater, a better understanding of aquifer processes can be gained. For example, identifying whether low nitrate concentrations are due to water entering the aquifer prior to the period of increased nitrogen loading after 1960, or due to chemical processes in the aquifer such as denitrification.
3) Regional models can be used to forecast the evolution of trends in nitrate concentration under different scenarios for land use change and of reductions in fertiliser application. Such tools are of major importance in supporting the implementation of groundwater regulations to control diffuse pollution including nitrate from agriculture.

Other Issues: In recent decades, pesticides have also been progressively been detected in groundwater of the ‘Geer river basin Cretaceous’ groundwater body. By comparison to nitrate, the spatial distribution and trend of pesticides are more complex to study due to their complex behaviour in soil and groundwater and due to the different land use settings which lead to the use of different pesticides (Hakoun et al., 2017).

As for nitrate contamination, the spatial distribution of pesticides compounds in the Hesbaye aquifer is governed by hydrogeological conditions but also by land use as the type of pesticides is function of the type of cultivation. Temporal trends in pesticides concentrations are related to the inertia of the aquifer system but also to the bio-geochemical behaviour of the compounds.

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Case study title: **Nitrate in Groundwater**	
Country: The Netherlands	Groundwater (real case)

Outline and general description: Nitrate concentrations in groundwater are dependent on the input at the surface. The current policy in the Netherlands aims, among other things, to improve the quality of groundwater with respect to nitrate. The existing standard for nitrate, however, is exceeded in some groundwater bodies. Due to over-fertilisation in the past, a historical nitrate load is present in the subsurface. The complexity of the processes in the subsurface makes it difficult to predict how and when this historical load will manifest in groundwater in the near future. Depending on the characteristics of the subsurface, attenuation (reduction of nitrate) and/or dilution will most likely diminish nitrate concentrations in time. The slow response time of the subsurface/groundwater ensures that in some areas it may take a longer time for the historical nitrate load to be discharged from the aquifer, whilst in other areas an increase in nitrate concentrations will occur before there is a decreasing trend. Reduction of nitrate in geochemical conditions provided by the presence of organic matter or iron sulphides locally present in the subsurface may also increase hardness and release trace metals such as arsenic.

Pressures: Increased concentrations of nitrate at the GWB level are mainly a result of historic over fertilisation. In highly conductive (sandy) aquifers, historical loads may continue to supply nitrate to groundwater for an extended period. The decrease of nitrate concentrations in groundwater depends on decreasing inputs at the surface, the hydrological system and the subsurface attenuation capacity. The hydrological system determines to what extent groundwater is diluted through mixing with low nitrate groundwater. The presence of organic matter or iron sulphides determines whether reduction of nitrate could occur. The hydrological characteristics and the attenuation capacity may vary between and within GWBs. It is important to account for these differences during trend prediction.

Measures: Since 2006 The Netherlands have adopted a fertiliser policy based on application standards. Various application standards apply to the use of total plant available nitrogen depending on the crop and soil type. The aim of these application standards is to restrict the loss of nitrate to the soil as much as possible. Consequently the loss of nitrogen to the soil has declined over the years from 408 million kg/yr (1992-1995) to 185 million kg/yr (2012-2014) (Fraters et al., 2016). Recent modelling of the impact of the national policy in drinking water protected areas indicated that the percentage of areas with concentrations > 50 mg/l NO_3 will decrease from 25% between 2010-2014 to 7% between 2026 and 2030, but the 28% of areas with nitrate concentrations > 40 mg/l will not change (Claessens et al., 2017).

Drinking water protected areas with high nitrate concentrations may have dry sandy soils in combination with crops with a high residue of nitrogen in the soil post-harvest. In these areas specific additional measures are required, and in places have been delivered through regional projects based on collaboration between drinking water companies, provincial authorities and farmers. These projects are already starting to lower nitrate inputs in such specific areas.

Justification: The length of time needed to overcome the supply of nitrate from historical loads, depends on the input at the surface but also on the characteristics of the subsurface. The application of Article 4.4 may be justified by the fact that the length of time needed to meet the nitrate standard is partially determined by the hydrological system and the degradation capacity of the subsurface. An important condition of applying Article 4.4 is that input concentrations eventually ensure good status.

Conclusions: Although nitrate concentrations have decreased due to the national policy on applications, the decrease is not sufficient to reach good status in 2015 in all groundwater bodies. Historic over application of fertilisers has created a nitrate store in the subsurface that will continue to supply nitrate to groundwater for some time. Eventually this historical store is be discharged from the aquifer and nitrate concentrations in the subsurface will then meet the standard. The time required for trend reversal is partially dependent on the characteristics of the subsurface (hydrology and degradation capacity).

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Case study title: **Applying the 'Natural Conditions' exemption to extend the timescale for achieving good chemical status in the Till Fell Sandstone Groundwater Body**	
Country: United Kingdom	Groundwater (real case)

Outline and general description: The Till Fell Sandstone GWB, located in the Solway-Tweed River Basin District (North East of England), has widespread elevated nitrate concentrations (38% of monitoring points exceed the 37.5 mg/l NO_3 threshold value) and subsequently is at poor chemical status. Increasing nitrate concentrations at a drinking water protected area for public water supply, and statistically and environmentally significant increases in nitrate concentrations within the GWB mean that it is assigned poor status under the trends and drinking water protected area tests.

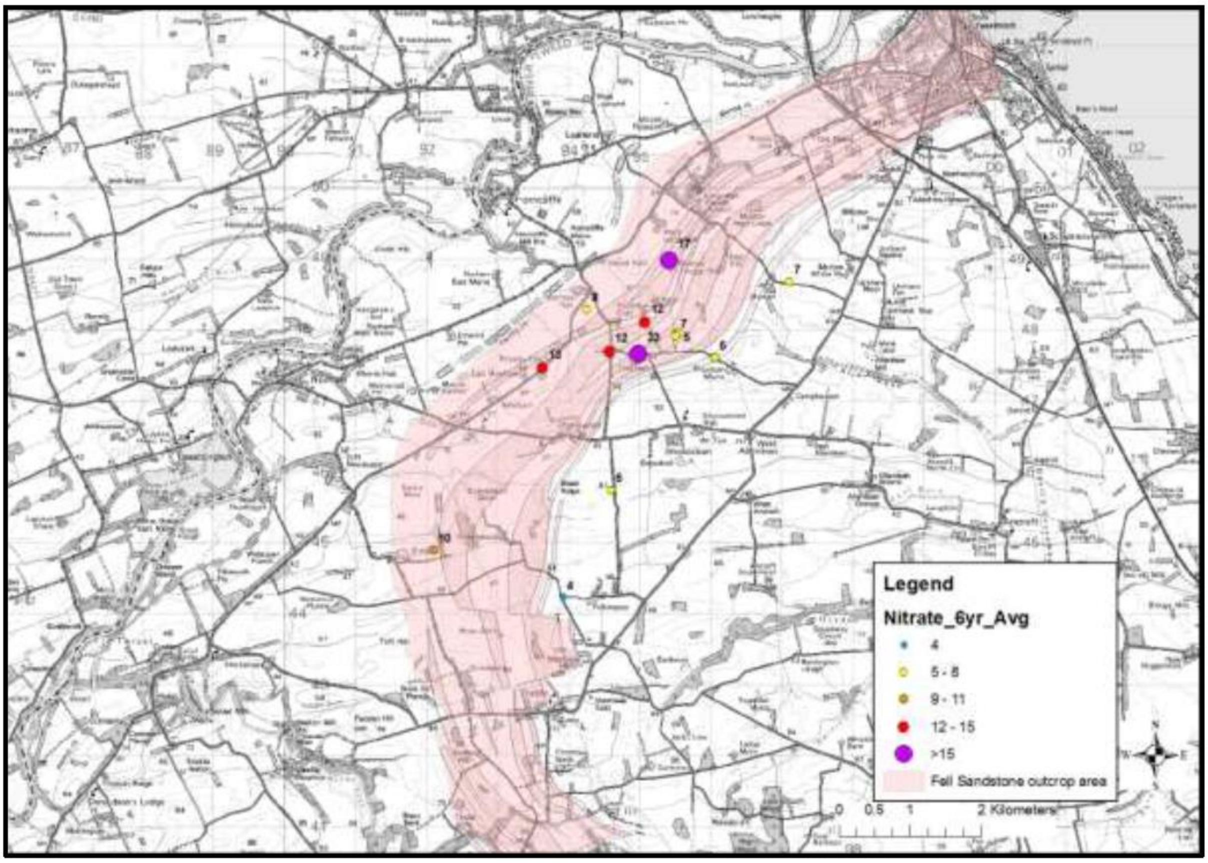

Figure 1: Nitrate (as N) concentrations in the Fell Sandstone near Berwick, presented as six year average (2009-2015)

Pressures: The main nitrate pressure on the GWB is from agriculture, (the predominant land-use is arable farming, followed by managed grassland) and small sewage discharges are locally important. As part of WFD investigations in 2012, agricultural fertiliser and small sewage discharges were identified as the main sources of nitrate in the Fell Sandstone. Estimated nitrate leaching from agricultural sources was less than observed concentrations in groundwater and the underestimation was suspected to be largely due to a poor understanding of the soil properties. Generalised soil maps available for the area do not appear to correspond with the understanding of the local geology. The soils are mapped as being slowly permeable, seasonally wet loamy and clayey soils, however, borehole logs and recent work suggested sandier and more free-draining soils are present. The difference in soil properties will have an impact on the quantity of leached nitrate. Additionally, large areas of the Fell Sandstone have no drift cover, suggesting that soils will develop directly on the bedrock, influencing the texture and drainage characteristics of the soil, and hence nitrate leaching.

Measures: Most of the measures take a Catchment Based Approach: working with local farmers to reduce nitrate leaching to the groundwater. We are also working to improve our knowledge of nitrate movement within the aquifer, to better predict travel times and likely impact to public water supplies. Examples of measures include:

1. Supporting a campaign to raise awareness of small sewage discharge (SSD) maintenance in partnership with the local water company and the Catchment Sensitive Farming (CSF) initiative in 2013-2014. This involved distributing leaflets and questionnaires to residents, and working with respondents where poor maintenance was identified.

2. Catchment sensitive farming initiative within the Till Fell Sandstone aquifer: providing advice and guidance to farmers via workshops and meetings on how to reduce nitrate leaching.

3. NVZ guidelines: although the action programme measures have been applied across the GWB, more specific information on nitrate management is necessary in highly vulnerable aquifers such as this.

4. Soil Analysis: Working with farmers to analyse soil mineral nitrogen so that fertiliser use can be more accurately targeted and hence nitrate leaching is reduced.

5. Soil Mapping and Direct Measurement of N leaching: We are currently joint-funding (with the water company) an MSc project focussing on the influences of soil type and land management practices on nitrate leaching. This involves using geophysical soil sensors to map the soil type within our pilot study area, coupled with measurements of nitrate leaching using porous cups. This study will help us quantify the amount of nitrate leaching based on soil type, allowing us to work directly with farmers to better manage nitrate fertiliser application.

6. Safeguard Zone Designation around public water supplies in the Till Fell Sandstone.

7. Quantification of nitrate movement in the highly-complex Fell Sandstone aquifer, including calculation of travel times to predict timescales in which historic nitrate stored in the aquifer will reach the public water supply boreholes.

8. The water company were supported in drilling new monitoring boreholes near their abstraction boreholes. In addition to providing additional monitoring points, analysis of porewater from cores collected above the water table will allow quantification of the amount of nitrate in the unsaturated zone.

Justification for exemption: The 'Natural Conditions' exemption in Article 4(4) of the Water Framework Directive has been applied to extend the timescale for achieving good chemical status in the Till Fell Sandstone GWB. We have stated in the 2015 Solway-Tweed River Basin Plan that this GWB will reach good status by 2040. Local hydrogeologists have a detailed conceptual understanding of the GWB and expert local knowledge to assess the effectiveness of the existing measures, concluding that the local measures are sufficiently robust to meet the good status objective. The delay to achieving good status was based on a combination of local data, national data (Wang et al, 2011) and expert judgement, with a prediction of relatively modest unsaturated zones travel time delays, and much longer saturated zone recovery times. The recovery time delay means that measures will not deliver the good status objective for an estimated 25 years, leading to the achievement of good status by 2040. However, we do acknowledge that there are considerable uncertainties associated with this prediction.

Conclusions: The main lesson learnt from this case study is that before using the Article 4(4) exemption local hydrogeologists must be confident that the planned measures will be put in place and that they will deliver good status in the long-term. Ideally, this confidence should be derived from a combination of field measurements, modelling assessments and expert judgement.

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