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NOVANA

National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments

Programme Description – Part 2

NERI Technical Report, No. 537

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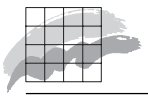

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Abstract: This report is Part 2 of the Programme Description of NOVANA – the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments. Part 2 comprises a detailed description of the nine NOVANA subprogrammes: Background monitoring of air quality and atmospheric deposition; Point sources; Agricultural catchments; Groundwater; Watercourses; Lakes; Marine waters; Species and terrestrial natural habitats; and the National Air Quality Monitoring Programme. For each subprogramme the report describes the background based on national requirements and international monitoring obligations, the objectives and strategy and a detailed description of the programme content. The Programme Description is in three parts. Part 1 (NERI Technical Report No. 532) comprises a general description of the background for the programme, the national requirements and international obligations regarding monitoring of nature and the environment and the programme's overall objectives, strategy, organization and economic framework. Part 3 (available in Danish on the NERI website: http://www.dmu.dk/Overvågning/NOVANA/) deals with general aspects concerning quality assurance, chemical analyses, data storage and transfer, reporting etc. and provides detailed tables of measurement variables and frequencies at the stations/localities covered by each subprogramme.

Key words:	Monitoring, NOVANA, aquatic environment, nature, watercourses, lakes, groundwater, marine waters, fjords, agricultural catchments, atmospheric deposition, point sources, species, habitat types, Water Framework Directive, Habitats Directive, nutrients, hazardous substances, heavy metals, models, monitoring requirements, monitoring obligations, directives, international conventions, monitoring strategy.
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Content

1 Introduction

When the Action Plan on the Aquatic Environment was adopted in 1987, a monitoring programme was established in order to follow the development in the actual discharges and losses of nutrients to the aquatic environment and record the ecological effects of the reduction in discharges. The monitoring programme was initiated on 1 October 1988 (Danish EPA, 1989). The programme supplemented environmental supervision by the regional authorities of the air, the groundwater, agricultural catchments, watercourses, lakes, the sea and wastewater treatment plants and other point sources.

The monitoring programme was subsequently adjusted in 1992 (Danish EPA, 1993) and revised in 1997 (Danish EPA, 2000), at which time the monitoring of hazardous substances was incorporated. The monitoring programme was renamed the Danish Aquatic Monitoring and Assessment programme (NOVA-2003).

In 2003 it was decided to undertake a major revision of NOVA-2003 such that the national monitoring programme integrated national monitoring of nature and the aquatic environment. The new programme was named NOVANA – the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments. The agreement covered the period 2004–2009. In addition to the areas previously monitored, NOVANA incorporates monitoring of species and terrestrial natural habitats. Moreover, greater priority has been accorded to aquatic species and habitats. At the same time, the monitoring of nutrients and their effects and of hazardous substances has been reduced.

The Programme Description for NOVANA consists of three parts, of which this report is Part 2 and consists of a detailed description of the individual NOVANA subprogrammes.

Part 1 comprises a general description of the background for the programme, including national requirements and international obligations as to monitoring of nature and the environment. The overall objectives and the scientific and strategic background for NOVANA are also described, as are the organization of the programme and the overall economy.

Part 3 deals with general aspects concerning quality assurance, chemical analyses, data storage and transfer and reporting of the results. It also provides detailed tables showing the monitoring variables and frequencies at the stations/locations encompassed by each element of the various subprogrammes. In addition, Part 3 includes a number of technical notes and further details of some of the subprogrammes.

Overall responsibility for preparation of the Programme Description lies with the Programme Management Board. The Monitoring, Advisory and Research Secretariat at the National Environmental Research Institute has been responsible for the overall editing of the Programme Description, while the individual subprogrammes have been drawn up by the Topic Centres.

Part 2 of the Programme Description was edited by:

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Chapter 3: Background monitoring of air quality and atmospheric deposition – *Thomas Ellermann*
Chapter 4: Point sources – *Karin Dahlgren Laursen and Lis Morthorst Munk*
Chapter 5: Agricultural catchments – *Ruth Grant and Gitte Blicher-Mathiesen*
Chapter 6: Groundwater – *Jens Stockmarr*
Chapter 7: Watercourses – *Jens Bøgestrand*
Chapter 8: Lakes – *Jens Peder Jensen and Torben Lauridsen*
Chapter 9: Marine waters – *Jesper H. Andersen (ed.)*
Chapter 10: Species and terrestrial natural habitats – *Jesper Fredshavn, Hans Løkke and Henning Noer (eds.)*
Chapter 11: Nationwide Air Quality Monitoring Programme (LMP IV) – *Finn Palmgren and Thomas Ellermann*.

In addition to the above-mentioned authors and editors, a number of other Topic Centre staff members have contributed to the preparation of the individual chapters. Finally, members of the steering committees and the Programme Management Board have contributed valuable comments. All these persons are thanked for their contributions.

This English translation of Part 2 of the Programme Description was prepared by David I Barry.

[Tom side]

2 Summary

The Nationwide Monitoring and Assessment Programme for the Aquatic and Terrestrial Environments (NOVANA) entered into force on 1 January 2004.

The overall objective of NOVANA is to monitor the status of the aquatic and terrestrial environments and the pressures upon them, i.e. to:

- Describe **sources of pollution** and other pressures and their impact on the status of the aquatic and terrestrial environments and identify trends
- Generally document the **effect** of national **action plans** and measures directed at the aquatic and terrestrial environments – including whether the **objectives** are achieved and whether the **trends** are in the desired direction
- Meet Denmark's **obligations** in relation to EU legislation, international conventions and national legislation
- Contribute to enhancing the **scientific basis** for future international measures, national action plans, regional management and other measures to improve the aquatic and terrestrial environments, including contributing to develop various tools.

With this programme Denmark can fulfil its international monitoring and reporting obligations concerning nature and the aquatic environment – at least at a minimum level.

The NOVANA programme replaces the Danish Aquatic Monitoring and Assessment Programme (NOVA-2003), which had been running since 1998. This programme derived from the 1987 Action Plan on the Aquatic Environment, which included the establishment of a monitoring programme for the aquatic environment to supplement environmental supervision by the regional authorities. The intention with NOVANA is to incorporate nature monitoring and especially monitoring of species and terrestrial natural habitats into the national monitoring, not least in the light of Denmark's obligations under the Habitats Directive. In contrast to NOVA-2003, NOVANA therefore includes monitoring of species and terrestrial natural habitats. Moreover, greater priority has been accorded to aquatic species and habitats.

The actors involved in the programme are the National Environmental Research Institute, the Geological Survey of Denmark and Greenland, the Danish EPA, the Danish Forest and Nature Agency, the regional authorities (the Counties, Regional Municipality of Bornholm, Copenhagen Municipality and Frederiksberg Municipality). Overall responsibility for the programme and for its coordination lies with the National Environmental Research Institute. NOVANA activities carried out by the regional authorities are funded via government block grants. In addition, the regional authorities have incorporated part of their environmental supervision activities into the aquatic environment monitoring.

The NOVANA Programme Description is in three parts. This part of the Programme Description, Part 2, describes the individual subprogrammes. In the order they are presented here, these are the subprogrammes for:

- Background monitoring of air quality and atmospheric deposition
- Point sources
- Agricultural catchments
- Groundwater
- Watercourses
- Lakes
- Marine waters
- Species and terrestrial natural habitats
- Nationwide Air Quality Monitoring Programme (LMP IV).

Each of the subprogrammes is described following the general format:

1. **Introduction**. Who is responsible for what, and what the subprogramme encompasses.
2. **Background and status**. Previous programmes, scientific experience and follow-up on scientific knowledge, and what needs to be determined. The most important parts of the inventory of monitoring requirements are described.
3. **Objectives**. Overall objectives of the subprogramme.
4. **Strategy**. The general method. Premises applied in designing the method. How the intensive and extensive parts are handled. How the international evaluation, the statistical optimization project and the inventory of monitoring requirements have been taken into account. How the programme is linked to the other subprogrammes. Summary of the common elements.
5. **Programme content**. An outline of the work, but not the details. The structure of the various elements, parameters, frequencies, intervals and stations.
6. **Main changes relative to NOVA-2003**. How the subprogramme differs from the corresponding subprogramme under the preceding monitoring programme NOVA-2003.
7. **Theme-specific assumptions** (not general assumptions, as these are dealt with in Part 1). Input from and output to other subprogrammes.

8. **Consequences of the programme in relation to the inventory of monitoring requirements**. Review of any problems regarding fulfilment of monitoring obligations.
9. **Annexes**. Summary of heavy metals and hazardous substances encompassed by the subprogramme.

The present Programme Description sometimes refers to detailed information in the Programme Description for the preceding monitoring programme, NOVA-2003. The latter is available at: http://www.dmu.dk/Overvågning/NOVA-2003+arkiv/.

3 Background monitoring of air quality and atmospheric deposition

3.1 Introduction

The subprogramme for background monitoring of air quality and atmospheric deposition concerns the monitoring of ambient air quality in background areas and the determination of atmospheric deposition. The programme is carried out by NERI. Ambient air quality is also monitored through the Nationwide Air Quality Monitoring Programme (LMP IV), which focuses on ambient air quality in the towns and health-related air pollutants. LMP IV is described in Chapter 11.

3.2 Background and status

The subprogramme for background monitoring of air quality and atmospheric deposition is a natural extension of the monitoring activities under the Action Plan on the Aquatic Environment and NOVA-2003 and is based on the experience gained during these programmes. The main objective has been determination of the average air quality and deposition and the trends in them for Denmark as a whole, although focussing on aquatic areas. Since 1996, ambient air quality and deposition have been determined using a combination of measurements and model calculations. The measurements have been used to determine the actual levels and assess the trends, while the model calculations have been used to determine the geographic distribution of deposition on the Danish open marine waters, fjords, coves and bays. In recent years, deposition on land has also been included in the calculations. The measurements are also used to assess the quality of the model calculations. The programmes have encompassed the main air pollutants that cause eutrophication and acidification, as well as selected heavy metals. The results have shown that the atmospheric deposition accounts for a considerable proportion of nutrient input to the Danish marine waters, and that deposition is a major source of the heavy metals in Danish marine waters.

With the inclusion of monitoring of the terrestrial environment in NOVANA it is necessary to determine air pollution and deposition of relevant substances at the local scale, taking into account the characteristics of the habitat types. The focus of the subprogramme for background monitoring of air quality and atmospheric deposition has therefore been redirected towards local pollution with respect to both measurements and model calculations. Among other things, this means that the programme now includes process studies of nitrogen deposition aimed at enhancing our understanding of the processes and improving the parameterization in the models.

The subprogramme has also been extended with a small monitoring programme for the hazardous organic substances. This extension reflects the continued focus on the negative effects of hazardous organic substances on nature and the environment. This group of substances is already included in NOVA-2003 in a number of other subprogrammes. These substances were therefore included in the present subprogramme in order to be able to provide a more complete picture of their effects and turnover in nature and the environment.

The subprogramme is designed to meet the reporting obligations pursuant to the Geneva Convention (EMEP), HELCOM, OSPAR and OECD/Eurostat.

In addition, the newly added terrestrial part of the subprogramme will enable it to focus on the effects of atmospheric deposition (in particular of nitrogen) on natural habitats.

3.3 Objectives

The overall objectives of the subprogramme are to:

- Describe the status and trend for **air quality** in Danish background areas
- Describe **deposition** of air pollutants on terrestrial and aquatic areas at the national, regional and local scales (including different habitat types)
- Document the overall **effect** on air quality and atmospheric deposition of national and international **action plans** and measures aimed at limiting air pollution, e.g. emission limits, including whether the **trend** is in the desired direction
- Fulfil Denmark's **obligations** regarding atmospheric monitoring in background areas pursuant to EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for political decisions in the form of air pollution models for scenario calculations, air quality forecasts, etc.

3.4 Strategy

The strategy employed in the subprogramme is a carefully considered combination of measurements and model calculations aimed at ensuring the best possible coverage of air pollution in Denmark given the reduced number of measurement stations. Model calculations on a local scale are particularly necessary in relation to the terrestrial environment monitoring in order to be able to cover the many different types of natural habitat that are expected to be included in NOVANA.

Wherever possible the air quality and deposition measurements performed under the subprogramme are to be integrated with the other NOVANA subprogrammes in order to ensure optimal use of the data in monitoring of the terrestrial environment.

The subprogramme should as far as possible meet international obligations regarding the measurement of air quality in background areas (see Section 3.9) and should use accredited and internationally accepted sampling and analysis methods.

The subprogramme is designed around the pre-existing monitoring network, this being the most economic and scientifically defensible solution. The subprogramme has been extended with measurements focusing on natural habitats that can also be used to validate model calculations for local areas and improve the air pollution models. In addition, this ensures the continuation of the existing time series dating back to the 1970s and 1980s – something that is necessary to meet the objective of assessing the trend in air quality and deposition. The long time series are extremely important for assessing the effect of measures taken in society to restrict the causes of the emissions.

With the current measurement programme it is possible to detect a 20–30% trend at station level over a ten-year period. It is therefore considered that the new measurement programme will continue to be able to detect trends greater than 2–3% per year over a ten-year period. Due to the subprogramme's size and geographic coverage, however, it will be difficult to assess trends at the national level for a number of the monitored parameters (primarily ammonia and heavy metals).

Regarding the air quality monitoring under NOVA-2003, the Statistical Optimization Project concluded that "*the number of stations in the current monitoring programme is appropriate*" and "*the frequency of monitoring for wet deposition is appropriate, whereas the frequency of filter samples could be reduced considerably without affecting the strength*". These conclusions have been incorporated in the Topic Centre for Air Quality's assessments. More specifically, the monitoring programme is designed around the existing measurement stations, except that two small stations for measuring nitrogen in natural habitats have been added to take account of the great geographic variation in nitrogen deposition. In the revised measurement programme, particle and gas measurements are carried out on a daily basis at three of the measurement stations and on a weekly basis at another three of the measurement stations. This solution is based on the recommendations and requirements of international programmes, consideration for validation of models and model calculations, the economic framework and the preservation of as many of the long time series as possible.

The International Evaluation concluded that the air quality monitoring under NOVA-2003 was adequate to meet its objectives. Several changes to the programme were proposed, however. These are:

- *"It would be desirable to extend the measurements to include POPs, VOC and PM_{10}"*. In response, the Topic Centre for Air Quality has included some measurements of selected hazardous organic substances. The measurements are limited in extent, however, partly due to financial constraints and partly because it is a new activity. Furthermore, it is considered that the measurements of PM_{10} made at the measurement stations at Keldsnor and Lille Valby (part of the Nationwide Air Quality Monitoring Programme) will be sufficient to meet EMEP requirements.
- *"Consideration should be given to increasing the sampling frequency of precipitation sampling to weekly in line with international guidelines"*. The Topic Centre for Air Quality considers that there are no significant problems associated with continuing to sample precipitation on a ½-monthly basis as in NOVA-2003. A disadvantage of the long sampling period is the risk of nitrogen turnover in the samples. However, by means of tests with cooled precipitation samples the Topic Centre has shown that this uncertainty factor is small under Danish conditions.
- *"The atmospheric deposition model (ACDEP) should be extended to provide estimates of the loads of hazardous substances and heavy metals"*. Unfortunately, it has not been possible to accord priority to this in the subprogramme.

The primary objective of the subprogramme for background monitoring of air quality and atmospheric deposition is to determine the extent to which atmospheric deposition affects the Danish aquatic and terrestrial environments. The subprogramme therefore provides input to the subprogrammes for marine waters, watercourses, lakes, agricultural catchments and species and terrestrial natural habitats, where knowledge about pressure from the atmosphere is important.

Table 3.1 Main elements of the subprogramme.

Element	Content
Measurement programme	Monitoring network Terrestrial part Hazardous organic substances
Model calculations	National scale Regional scale Local scale

3.5 Programme content

The monitoring consists of intensive measurements of ambient air quality and deposition in combination with model calculations.

The actual concentrations and deposition are measured at a network of measurement stations, while the model calculations are used to calculate the deposition on aquatic and terrestrial areas. The measurements

also serve as the basis for assessing the trends and evaluating the quality of the modelling results.

3.5.1 Measurement programme

The measurement programme is designed to determine ambient air quality and deposition at the regional level for the following substances:

- Nitrogen: Concentration of NO_2, NH_3, HNO_3, particulate NH_4 and NO_3. Wet deposition of soluble NH_4, NO_3 and total-N.
- Phosphorus: Concentration and wet deposition of dissolved phosphorus.
- Sulphur: Concentration of SO_2 and particulate SO_4. Wet deposition of SO_4.
- Basic cations: Wet deposition and concentration of Na, K, Ca and Mg.
- Heavy metals: Concentration and wet deposition of Cr, Mn, Fe, Ni, Cu, Zn, As, Cd and Pb.
- Hazardous organic substances: Wet deposition and concentration of selected substances.
- Ozone.

As regards nitrogen compounds, the measurements should enable determination of ambient air quality and deposition on a local scale. The deposition is determined from the measured wet deposition (½-monthly) and the dry deposition calculated on the basis of measured air concentrations.

As regards phosphorus, the measurements should enable estimation of phosphorus deposition. This is done partly using measurements of dissolved phosphorus and partly using campaign measurements of total-P (1-year measurements at three measurement stations).

Ozone is measured for use in assessing direct ozone damage to plants and as a supplement to the ozone measurements made in the Nationwide Air Quality Monitoring Programme (LMP IV) for the ozone warning service.

The subprogramme is divided into three parts:

- The monitoring network. This is the core of the monitoring programme and consists of eight measurement stations at which wet deposition and the ambient concentration of gasses and particle-bound substances are measured. The basic network encompasses measurements of nutrients, acidifying substances, basic cations, heavy metals and ozone.
- The terrestrial part. This encompasses a special monitoring programme for local deposition of ammonia.
- Hazardous organic substances. This encompasses measurements of a number of selected organic substances (aromatic compounds and PAH, pesticides, phthalates and nitrophenols).

3.5.1.1 The monitoring network

The network of measurement stations is built up around the pre-existing measurement stations from earlier programmes. Some of the measurement stations were established as early as the late 1970s. The use of these measurement stations ensures continuity in the monitoring of ambient air quality and deposition in Denmark and enables the trends to be assessed. The measurement stations are briefly described in Table 3.2 indicating the landscape/habitat type, etc., and their geographic location is shown in Figure 3.1.

The methods used to measure ambient air quality – i.e. the air's content of air pollutants in gaseous and particulate form – at the measurement stations are:

- Filter-pack samplers. A known amount of air is drawn through an array of filters (a particle filter and two impregnated filters) which can separate the substances from each other. After sampling the filters are extracted in water, and the aqueous solutions are analysed for ammonia, sulphur dioxide, sum-nitrate (nitric acid + particulate nitrate) and for the content of particulate ammonium, sulphate, phosphate, sodium, chloride, magnesium, potassium, calcium and selected heavy metals.
- Continually recording monitors. Nitrogen dioxide and ozone are determined using monitors.

In addition, atmospheric deposition is measured at the measurement stations. This consists of two components:

- Wet deposition, which is the deposition of substances on soil, plant and water surfaces, etc. in connection with precipitation.
- Dry deposition, which is the deposition of gasses and particles upon contact between the air and the surfaces.

Wet deposition can be measured directly using a precipitation sampler. In NOVANA, two types of sampler are used – bulk samplers, which are permanently open, and wet-only samplers, which are only open when it rains. The precipitation samples are collected every half month and thereafter analysed by the NERI Department of Atmospheric Environment for ammonium, nitrate, sulphate, phosphate, chloride, sodium, potassium, calcium and magnesium.

Wet deposition of heavy metals is determined on a monthly basis through sampling of precipitation using bulk samplers, with the sample being stabilized with HNO_3.

Table 3.2 Measurement stations used by the subprogramme. The geographic location is indicated by UTM-32 coordinates (Universal Transverse Mercator Grid). The landscape/habitat type, local sources of pollution, the types of sample collector present and the date the station was established are also shown.

Station name	UTM coordinates (km E, km N)	Landscape/ habitat type	"Local" sources of pollution	Sample collectors[1]		Establishment date
Anholt	657, 6287	Coast	Few	Precip., HM	Gas/Part.	88.09.15
Frederiksborg	709, 6206	Forest	Hillerød town	Precip., HM	Gas/Part.	85.05.23
Gunderslevholm	664, 6135	Forest, lake	Few	HM		93.01.01
Hansted	473, 6322	Forest	Few	Precip., HM		94.04.01
Keldsnor[2]	611, 6066	Coast	Agriculture	Precip.	Gas/Part.	78.10.01
Lindet	493, 6111	Forest	Agriculture	Precip., HM	Gas/Part.	88.06.01
Pedersker	880, 6113	Coast	Few	Precip., HM		89.06.06
Sepstrup Sande	526, 6215	Heath	Few	Precip., HM		89.06.01
Tange	537, 6246	Forest, lake	Agriculture		Gas/Part.	78.10.01
Ulborg	465, 6239	Forest	Few	Precip., HM	Gas/Part.	85.05.23

[1)] Precip.: Bulk-samplers for collection of precipitation; HM: Wet deposition of selected heavy metals; Gas/Part.: Filter-pack samplers for determination of gasses and particles, denuders for measurement of gasses, monitors for measurement of O_3 and NO_2.
[2)] Consists of closely located measurement stations on the southern tip of Langeland.

Figure 3.1 Measurement stations used in the subprogramme. (●) Stations used to measure wet deposition of nitrogen, phosphorus, sulphate and heavy metals. Grey bullet indicates that the station is only used for wet deposition of heavy metals. (▲) Stations used for measurement of air concentrations of the most important gaseous and particulate forms of nitrogen, phosphorus and sulphur compounds. The air content of selected particle-bound heavy metals is also determined.

Dry deposition cannot be measured directly in connection with a routine monitoring programme. Instead, the monitoring network uses calculated dry deposition based on the measured air concentrations and knowledge of the deposition rates for the components in question. The calculations incorporate the meteorological conditions pertaining at the time of sampling. These calculations are supplemented with measurement of dry deposition of ammonia in selected periods in connection with the terrestrial part of the subprogramme (see next section).

Finally, the ozone concentration is measured at one measurement station to assess the ozone concentrations in the background areas to enable assessment of ozone's harmful effects on plants.

The parameters measured and the measurement frequency are shown for the individual measurement stations in Table 3.3.

3.5.1.2 The terrestrial part

This part of the monitoring programme focuses on the measurement of nitrogen concentrations and deposition and is designed to provide knowledge about both concentration levels and the processes behind deposition.

The measurements are carried out partly at measurement stations in the monitoring network and partly at "mobile" measurement stations. The location of the "mobile" measurement stations has not yet been finalized. The "mobile" measurement stations will be relocated at 1–2-year intervals so as to enable as many localities and habitat types to be covered as possible during the programme period (probably 8–12).

The concentration levels of nitrogen gasses and particles are determined using denuders and particle filters on a ½-monthly basis at five stationary measurement stations and two "mobile" measurement stations. With this method a known amount of air is drawn through a 50-cm long coated glass tube and a particle filter. Gasses in the air diffuse out to the inner side of the glass tube and are absorbed by the coating. The particles are sucked right through the tube and caught by the particle filter. After sampling the tube and filter are extracted in water, and the aqueous solutions are analysed. The method yields good separation of ammonia and particulate ammonium and of nitric acid and particulate nitrate.

The more detailed measurements for investigation of the processes behind deposition consist of:

- Measurement of the temporal variation in the ammonia concentration using measurement methods with high temporal resolution (½-hour mean values).
- Measurement of dry deposition of ammonia in field campaigns (four weeks combined duration) using the gradient method (to be assessed).

These measurements will be carried out partly at the permanent measurement stations and partly at the "mobile" measurement stations.

Table 3.3 Measurements made at the various measurement stations indicating the frequency and substances measured.

	Wet deposition			**Concentration of gasses and particles**			
	Inorganic	Heavy metals	Hazardous organic substances	Filter-pack Inorganic	Filter-pack Heavy metals	Denuder	Monitor
	½-month	Month	Month	Day	Day/week	½-month	Hour
	NO_3, NH_4, P, SO_4, Cl, Na, K, Mg, Ca, pH, cond., total-N	Pb, Cr, Zn, Mn, Fe, Cd, Cu, As, Ni	Aromatic, PAH, pesticides, phthalates	NH_3, SO_2, sum-NO_3, Cl, NH_4, P, Na, K, Ca	Pb, Cr, Zn, Mn, Fe, Cd, Cu, As, Ni	NH_3+NH_4 HNO_3+NO_3	NO_2, O_3
Anholt	X	X	X	Day	Day		NO_2
Frederiksborg	X	X		Week	Week	X	
Gunderslevholm		X					
Hansted	X	X					
Keldsnor	X	X		Week	Week	X	
Lindet	X	X		Week	Week	X	
Pedersker	X	X					
Sepstrup Sande	X	X	X				
Tange				Day	Day	X	
Ulborg	X	X		Day	Day	X	NO_2, O_3

3.5.1.3 Hazardous organic substances

The monitoring programme for hazardous organic substances will initially consist of the measurement of wet deposition at two of the permanent measurement stations. Wet deposition is sampled using cooled wet-only samplers with an averaging time of 1–2 months. The samples are thereafter analysed for a number of PAHs, pesticides, nitrophenols and phthalates (see Table 3.4 and Annexes 3.2 and 3.3).

After 1–2 years the results will be evaluated with a view to initiating measurement of the concentrations of these substances in ambient air. The substances will be sampled using so-called "pufs" (foam rubber filters) on a monthly basis (the frequency has not yet been finalized).

Table 3.4 Hazardous organic substances for which wet deposition is measured at two measurement stations.

Compound group	Number of substances
Aromatic compounds and PAH	17
Pesticides	20
Nitrophenols	4
Phthalates	5

3.5.2 Model calculations

Model calculations are made for the deposition of relevant substances at the national and regional scales. The modelling is performed in two steps:

The first step consists of calculation of the deposition at the national scale using the ACDEP model with a spatial resolution of 30 km x 30 km. These calculations yield the deposition of components whose geographic variation is small, i.e. wet deposition and dry deposition of SO_2, NO_2 and particulate nitrogen and sulphur, as well as an estimate of the mean deposition of ammonia.

From 2005–2006 onwards, the ACDEP calculations will be replaced by calculations made using the more detailed model REGINA, which has a spatial resolution of 5 km x 5 km for areas in and around Denmark.

The calculations made using ACDEP/REGINA will encompass deposition on Danish terrestrial areas and water bodies. Calculations of deposition of sulphur compounds are not performed for Danish open marine waters as sulphate is a natural constituent of seawater.

In the second step the modelling results from ACDEP/REGINA will be used as the basis for detailed calculations of deposition of ammonia at the local scale, i.e. 100 m x 100 m. These calculations are performed using OML-DEP for selected areas (20–30 per year). Thereafter the total deposition of nitrogen on natural countryside will be determined by combining the ACDEP/REGINA and OML-DEP results.

3.5.2.1 Deposition of other substances

A number of substances are not included in the model calculations of deposition, among other reasons due to a lack of adequate emission inventories. This applies to phosphorus, heavy metals and the hazardous organic substances.

With these substances, annual deposition is calculated for selected areas based on the measured wet deposition and estimated dry deposition. In the case of the hazardous organic substances the estimates are based solely on the wet deposition, however.

3.6 Main changes relative to NOVA-2003

The main changes in the subprogramme for background monitoring of air quality and atmospheric deposition relative to NOVA-2003 are:

- Changed measurement frequency for gasses and particles at three measurement stations such that the subprogramme will consist of diurnal measurements at three stations and weekly measurements at three stations
- Extension of the deposition measurements to also encompass natural countryside, including the establishment of a measurement programme for more detailed monitoring of ammonia concentrations and ammonia deposition on natural countryside, including the establishment of two "mobile" measurement stations
- Initiation of measurements of selected hazardous substances
- Extension of model calculations with higher geographic resolution. For nitrogen the calculations have been extended to include calculations at the local scale for 20–30 selected areas (100 m x 100 m).

The differences between the two programmes are summarized in Table 3.5.

3.7 Theme-specific assumptions

The sampling and analysis methods used in the subprogramme are described in a report by the Topic Centre for Air Quality. The NERI Department of Atmospheric Environment is accredited to perform the majority of the methods used in the subprogramme. Technical instructions (Procedures and Instructions) are described in connection with accreditation. The Department of Atmospheric Environment has also drawn up relevant technical instructions for those methods for which the Department is not accredited.

In addition, the Topic Centre for Air Quality has prepared a general description of the air pollution models employed. The report describes the necessary input data and the principles for the calculations and assesses the quality of the models. The air pollution models are further documented in a number of scientific articles and in NERI Technical Reports.

The subprogramme for background monitoring of air quality and atmospheric deposition is coordinated

with the other activities pertaining to air quality carried out by the Department of Atmospheric Environment. Of key importance is the cooperation with the Nationwide Air Quality Monitoring Programme (LMP IV) (see Chapter 11) concerning measurement methods, measurement stations, etc. In addition, the best possible coverage of international obligations is ensured via coordination of the measurements made in the two subprogrammes.

The subprogramme for background monitoring of air quality and atmospheric deposition employs sampling and analysis methods recommended in the international monitoring programmes or methods that are equivalent to these.

The subprogramme activities have been coordinated with a number of other NOVANA subprogrammes so that the measurement programme fits as well as possible with the monitoring carried out in the other subprogrammes. Wherever possible the "mobile" measurement stations will be placed in areas of natural countryside where other subprogrammes also operate.

The results from the measurement and modelling of ambient air quality and deposition are utilized in a number of the other subprogrammes (Figure 3.2).

The subprogramme uses emission inventories prepared by the NERI Department of Policy Analysis as the basis for the air pollution calculations and interpreting the monitoring results. Under the subprogramme for species and terrestrial natural habitats, information is collected about the natural habitats in which the monitoring stations are located.

Table 3.5 Summary of differences between NOVA-2003 and NOVANA subprogrammes.

	NOVA-2003			NOVANA		
	No. of stations	**Total no. of samples**	**Averaging period**	**No. of stations**	**Total no. of samples**	**Averaging period**
Wet deposition:						
Nutrients, sulphur and basic cations	8	696	½-month	8	672	½-month
Heavy metals	8	96	Month	9	108	Month
Gasses and particles:						
Filter-pack samplers	6	2,190	Day	6	1,460	Day/week
NO_2	2	365/17,520	Day/½-hour	2	17,520	½-hour
O_3	1	17,520		1	17,520	½-hour
Terrestrial:						
Denuders NH_3/NH_4 and HNO_3/NO_3				5	120	½-month
Mobile stations (denuders)				2	48	½-month
Flux measurements				2	In campaigns	
High temporal resolution				2	In campaigns	
Hazardous organic substances:						
Wet deposition				2	12	2-month

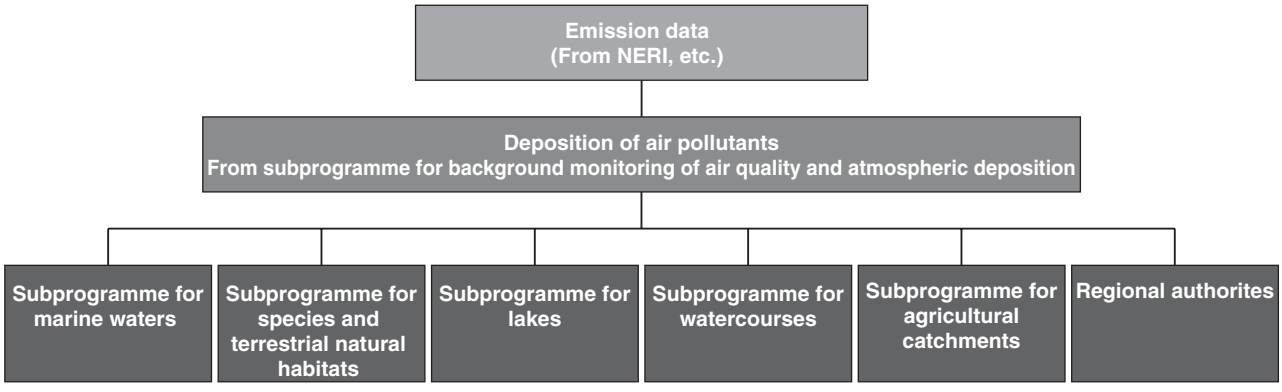

Figure 3.2 Data flow between subprogrammes focusing on deposition data from the subprogramme for background monitoring of air quality and atmospheric deposition. The red boxes indicate recipients of deposition data.

Attempts will be made to utilize this information in connection with the evaluation of the measurement and modelling results. In addition, information is collected under the subprogramme for agricultural catchments concerning nitrogen budgets, etc. in the agricultural monitoring catchments. Attempts will be made to utilize this information too.

The results from the measurement and modelling of ambient air quality and deposition are utilized in a number of the other subprogrammes (Figure 3.2).

3.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

It is concluded that the transition from NOVA-2003 to NOVANA will not entail any major changes as regards meeting international and national monitoring obligations. The subprogramme is reviewed below in the light of the obligations pursuant to relevant directives and international conventions.

The majority of existing requirements and obligations concerning monitoring and reporting of ambient air quality are fulfilled through the subprogramme for background monitoring of air quality and atmospheric deposition and the revised Nationwide Air Quality Monitoring Programme (LMP IV). This applies to airborne sulphur and nitrogen compounds in gaseous and particulate form, heavy metals in airborne particles and sulphur and nitrogen compounds and heavy metals in precipitation. Table 3.6 indicates the international agreements that utilize the results from each measurement station.

Mercury is not measured as the EMEP considers the need for this to be fulfilled by the existing stations in other countries in the EMEP network.

As regards POP and PAH in air and precipitation, no final decisions have yet been reached in EMEP or the marine conventions (among other reasons because these measurements are considered to be costly and resource-heavy). In addition, the provisions of the EU daughter directives and the Stockholm Convention have not yet been finalized.

For this reason, only a few selected hazardous organic substances are being monitored and only to a limited extent in the early stages of NOVANA. The requirements of the Framework Directive on Ambient Air Quality regarding measurement of particles (PM_{10}) will be met by reporting particle measurements made as background measurements for the urban air quality measurements under the Nationwide Air Quality Monitoring Programme (LMP IV).

Table 3.6 International agreements that utilize data from the Danish air measurement stations. EU-EoI refers to Council Decision 97/101/EC of 27 January 1997 establishing a reciprocal exchange of information and data collection from networks and individual stations measuring ambient air pollution within the Member States.

Measurement stations	International agreement
Anholt	EMEP, HELCOM, EU-EoI
Keldsnor	EMEP, HELCOM, EU-EoI
Tange	EMEP, EU-EoI
Ulborg	OSPARCOM, EMEP, EU-EoI, ICP Forest (Level II)
Frederiksborg	EU-EoI, ICP Forest (Level II)
Lindet	EU-EoI, ICP Forest (Level II)
Pedersker	HELCOM, EU-EoI

3.9 Annexes

Annex 3.1 Heavy metals encompassed by the subprogramme for background monitoring of air quality and atmospheric deposition.

	Detection limit			
	Particles		Precipitation	
Arsenic (As)	0.3	ng/m^3	0.08	µg/l
Lead (Pb)	0.5	ng/m^3	0.035	µg/l
Cadmium (Cd)	1.0	ng/m^3	0.005	µg/l
Chromium (Cr)	0.5	ng/m^3	0.04	µg/l
Copper (Cu)	0.2	ng/m^3	0.07	µg/l
Nickel (Ni)	0.5	ng/m^3	0.14	µg/l
Zinc (Zn)	0.2	ng/m^3	3.0	µg/l
Manganese (Mn)	0.5	ng/m^3	4.5	µg/l
Iron (Fe)	0.5	ng/m^3	4.0	µg/l

Annex 3.2 Hazardous organic substances encompassed by the subprogramme for background monitoring of air quality and atmospheric deposition.

	Detection limit
Aromatic hydrocarbons:	
1-methylnaphthalene	0.01 µg/l
2-methylnaphthalene	0.01 µg/l
Naphthalene	0.01 µg/l
Polyaromatic hydrocarbons (PAHs):	
Acenaphthene	0.01 µg/l
Acenaphthylene	0.01 µg/l
Anthracene	0.01 µg/l
Benz(a)anthracene	0.01 µg/l
Benz(a)pyrene	0.01 µg/l
Benz(e)pyrene	0.01 µg/l
Benz(ghi)perylene	0.01 µg/l
Benzo(b+j+k)fluoranthenes	0.01 µg/l
Chrysene and triphenylene	0.01 µg/l
Dibenz(a+h)anthracene	0.01 µg/l
Dibenzothiophene	0.01 µg/l
3,6-dimethylphenanthrene	0.01 µg/l
Fluoranthene	0.01 µg/l
Fluorene	0.01 µg/l
Indeno(1,2,3-cd)pyrene	0.01 µg/l
2-methylphenanthrene	0.01 µg/l
Perylene	0.01 µg/l
Phenanthrene	0.01 µg/l
Pyrene	0.01 µg/l
Plasticizers:	
Butylbenzylphthalate	0.02 µg/l
Di(2-ethylhexyl)phthalate (DEHP)	0.02 µg/l
Diisononylphthalate	0.02 µg/l
Dibutylphthalate	0.02 µg/l
Diethylphthalate	0.02 µg/l

Annex 3.3 Pesticides encompassed by the subprogramme for background monitoring of air quality and atmospheric deposition.

	Detection limit
Atrazine	0.01 µg/l
Chloridazon	0.01 µg/l
Desethylatrazine	0.01 µg/l
Desethylterbuthylazine	0.01 µg/l
Desisopropylatrazine	0.01 µg/l
Dichlorprop	0.01 µg/l
Disulfoton	0.01 µg/l
Diuron	0.01 µg/l
DNOC	0.01 µg/l
Ethofumesate	0.01 µg/l
Fenpropimorph	0.01 µg/l
Hydroxyatrazine	0.01 µg/l
Hydroxysimazine	0.01 µg/l
Isoproturon	0.01 µg/l
MCPA	0.01 µg/l
Mechlorprop	0.01 µg/l
Metamitron	0.01 µg/l
Metazachlor	0.01 µg/l
Pendimethalin	0.01 µg/l
Terbuthylazine	0.01 µg/l
4-nitrophenol	0.01 µg/l
2,4-nitrophenol	0.01 µg/l
3-methyl-2-nitrophenol	0.01 µg/l
3-methyl-4-nitrophenol	0.01 µg/l

4 Point sources

4.1 Introduction

The subprogramme for point sources is largely based on the existing wastewater inspection by the regional authorities and the in-house control carried out by the municipal wastewater treatment plants and enterprises.

The point sources described here are wastewater treatment plants, industries, stormwater outfalls, sparsely built-up areas, freshwater fish farms and mariculture farms.

The subprogramme calculates discharges of nutrients, organic matter, heavy metals and hazardous substances. The amount of water discharged is also determined in order to enable calculation of the total discharges.

4.2 Background and status

The current revised subprogramme for point sources is based on the experience gained through the monitoring carried out since adoption of the Action Plan on the Aquatic Environment in 1987. The criticisms and proposals for improvements to the monitoring programme made in the international evaluation of the previous programme, NOVA-2003, have been addressed and largely met in the present subprogramme.

The previous monitoring programme was generally considered appropriate to meet the objectives, and the monitoring of nitrogen, phosphorus and organic matter under the subprogramme for point sources can be continued largely unchanged.

The point sources are determined to ensure the quality of the inland and marine waters and should be viewed in the context of the overall objective of demonstrating the effect of the regulations and investments made pursuant to the Action Plan on the Aquatic Environment, the county regional plans and the municipal wastewater plans. The loading reduction targets set in connection with Action Plan on the Aquatic Environment I have long been met, and the total reduction from all sources is 70% for nitrogen, 84% for phosphorus and 81% for organic matter (BOD_5). The discharges of organic matter and phosphorus from sparsely built-up areas correspond to approx. 24% of the total discharges in wastewater, but their environmental impact is greater because they are usually discharged into small watercourses or lakes. Stormwater outfalls also cause large periodic discharges of nitrogen, phosphorus and organic matter.

The monitoring is also undertaken to meet Denmark's many international obligations, including those pursuant to international conventions on protection of the Baltic Sea, the inner Danish marine waters and the North Sea aimed at reducing discharges of heavy metals and hazardous substances, and the reporting obligations towards the EU Commission regarding discharges of heavy metals and hazardous substances, which are regulated by the Council Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (76/464/EEC).

The inventory of monitoring requirements prepared in connection with revision of the monitoring programme describes the current and expected future obligations and requirements as to monitoring of point sources. Data on pollution of the aquatic environment from point sources have to be reported to various international fora. In all, there are over 90 obligations in relation to the EU, the international conventions OSPAR and HELCOM and several of the other international organizations (OECD, Eurostat, EEA).

The future obligations predominantly relate to implementation of the Water Framework Directive, although the IPPC Directive (Integrated Pollution Prevention and Control) may also entail an increased need for monitoring data on industrial sources.

Since 1998, the subprogramme for point sources has encompassed the monitoring of a large number of heavy metals and hazardous substances in influent and effluent wastewater from wastewater treatment plants, in sewage sludge and in discharges from industries. Heavy metals and hazardous substances have previously also been monitored in discharges from stormwater outfalls through an intensive programme. Due to "teething troubles", however, evaluation of the data has not yet been completed. These monitoring data have been used to calculate the total discharge to inland surface waters and marine waters. The concentrations of heavy metals and hazardous substances measured in effluent wastewater are generally at the same level as the quality criteria for the aquatic environment (i.e. after mixing in the recipient water body) stipulated in Statutory Order No. 921 of 8 October 1996. The concentration of the occasional substance sometimes exceeds the quality criterion stipulated in the Statutory Order, though. During the programme period, the need has arisen to monitor new hazardous substances to meet both national and international requirements.

The national strategy for sustainable development describes a number of long-term goals pertaining to hazardous substances and alternative uses of wastewater that should be followed up through enhanced monitoring of point sources. At some time in the future the monitoring programme should therefore incorporate:

- Whole effluent assessment.

In addition, consideration should be given to incorporating the following elements into the monitoring programme:

- Assessment of the hygienic quality of wastewater and the environmental effects of wastewater of low hygienic quality
- Environmental impact assessment of loading with heavy metals and hazardous substances.

The above-mentioned effect assessments can be considered as monitoring requirements in relation to the media that the discharged substances affect.

How the subprogramme could be optimized in order to achieve the desired sampling precision was examined in the statistical optimization project carried out in connection with revision of the monitoring programme. The project report recommends increasing the annual sampling frequency to a minimum of 26 samples for all point sources. With point sources for which calculation of the total load is based on measurements, sampling and analysis are typically carried out 24 or more times per year at the largest and most significant discharges. In view of the cuts made elsewhere in the programme, it is not considered feasible to increase the analysis frequency here.

The scientific background for the monitoring of the individual types of point source is examined below.

4.2.1 Wastewater treatment plants

The Action Plan on the Aquatic Environment stipulated that all the major wastewater treatment plants were to be upgraded with nutrient removal. All the wastewater treatment plants have now been upgraded. This has not only reduced discharges of nitrogen, phosphorus and organic matter, but also of heavy metals and hazardous substances. The results of the monitoring carried out in recent years as part of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment have provided a good foundation for assessing nitrogen, phosphorus and organic matter loading of the aquatic environment from wastewater treatment plants.

During the last programme period more than 200 heavy metals and hazardous substances were monitored at 37 wastewater treatment plants. The data show that the content of heavy metals and hazardous substances decreases markedly between the inflow and the outflow, with the reduction being greater than 90% for most substances. While the concentration of most substances in the inflow to wastewater treatment plants is above the detection limit, this is only the case for a few substances in the outflow, in particular phenols, plasticizers and sum parameters such as AOX, NVOC and EOX.

4.2.2 Separate industrial discharges

The Nationwide Monitoring Programme provides a good foundation for determining total nitrogen, phosphorus and organic matter loading of the aquatic environment from separate industrial discharges.

During the last programme period, heavy metals and hazardous substances were monitored at 17 selected enterprises. In addition, available inspection and in-house control data on discharges of heavy metals and hazardous substances by enterprises have been submitted to the Danish EPA in recent years, among other reasons for reporting to the EU Commission.

4.2.3 Sparsely built-up areas

Wastewater discharges from areas outside the sewerage catchments have been included in the monitoring programme since 1993 because such discharges can be of major local significance for the state of the aquatic environment. Over the years, the monitoring programme has provided a reasonably good foundation for assessing nitrogen, phosphorus and organic matter loading of the aquatic environment from sparsely built-up areas.

4.2.4 Stormwater outfalls

Good estimates are now available for nutrient and organic matter concentrations and hydrological norms for the separate stormwater outfalls. In contrast, the norms for areas serviced by combined sewerage systems are still subject to considerable uncertainty. The results of the monitoring carried out in recent years as part of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment have generally provided an improved foundation for calculating nitrogen, phosphorus and organic matter loading of the aquatic environment from stormwater outfalls.

The results for wastewater treatment plants with a capacity exceeding 5,000 PE show that even though the overflows only account for 1–2% of the load in the catchment areas of the treatment plants, the discharge from overflows is often of the same magnitude as that from the treatment plants themselves. On average, though, they only account for 10% of the nitrogen, 26% of the phosphorus and 18% of the COD.

In 1997, the Danish EPA carried out an investigation of hazardous substances in surface runoff from surfaced areas (Danish EPA, 1997b). The study showed that a large number of hazardous substances were present in surface runoff from two investigated catchments. A number of substances could not be detected in the water samples, however, including PCB and chlorinated insecticides, as well as certain chlorobenzenes. Conversely, all the heavy metals investigated were detected in all the samples together with many PAHs, pentachlorophenol, DEHP and other phthalates, tributyl- and triphenylphosphate, and nonylphenol (see *Bearbejdning af målinger af regnbetingede udled-*

ninger af NPo og miljøfremmede stoffer fra fællessystemer i forbindelse med NOVA 2003 (Analysis of measurements of nitrogen, phosphorus, organic matter and hazardous substances in stormwater outfalls from combined sewerage systems in connection with NOVA-2003), Environmental Project No. 701, Danish EPA, 2002).

4.2.5 Freshwater fish farms

The results of the monitoring carried out in recent years as part of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment have provided an improved foundation for calculating nitrogen, phosphorus and organic matter loading of the aquatic environment from freshwater fish farms.

Discharges of heavy metals and hazardous substances from freshwater fish farms are determined from data on the consumption of disease control agents and ancillary substances. Increasing awareness of the use of hazardous substances has led to improved reporting of the consumption of these substances. New studies indicate that little of these substances is retained within the fish farms. Focus on the use of disease control agents and ancillary substances by freshwater fish farms can therefore be expected to increase in the coming years.

4.2.6 Mariculture

The results of the monitoring carried out in recent years as part of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment have provided an improved foundation for calculating nitrogen, phosphorus and organic matter loading of the aquatic environment from mariculture farms. In recent years, moreover, the information reported to the Danish EPA has included the consumption of disease control agents and ancillary substances.

4.3 Objectives

The overall objectives of the subprogramme for point sources are to:

- Determine the discharge of **household wastewater outside the sewerage catchments**
- Determine nutrient, organic matter, heavy metal and hazardous substance loading from **freshwater fish farms and mariculture**
- Calculate total loading of watercourses, lakes and the sea from **point sources**
- Establish the foundation for calculating the runoff from **diffuse sources**
- Document the **effect** of reductions in nitrogen, phosphorus, organic matter, heavy metal and hazardous substance loading through sampling of discharges from municipal **wastewater treatment plants, stormwater outfalls and industrial sources**
- Fulfil Denmark's **obligations** pursuant to EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve the aquatic environment and nature, including helping to develop various tools.

Table 4.1 Elements of the monitoring strategy employed in the subprogramme for point sources.

	Wastewater treatment plants	Industry	Sparsely built-up areas	Stormwater	Freshwater fish farms	Mariculture
			Wastewater			
Water volume	x	x	x	x	x	
Nutrients and organic matter	x	x	x	x	x	x
Hazardous substances	x	x	x	x	x	x
Heavy metals	x	x	x	x	x	x
			Sewage sludge[1]			
Water volume	x	-	-	-	-	-
Nutrients	x	-	-	-	-	-
Hazardous substances	x	-	-	-	-	-
Heavy metals	x	-	-	-	-	-

[1] Information about sewage sludge is collected for the wastewater treatment plants selected for the monitoring programme for heavy metals and hazardous substances.

Table 4.2 Programme for monitoring nutrients, organic matter and water volume from point sources.

Variables	Wastewater treatment plants		Industry	Stormwater	Freshwater fish farms
	Type 1	Type 2	Type 1		
COD	x	x	x	x	-
BOD_5 (mod.)	x	x	x	x	x
Nitrogen, total-N	x	x	x	x	x
Phosphorus, total-P	x	x	x	x	x
Ammonium-N, NH_3-N	-	x	-	x	-
Suspended solids, SS	-	x	-	x	-
Oxygen content	-	x	-	-	-
Settleable matter	-	x	-	-	-
Water volume	x	x	x[1]	x	x

[1)] By way of exception the water volume can be determined from calculations.

4.4 Strategy

The main principle behind the design of the subprogramme for monitoring of discharges from all point sources is to ensure maximum exploitation of all implemented inspection and control activities. This includes existing inspection programmes as well as special programmes that are a necessary precondition for future county planning regarding the quality of groundwater, watercourses, lakes and marine waters.

The subprogramme has been evaluated together with the other subprogrammes in the international evaluation of NOVA-2003 and the statistical optimization project. It was concluded that the subprogramme is appropriate with regard to meeting the objectives, and there are no obvious possibilities for optimizing the subprogramme.

The various elements of the strategy for monitoring of point sources are summarized in Table 4.1. The individual strategy for each element is described below.

The strategy has two pillars, which are examined below:

1. Determination of nutrients, organic matter and water volume
2. Determination of heavy metals and hazardous substances.

4.4.1 Nutrients, organic matter and water volume

The parameters used to monitor discharges of nutrients, organic matter and water are summarized for the different types of point source in Table 4.2. The parameters selected depend on the treatment method, including requirements concerning control of wastewater discharges. The analysis programme for outflow samples from wastewater treatment plants with a capacity exceeding 30 PE always encompasses measurement of chemical oxygen demand (COD), biochemical oxygen demand (BOD_5 (modified)), nitrogen (total-N) and phosphorus (total-P) as well as the measurement of water flow during the sampling period (type 1). In addition, the content of ammonium, suspended solids and oxygen and the amount of settleable matter are determined at those wastewater treatment plants (type 2) where the discharge authorizations require these parameters to be monitored.

In the case of industrial wastewater treatment plants, the minimum requirement corresponds to type 1 (see Table 4.2).

4.4.1.1 Wastewater treatment plants

The monitoring programme encompasses all public and private wastewater treatment plants with a capacity exceeding 30 PE. The wastewater is comprised of both household sewage and wastewater from the enterprises connected to the public wastewater treatment plants.

At wastewater treatment plants the wastewater undergoes various forms of treatment depending on the size of the plant and the recipient water body. Mechanical treatment (M) involves the sedimentation of suspended solids, which are subsequently removed as sewage sludge. In addition, there is always a bar strainer to remove large objects, as well as a sand and fat trap. Biological treatment (B) involves the use of microorganisms. Chemical treatment (C) mainly aims at the removal of phosphorus through precipitation with limestone, iron or aluminium salts. Nitrogen removal (ND) is an advanced biological process whereby the ammonium and organic nitrogen in the wastewater is first converted to nitrate in the presence of oxygen (nitrification; N), whereafter the nitrate nitrogen is converted to gaseous nitrogen under anaerobic conditions (denitrification; D).

The treatment efficiency for plants of the MBNDC type is around 90% for all nitrogen, phosphorus and organic matter parameters. As 87% of all wastewater is treated by this type of plant, the majority of Danish wastewater is thus treated very effectively.

Table 4.3 Annual sampling frequency (minimum) for wastewater treatment plant outflows, including the number of samples required by the regional authorities.

Plant capacity (PE)	Frequency/yr (min.)[1]	Sampling method
30≤x< 200	2	Random samples [2]
200≤x< 1,000	4	Time-weighted daily samples[3]
1,000≤x< 50,000	12	Time-weighted daily samples
50,000≤x	24	Time-weighted daily samples

[1)] Of these, the regional authorities collect 0–4 samples annually.
[2)] Time-weighted samples, random samples or empirical values.
[3)] Time-weighted samples or random samples if the necessary facilities for collection of flow-weighted samples are not available.
PE: Person equivalent, understood pursuant to Paragraph 4(5) of the Statutory Order on Wastewater to be equivalent to 21.9 kg organic matter per year measured as biochemical oxygen demand (BOD_5), 4.4 kg total-N per year or 0.1 kg total-P per year.

The sampling frequency, including any in-house control of outflow samples for determination of nutrients and organic matter, depends on the size of the treatment plant (Table 4.3). It should be noted that the sampling frequency can sometimes be higher than indicated in Table 4.3 for various reasons. Sampling at wastewater treatment plants is to be carried out using representative samples, including sampling during the weekends.

For plants with a capacity between 1,000 PE and 50,000 PE the outflow samples have to be flow-weighted and collected 12 times annually. For plants exceeding 50,000 PE the outflow samples have to be flow-weighted and collected 24 times annually. For plants with a capacity between 200 PE and 1,000 PE, at which the outflow only has to be sampled 4 times per year, time-weighted samples or random samples can be accepted if the necessary facilities for the collection of flow-weighted samples are not available. In the case of plants with a capacity of less than 200 PE it is acceptable to use time-weighted samples, random samples or empirical values, i.e. available data. Measurement of the water volume discharged should as far as possible be based on continual registration of the water volume on the day in question.

Available data can also be collected and reported concerning inputs to treatment plants with a capacity exceeding 30 PE. In addition, the apportionment of the input load between households and industry must be assessed on the basis of the best possible information (see the Technical Instructions for Point Sources).

Finally, the physical characteristics of the treatment plants, information on ownership, plant capacity in PE, current and planned treatment measures, the location of the outflow expressed in terms of hydrological reference and UTM coordinates, etc. are also to be determined so that loading calculations can be made for selected water bodies. In addition, the magnitude of leakage from and infiltration to the sewerage system is to be calculated based on the best possible information (the calculation method is described in the Technical Instructions for Point Sources).

4.4.1.2 Separate industrial discharges

Under the Action Plan on the Aquatic Environment, the discharge of nutrients was to be reduced from enterprises with separate discharges, and loading from the major industrial discharges was to be reduced by implementation of the best available technology. The extent of the monitoring activity has to be planned according to the magnitude and nature of the discharges.

The wastewater from the industrial discharges has to be analysed for the same parameters as the wastewater from wastewater treatment plants (Table 4.2). At each sampling session a flow-weighted wastewater sample has to be collected. If flow-weighted sampling cannot be carried out, the wastewater sample has to be time-weighted. Random sampling should only be used exceptionally, and attempts should be made to ensure that the sample is representative for a whole day. The amount of wastewater discharged per day (or possibly per hour) can be determined by calculation rather than by direct measurement, however.

The sampling frequency for sampling at enterprises depends on the discharge class (Table 4.4). The size of the discharge is determined by measuring or calculating the size of discharge at the existing outfall. If a wastewater treatment plant is present, the measurement or calculation must be made after the outflow from the plant. If an enterprise's discharge exceeds any one of the parameters listed, the enterprise is reassigned to a higher class.

In the case of discharges below discharge class I, which corresponds to a discharge of less than approx. 30 PE, each discharge must be assessed with respect to size and location in relation to the recipient. At minimum, the assessment should be based on a level of knowledge equivalent to that required by the routine environmental inspection and, depending on requirements, can be based on one or more measurements of the discharge.

Any small industrial discharges that are not included in the calculations for separate industrial discharges must be included under sparsely built-up areas.

Table 4.4 Discharge classes for enterprises with separate wastewater discharges indicating the amount of nitrogen (total-N), phosphorus (total-P) and organic matter (BOD_5 (modified) and COD) discharged shown together with the sampling frequency.

	Discharge (tonnes/yr)				
Discharge class	**BOD_5 (mod.)**	**COD**	**Total-N**	**Total-P**	**Frequency/yr**
I	0.6 < x < 4.3	1.6 < x < 10.8	0.13 < x < 0.9	0.005 < x < 0.3	2 samples
II	4.3 < x < 21.6	10.8 < x < 54	0.9 < x < 4.4	0.3 < x < 1.5	4 samples
III	21.6 < x < 108	54 < x < 270	4.4 < x < 22	1.5 < x < 7.5	12 samples
IV	x > 108	x > 270	x > 22	x > 7.5	12 samples

The wastewater samples must be accompanied by information on the enterprise's name and address, branch, treatment method, recipient water body, location in terms of hydrological reference and UTM coordinates, etc., such that loading calculations can be made for selected water bodies.

4.4.1.3 Sparsely built-up areas

The monitoring programme encompasses the wastewater discharge from areas outside the sewerage catchments and only wastewater that is discharged via small wastewater treatment plants with a capacity of less than 30 PE. In practice, this concerns household sewage from scattered dwellings, farmhouses and small villages. Summer cottage and allotment chalet districts located outside the sewerage catchment are also included under sparsely built-up areas.

The calculations of wastewater inputs from sparsely built-up areas are based on a property count and the level of treatment to which the wastewater is subjected, with the removal rates and loads used being based on empirical values. Calculations are made for the nitrogen, phosphorus and organic matter (BOD_5) loads (Table 4.1). All the calculations are related to water bodies and municipalities.

The counties must submit information to the Danish EPA concerning wastewater treatment planning in the rural areas. The following topics related to rural areas are focused on:

- Their regional planning with regard to quality objectives for the water bodies seen in relation to pollution from rural properties
- The extent to which the municipal wastewater plans for rural areas are in accordance with the Regional Plans
- Designation of areas where improved wastewater treatment is required
- Timeframe for the municipal plans to improve treatment.

The data on sparsely built-up areas are to be submitted every second year during the NOVANA period.

4.4.1.4 Stormwater outfalls

The monitoring programme for stormwater overflows in catchments with combined stormwater and sewerage systems, and stormwater outfalls in catchments with separate stormwater and sewerage systems consists of both a general programme carried out by all regional authorities and a supplementary intensive programme that is carried out by Copenhagen Municipality and Nordjylland County.

The aim of the intensive programme is to improve the scientific basis for the theoretical calculations used to determine the total discharge from all stormwater outfalls.

General programme

Calculations have to be made of the amount of water, nitrogen (total-N), phosphorus (total-P) and organic matter (BOD_5 and COD) discharged. In addition, the sewerage catchment areas and surfaced areas have to be calculated for both separate and combined sewerage systems, and for treatment measures in the form of lagoons, etc. These calculations should not be at outflow level, but should instead be related to water bodies. The calculations also have to be made at treatment plant level.

The fundamental step is the registration of all outfalls with a description of the assumptions on the basis of which they have been dimensioned. Every second year the following are undertaken:

- Registration of the catchment-related precipitation at existing and if necessary new precipitation stations
- Modelling of the amount of water, nitrogen, phosphorus and organic matter discharged for both a normal year and the specific year in question.

The amount of water and nutrients/organic matter discharged is determined using a simple calculation method and data material equivalent to that used in the municipal wastewater plans.

Thereafter the data and calculation method are to be continually improved in order to ensure more accurate calculation of the loads.

Intensive programme

The aim of the intensive programme is to improve and verify the foundation for the calculation assumptions used in the general programme. During the programme period, measurements are performed in three combined sewerage system catchments and a single separate sewerage system catchment. Each catchment is

monitored over a three-year period. One round of nitrogen, phosphorus and organic matter monitoring will thus be carried out in each of the selected catchments during the programme period, and one monitoring station will continually be in operation in each of the selected counties. Over a three-year period, at least 21 samples have to be collected at each station.

The following are to be carried out each year:

- Intensive measurements of the amounts of water and nutrients/organic matter discharged during recorded precipitation
- Detailed outfall-specific model calculations.

The general and intensive programmes are both described in the Danish EPA report Wastewater Research No. 4/1990 "Determination of loading from stormwater outfalls".

4.4.1.5 Freshwater fish farms

The production of fish in freshwater fish farms affects the surrounding environment due to the discharge of nutrients in feed residues and faeces. The monitoring programme for freshwater fish farms therefore focuses on nutrients and organic matter.

At freshwater fish farms, data are to be collected once annually on the year's production and feed consumption, as well as the results of the fish farms' in-house control. Moreover, an extended loading study is to be carried out at no less than 10% of the fish farms each year. The results of the fish farms' in-house control are to be included in the loading study (see also Ministry of Environment and Energy Statutory Order No. 900 of 31 October 1994 on freshwater fish farms).

It can be expected that more measurements will be carried out at the fish farms in the future.

The information on production conditions at the freshwater fish farms is used to calculate the nitrogen, phosphorus and organic matter loads from the fish farms.

In addition, information must be collected concerning each fish farm's design and operation, including treatment measures, water intake, feed consumption, production, feed quotient and fish stock, as well as information on the fish farm's authorization status. Information must also be collected on the recipient water body, including water flow, quality objective and quality of the stream and fauna passages as assessed using the Danish Stream Fauna Index.

4.4.1.6 Mariculture

The production of fish in land-based and sea-based mariculture farms affects the surrounding water bodies, among other means due to nutrients from feed residues and faeces.

Annual calculations are made of the year's production, feed consumption, in-house control data, etc. These annual calculations are prepared on the basis of the daily operational records kept pursuant to Ministry of Environment Statutory Order No. 640 of 17 September 1990 on mariculture.

The annual calculations are used to calculate nitrogen, phosphorus and organic matter loading by land-based and sea-based mariculture farms. These calculations are thereafter collated at a national level with information on gross production, net production, permissible feed consumption, actual feed consumption, feed quotient, etc.

4.4.2 Heavy metals and hazardous substances

Systematic monitoring of heavy metals and hazardous substances is carried out to provide national loading calculations.

With wastewater treatment plants, the monitoring strategy is based on the selection of a number of plants differing in the type of wastewater input. This is ensured by collecting information from all regional authorities in order to provide a nationwide overview of inputs to the aquatic environment. In addition, selection of the plants has to be representative with respect to type of treatment and plant capacity. The amount of sewage sludge and its content of nutrients, heavy metals and hazardous substances have to be determined.

With separate industrial discharges, the monitoring strategy is likewise based on the selection of a number of different types of enterprise so as to ensure a nationwide overview of inputs to the water bodies. It is also assumed that information arising in connection with inspection and in-house control will be utilized in the assessments.

With stormwater outfalls, the monitoring encompasses a number of measurements that enable an overall evaluation of the significance of these discharges for inputs of heavy metals and hazardous substances to the water bodies.

With sparsely built-up areas, discharges are to be calculated using empirical values and data for wastewater treatment plants that do not receive inputs from industrial sources.

Wherever possible, inputs of hazardous substances (including disease control agents) and heavy metals are also to be determined for both freshwater fish farms and mariculture farms.

4.4.2.1 Wastewater treatment plants

The monitoring of heavy metals and hazardous substances consists of an intensive monitoring programme at selected municipal wastewater treatment plants and encompasses wastewater inflows, outflows and sewage sludge. The programme strategy is largely based on previous experience gained during the NOVA-2003 programme period.

The treatment plants are selected such that the wastewater represents just over half of the Danish wastewater production. At each treatment plant an intensive monitoring programme is carried out every three years to determine the concentration levels of

heavy metals and hazardous substances in the outflow through the analysis of outflow samples. Together with information on the amount of wastewater treated by the plant, this will enable calculation of the total load discharged. At the same time, inflow samples are to be collected for analysis of heavy metals and hazardous substances to determine the removal rate in the wastewater treatment plant. In addition, sludge samples are to be collected to determine loading with heavy metals and hazardous substances in sewage sludge. The samples collected must represent the average situation.

4.4.2.2 Separate industrial discharges

With enterprises discharging major amounts of heavy metals and hazardous substances, data have to be submitted annually. This applies to waste depositories, ash depositories, landfills, remedial groundwater pumping, etc. where discharges are controlled. The data submission requirement encompasses the enterprises' in-house control data collected and coordinated by the regional authorities, as well as the regional authorities' own inspection data for the enterprises. With enterprises for which it is justifiably suspected that heavy metals and hazardous substances are discharged without specific information about this being available, information is submitted about the enterprise's name, location, etc.

In addition, a monitoring programme for heavy metals and hazardous substances is being established for a selection of enterprises with separate discharges considered to be most significant with respect to heavy metals and hazardous substances. When selecting the enterprises, attempts are made to include all relevant branches.

During the six-year programme period, wastewater samples are to be collected at each of the selected enterprises on two occasions for analysis of heavy metals and hazardous substances.

For each sampling round, flow-weighted daily samples are to be collected at each of the selected enterprises over a four-week period. These are to be pooled to four weekly samples weighted according to the daily water flow. In addition, four random samples are to be collected at each outflow for determination of volatile organic compounds. The sampling times have to be adapted to production conditions.

4.4.2.3 Sparsely built-up areas

Heavy metals and hazardous substances are not to be monitored in sparsely built-up areas. Instead, the Danish EPA will calculate the discharge of heavy metals and hazardous substances from sparsely built-up areas on the basis of information from the regional authorities on the number of properties and the associated treatment methods.

4.4.2.4 Stormwater outfalls

An intensive monitoring programme for heavy metals and hazardous substances is to be carried out for separate stormwater outfalls from surfaced areas. In connection with the monitoring of nitrogen, phosphorus and organic matter at a stormwater outfall from a separate sewerage system, heavy metals and hazardous substances are also to be monitored at the same outfall with at least nine samples being collected over a three-year period.

The parameters relating to heavy metals and hazardous substances that are to be analysed for in the overflows from combined sewerage systems are the same as those analysed in inflows and outflows from wastewater treatment plants (See Annexes 4.1 and 4.2).

This intensive monitoring programme for heavy metals and hazardous substances in separate stormwater outfalls and overflows from combined sewerage systems is to be carried out and reported in connection with the ongoing intensive stormwater monitoring programme.

The results from the intensive monitoring programme are to be used to estimate the amounts of heavy metals and hazardous substances discharged at the national level.

4.4.2.5 Freshwater fish farms

The production of fish in freshwater fish farms affects the surrounding environment through the discharge of certain heavy metals and hazardous substances in connection with the use of disease control agents and ancillary substances.

The regional authorities therefore have to submit to the Danish EPA information on freshwater fish farm consumption of disease control agents and ancillary substances and discharges of heavy metals and hazardous substances.

4.4.2.6 Mariculture

The production of fish by land-based and sea-based mariculture affects the surrounding environment through the discharge of certain heavy metals and hazardous substances in connection with the use of disease control agents and ancillary substances. The monitoring programme for mariculture therefore focuses on these factors.

Pursuant to Ministry of Environment Statutory Order No. 640 of 17 September 1990 on mariculture, mariculture farms have to submit records of their consumption of disease control agents once each year. On this basis the regional authorities have to submit information on the consumption of disease control agents and ancillary substances, etc. to the Danish EPA.

4.4.2.7 Marine dumping of seabed material and offshore industry

Data collected outside NOVANA in connection with marine dumping of seabed material and discharges from offshore industry will be reported and subjected to quality assurance as an integral part of the subprogramme for point sources from 2004 onwards. Among other things, such data are a precondition for quantifying the total discharge of a number of substances.

4.5 Programme content

4.5.1 Wastewater treatment plants

4.5.1.1 Nutrients and organic matter

The monitoring programme encompasses all Danish wastewater treatment plants with a capacity exceeding 30 PE, i.e. 1,311 municipal and private wastewater treatment plants in all (2002 figure). These plants are shown subdivided according to treatment type in Table 4.5. The name, location and characteristics of each of the 993 municipal plants monitored under NOVANA are given in Annex 10.1 of Part 3 of the Programme Description. For all 1,311 treatment plants, the regional authorities submit data to the Danish EPA concerning physical parameters, the hydrological reference, available inflow data, infiltration and leakage to and from the sewers, criteria compliance, etc.

4.5.1.2 Heavy metals and hazardous substances

Section 4.4.2 describes an intensive programme for monitoring heavy metals and hazardous substances at selected wastewater treatment plants – a total of 36 from around the country as indicated in Table 4.6. When selecting the treatment plants, emphasis has been placed not only on ensuring that major plants are represented, but also on ensuring regional distribution such that the majority of counties are represented, as far as possible with one plant per year. The plants have been selected such that many of them are among the largest wastewater treatment plants in the country, while the remainder represent various types of wastewater, various types of treatment plant, various sizes of treatment plant and plants that discharge to water bodies where hazardous substances are also monitored.

Annexes 4.1 and 4.2 summarize the analysis programme for heavy metals and hazardous substances in outflows, inflows and sewage sludge. The required detection limits are also shown. The parameters to be analysed in influent and effluent wastewater and overflows from combined sewers are shown in the column headed "wastewater", while parameters to be analysed in separate stormwater outfalls are shown in the column headed "rainwater".

At each plant, flow-weighted daily samples are to be collected from the inflow and outflow over a four-week period. Thereafter these are to be pooled to four weekly pooled samples weighted according to the daily water flow. At each treatment plant, moreover, four random samples are to be collected for determination of volatile organic compounds as well as 10 random sludge samples that are to be pooled as a single pooled sample for each plant.

In support of this monitoring programme, information has to be reported to the Danish EPA about these substances in cases where selected substances are analysed for in connection with the routine inspection of the treatment plants and the in-house control pursuant to the Environmental Protection Act depending on what industries are connected to the plant. This entails inclusion of discharges that are not particularly representative at the national level, but which nevertheless contribute to total loading with hazardous substances.

In addition, discharge criteria for heavy metals and hazardous substances applicable to the individual treatment plant and information about outflow quality and compliance with the criteria have to be collated at the national level.

The timetable for the monitoring programme for heavy metals and hazardous substances at the 36 selected plants is shown in Table 4.6.

Table 4.5 Danish wastewater treatment plants (2002) apportioned by treatment type and plant capacity/sampling frequency.

Treatment type	Plant capacity "x" in PE and sampling frequency/yr[1]			No. of plants
	30<x<200	200<x<1,000	x>1,000	
	2 samples[2]	4 samples	12–24 samples	
Mechanical (M)	244	63	12	319
Mechanical, chemical phosphorus removal (MC)	2	8	7	17
Mechanical, biological (MB)	194	156	109	459
Mechanical, biological, chemical phosphorus removal (MBC)	17	43	160	220
Mechanical, biological, nitrogen removal (MBND)	0	1	9	10
Mechanical, biological, nitrogen removal, chemical phosphorus removal (MBNDC)	0	3	283	286
Total	457	274	580	1,311

Treatment type: M: Mechanical, B: Biological, C: Chemical phosphorus removal, ND: Nitrogen removal.

[1)] With smaller, private plants, data only have to be reported to the extent that they are available.

[2)] Data if available.

Table 4.6 Selected wastewater treatment plants (WWTP) and timetable for the monitoring programme for heavy metals and hazardous substances.

		Sampling year					
County	**WWTP name**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Copenhagen Municipality	Lynetten	x	-	-	x	-	-
	Damhusåen WWTP	-	x	-	-	x	-
Copenhagen County	Tårnby WWTP	x	-	-	x	-	-
	Lundtofte WWTP	x	-	-	x	-	-
	Spildevandscenter Avedøre	-	x	-	-	x	-
	Måløv WWTP	-	x	-	-	x	-
	Vedbæk WWTP	-	-	x	-	-	x
	Kallerup WWTP	-	-	x	-	-	x
Frederiksborg County	Helsingør WWTP	-	x	-	x	-	-
	Skævinge C. WWTP	-	-	-	-	-	x
	Gadevang WWTP	-	-	x	-	x	-
Roskilde County	Køge Egnen WWTP	-	x	-	-	x	-
	Bjergmarken WWTP	-	-	x	-	-	x
Vestsjælland County	Ringsted C. WWTP	-	x	-	-	x	-
Storstrøm County	Fakse WWTP	x	-	-	x	-	-
	Næstved WWTP	-	x	-	-	x	-
	Mern WWTP	-	-	x	-	-	x
	Errindlev Harbour*	x	-	-	x	-	-
Funen County	Ejby Mølle WWTP	x	-	-	x	-	-
	Nyborg C. WWTP	-	x	-	-	x	-
	Gislev WWTP	-	-	x	-	-	x
Sønderjylland County	Skovby WWTP	-	x	-	-	x	-
	Haderslev WWTP	-	-	x	-	-	x
Ribe County	Grindsted Øst WWTP	x	-	-	x	-	-
	Vorbasse WWTP	-	x	-	-	x	-
	Esbjerg Vest WWTP	-	-	x	-	-	x
Vejle County	Vejle C. WWTP	x	-	-	x	-	-
	Fredericia C. WWTP	-	x	-	-	x	-
	Horsens C. WWTP	-	-	x	-	-	x
Ringkjøbing County	Herning C. WWTP	-	-	x	-	-	x
	Holstebro WWTP	-	x	-	-	x	-
Aarhus County	Randers C. WWTP	x	-	-	x	-	-
	Marselisborg C. WWTP	-	x	-	-	x	-
	Søholt WWTP	-	-	x	-	-	x
Viborg County	Skive WWTP	-	x	-	-	x	-
	Thisted WWTP	-	-	x	-	-	x

* Sludge is not sampled.

4.5.2 Separate industrial discharges

4.5.2.1 Nutrients and organic matter

All enterprises with a separate discharge of nutrients and organic matter corresponding to more than 30 PE are encompassed by the monitoring programme for nitrogen, phosphorus and organic matter, as well as the requirement to submit various administrative information, including discharge criteria, outflow concentrations, etc.

4.5.2.2 Heavy metals and hazardous substances

Each year, all enterprises with significant discharges of heavy metals and hazardous substances have to submit inspection and in-house control data, etc. All these enterprises are also encompassed by the requirement to submit administrative information, including discharge criteria, outflow concentrations, etc., as previously described. The enterprises involved are listed in Annex 10.2 of Part 3 of the Programme Description. It is assumed that the list of enterprises encompassed by the above-mentioned data submission requirement will be regularly updated after a concrete evaluation in connection with changes in production, enterprise closures and establishment of new enterprises. The evaluation has to take into account any discharges of the heavy metals and hazardous substances listed in Annexes 4.1 and 4.2. If routine inspection reveals the presence of significant discharges of problematic substances additional to those specified in Annexes 4.1 and 4.2, this information must also be submitted.

Section 4.4.1.2 describes the monitoring programme for heavy metals and hazardous substances for selected enterprises. These enterprises are summarized in Table 4.7 subdivided by county. During the six-year programme period, wastewater samples are to be collected at each of the selected enterprises on two occasions for analysis of heavy metals and hazardous substances. Table 4.7 also shows the timetable for monitoring at these enterprises.

The substance groups encompassed by the analysis programme for each enterprise are summarized in Annex 10.3 of Part 3 of the Programme Description. The substances analysed for within each substance group are the same as those encompassed by the analysis programme for wastewater treatment plants as shown in Annex 4.1 in the column headed wastewater (see Annexes 4.1 and 4.2).

Table 4.7 Selected enterprises and timetable for the monitoring of heavy metals and hazardous substances.

County	Enterprise	Branch	Monitoring year					
			2004	2005	2006	2007	2008	2009
Frederiksborg County	Dansteel	Recycling of metal waste products	x	-	-	x	-	-
Roskilde County	Sun Chemical A/S	Manufacture of inks and pigments	x	-	-	x	-	-
	Junckers Industries A/S	Manufacture of wooden parts for buildings	-	x	-	-	x	-
	CP Kelco	Manufacture of foodstuffs	-	-	x	-	-	x
Vestsjælland County	Statoil A/S	Manufacture of refined oils and fats	x	-	-	x	-	-
	Stigsnæs Industrimiljø A/S	Sewerage utility and wastewater treatment plant	-	x	-	-	x	-
	Daka A.m.b.a.	Incineration plant and bone meal factory	-	-	x	-	-	x
Funen County	ITW Construction Products	Manufacture of wire goods	x	-	-	x	-	-
	Stige Ø Losseplads	Landfill and incineration plant	-	x	-	-	x	-
Ribe County	Danisco Cultor Grindsted	Polishing and cleaning agent factory	x	-	-	x	-	-
Ringkjøbing County	Skjern Tricotage-Farveri A/S	Textile finishing	x	-	-	x	-	-
	Fjelstervang Farveri A/S	Textile finishing	-	x	-	-	x	-
	Skjern Papirfabrik A/S	Manufacture of paper and cardboard	-	-	x	-	-	x
	Cheminova A/S	Manufacture of pesticides and other agrochemical products	x	-	-	x	-	-
Aarhus County	BASF Health & Nutrition A/S	Manufacture of pharmaceutical raw materials	x	-	-	x	-	-
Viborg County	Tarco Vej A/S, Ans	Asphalt and roofing felt factory	x	-	-	x	-	-

Administrative information such as the enterprise's name and address, branch, treatment method, recipient water body, location expressed by hydrological reference and UTM coordinates, etc., is also to be reported so as to enable loading calculations to be made for selected water bodies. In addition, summaries have to be prepared of discharge criteria, outflow concentrations and the amounts discharged by the enterprises.

4.5.3 Sparsely built-up areas

4.5.3.1 Nutrients and organic matter

Table 4.8 summarizes the number of properties outside the sewerage catchments discharging less than 30 PE. The regional authorities are obliged to submit data on the number of properties and the associated treatment method for the calculations of nitrogen, phosphorus and organic matter loading (see Section 4.4.1.3).

Table 4.8 Number of properties outside the sewerage catchments (2002).

Type of district	Number of properties
Summer cottage and allotment chalet districts	118,738
Sparsely built-up areas, villages, etc.	236,511
Total	355,249

4.5.3.2 Heavy metals and hazardous substances

The Danish EPA's calculations of the discharge of heavy metals and hazardous substances from sparsely built-up areas must encompass all properties discharging less than 30 PE located outside the sewerage catchments. A precondition, therefore, is that all such properties are included when the regional authorities submit data on the number of properties and associated treatment methods.

The calculations will be based on the available knowledge on the composition of household sewage, among other things from an intensive household sewage monitoring programme conducted for the Danish EPA (Danish EPA, 1997b) and monitoring of wastewater treatment plants that only receive household wastewater (see Table 4.9). The expected removal rates for mechanical treatment, biological treatment, etc. determined from the monitoring of wastewater treatment plants will also be included in the calculations.

4.5.4 Stormwater outfalls

4.5.4.1 Nutrients and organic matter

All counties and hence all stormwater outfalls are included in the general nitrogen, phosphorus and organic matter monitoring programme as described in Section 4.4.1.4 above, i.e. all overflows from combined sewerage systems and all separate stormwater outfalls.

In contrast, the supplementary intensive nitrogen, phosphorus and organic matter programme described in Section 4.4.1.4 is only performed in Nordjylland County and Copenhagen Municipality. During the programme period, the monitoring in Nordjylland County will initially be carried out in a single combined sewerage system catchment (for approx. three years) and subsequently in a single separate sewerage system catchment (for approx. three years). In Copenhagen Municipality the monitoring will be carried out in two combined sewerage system catchments, each for approx. three years. The intensive monitoring programme for nitrogen, phosphorus and organic matter in stormwater outfalls is summarized in Table 4.10, including the timetable.

Table 4.9 Wastewater treatment plants (WWTP) solely receiving household wastewater.

Wastewater treatment plant	Municipality	County	Plant type[1]	Capacity (PE)	Load (PE)
Gadevang WWTP	Hillerød	Frederiksborg County	MBNC	2,000	720
Kallerup WWTP [2]	Høje-Taastrup	Copenhagen County	MBNDC	9,500	7,444
Vedbæk WWTP [2]	Søllerød	Copenhagen County	MBNDC	18,000	11,250
Gislev WWTP	Ryslinge	Funen County	MBNCL	2,000	1,100
Vorbasse WWTP	Billund	Ribe County	MBNDCL	2,000	994
Mern WWTP	Langebæk	Storstrøm County	MBN	1,834	1,200
Errindlev Harbour	Holeby	Storstrøm County	MBS	110	99
Skovby WWTP	Lundtoft	Sønderjylland County	M	300	300

[1)] Plant type: M: Mechanical, B: Biological, C: Chemical phosphorus removal, N: Nitrification, D: Denitrification, L: Lagoon, S: Sand filtration.

[2)] The WWTP also receives a small amount of wastewater from small businesses.

Table 4.10 Intensive monitoring programme for nitrogen, phosphorus and organic matter in stormwater outfalls..

Sewerage system	No. of stations	Time period	Frequency	County	Municipality
Combined	1	2004–2006	21 samples over 3 yr	Copenhagen Municipality	Copenhagen Municipality
Combined	1	2004–2006	21 samples over 3 yr	Nordjylland County	Aalborg Municipality
Combined	1	2007–2009	21 samples over 3 yr	Copenhagen Municipality	Copenhagen Municipality
Separate	1	2007–2009	21 samples over 3 yr	Nordjylland County	Aalborg Municipality

Table 4.11 Intensive monitoring programme for heavy metals and hazardous substances in stormwater outfalls.

Sewerage system	No. of stations	Time period	Frequency	County	Municipality
Combined	1	2004–2006	9 samples over 3 yr	Copenhagen Municipality	Copenhagen Municipality
Combined	1	2004–2006	9 samples over 3 yr	Nordjylland County	Aalborg Municipality
Combined	1	2007–2009	9 samples over 3 yr	Copenhagen Municipality	Copenhagen Municipality
Separate	1	2007–2009	9 samples over 3 yr	Nordjylland County	Aalborg Municipality

4.5.4.2 Heavy metals and hazardous substances

Heavy metals and hazardous substances are to be monitored in separate outfalls from surfaced areas in Nordjylland County through expansion of the existing intensive monitoring programme for nitrogen, phosphorus and organic matter in stormwater. When nitrogen, phosphorus and organic matter are monitored over a three-year period at an outfall from a separate sewerage system, heavy metals and hazardous substances are to be monitored at the same outfall with at least nine samples being collected over the three-year period.

The heavy metals and hazardous substances to be monitored in the separate stormwater outfall are listed in Annexes 4.1 and 4.2, respectively. The required detection limits are also given.

As far as concerns stormwater overflows from combined sewerage systems, heavy metals and hazardous substances are also to be monitored through a corresponding expansion of the nitrogen, phosphorus and organic matter monitoring programme in Nordjylland County and Copenhagen Municipality. During the programme period, the monitoring in Nordjylland County will initially be carried out in a single combined sewerage system catchment (for approx. three years) and subsequently in a single separate sewerage system catchment (for approx. three years). In Copenhagen Municipality the monitoring will be carried out in two combined sewerage system catchments, each for approx. three years.

The substances to be analysed for in the overflows from combined sewerage systems are the same as those monitored in inflows and outflows from wastewater treatment plants (see Annexes 4.1 and 4.2). The detection limits are also given.

The intensive monitoring programme for heavy metals and hazardous substances in separate stormwater outfalls and overflows in combined sewerage systems is to be carried out and reported in connection with the ongoing intensive stormwater monitoring programme.

4.5.5 Freshwater fish farms

The data submission requirements described in Section 4.4.1.5 on nitrogen, phosphorus and organic matter and in Section 4.4.2.5 on heavy metals and hazardous substances encompass all freshwater fish farms in Denmark, i.e. 370 fish farms (2001). The name, location, etc. of the individual fish farms are given in Annex 10.4 of Part 3 of the Programme Description.

4.5.6 Mariculture

The land-based and sea-based mariculture farms are mainly located in protected coastal waters. The distribution of the mariculture farms by county is shown in Table 4.12. All the establishments are listed in Annex 10.5 of Part 3 of the Programme Description.

Table 4.12 County distribution of land-based and sea-based mariculture farms.

County	Number
Funen County	1
Storstrøm County	7
Ringkjøbing County	8
Sønderjylland County	4
Vejle County	8
Vestsjælland County	5
Viborg County	2
Aarhus County	1
Whole country	36

4.5.7 Heavy metals and hazardous substances

The lists of heavy metals and hazardous substances monitored under NOVANA were drawn up on the basis of:

- Requirements pursuant to directives and conventions
- Results of previous monitoring and of corresponding investigations performed outside the monitoring programme
- A desire to reduce the extent of monitoring of heavy metals and hazardous substances
- A desire to ensure the greatest possible coherence in the programme across the various matrices
- A decision not to include new substances unless there is a documented need to do so and the possibility to analyse them exists.

4.6 Main changes relative to NOVA-2003

The main changes relative to the preceding programme period (NOVA-2003) are as follows:

- At wastewater treatment plants smaller than 1,000 PE, NOVANA now finances two measurements per year compared with four previously
- The reporting of data for sparsely built-up areas has been reduced to every second year
- The reporting of data for stormwater outfalls has been reduced to every second year. At the same time, the intensive programme has been reduced from three outfalls to two outfalls
- Offshore industry and marine dumping of seabed material are now reported by the State.

In addition, the updated number of point sources of each type has been taken into account. The differences in sampling frequency between the NOVA-2003 and NOVANA subprogrammes for point sources are apparent from Table 4.13. The number of stormwater overflows for which calculations are made has increased from 11,841 under NOVA-2003 to 14,661 under NOVANA. As regards sparsely built-up areas the number of properties for which calculations are made has increased correspondingly from 351,809 to 355,249.

4.7 Theme-specific assumptions

Point sources contribute to loading of inland surface waters and marine waters, and the exchange of data with the other Topic Centres is based on calculations of nutrient and organic matter discharges distributed by a list of hydrological references. The list of hydrological references are the catchments for which the Topic Centre for Inland Surface Waters and the Topic Centre for Hydrological Point Sources have agreed to calculate the discharge of nutrients and organic matter.

The Topic Centre for Inland Surface Waters provides the Topic Centre for Hydrological Point Sources with calculations of riverine inputs of nutrients and organic matter (point sources to marine waters). The Topic Centre for Hydrological Point Sources can then calculate the discharges to marine waters from all point sources subdivided by indirect and direct discharges.

The Topic Centre for Hydrological Point Sources provides the Topic Centre for Inland Surface Waters with calculations of nutrient discharges from land-based point sources apportioned by the list of hydrological references.

4.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

The subprogramme meets all reporting obligations with the exception of certain obligations concerning "hazardous substances" pursuant to the Reporting Directive, etc.

There are a number of problems in this connection as it is not possible to document that it is the correct substances that are monitored and reported. Moreover, it is not possible to fully report the number of authorizations issued for the discharge of List I substances to the sewerage system and the general emission norms for the discharge of List I substances directly to the aquatic environment and the sewerage system. Finally, it is not possible to report the total authorized discharge of List I and List II substances to the sewerage system.

Table 4.13 Differences between point source monitoring under NOVA-2003 and NOVANA.

	NOVA-2003		NOVANA	
	No.	**Frequency (samples/yr)**	**No.**	**Frequency (samples/yr)**
Wastewater treatment plants:				
Wastewater treatment plants NPo type 1	847	4/1	596	4/1
Wastewater treatment plants NPo type 2	402	4/1	397	4/1
Heavy metals and hazardous substances – inflow	37	4/3	36	4/3
Heavy metals and hazardous substances – outflow	37	4/3	36	4/3
Heavy metals and hazardous substances – sewage sludge	37	1/3	36	1/3
Separate industrial discharges:				
Industrial NPo type 1	11	2–12/1	83	2–12/1
Industrial NPo type 2	96	2–12/1	0	
Heavy metals and hazardous substances[1]	17	4/3	16	4/3
Stormwater outfalls:				
NPo[2]	6	21/3	4	21/3
Heavy metals and hazardous substances	4	9/3	4	9/3
Sparsely built-up areas	Calculation of the discharges		Calculation of the discharges	
Freshwater fish farms	Calculation of the discharges		Calculation of the discharges	
Mariculture	Calculation of the discharges		Calculation of the discharges	

NPo: Nitrogen, phosphorus and organic matter.
[1)] Available inspection and in-house control data are also reported for relevant enterprises.
[2)] Measurements are only reported in connection with the intensive programmes.

4.9 Annexes

Annex 4.1 Analysis programme for heavy metals and inorganic trace elements under the subprogramme for point sources.

Heavy metals and inorganic trace elements, etc.	Detection limits		
	Wastewater	Sewage sludge	Stormwater
Antimony (Sb)	0.2 µg/l	200 µg/kg DM	0.2 µg/l
Arsenic (As)	1.0 µg/l	200 µg/kg DM	1.0 µg/l
Barium (Ba)	1.0 µg/l	2,000 µg/kg DM	1.0 µg/l
Lead (Pb)	1.0 µg/l	100 µg/kg DM	1.0 µg/l
Boron (B)	10 µg/l	2,000 µg/kg DM	10 µg/l
Cadmium (Cd)	0.05 µg/l	10 µg/kg DM	0.05 µg/l
Chromium (Cr)	0.5 µg/l	100 µg/kg DM	0.5 µg/l
Copper (Cu)	1.0 µg/l	200 µg/kg DM	1.0 µg/l
Cobalt (Co)	1.0 µg/l	100 µg/kg DM	1.0 µg/l
Mercury (Hg)	0.3 µg/l	20 µg/kg DM	0.3 µg/l
Molybdenum (Mo)	0.1 µg/l	200 µg/kg DM	0.1 µg/l
Nickel (Ni)	0.3 µg/l	100 µg/kg DM	0.3 µg/l
Selenium (Se)	0.05 µg/l	2,000 µg/kg DM	0.05 µg/l
Silver (Ag)	1.0 µg/l	200 µg/kg DM	1.0 µg/l
Thallium (Th)	0.4 µg/l	100 µg/kg DM	0.4 µg/l
Tin (Sn)	1.0 µg/l	1,000 µg/kg DM	1.0 µg/l
Uranium (U)	0.1 µg/l	200 µg/kg DM	0.1 µg/l
Vanadium (V)	1.0 µg/l	500 µg/kg DM	1.0 µg/l
Zinc (Zn)	5.0 µg/l	5,000 µg/kg DM	5.0 µg/l

Annex 4.2 Analysis programme for pesticides and hazardous substances in the subprogramme for point sources.

	Wastewater	Sewage sludge	Stormwater
Pesticides:			
2,6-dichlorobenzamide (BAM)			0.01 µg/l
Aldrin			0.01 µg/l
Aminomethylphosphonic acid (AMPA)			0.01 µg/l
Dieldrin			0.01 µg/l
Endrin			0.01 µg/l
Glyphosate			0.01 µg/l
gamma-Lindane (HCH)			0.01 µg/l
Isodrin			0.01 µg/l
MCPA			0.01 µg/l
Simazine			0.01 µg/l
Aromatic hydrocarbons:			
Benzene	0.05 µg/l	10 µg/kg DM	0.05 µg/l
Biphenyl	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Ethylbenzene	0.1 µg/l	10 µg/kg DM	0.1 µg/l
1-methylnaphthalene			0.1 µg/l
2-methylnaphthalene			0.1 µg/l
5-tert-butyl-2,4,6-trinitro-m-xylene	0.1 µg/l	10 µg/kg DM	0.1 µg/l
Naphthalene	0.05 µg/l	10 µg/kg DM	0.05 µg/l
Toluene	0.1 µg/l	10 µg/kg DM	0.1 µg/l
P-tert-butyltoluene	0.1 µg/l	10 µg/kg DM	0.1 µg/l
Xylenes (p-xylene, m-xylene and o-xylene)	0.1 µg/l	10 µg/kg DM	0.1 µg/l
Phenols:			
Bisphenol A	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Nonylphenols	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Nonylphenol monoethoxylates	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Nonylphenol diethoxylates	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Phenol	0.1 µg/l	10 µg/kg DM	0.1 µg/l
Halogenated aliphatic hydrocarbons:			
3-chloropropene	0.1 µg/l	2 µg/kg DM	
Dichloromethane	0.1 µg/l	2 µg/kg DM	
Hexachlorobutadiene (HCBD)	0.05 µg/l	2 µg/kg DM	
Tetrachloroethylene	0.1 µg/l	2 µg/kg DM	
Tetrachloromethane	0.1 µg/l		
Trichloroethylene	0.1 µg/l	2 µg/kg DM	
Trichloromethane (chloroform)	0.1 µg/l	2 µg/kg DM	
Halogenated aromatic hydrocarbons:			
2,5-dichloroaniline	0.05 µg/l	1 µg/kg DM	
1,4-dichlorobenzene	0.1 µg/l	1 µg/kg DM	
Hexachlorobenzene (HCB)			0.005 µg/l
Pentachlorobenzene	0.01 µg/l	1 µg/kg DM	
Polychlorinated phenyls:			
Polychlorinated biphenyl (PCB # 28)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 31)		5 µg/kg DM	
Polychlorinated biphenyl (PCB# 52)		5 µg/kg DM	

Annex 4.2 Analysis programme for pesticides and hazardous substances in the subprogramme for point sources.

	Wastewater	Sewage sludge	Stormwater
Polychlorinated biphenyl (PCB # 101)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 105)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 118)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 138)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 153)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 156)		5 µg/kg DM	
Polychlorinated biphenyl (PCB # 180)		5 µg/kg DM	
Polychlorinated terphenyls		5 µg/kg DM	
Chlorophenols:			
4-chloro-3-methylphenol	0.1 µg/l	1 µg/kg DM	0.1 µg/l
2,4-dichlorophenol	0.1 µg/l	1 µg/kg DM	0.1 µg/l
Pentachlorophenol (PCP)	0.05 µg/l	1 µg/kg DM	0.05 µg/l
2,4,6-trichlorophenol	0.05 µg/l	1 µg/kg DM	0.05 µg/l
Polyaromatic hydrocarbons (PAHs):			
Acenaphthene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Acenaphthylene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Anthracene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(a)anthracene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(a)fluorine	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(a)pyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(e)pyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(ghi)perylene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Benzo(b+j+k)fluoranthenes	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Chrysene and triphenylene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Dibenz(a,h)anthracene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Dibenzothiophene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
3,6-dimethylphenanthrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Fluoranthene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Fluorene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Indeno(1,2,3-cd)pyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
2-methylphenanthrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
1-methylpyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
2-methylpyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Perylene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Phenanthrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Pyrene	0.01 µg/l	10 µg/kg DM	0.01 µg/l
Phosphotriesters:			
Tri-n-butylphosphate	0.02 µg/l	20 µg/kg DM	0.02 µg/l
Trichloropropylphosphate (TCPP)	0.02 µg/l	20 µg/kg DM	0.02 µg/l
Tricresylphosphate (unspec.)	0.02 µg/l	20 µg/kg DM	0.02 µg/l
Triphenylphosphate	0.02 µg/l	20 µg/kg DM	0.02 µg/l
Plasticizers:			
Butylbenzylphthalate (BBP)	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Di(2-ethylhexyl)adipate	0.1 µg/l	100 µg/kg DM	0.1 µg/l

Annex 4.2 Analysis programme for pesticides and hazardous substances in the subprogramme for point sources.

	Wastewater	Sewage sludge	Stormwater
Di(2-ethylhexyl)phthalate (DEHP)	0.1 µg/l	100 µg/kg DM	0.1 µg/l
Diisononylphthalate (DNP)	0.1 µg/l	50 µg/kg DM	0.1 µg/l
Di-n-octylphthalate (DnOP)	0.1 µg/l	50 µg/kg DM	0.1 µg/l
Dibutylphthalate (DBP)	0.1 µg/l	100 µg/kg DM	0.1 µg/l
Diethylphthalate (DEP)	0.1 µg/l	20 µg/kg DM	0.1 µg/l
Anionic detergents:			
Linear alkylbenzene sulphonates	30 µg/l	5.000 µg/kg DM	
Cationic detergents:			
Sum of cationic detergents	10 µg/l		
Ether:			
Methyl tertiary-butyl ether (MTBE)	1 µg/l	5 µg/kg DM	1 µg/l
Organotin compounds:			
Triphenyltin (TPhT)	0.001 µg/l	50 µg/kg DM	
Dioxins and furans:			
1234678-HpCDF		0.2 ng/kg DM	
1234789-HpCDF		0.2 ng/kg DM	
1234678-HpCDD		0.2 ng/kg DM	
123478-HxCDF		8.0 ng/kg DM	
123678-HxCDF		8.0 ng/kg DM	
123789-HxCDF		8.0 ng/kg DM	
234678-HxCDF		8.0 ng/kg DM	
123478-HxCDD		2.0 ng/kg DM	
123678-HxCDD		2.0 ng/kg DM	
123789-HxCDD		2.0 ng/kg DM	
OCDD		0.1 ng/kg DM	
OCDF		0.1 ng/kg DM	
12378-PeCDF		8.0 ng/kg DM	
23478-PeCDF		8.0 ng/kg DM	
12378-PeCDD		8.0 ng/kg DM	
2378-TCDF		1.0 ng/kg DM	
2378-TCDD		3.0 ng/kg DM	
Brominated flame retardants:			
BDE #47	0.05 µg/l	50 µg/kg DM	0.05 µg/l
BDE #99	0.05 µg/l	50 µg/kg DM	0.05 µg/l
BDE #100	0.05 µg/l	50 µg/kg DM	0.05 µg/l
BDE #153	0.05 µg/l	50 µg/kg DM	0.05 µg/l
BDE #154	0.05 µg/l	50 µg/kg DM	0.05 µg/l
Octabromodiphenyl ether	0.05 µg/l	50 µg/kg DM	0.05 µg/l
BDE #209	0.05 µg/l	50 µg/kg DM	0.05 µg/l
Brominated biphenyl ethers	0.05 µg/l	50 µg/kg DM	0.05 µg/l
Sum parameters:			
AOX	10 µg/l	25 µg Cl/kg DM	10 µg/l

[Tom side]

5 Agricultural catchments

5.1 Introduction

The subprogramme for agricultural catchments is carried out cooperatively by the regional authorities, the Topic Centre for Agricultural Monitoring Catchments/NERI and the Geological Survey of Denmark and Greenland. The regional authorities are responsible for sample collection and the interview surveys on agricultural production, quality assurance, data processing and reporting of their own data. The regional authorities transfer data to the Topic Centre, which is responsible for the overall reporting. The regional authorities and the Topic Centre jointly develop the database systems used for processing the agricultural data. As far as possible, these database systems are based on the tools already in use by the agricultural sector.

5.2 Background and status

An important aspect of the monitoring of the cultivated areas is to determine how the Action Plans on the Aquatic Environment and other measures within the agricultural sector affect management and production conditions and hence leaching of nutrients from the root zone and nutrient loading of the groundwater, watercourses, lakes and marine waters from agricultural sources.

Under the Nitrates Directive (Directive 91/676/EEC of 12 December 1991 on the protection of water against pollution by nitrates derived from agriculture), Denmark is required to describe the extent to which the legal measures to regulate agriculture have been implemented in practice, and to monitor the environmental effects thereof. Denmark has been granted temporary derogation from the Nitrates Directive such that up to 2.3 LU/ha can be permitted on cattle holdings that have fodder crops on more than 70% of their land. A precondition for this derogation is that agricultural catchment monitoring is continued to describe the trend in nitrogen loss such that further measures can be implemented if necessary.

The subprogramme for agricultural catchments has hitherto been carried out in 6–7 small (5–15 km^2) well-defined agricultural catchments (Danish EPA, 1989 and 2000). Information has been collected on land use and leaching from the root zone. These results have subsequently been used to assess the trend in the nutrient load from fields. Information on agricultural practice is compared with measurements and calculations of nutrient concentrations and transport in the whole of the hydrological cycle (Grant *et al.*, 2004).

With regard to land use data in the subprogramme for agricultural catchments, the use of personal interview surveys has ensured that the collected data have been of high quality with a considerably better resolution than for example the available statistical information. Land use data have contributed valuable knowledge on current agricultural practice and trends. It has thereby been possible to closely follow the implementation of measures to improve the environment. The land use data collected have also helped to build up valuable knowledge on the relationship between agricultural practice and leaching that was of value when evaluating the Action Plans on the Aquatic Environment (Iversen *et al.*, 1998; Grant & Kristensen, 2001; Grant *et al.*, 2000; Grant & Waagepetersen, 2004).

As land use varies considerably in agriculture, it is neither practical nor economically feasible to establish root zone measurements for direct calculation of leaching from agricultural land. Calculation of leaching from the root zone must therefore be made by means of leaching models based on information on climate, soil conditions and land use. The models will be evaluated by means of experimental measurements from the soil water stations.

The subprogramme for agricultural catchments does not have any direct obligations in respect of the Water Framework Directive, but will contribute knowledge about the magnitude and trend in nitrogen and phosphorus losses from agricultural land and about their transport and possible retention in the water cycle. The subprogramme will also contribute knowledge about methods/tools that can be used by the state and regional authorities in the administration of agricultural losses of nutrients to our surroundings, including the regional administration of the Water Framework Directive. Among other means, this will be achieved by strengthening efforts to calculate nutrient balances at farm level.

The following specific scientific considerations apply regarding nitrogen and phosphorus:

5.2.1 Nitrogen

One of the important objectives of the subprogramme for agricultural catchments is to calculate the amount of nitrogen leaching from the root zone. Nitrogen leaching has therefore been calculated by means of empirical leaching functions. These functions were also used to undertake a number of scenario calculations of the effect of changed agricultural practice (Iversen *et al.*, 1998).

Basically, the leaching functions are easily manageable and simplified and hence are well suited for upscaling. On the other hand, though, they are not applicable beyond the conditions for which they were developed. The choice of models for calculating nitrogen leaching from the root zone needs to be regularly re-evaluated. Similarly, it is necessary to be able to undertake actual modelling of nutrient transport in the

hydrological cycle. The data material used for the establishment of such models in the former monitoring programme has proven to be inadequate, however. This applies, for example, to the root zone soil physics data.

During a pesticide programme over the period 1998–2002, hydrological modelling of two agricultural monitoring catchments was carried out to determine pesticide transport. The experience gained will be exploited in the modelling work under the present agricultural catchment monitoring.

5.2.2 Phosphorus

There is a considerable need for improved knowledge of phosphorus loss to the aquatic environment from agriculture. The former agricultural catchment monitoring (1988–97) focused on nitrogen (Danish EPA, 1989). The monitoring results and parallel research programmes have revealed that diffuse phosphorus loss from agricultural sources plays a significant role in eutrophication of the Danish lakes and estuarine fjords (Windolf *et al.*, 1997). NOVA-2003 included determination of the soil Olsen phosphorus content. As this changes slowly, repeat determination of the Olsen phosphorus content in the present programme period would not contribute anything new. On the other hand, analysis of the data has revealed a need for greater knowledge about phosphorus solubility and immobilization in the soil profile.

The development of a leaching model for phosphorus is a very research-heavy task, and one that is not immediately within the scope of the subprogramme for agricultural catchments. However, together with the knowledge on phosphorus and agriculture already available, for example at the Danish Institute of Agricultural Sciences, it will be possible to incorporate the data on agricultural losses of phosphorus collected and measured under the subprogramme for agricultural catchments in a possible future model. Priority has therefore been accorded to continuing the intensive measurement of phosphorus in the watercourses of the catchments.

5.3 Objectives

The overall objectives of the subprogramme are to:

- Describe the trend in **agricultural loss** of nutrients to the terrestrial and aquatic environment
- Describe the trend in **agricultural loss** of pesticides and other hazardous substances to the upper groundwater
- Document changes in agricultural practice and the trend in nutrient loss
- Document the overall **effect** of the national **Action Plans on the Aquatic Environment** and other regulatory measures in the agricultural sector on leaching of nutrients from the root zone and agricultural loss of nutrients and hazardous substances to groundwater, watercourses, lakes and marine waters, including whether the **objectives** have been attained and whether the **trend** is moving in the right direction
- Help strengthen the **scientific basis** for state and regional administrative and other measures to limit pollution from agricultural sources.

5.4 Strategy

5.4.1 Overall strategy

The overall strategy for agricultural catchment monitoring is to measure agricultural losses of nutrients and pesticides and to collect information on agricultural practice, climate and soil type so as to enable modelling of agricultural losses of nutrients in the various media. The catchments encompassed by the subprogramme have been selected so as to broadly cover the variation in agricultural practice, climate and soil type.

The agricultural catchment monitoring strategy encompasses two levels:

Level A *Agricultural practice/measurement in aquatic media*
The monitoring in five catchments employs direct measurements and modelling to determine the relationships between agricultural practice and loss of nutrients to the surroundings. The activities primarily focus on nutrients, while monitoring of pesticides and their degradation products, other hazardous substances and heavy metals is also carried out on the upper groundwater. The investigations encompass the collection of detailed information on cultivation practice at field level with respect to nutrients, collection of data concerning fodder consumption, purchase and sale of products at farm level for calculation of farm balances for nutrients, and measurement of phosphorus solubility and immobilization in the soil profile at the soil water stations. Under NOVA-2003, soil physics data were measured in two catchments for use in establishing the root zone model DAISY. These measurements will now also be performed for a further three catchments. In addition, the amount and transport of nutrients and their possible retention in the hydrological cycle will be measured and modelled.

Level B *Agricultural practice*
In one agricultural monitoring catchment, detailed information is collected on cultivation practice at field level regarding nutrients, and data are collected concerning fod-

der consumption and the purchase and sale of products at farm level for the establishment of nutrient balances at farm level. This catchment was included in 1998 in order to render agricultural practice in the monitoring catchments more representative.

The international evaluation of the subprogramme for agricultural catchments performed in connection with revision of the monitoring programme stressed the following:

Phosphorus models are lacking: As yet, too little is known about which key parameters are important for the establishment of an actual phosphorus leaching model. The Danish Institute of Agricultural Sciences has accumulated considerable knowledge of phosphorus in the soil and is working to systematize this form of models/expert systems at various levels. There is thus no idea in initiating independent work on this aspect under the subprogramme for agricultural catchments.

Pesticide models are lacking: In order to be able to understand watercourse pesticide measurements, considerable development work needs to be done on measurements and modelling. Such work is being carried out in development and monitoring programmes outside the subprogramme for agricultural catchments. One of the major contributions is the pesticide programme carried out in two agricultural monitoring catchments over the period 1998–2002 and the Danish Pesticide Leaching Assessment Programme initiated in 1998 (Kjær *et al*., 2002).

In the report of the statistical optimization project performed in connection with revision of the monitoring programme, calculations were made of how many soil water stations were needed to be able to estimate leaching at the national level. The calculations show that more than 200 station fields will be needed in order to be able to determine the level with an accuracy of 20%. This figure can be halved by including knowledge of cultivation practice and climate. The calculations also show that the present number of soil water stations is sufficient to describe the trend in the level of leaching.

The subprogramme for agricultural catchments has to use data on the input of nutrients to agriculture. These data are obtained through interview surveys in the monitoring catchments and statistical data at the national and regional levels. In addition, data are needed on deposition of nutrients from the atmosphere. It is presumed that these data can be obtained from the subprogramme for background monitoring of air quality and atmospheric deposition.

The subprogramme for agricultural catchments is under no direct obligation to supply data to other subprogrammes, but the experience gained in the subprogramme is used in cooperation with the subprogrammes for watercourses and lakes for catchment analyses and for interpretation of watercourse data.

5.5 Programme content

The monitoring is performed by annual determination of fertilization practice and land use in the monitoring catchments, partly in order to follow the trend in agricultural practice, partly in order to be able to calculate the loss of nitrate in particular from the catchments, as well as to calculate the nutrient load from fields at the national level by means of models. The monitoring is also undertaken by direct measurements of nitrate and phosphorus loss from the root zone of cultivated land as well as in the other parts of the hydrological cycle.

The subprogramme for agricultural catchments thus follows the effects of changed nutrient loss from cultivated land in the various parts of the water cycle, i.e. the effect on nitrogen and phosphorus concentrations in drainage water and groundwater, and on the resultant runoff via watercourses. The development in the quality of the subsurface groundwater is also followed in order to determine the occurrence of hazardous substances and inorganic trace elements (heavy metals) in the agricultural monitoring catchments so as to obtain early warning of the occurrence of pesticides in the groundwater.

Table 5.1 Overview of level A and B catchments indicating soil type in the catchment.

		Soil type	
Agricultural monitoring catchment	**Catchment level**	**Clayey soil catchment**	**Sandy soil catchment**
Højvads Rende, Storstrøm County	A	X	
Lillebæk, Funen County	A	X	
Horndrup Bæk, Vejle/Aarhus County	A	X	
Odderbæk, Nordjylland County	A		X
Bolbro Bæk, Sønderjylland County	A		X
Hulebæk, Vestsjælland County	B	X	

5.5.1 The root zone – water chemistry and physics measurements

5.5.1.1 Climate data

For each catchment, daily information on temperature, irradiance, potential evaporation calculated using the Makkink formula and precipitation is obtained from the Danish Meteorological Institute's climate grid. The climate parameters are used to calculate the amount of water that infiltrates the soil. The calculations are made by means of the EVACROP and DAISY models, which are applied to the catchments each year in connection with the calculation of nutrient leaching from the root zone at the soil water stations. In addition, these data are needed for model calculations of nitrogen leaching from the root zone at catchment level. The Topic Centre makes this model calculation for all catchments using the average climate for the period 1990–2000. The climate data are also used to explain, interpret and possibly also to correct the year's monitoring data.

Grid data with a resolution of 20×20 km^2 are sufficient, although precipitation has to be calculated using a 10×10 km^2 grid.

5.5.1.2 Soil water

Soil water measurements are carried out in catchments with soil water stations. Six to eight soil water stations have been established in each of these catchments. A soil water station consists of 10 suction cells placed at a depth of approx. 1 m. During the runoff period, weekly samples ("Common") are collected at these stations for determination of pH, nitrite+nitrate, ammonium, total nitrogen and dissolved orthophosphate (Table 5.2). The average annual sampling frequency is fixed at 30 times per year. In addition, further samples ("Extended") are collected twice yearly for determination of total phosphorus (total-P), potassium, conductivity, chloride, sulphate and total iron (Table 5.2). Sample collection and analysis are undertaken in accordance with the guidelines on the operation of soil water stations in the agricultural monitoring catchments (NERI, 1991).

The groundwater table is measured at each soil water station once weekly during the runoff period and once monthly during the remainder of the year.

Water flow is calculated by means of the water balance model EVACROP (for the sandy soil catchments and the clayey soil catchments with free drainage) or the water balance module in DAISY (for drained clayey soil catchments).

5.5.1.3 Nutrient input to the soil water sites

The farmer provides information about the amount of fertilizer applied to the fields within the soil water sites, and nutrient input is calculated with the help of fertilizer norms. With manure, in particular, there is considerable uncertainty about the actual nutrient content, and the figures for nutrient application are therefore checked against production at farm level.

The vegetation at the soil water site is described each year with respect to uniformity and in relation to the surrounding field.

Table 5.2 Summary of soil water and drainage water nutrient analyses, sample types and annual sample collection frequency in the subprogramme for agricultural catchments. The analysis detection limit is also given.

Variable	Soil water		Drainage water		Detection limit
	Common	Extended	Point sample	Intensive	
- pH	30	-	26	-	-
- Nitrite+nitrate, NO_3+NO_2-N	30	-	26	-	0.02 mg/l
- Ammonium, NH_4-N	30	-	26	-	0.01 mg/l
- Total nitrogen, total-N	30	-	26	-	0.06 mg/l
- Phosphate, ortho-P, dissolved	30	-	26	26	0.005 mg/l
- Total phosphorus, total-P	-	2	26	26	0.01 mg/l
- Potassium, K	-	2	26	-	0.2 mg/l
- Conductivity	-	2	26	-	
- Alkalinity/bicarbonate	-	-	26	-	
- Organic matter, BOD_5/BOD_7	-	-	26	-	2 mg/l
- Suspended solids	-	-	-	26	2 mg/l
- Chloride, Cl^-	-	2	-	-	1 mg/l
- Sulphate, SO_4^{--}	-	2	-	-	0.5 mg/l
- Total iron, total-Fe	-	2	-	-	0.05 mg Fe/l

5.5.1.4 Drainage water

In catchments with drainage runoff, drainage water stations (1–4 stations per catchment) have been established for the continuous measurement of water flow. Sample collection is done manually. At a number of these drainage water stations automatic sample collection equipment has also been established for the collection of intensive samples. Sample collection at the drainage water stations thus consists of:

- Weekly point samples from stations (Point sample) for determination of the nutrient content (Table 5.2), and
- Time-weighted/flow-weighted pooled samples from intensive stations (Intensive) for determination of the content of dissolved orthophosphate, total phosphorus and suspended solids content (Table 5.2).

The sample collection frequency is set at an average of 26 times annually per station (see Table 5.2).

Sample collection and analysis are undertaken in accordance with the guidelines concerning sample collection and chemical analyses of drainage water in the agricultural monitoring catchments (NERI, 1991) and the guidelines containing recommendations concerning intensive sample collection from drains in the agricultural monitoring catchments (NERI, 1998).

5.5.1.5 Soil physics data

Saturated hydraulic conductivity and water retention analyses are to be carried out on 20–35 soil profiles from three of the catchments. The soil physics data are used to establish and calibrate detailed water and nitrogen transport models.

When the regional authorities plan the hydrological modelling, an assessment has to be made of whether the present data material is adequate or whether further analyses are needed.

5.5.1.6 Soil phosphorus

The phosphorus binding capacity is analysed in the soil profile (0–100 cm) at the soil water stations. This parameter is of importance for the description and possible future modelling of phosphorus transport in the soil.

5.5.2 Groundwater

The groundwater measurements are carried out in level A catchments. The groundwater stations in these catchments consist of 2–3 screens located at a depth of 1.5–5.0 m and a few deeper screens. The deep screens have been established to improve the description of nutrient circulation in the catchments. The analyses are carried out at either 20 or 8 screens per catchment depending on the analysis parameters. Analysis programmes, sampling frequency and number of screens are shown in Table 5.3. The scientific background and strategy for selection of the individual parameters for groundwater monitoring in the agricultural monitoring catchments are described in Chapter 6 on the subprogramme for groundwater and in the accompanying annexes. Sample collection and analysis are further described in the guidelines on groundwater monitoring in the agricultural monitoring catchments 1998–2003 (GEUS, 1998).

Table 5.3 Summary of analysis frequency and number of screens for each of the monitoring programmes in the level A agricultural monitoring catchments.

Groundwater analyses in agricultural monitoring catchments	Frequency/yr	Screens	Annex
Main chemical elements of groundwater:			
- Limited programme	6	100	6.1
- Other main chemical elements	1/3	100	6.1
- Field measurements	6	100	6.1
Inorganic trace elements:			
- Limited programme	1/3	40	6.2
Organic micropollutants:			
- Pesticides	4	40	6.4
- Aromatic hydrocarbons	1/3 *	40	6.3
- Alkylphenol compounds	1/3 *	40	6.3
- Phthalates	1/3 *	40	6.3
- Detergents	1/3	40	6.3
Groundwater age:			
- CFC dating	1/6	80	

* Frequency is only 1/6 in the agricultural monitoring catchments in Vejle County and Nordjylland County.

5.5.3 Watercourses

Watercourse measurements are carried out in all catchments – in the level A catchments under the subprogramme for agricultural catchments and the level B catchment under the subprogramme for watercourses.

In each of the agricultural monitoring catchments a single main watercourse station has been established that represents total nutrient transport from the catchment. Water flow is measured continuously. Samples are collected from the watercourse stations every 14th day. The samples are analysed for nutrient content. In the level B catchment the monitoring also encompasses intensive measurement of phosphorus transport with a view to future modelling of phosphorus transport in the agricultural monitoring catchments. The sampling frequencies are shown in Table 5.4.

The watercourse stations in the catchments are also included in the subprogramme for watercourses, where the catchment analyses are supplemented with data at GIS-level (Kronvang *et al.*, 1998) and in some of the catchments with biological investigations (Skriver *et al.*, 1998). The sample collection methods are further described in a technical instruction (Kronvang *et al.*, 1998).

5.5.4 Interview surveys

The interview surveys are carried out in order to follow the trend in agricultural practice and to determine the input of nutrients and pesticides to fields in the catchments. All farms in the catchments should be encompassed by the interview surveys.

At 120 farms mainly inside the catchments information is also collected on purchases and sales at farm level in order to enable calculation of the overall nutrient balance at farm level. For farms at which fodder consumption is registered, nutrient balances are also calculated at stable and field level. Ongoing collaboration between the Agricultural Advisory Centre, the Danish Institute of Agricultural Sciences and the NERI concerning "Green accounts" in agriculture aims at the development of common methods for calculating nutrient balances at farm level. Together with experience from the agricultural catchment monitoring undertaken so far, the results of this work will be incorporated into a technical instruction for determining the overall, stable and field nutrient balances at farm level. The guidelines will be completed in 2004.

5.5.4.1 Status with regard to agricultural practice and nutrient leaching

Based on the annual interview surveys in the catchments an analysis is made of the trend in agricultural practice, including changes in crop selection, fertilization level, exploitation of the nitrogen content of manure, the use of pesticides, etc. Nutrient balances (inputs minus harvest) and pesticide application frequency are calculated at field level. Work will also be carried out determining the overall, stable and field nutrient balances at farm level. Finally, sites used for washing pesticide spraying equipment will be registered.

The annual nitrogen leaching from the root zone (the nutrient load from fields) in the catchments is calculated by means of models. Scenario calculations of the effect of changed agricultural practice are carried out using this data material.

The catchments have been selected such that the data material is broadly representative for the country as a whole, and the calculations therefore broadly represent the national average.

In the catchments in which nutrient measurements are made, nutrient circulation in the catchments is calculated in relation to agricultural practice, partly through simple relationships between agricultural practice and measured values for nutrient transport in watercourses and nutrient concentrations in the near-surface groundwater, and partly through actual high-resolution modelling.

5.5.5 Dynamic modelling

Nitrogen leaching in the agricultural monitoring catchments has hitherto been calculated by means of empirical leaching functions, which are easy to comprehend and use. However, they are less suitable for scenario calculations of changes in agricultural practice where the practice differs markedly from that on which the function input data were based. In NOVA-2003, the DAISY model is partly calibrated to soil water stations in two catchments, where the model calculations of nitrogen leaching for all fields will be used as input to model calculations of nitrogen transport in the whole hydrological cycle.

Table 5.4 Summary of content, number of stations and annual frequency for monitoring of watercourses encompassed by the subprogramme for agricultural catchments (level A catchments).

	Number of stations per catchment	Frequency/yr
Water flow measurements	1	10–26
Nutrients	1	18–26
Biological investigations	-	-
Intensive nutrient transport (phosphorus)	1	26

In order to be able to perform detailed scenario calculations for all fields in the agricultural monitoring catchments DAISY will have to be calibrated to all soil water stations, i.e. also the remaining three catchments. To this end it is necessary to describe the soil profiles, measure the soil texture and measure water retention.

Description of the onward transport and turnover of nitrogen in the root zone through the aquifers to the surface waters requires dynamic modelling for water and nitrogen through the establishment of a water and nitrogen transport model for groundwater and watercourses. This modelling requires further development of modelling of the unsaturated zone with DAISY. Integrated modelling of water and nitrogen would enhance our knowledge of:

- Nitrogen turnover in the aquifer
- The relationship between nitrogen turnover and landscape type, hydrogeology, etc.
- The delay, i.e. how long it takes before the full effect of a change in root zone nitrogen leaching is reflected in watercourse nitrogen transport in various landscapes.

A further aim of the hydrological modelling is to facilitate validation of the water balance. For the figures for nutrient leaching to be reliable, the water balance must be reliable. By modelling the hydrological cycle (precipitation-evaporation-infiltration-groundwater transport-upwelling in watercourses) it is possible to compare the calculations with the measured watercourse transport. In small catchments a considerable part of the groundwater can run off to neighbouring catchments thereby bypassing the monitoring station at the lower part of the catchment. By establishing a hydrological model for a larger catchment of which the agricultural monitoring catchment is a subcatchment it will be possible to determine the water balance for the agricultural monitoring catchment with greater accuracy as it will be possible to quantify the groundwater flow between subcatchments.

NOVANA encompasses integrated modelling of water and nutrients in up to three large watercourse catchments of which an agricultural monitoring catchment forms part. The model could also be set up with a finer spatial resolution for the agricultural monitoring catchment. Hydrological monitoring of the Lillebæk catchment is described in Part 3 of the NOVANA Programme Description.

Sample collection and analysis frequency are summarized in Table 5.5.

5.6 Main changes relative to NOVA-2003

The most important changes are as follows:

- Interview surveys and nutrients balances at farm level have been accorded greater priority
- Hydrological modelling has been accorded greater priority
- Analysis of pesticides in drainage water and watercourses has been discontinued
- Measurement of soil humidity by TDR has been discontinued
- One agricultural monitoring catchment has been closed down.

The differences between the two programmes are shown in Table 5.6.

Table 5.5 Summary of the annual frequency of interview surveys, sample collection and analysis for organic matter, nutrients, hazardous substances and heavy metals in six catchments, although in only five catchments for the interview surveys on pesticide use.

Medium/substance group	Frequency/yr
Interview surveys (level A+B)	
- Field level	1
- Farm level	1
Interview surveys (level A)	
- Pesticide use	1
Soil water (level A)	
- pH, NO_{2+3}, NH_4, total-N, ortho-P	30
- total-P, K, conductivity, Cl^-, SO_4^{--}, total-Fe	2
Drainage water (level A)	
- pH, NO_{2+3}, NH_4, total-N, ortho-P, total-P, K, conductivity, alkalinity, $BOD_{5/7}$, suspended solids	26
Watercourses (see the subprogramme for watercourses, level A1)	
- Water flow, water level	10–26
- pH, temp., NO_{2+3}, NH_4, total-N, ortho-P, total-P, alkalinity[1], BOD_5, total-Fe[2], conductivity	18–26
- Biological investigation	1
Groundwater (see the subprogramme for groundwater)	

[1] Alkalinity is only measured if the alkalinity is less than 1.5 mg $CaCO_3$/l.
[2] Fe is only measured if the concentration is greater than 0.3 Fe/l, with a frequency of 4 times per year.

5.7 Theme-specific assumptions

Relation to other subprogrammes:

- Agriculture receives nitrogen from the atmosphere by deposition (subprogramme for background monitoring of air quality and atmospheric deposition)
- Agriculture emits ammonia to the atmosphere and thereby contributes to nitrogen deposition on the surrounding countryside (subprogramme for species and terrestrial natural habitats)
- N and P are lost to surface waters (subprogramme for watercourses)
- N, P and pesticides etc. are transported to the groundwater (subprogramme for groundwater – GRUMO).

Synergy between the subprogrammes in relation to reporting and economy:

- Atmospheric modelling is considered to be an activity purely for the subprogramme for background monitoring of air quality and atmospheric deposition
- New knowledge is provided in the subprogramme for agricultural catchments.
- Catchment modelling is considered to be an activity purely for the subprogramme for watercourses.

Calculation of N deposition on agricultural monitoring catchments will be decided with the subprogramme for background monitoring of air quality and atmospheric deposition when modelling starts.

5.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

The subprogramme for agricultural catchments fulfils the requirements stipulated in the inventory of monitoring requirements. These are described in Table 5.7.

Table 5.6 Comparison of agricultural catchment monitoring under NOVA-2003 and NOVANA.

	NOVA-2003		NOVANA		
	Catch./station	**Frequency/yr**	**Catch./station**	**Frequency/yr**	**Notes**
Interview – agricultural data					
Extensive interview, catchment analysis	20 catch.	1/6			
Interview, nutrients at field level	7 catch.	1	6	1	
Interview, pesticides at field level	5 catch.	1	5	1	
Interview, nutrients at farm level	40 farms	1	100 farms	1	
Monitoring programme					
Soil water (common samples)	40 st.	30	32 st.	30	
Soil water (extended)	40 st.	2	32 st.	2	
Drainage water (automatic)	7 st.	26	7 st.	26	
Drainage water (intensive)	5 st.	26	5 st.	26	
Drainage water (pesticides)	4 st.	8			
Watercourses (normal)	5 st.	26	5 st.	26	
Watercourses (intensive)			5 st.	26	
Watercourses (pesticides)	5 st.	16			
Groundwater (main chemical elements, restricted)	100 screens	6	100 screens	6	
Groundwater (main chemical elements, other)	100 screens	1	100 screens	1/3	
Groundwater (field analyses)	100 screens	6	100 screens	6	
Groundwater (pesticides)	40 screens	4	40 screens	4	Modified parameter list
Groundwater (chlorophenols)	40 screens	4	40 screens	1/3 – 1/6	Reduced (1/6) frequency in Vejle and Nordjylland Counties
Groundwater (org. micropollutants, other)	40 screens	1/3	40 screens	1/3 – 1/6	
Groundwater (detergents)	40 screens	1/3	40 screens	1/3	Several parameters
Groundwater (inorg. trace elements)	10 screens	4	-	-	
Groundwater (inorg. trace elements)	30 screens	1/3	40 screens	1/3	Several parameters
Groundwater (CFC dating)	20	1/6	80	1/6	Screens in Sønderjylland County are dated
Manure (hazardous substances)	6 catch.	1/6			
Soil phosphorus (Pt)	5 catch.	1/6			
P binding capacity			5 catch.	1/6	
TDR measurement of soil humidity	2 catch.	5	-	-	
Modelling					
DAISY, on soil water station data			3 catch.	1/6	
Hydrological model	1 catch.	1/6	2–3 catch.	1/6	

Table 5.7 Subprogramme for agricultural catchments – compliance with the requirements stipulated in the inventory of monitoring requirements.

Topic	Water Framework Directive	Nitrates Directive	OSPAR/HELCOM	Action Plan on the Aquatic Environment I and II	Action Plan on the Aquatic Environment III
Water chemistry – nutrients	Measurement of nutrients in soil water, drainage water and groundwater in representative catchments. Can be used to calibrate or validate submodels for land use and agricultural practice	Measurement of nitrate in soil water, drainage water and groundwater in representative catchments to document the trend and relationship to agricultural practice; special obligations regarding Denmark's derogation from the Nitrates Directive		Measurement of nitrate in soil water for establishing models for N leaching	Establishment of relationship between agricultural practice and N and P in the root zone water; an actual P leaching model is not expected to be developed
Agricultural practice	Annual interview survey to describe agricultural practice in model calculations of nutrient loss to the aquatic environment in representative catchments	Annual interview data about agricultural practice in representative catchments to document the trend and for modelling of N leaching from the root zone: special obligations regarding Denmark's derogation from the Nitrates Directive	Interview data about agricultural practice in representative catchments for calculating nutrient balances and loss from the root zone; input to possible subsequent modelling of nutrient transport in the hydrological cycle	Trend in agricultural practice and calculated nitrogen leaching to evaluate national action plans (has to be up-scaled to the national level)	Establishment of scenarios for agricultural practice for use in scientific assessment and evaluation of measures to limit N loss and P surplus in agriculture

6 Groundwater

6.1 Introduction

The primary reason for monitoring the groundwater is to preserve and improve the aquatic environment and to ensure the drinking water supply, which in Denmark is based almost entirely on groundwater. Monitoring of the amount and quality of the groundwater is also of considerable importance for the quality of the water in the inland surface waters, especially the watercourses, and, in the final analysis, also for the quality of the marine environment. There are therefore special reasons to protect and monitor the groundwater.

Monitoring of the groundwater is the responsibility of the regional authorities, while control of the groundwater that is used to produce drinking water is the responsibility of the waterworks (well control). The regional authorities undertake the regional reporting and submission of data to the Topic Centre for Groundwater and Wells at the Geological Survey of Denmark and Greenland. The Topic Centre is responsible for data collection and reporting at the national level.

6.2 Background and status

Monitoring of groundwater quality is carried out in waterworks wells (Ministry of Environment and Energy, 2001), in wells specially established for groundwater monitoring (groundwater monitoring sites) and in wells in the agricultural monitoring catchments (Finance Committee, 1987). In addition, the groundwater is monitored in connection with investigations and monitoring of waste depositories, landfills and other places where there is soil and groundwater contamination, even though this monitoring has hitherto only been sporadically incorporated in the regional groundwater monitoring.

As regards the monitoring of groundwater quality in the particularly valuable groundwater abstraction areas, the Statutory Order on groundwater protection achievement plans (Ministry of Environment and Energy, 2000) stipulates that the groundwater in areas designated by the regional authorities in the Regional Plans to safeguard the drinking water resource must be monitored to determine the effects of the measures implemented. The monitoring is initiated in step with adoption and implementation of the groundwater protection plans.

It is not yet clear what groundwater monitoring will be required under the Water Framework Directive (EU 2000/60) and the forthcoming Groundwater Directive (COM 2003/550).

The size and variation in the groundwater resource are monitored partly through measurement of the groundwater level in the individual waterworks wells and partly through the regional networks for measurement of the groundwater level. With initiation of NOVANA, the state programme for measuring the groundwater level has been transferred to the regional authorities. The Geological Survey of Denmark and Greenland retains access to primary data from selected wells, however. Annual water abstraction data are collected by the water utilities for use by the regional authorities in managing the water resource and for use in the annual report by the Geological Survey of Denmark and Greenland.

The drinking water is monitored to control that the waterworks produce drinking water of good quality that complies with current standards for drinking water quality. The drinking water control is carried out at the waterworks, in the water mains and in the homes of consumers. The drinking water supply is normally based on groundwater abstracted from several wells and sometimes also from several aquifers. Moreover, the raw water used by the waterworks undergoes some treatment before being supplied to the consumers. Thus only a small part of the data from the drinking water control can be used to assess the quality of the groundwater, and the monitoring of drinking water is not part of NOVANA.

All groundwater monitoring data (qualitative and quantitative) are collected, quality-assured and stored by the regional authorities for use in their annual reports on groundwater status and trend. Data are submitted to the Geological Survey of Denmark and Greenland once per year together with the regional authorities' annual reports, where they are fed into the environmental database JUPITER.

The well control and abstraction volume data submitted by the waterworks are collected by the regional authorities for forwarding to the Geological Survey of Denmark and Greenland together with corresponding data on drinking water quality. Here they are stored in the environmental database JUPITER.

To facilitate calculation of groundwater recharge, including net precipitation, relevant climate data (corrected daily precipitation, evaporation and mean temperature) are obtained from the Danish Meteorological Institute.

In connection with transposition of the Water Framework Directive into Danish legislation, further information will be needed concerning the size and variation of the groundwater resource. This assessment will be partly based on models established for the individual river basin districts. The groundwater models established within the framework of NOVANA will contribute to this.

6.2.1 Inventory of monitoring requirements

The groundwater is monitored by the waterworks pursuant to the Statutory Order on water quality and supervision of water supply plants (Ministry of Environment and Energy, 2001) issued pursuant to the Water Supply Act. In addition to requiring the waterworks to control the quality of the drinking water, the Statutory Order also requires them to control the water from the individual water supply wells in fixed rotation depending on the total amount abstracted. In addition, it requires water consumption to be controlled and the groundwater level to be measured.

The nitrate content of the groundwater is monitored pursuant to the Nitrates Directive (91/676/EEC) in particular. The Ministry of the Environment notifies the EU Commission about nitrate contamination, including the nitrate concentration in the groundwater and the trend therein (Danish Forest and Nature Agency, 2001).

The groundwater is also monitored at a number of groundwater monitoring sites and agricultural monitoring catchments as originally described in the Action Plan on the Aquatic Environment (Folketinget, 1987a, 1987b).

The NOVANA subprogramme for groundwater aims to meet Denmark's expected monitoring obligations pursuant to the Water Framework Directive (2000/60/EC) and the forthcoming Groundwater Directive. As implementation of these two directives is still ongoing, it can be expected that the subprogramme will need to be adjusted during the programme period.

6.2.2 Scientific background

The subprogramme for groundwater monitoring originated outside the Nationwide Monitoring Programme. Since initiation of monitoring in 1988 the subprogramme has thus encompassed a wider range of variables than the remainder of the programme. Moreover, the objective has also been broader since the use of the groundwater for the production of drinking water necessitates more precise information about its chemical contents.

Discussions about groundwater monitoring have thus been going on since the beginning of the 1980s based on increasing awareness of groundwater contamination with nutrients from agriculture and organic substances from various industries and service enterprises. Actual groundwater monitoring was not established until the initiation of the so-called NPo (nitrogen, phosphorus and organic matter) research programme in 1985, however.

The intention was that 19 groundwater monitoring sites should be established called the 1st order network (Andersen, 1987). These were selected so as to include the most important types of aquifer found in Denmark while concomitantly ensuring that the sites were evenly distributed throughout the country. It was at these 19 sites established under the NPo research programme (Andersen, 1990) that the original philosophy for groundwater monitoring was formulated, namely that the groundwater should be monitored from the time of its formation until the time it reached the water supply wells.

When the Action Plan on the Aquatic Environment was adopted, an aquatic monitoring programme was also adopted (Finance Committee, 1987). As far as concerns the groundwater, this resulted in a monitoring programme based on 67 groundwater monitoring sites and six agricultural monitoring catchments operated by the regional authorities, including the 19 groundwater monitoring sites that were already in the process of being established under the NPo research programme.

Since then, the number of groundwater monitoring sites and agricultural monitoring catchments has been optimized. Thus under NOVANA there are 70 groundwater monitoring sites, of which 20 are monitored using a limited programme, five agricultural monitoring catchments, each with approx. 20 intakes, and six redox wells.

In total, the groundwater is monitored in 1,611 intakes – 1,415 at groundwater monitoring sites, 96 in redox wells and 100 at agricultural monitoring catchments (as per 1 October 2003).

The waterworks well control is carried out in such a way that groundwater quality in the individual water supply wells is regularly analysed and incorporated into the groundwater monitoring programme, although usually with only a limited number of variables being measured. At the end of 2001, a total of 6,187 wells were included in the well control carried out by the waterworks.

Prior to initiation of monitoring, knowledge of groundwater quality was largely limited to the main chemical elements. However, a little was known about local contamination of groundwater with organic solvents, chlorinated hydrocarbons and in isolated cases pesticides such as atrazine.

Since then, the groundwater monitoring has considerably enhanced our knowledge of groundwater quality, and the current programme monitors a total of 97 substances: 26 main chemical elements, 14 inorganic trace elements, 23 organic micropollutants and 34 pesticides or pesticide degradation products.

6.3 Objectives

The overall objectives of the subprogramme are to:

- Provide the necessary knowledge about the **quantitative** and **qualitative status** of the groundwater and the trends therein, as well as about the causes of changes. The aim here is to ensure that there will be sufficient water of the right quality to meet both society's water supply needs and society's needs

for water in natural habitats to achieve the desired environmental objectives
- Document the overall **effect** of the **Action Plans** on the Aquatic Environment and other measures on the quality and size of the groundwater resource – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to protect and exploit the groundwater resource, including contributing to the development of various tools and the achievement of a better understanding of the relationship between groundwater and surface water
- Regularly inform about the qualitative and quantitative status of the groundwater nationally and regionally.

The monitoring at the groundwater monitoring sites and agricultural monitoring catchments must also ensure knowledge about groundwater status and the trend therein so as to enable future adjustment of well control by the waterworks. The aim is to ensure an adequate supply of groundwater of a quality suitable for the production of drinking water complying with the applicable quality requirements.

In addition, the subprogramme for groundwater is intended to provide documentation for the future assessment of the utility of pesticides in Danish agriculture and in other contexts. In this connection it will be natural to incorporate the results of the Danish Pesticide Leaching Assessment Programme (PLAP) into the present subprogramme.

In order to improve understanding of the qualitative relationship between groundwater and surface water (watercourses, lakes and wetlands), monitoring of groundwater flow to lakes and watercourses is to be enhanced, especially with respect to nitrate, phosphate and pesticide contamination of surface water.

In order to improve understanding of the quantitative relationship between groundwater and surface water, monitoring of the freshwater cycle and groundwater recharge is to be enhanced. The aim is to facilitate annual calculation and reporting of the status and trend in groundwater recharge in the upper and deeper aquifers to enable assessment of whether exploitation of the groundwater resource is sustainable, and to facilitate quality assurance of the established water balances at catchment level, including in particularly valuable groundwater abstraction areas.

Knowledge of the status and trend in groundwater chemical composition is also important when assessing the risk of corrosion in water supply plants and pipes and when selecting new materials for their construction.

6.4 Strategy

There are four main aspects that need to be incorporated in the groundwater monitoring:

- Water quality and the trend in quality
- The water balance, including the relationship between groundwater and surface water
- The Water Framework Directive
- Integration of modelling and monitoring.

The groundwater monitoring is based on the following main elements:

- All important elements of the water and chemical element cycles are to be monitored through the collection of field data from representative catchments/areas. This will naturally be based on the continuation of many of the existing activities at the groundwater monitoring sites and agricultural monitoring catchments, etc.
- The hydrogeological modelling already carried out at the groundwater monitoring site and agricultural monitoring catchment scales is to be continued. The main aim here is to ensure adequate quality assurance of the data, and that their resolution is sufficient to allow the continued build-up of knowledge, and to provide information for regular optimization of the subprogramme.

A hydrological model is to be established for the water balance and groundwater recharge at the river basin district and national scales. This is to be updated annually with new climate data and abstraction data. The main changes in the subprogramme for groundwater relative to the preceding monitoring programme are the focus on groundwater recharge and the freshwater cycle, the greater emphasis on the uppermost and youngest groundwater and the clearer division of the subprogramme into an extensive monitoring programme, a standard monitoring programme and an intensive monitoring programme. The extensive programme consists of chemical analyses carried out with a frequency of less than once per year. The standard programme consists of chemical analyses carried out with a frequency of once per year, while the intensive programme consists of chemical analyses carried out with a frequency of more than once per year.

The groundwater monitoring has been evaluated in several contexts: the statistical optimization project, the international evaluation of NOVA-2003 and the EU Working Group 2.8 on the identification of groundwater pollution trends.

The general assessment is that the number of groundwater monitoring sites is acceptable. The structure recommended is one where organic micropollutants and inorganic trace elements (mainly heavy metals) are mainly monitored in those parts of the groundwater where they can be expected to occur, e.g. in the younger groundwater.

The assessment of the necessary frequencies and number of monitoring localities is conflicting. The statistical assessment is that the frequencies at minimum should not be reduced, but perhaps should rather be raised. Correspondingly, the statistical analysis should encompass more intakes at the individual localities. It is also concluded that monitoring will need to be performed for many years, perhaps decades, before it is possible to document the trend in nitrate concentration with reasonable certainty. The data material on the trend in pesticide concentrations is considered to be far from adequate at present.

Regarding data processing, the statistical assessment further recommended that the present use of linear regression and Kendall's τ should be supplemented with trend and reverse trend analysis and possibly also with kriging analysis.

6.4.1 Groundwater monitoring sites

The purpose of the groundwater monitoring sites is to characterize the quantitative and the qualitative status of Danish aquifers. Denmark's geology is very varied, not least due to the glacial rearrangement of the upper soil layers and the resultant inhomogenous distribution of the aquifers. To perform reliable monitoring of the groundwater with an acceptable number of wells evenly distributed throughout the country would not be optimal from the resource point of view.

The subprogramme for groundwater is therefore designed around a representative structure comprised of groundwater monitoring sites selected to describe the geological/hydrological types of aquifer found nationally and regionally. A groundwater monitoring site is normally the catchment of a water supply well and a number of line and point-monitoring wells/intakes located upstream of the volume-monitoring water supply. These groundwater monitoring sites can be assumed to be worthy representatives of the other corresponding aquifers.

In order to optimize the monitoring at the groundwater monitoring sites and obtain sufficient geological-hydrological understanding of the composition of the soil layers and groundwater flow it is considered necessary to considerably upgrade the individual sites. At the same time, sampling needs to be optimized through extensification of sampling in aquifers where variation in water chemistry is small combined with corresponding intensification in aquifers where water chemistry varies considerably throughout the year. For economic reasons, such upgrading of the individual groundwater monitoring sites will necessitate a reduction in the number of groundwater monitoring sites – something that is considered to be scientifically acceptable.

The chemical analysis programme has not been changed much relative to the NOVA-2003 analysis programme. The analysis frequency will be considerably extensified for some elements, though, e.g. a number of the main chemical elements that do not derive from land use related activities on the surface. In contrast, other chemical substances in certain intakes will be analysed more intensively than under NOVA-2003.

An important element of this part of the subprogramme will be the greater focus on the young groundwater and on the redox conditions and their significance for understanding the extent of contamination and degradation of the contaminants. In the future, more emphasis will be placed on sampling of groundwater for which the redox conditions have been clearly determined, and on actual chronological comparisons rather than depth-related differences.

6.4.2 Agricultural monitoring catchments

The groundwater monitoring in the agricultural monitoring catchments has hitherto only revealed minor changes in groundwater nutrient balance. This is probably mainly attributable to the considerable and variable impact of the varying precipitation and evaporation over the years. The climate effects thus need to be "filtered out" of the data such that nutrient data do not primarily show the variation due to variation in the amount of precipitation, as is presently the case. For information on programme content see Section 5.5.2 of the subprogramme for agricultural catchments and Section 6.5.2 of the present subprogramme.

6.4.3 Waterworks wells (well control)

The water quality monitoring in waterworks wells (well control) currently provides considerable knowledge about the qualitative status of the groundwater in the aquifers presently in use. The information is very much influenced by the trend over the past 10–15 years, however, during which many contaminated wells have been closed. The information has therefore become statistically skewed such that the groundwater seems less contaminated than it really is. Well control thus primarily comprises control of the raw material used to produce drinking water and does not comprise general monitoring of the quality of the groundwater.

As regards the waterworks wells, the submitted data should be specified in such a way that the wells can be subdivided into actual production wells and wells used for other purposes, e.g. measuring the groundwater level and remedial abstraction, as these data are vital for describing the relationship between aquifers, abstraction and watercourses/lakes, saltwater intrusion, etc.

Only a small part of the well control costs is covered by NOVANA as the programme only pays salary costs in connection with data transfer and reporting. The waterworks cover the actual sampling and analysis costs.

6.4.4 Redox wells

The redox wells were introduced to enhance understanding of the chemical processes associated with the

oxygen and nitrogen fronts in particular, not least due to the marked variation recorded as a result of changes in the position of the water table.

The four redox wells already in operation have already provided good results, and it is considered vital that the number of redox wells be increased. The new wells should preferably be located in connection with a groundwater monitoring site or an agricultural monitoring catchment. The redox wells are established in aquifers with well-developed oxic, anoxic and upper reducing zones, i.e. predominantly unconfined sand aquifers. The preference is therefore for a total of six redox wells combined with continuation of the Rabis Bæk monitoring site.

The analysis programme should be intensive with six analyses per year for a limited number of main chemical elements that are of significance for understanding the changes in the redox fronts. The groundwater table is measured at all intakes in connection with sampling.

In addition, the water in all new intakes and in all intakes in the six redox wells is to be dated. Two intakes in each of the six redox wells are to be selected for frequent analysis for pesticides and pesticide degradation products, the aim being to determine the ability of the aquifers to degrade pesticides and their degradation products under various redox conditions. If it proves impossible to perform these pesticide analyses, or if no pesticides are detected in the redox wells, attempts will be made to continue the present analysis programme with frequent pesticide analyses in selected wells.

6.4.5 Quantitative monitoring

The water balance and groundwater recharge should be monitored through combined use of measurements and modelling.

In 2001 it became apparent that the calculations of the water balances posed considerable problems and that these problems have consequences for the assessment of both groundwater recharge and nitrate leaching (Refsgaard *et al*., 2001). Recently, for example, the Geological Survey of Denmark and Greenland and the Danish Institute of Agricultural Sciences detected a water "surplus" of the order of magnitude of 70–150 mm per year when calculating the water balance for certain large catchments representing various regions of Denmark (Plauborg *et al*., 2002).

At the present time the regional authorities are carrying out detailed modelling of the water balance and groundwater recharge in the particularly valuable groundwater abstraction areas in order to facilitate the preparation of groundwater protection plans. It would be natural to incorporate the results of this in the future monitoring and modelling, although the spatial resolution does not have to be as high as that needed for the above-mentioned groundwater protection plans. In the context of NOVANA it will be sufficient to model the water balance and groundwater recharge at the river basin district and national scales using the same spatial resolution as used in the national water resource model "DK-modellen". At the same time, it is clear that the modelling performed under NOVANA will be inadequate to enable modelling of such aspects as nutrient balances and groundwater protection planning at the river basin district scale pursuant to the Water Framework Directive.

In order to ensure comprehensive modelling of the freshwater resource, regional registration of all abstraction data will continue.

The groundwater level and abstraction data are together submitted to the Topic Centre for Groundwater and Wells once a year, while selected data are to be submitted to the Topic Centre continually.

Water balance modelling under NOVANA shall encompass the following elements:

- Modelling of flow pathways and water balance in local catchments (including groundwater monitoring sites, agricultural monitoring catchments, etc.)
- Modelling of water balance and groundwater at the river basin district scale.

By integrating monitoring and modelling of groundwater and surface water both nationally and regionally, consistent and coordinated monitoring and calculation of the water balance can be ensured for the country as a whole.

In order to be able to determine the size of the freshwater resource it is necessary to know the groundwater potential. The national programme, which is presently run by the Geological Survey of Greenland and Denmark, will be transferred to the regional authorities, where it will be coupled with regional groundwater level measurement programmes and incorporated as a part of NOVANA. In addition, it is expected that the regional authorities will upgrade the regional groundwater level measurement programmes so as to meet the requirements of the Water Framework Directive. The 10 groundwater level measurement stations presently run by the Geological Survey of Denmark and Greenland with on-line registration will continue to be available to the institution. The remainder of the groundwater level measurement wells are the responsibility of the regional authorities, including maintenance and possible reassignment.

In places where regional programmes for measuring the groundwater level do not exist, appropriate programmes will have to be established. It is thus estimated that implementation of the Water Framework Directive will necessitate the establishment of a number of stations for measuring the groundwater level in each river basin district to meet the requirements of the directive. It is also necessary to assess the extent to which the measurements made in the abstraction catchments by the waterworks can be utilized when describing the relationship between watercourses and groundwater in the cases where the groundwater level

measurement wells are unaffected by the initiation and cessation of abstraction.

It has become apparent that variations in groundwater potential are of considerable importance for groundwater flow to the monitoring screens and hence for the understanding of the trend in groundwater quality.

The data material for precipitation correction factors (solid and liquid precipitation) and reference evaporation from various surfaces (types of vegetation), etc. is imprecise. Modelling at the river basin district and national scales therefore has to be included in an assessment of whether the present station network for hydrological data needs to be expanded and/or upgraded in order to be able to model water balance conditions satisfactorily at the different scales. This question, including the extent and quality of hydrological data for modelling, has initially been examined on the basis of the national water resource model (DK-modellen) in connection with the preparation of the NOVA theme report on the freshwater cycle (Henriksen and Sonnenborg, 2003). It will be possible to further examine this question at different scales on the basis of the modelling under NOVANA.

6.4.6 Geographic/geological representativeness

As a consequence of the transposition of the Water Framework Directive into Danish legislation the country will be subdivided into a number of river basin districts. In addition, the qualitative and quantitative status of the groundwater will have to be monitored in all the future river basin districts taking into account the geologically dominant aquifers within the individual river basin districts and ensuring a roughly even distribution of the groundwater monitoring sites throughout the country. It has to be possible to assess groundwater status at aquifer level or, at minimum, for the types or groups of aquifers represented in the river basin district in question.

Relative to NOVA-2003, the subprogramme for groundwater has been revised such that some of the groundwater monitoring sites are only monitored at a limited number of intakes and with a limited analysis programme while the remainder are expanded to ensure the necessary knowledge about the qualitative status and trend for the upper aquifers in particular.

Under NOVA-2003, some emphasis was placed on upgrading the monitoring of the upper groundwater at the expense of the deeper groundwater. This trend has been further strengthened such that the deep, reduced groundwater is only monitored to a limited extent (extensive monitoring), while the upper groundwater (the oxic and anoxic (nitrate-rich)) and perhaps the uppermost part of the reduced groundwater (the youngest) are monitored at the same or possibly higher frequency than is presently the case (standard and intensive monitoring).

A certain number of wells/intakes are needed in which nitrate is monitored considerably more frequently than today, for example 6–10 times per year. This intensive monitoring could be established in connection with a mid-term adjustment of NOVANA by concomitantly reducing the frequency at other wells.

A fundamental principle for the selection of analysis frequency is that the closer a sampling intake is to the surface, the greater the variation that can be expected during the course of the year and the more frequently the analysis needs to be performed. Knowledge gained from the groundwater monitoring undertaken hitherto enables analysis frequency to be reduced for some chemical elements.

In assessing the necessary sampling frequency, account has been taken of the results of the statistical optimization project (Grath *et al*., 2001) and the international evaluation of NOVA-2003 (see Section 6.4).

The subprogramme for groundwater is thus considered to be adequate to form the basis for an overall description of the quality of Danish groundwater and the trend therein (see Table 6.1).

Allowance must be made for implementation of the Water Framework Directive and Groundwater Directive in Denmark, however, as this could entail the need to modify the extent/frequency of monitoring.

6.4.7 The Danish Pesticide Leaching Assessment Programme (PLAP)

The Danish Pesticide Leaching Assessment Programme has been monitoring pesticide leaching since 1998 to evaluate the risk of selected pesticides and their degradation products leaching to the groundwater under field conditions when applied in accordance with current regulations. The programme is designed in such a way that the results can be directly utilized in the Danish registration procedure for pesticides. The programme will continue for some years to come, and it would be natural to incorporate the results, which among other things will describe the input of pesticides and associated degradation products to the groundwater, when reporting the subprogramme for groundwater and when making future adjustments to NOVANA. To some extent this has already been done through the incorporation of two new substances into the pesticide analysis programme (Kjær *et al*., 2004).

Table 6.1 Elements of the NOVANA subprogramme for groundwater.

Element	Groundwater monitoring sites					Agricultural monitoring catchments	Waterworks	Regional authorities
	Young groundwater	Old groundwater	New wells	Wells with limited prog.	Redox wells	Groundwater wells	Well control and water abstraction	Water abstraction
Groundwater abstraction volume							×	×
Position of water table	×	×	×	×	×		×	×
Main chemical elements	×	×	×	×	×	×	×	
Inorganic trace elements	×	×				×	×	
Organic micropollutants	×					×	×	
Pesticides and degradation products	×		×		×	×	×	
Groundwater dating			×		×	×		

6.5 Programme content

The groundwater in Denmark is monitored through the subprogramme for groundwater and the subprogramme for agricultural catchments, as well as through the well control carried out by the waterworks and registration of water abstraction carried out by the regional authorities. The monitoring encompasses measurement or analysis of:

- The age of the groundwater
- The main chemical elements (including status variables)
- Inorganic trace elements (mainly heavy metals)
- Organic micropollutants
- Pesticides and pesticide degradation products
- Groundwater level
- Water abstraction and size of the water resource.

All the variables encompassed by the subprogramme for groundwater are summarized in Annexes 6.1–6.4 together with the frequencies and detection limits.

The monitoring that is carried out by the waterworks encompasses analysis of water quality in the individual abstraction wells (well control), registration of the amount of water abstracted, measurement of the groundwater level and analysis of the quality of the drinking water in the outflow from the waterworks and in the mains supply (drinking water control). The results of the waterworks' well control and measurement of the amount of water abstracted are included as part of the subprogramme for groundwater.

6.5.1 Groundwater monitoring sites

The groundwater monitoring encompasses 70 groundwater monitoring sites selected taking into account geology, hydrology, land use, etc. As far as possible, efforts are made to ensure that the groundwater monitoring sites within each county and river basin district are also representatively distributed (see Table 6.1 and Figure 6.1).

Of the 70 established groundwater monitoring sites, 50 have the full complement of 23 intakes (except that four of the sites have slightly fewer intakes (17–20), and one groundwater monitoring site is designed in a special manner (the Rabis Bæk site)). As a consequence, 329 new wells for monitoring the very young groundwater have to be established in these 50 groundwater monitoring sites. In Ribe County it has been decided not to analyse for organic micropollutants and pesticides at the Bramming groundwater monitoring site and for inorganic trace elements at the Vorbasse groundwater monitoring site. In Roskilde County it has proven difficult to find aquifers with very young groundwater within the existing groundwater monitoring sites, and it has therefore been decided that in this case the new shallow wells can be located in a separate catchment outside the existing groundwater monitoring sites where it is possible to establish intakes in the very young groundwater.

At 20 groundwater monitoring sites the monitoring is restricted to a limited number of main chemical elements solely in intakes with young groundwater. Thus wells in old groundwater (from before 1950) are not monitored at these 20 groundwater monitoring sites. For the time being, though, these wells can be preserved for possible future monitoring or reassigned for other purposes.

The location of the groundwater monitoring sites and agricultural monitoring catchments at which the full analysis programme is performed is shown in Figure 6.1, while that of the groundwater monitoring sites at which the limited analysis programme is performed is shown in Figure 6.2. The site names and identification codes are shown in Table 6.2 (full analysis programme) and Table 6.3 (limited analysis programme).

Table 6.2 Groundwater monitoring sites and agricultural monitoring catchments at which the full analysis programme is performed, listed by county.

Cph./Frb. Muncipalities		**Storstrøm County**		**Ribe County**		**Aarhus County**	
13.11	Frederiksberg	35.03	Hjelmsølille	55.01	Grindsted	70.01	Havdal
Copenhagen County		35.11	Vesterborg	55.11	Bramming*	70.11	Nordsamsø
15.11	Søndersø	35.12	Sibirien	55.14	Vorbasse*	70.12	Fillerup
15.12	Ishøj	35.13	St. Heddinge	**Vejle County**		70.13	Hvinningdal
Frederiksborg County		AMC	Højvads Rende	60.11	Thyregod	70.14	Homå
20.11	Skuldelev	**Bornholm County**		60.12	Trudsbro	**Viborg County**	
20.12	Asserbo*	40.01	Smålyng	60.13	Follerup	76.01	Rabis Bæk
20.13	Attemose	**Funen County**		60.14	Ejstrupholm	76.11	Viborg 'Nord'
20.14	Espergærde	42.01	Nyborg	AMC	Horndrup Bæk	76.12	Skive
Roskilde County		42.11	Svendborg	**Ringkjøbing County**		76.13	Nykøbing M.
25.01	Torkilstrup	42.12	Nørre Søby	65.11	Brande*	76.14	Thisted
25.02	Brokilde	42.13	Harndrup	65.12	Haderup	**Nordjylland County**	
25.11	Asemose	42.14	Jullerup	65.13	Finderup	80.01	Tornby
Vestsjælland County		AMC	Lillebæk	65.15	Klosterhede	80.11	Drastrup
30.12	Store Fuglede	**Sønderjylland County**				80.13	Albæk
30.15	Jyderup Skov	50.11	Bedsted			80.14	Gislum
		50.12	Rødding			AMC	Odderbæk
		50.14	Frøslev				
		AMC	Bolbro Bæk				

* At the Asserbo, Bramming, Vorbasse and Brande sites the programme is run with a slightly reduced number of intakes (17, 20, 20 and 20, respectively). Cph./Frb.: Copenhagen/Frederiksberg. AMC: Agricultural monitoring catchment.

Table 6.3 Groundwater monitoring sites at which the limited analysis programme is performed in intakes with young groundwater, listed by county.

Copenhagen County		**Vestsjælland County**		**Sønderjylland County**		**Ringkjøbing County**	
15.13	Gladsaxe	30.01	Holbæk	50.01	Abild	65.01	Herning
Frederiksborg County		30.11	Munke Bjergby	50.02	Mjang Dam	65.14	Herborg
20.01	Endrup	30.13	Nykøbing Sj.	50.13	Christiansfeld	**Aarhus County**	
Roskilde County		30.14	Eggeslevmagle	**Ribe County**		70.02	Kasted
25.12	Osted	**Storstrøm County**		55.12	Ølgod	**Nordjylland County**	
		35.01	Holeby	55.13	Forumlund	80.02	Råkilde
		Funen County		**Vejle County**		80.12	Skerping
		42.02	Borreby	60.01	Egebjerg		

At the groundwater monitoring sites, the groundwater in the smaller, subsurface aquifers is monitored using so-called point-monitoring intakes, while that in the larger, deeper-lying aquifers is monitored using line-monitoring intakes. In addition, the groundwater is normally monitored in a single abstraction well (the volume-monitoring well) in the main aquifer at each groundwater monitoring site (Figure 6.3). At the agricultural monitoring catchments it is the newly formed, uppermost groundwater that is monitored.

With the increase in the number of wells at the beginning of the NOVANA period a groundwater monitoring site should normally consist of a single abstraction well and 22 monitoring intakes located upstream of the abstraction well so as to enable the quality of the water in both the main aquifer and that in the near-surface, secondary aquifers to be monitored. With the initiation of NOVANA, greater emphasis has been placed on the young groundwater through the establishment of 329 new wells with intakes in the uppermost groundwater.

In 2001–2002, the Geological Survey of Denmark and Greenland and the regional authorities investigated the suitability of wells for analysis (Geological

Survey of Denmark and Greenland, 2002). It was found that by far the majority of the active intakes used in the monitoring programme functioned satisfactorily. However, conditions at a number of intakes were such that further investigation was required to determine whether these reflected natural conditions or possible leaks. Wells confirmed to be unsuitable have either been repaired or replaced before the end of 2003.

This does not necessarily apply if the wells are located in groundwater monitoring sites at which monitoring only encompasses a limited analysis programme in young groundwater. Thus the number of wells at the groundwater monitoring sites at which the full analysis programme is continued after 2004 is unaffected by the results of the investigation.

Of the total number of intakes it has to be possible to use the abstraction well and approx. 21 monitoring intakes at each groundwater monitoring site for special analyses, i.e. inorganic trace elements, organic micropollutants, pesticides and pesticide degradation products, etc. At the end of 2001, approx. 570 intakes at the 50 groundwater monitoring sites were considered suitable for special analyses. The 329 newly established shallow wells all have to be suitable for special analyses.

The groundwater potential is measured in the individual monitoring wells. If the seasonal variation needs to be determined, for example in connection with modelling of the individual monitoring sites, measurement of the groundwater potential should be carried out 4–6 times annually per well, evenly distributed throughout the year. This will not be practicable with all wells, however, and at minimum the groundwater potential in the wells should therefore be measured whenever they are checked or sampling is performed.

All sampling at the groundwater monitoring sites must be performed using on-line sampling equipment with a built-in filtering capability for field measurements of pH, conductivity, dissolved oxygen, temperature and, as something new, measurement of redox potential (Eh).

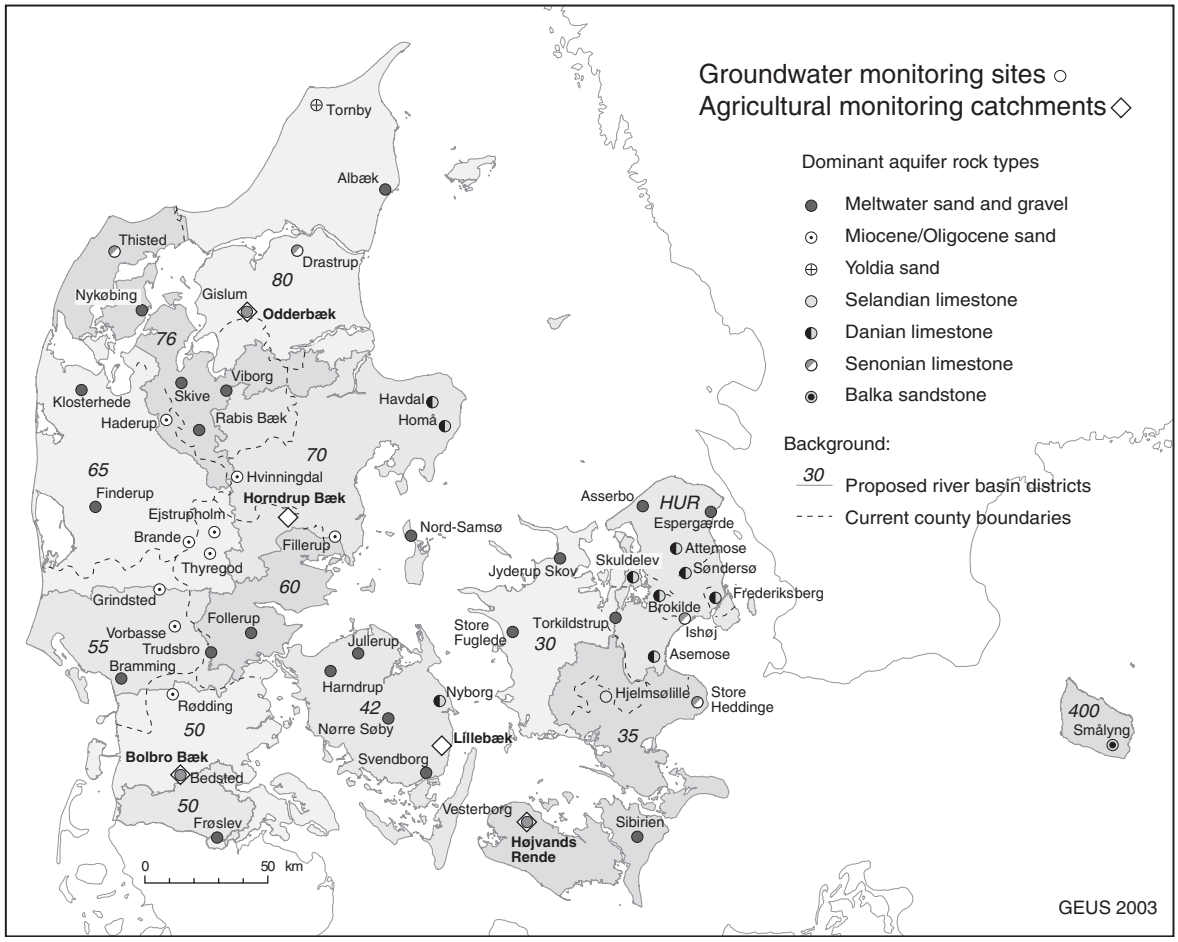

Figure 6.1 Groundwater monitoring sites (•) and agricultural monitoring catchments (◊) in the proposed rinver basin districts.

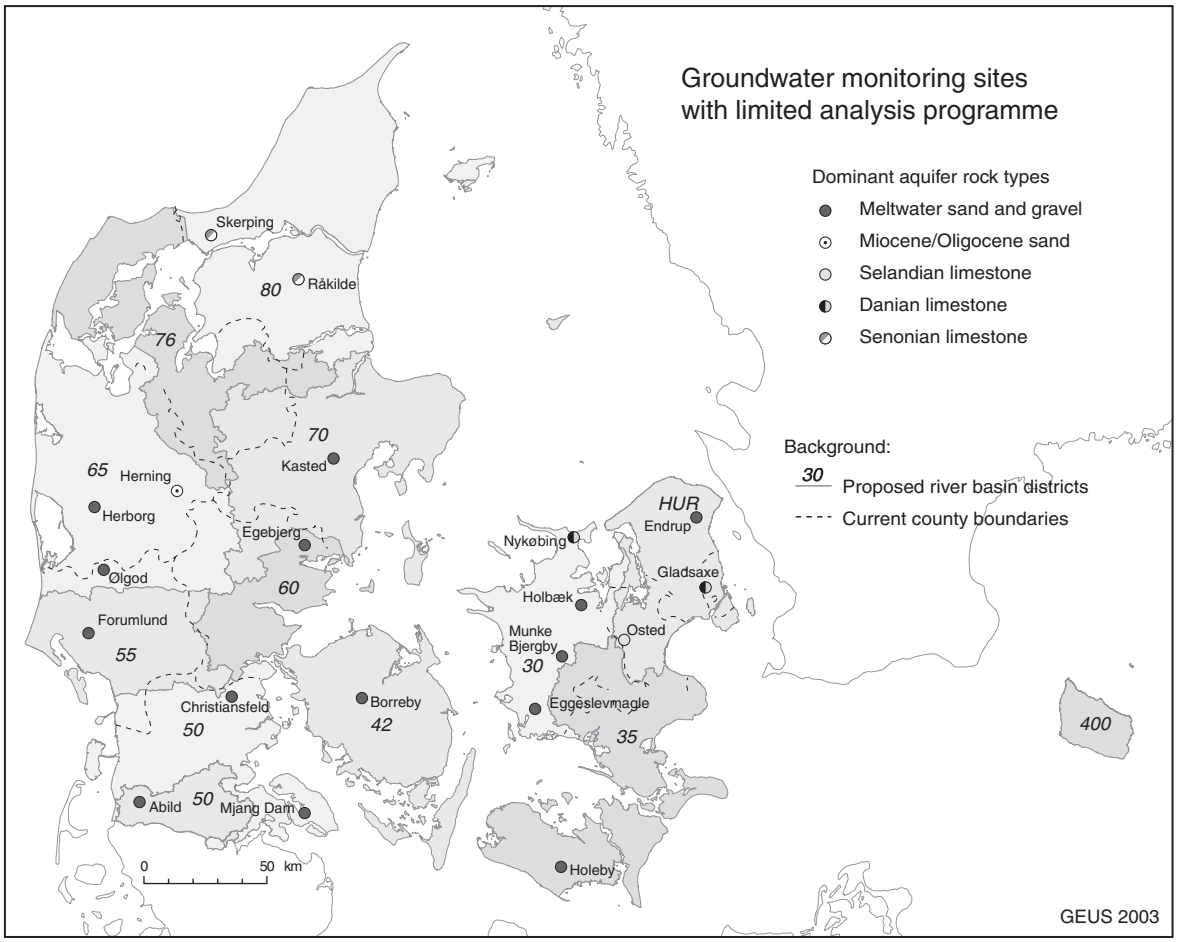

Figure 6.2 A number of groundwater monitoring sites (•) will continue with a limited analysis programme in intakes with young groundwater.

All the pre-existing groundwater monitoring site intakes found to be located in young groundwater formed after 1950 (CFC dating) at the beginning of the programme period are analysed once yearly using a limited programme (Annex 6.1). This also applies to intakes in young groundwater at groundwater monitoring sites at which monitoring with a limited programme is continued. The newly established shallow wells are analysed using a limited programme twice each year. Young groundwater is only analysed for the remaining main chemical elements once during the programme period at both the existing intakes and the new intakes.

No analyses are planned for the newly established shallow wells during the first year.

Intakes in old groundwater are only analysed once during the programme period using a full analysis programme for main chemical elements.

Analysis for aggressive carbon dioxide, methane and hydrogen sulphide is only required in wells preselected for the purpose and only once during the programme period.

Young groundwater is analysed for inorganic trace elements every second year using a limited programme comprising substances largely assumed to derive from activities at the surface. Old groundwater is analysed every second year using a different limited programme (among other things including nickel and arsenic).

Under NOVA-2003, iodine could not be included in the monitoring programme because no qualified laboratories existed. Laboratories able to perform acceptable analysis of iodine are now available, however, and iodine is therefore included in the present programme.

Previous monitoring of inorganic trace elements shows that approximately half of the investigated substances occur in very low concentrations considerably below the limit value for drinking water. The inorganic trace elements that do not appear to derive from human activities or which do not occur in concentrations close to the limit value for drinking water are not to be monitored during the current programme period, but instead monitored during the next programme period starting in 2010.

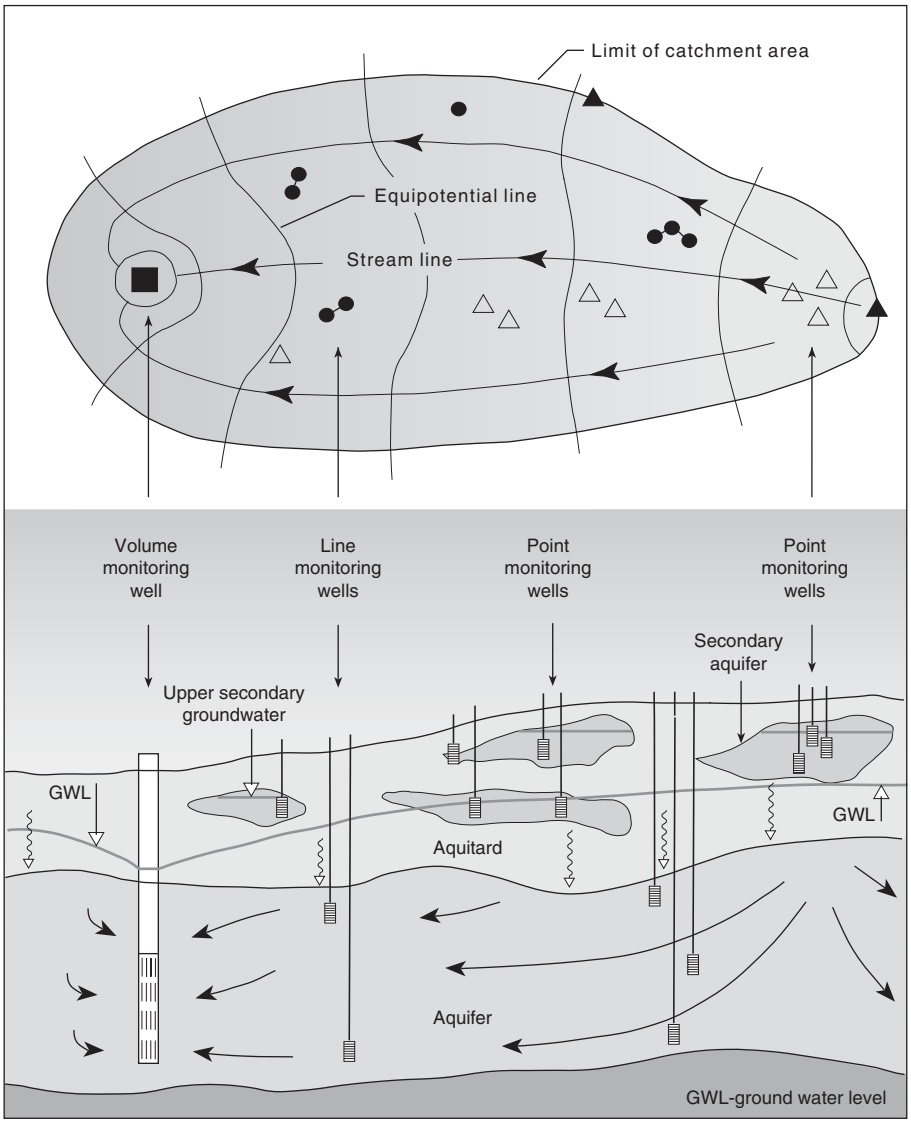

Figure 6.3 Diagram indicating the principles of monitoring intake placement at a groundwater monitoring site (after Andersen, 1987).

Organic micropollutants are exclusively analysed for in wells with young groundwater that existed at the beginning of the programme period and which are assessed as being suitable for special analyses. Thus organic micropollutants are not to be analysed for in the new shallow wells in the upper groundwater. Phenols, chlorophenols, anionic detergents (both sum-variables and specific LAS analyses), alkylphenols and phthalates are analysed for every third year, while aromatics and halogenated aliphatic hydrocarbons are only analysed for every sixth year because aromatic hydrocarbons and halogenated aliphatic hydrocarbons have only been detected to a limited extent, and mainly in monitoring wells located in the open countryside. The phthalate analysis has been extended from DBP alone to also include DEHP and DNP. MTBE is analysed for twice during the programme period in existing monitoring intakes with young groundwater located in Copenhagen and Frederiksberg Municipalities and Copenhagen County.

Analysis for pesticides is restricted to the young groundwater in both the existing and the new wells, with the analysis being performed once per year.

The groundwater in all new intakes, i.e. the 329 new shallow wells and the 96 intakes in the six redox wells is to be dated using the CFC method, partly to know the age of the groundwater sampled for analysis and partly to ensure that these wells really represent the youngest groundwater. Wells established to replace existing wells are also to be dated.

See also Table 6.4 and Annexes 6.1–6.4.

Table 6.4 Analysis programme used at the groundwater monitoring sites (excluding the Rabis Bæk site and the redox wells) indicating analysis type, number of intakes, annual sampling frequency and selection principle. For the parameter list see Annexes 6.1–6.4.

Analysis type	Number of intakes	Analysis frequency	Selection principle
Groundwater age:			
CFC dating of new wells	329	1/6	New wells
Main chemical elements:			
Limited programme	623	1	Existing well in young g.w.
Limited programme	163	1/6	Old groundwater
Limited programme	329	2	New wells
Limited programme	188	1	Limited programme
Aggressive carbon dioxide	639	1/6	Depending on initial result
Methane	659	1/6	Depending on initial result
Hydrogen sulphide	278	1/6	Depending on initial result
Other main chemical elements	1,115	1/6	All active intakes
Field measurements	1,415	Each time	All active intakes
Inorganic trace elements:			
Limited programme 1	570	½	Existing well in young g.w.
Limited programme 1	326	½	New wells
Limited programme 2	151	½	Old groundwater
Organic micropollutants:*			
Aromatic hydrocarbons	569	1/6	Existing well in young g.w.
Halogenated aliphatic hydrocarbons	569	1/6	Existing well in young g.w.
Phenols and chlorophenols	569	1/3	Existing well in young g.w.
Alkylphenols and phthalates	569	1/3	Existing well in young g.w.
MTBE**	40	1/3	Existing well in young g.w.
Detergents	569	1/3	Existing well in young g.w.
Pesticides and degradation products:*			
Annual analysis	569	1	Existing well in young g.w.
Annual analysis	321	1	New wells

* Intakes assessed as being suitable for special analyses.

** Only in Copenhagen and Frederiksberg Municipalities and Copenhagen County

6.5.2 Groundwater monitoring in agricultural monitoring catchments

The groundwater monitoring performed in the agricultural monitoring catchments describes the status and trend for the uppermost groundwater, and is an integral part of the subprogramme for groundwater.

In order to ensure the best possible knowledge of when the groundwater in the intakes in the agricultural monitoring catchments was formed, the groundwater from all the intakes will be CFC dated at the beginning of the programme period wherever technically feasible.

The groundwater in the agricultural monitoring catchments is analysed using a limited programme comprising selected main chemical elements, with N and P being analysed for six times annually in 20 intakes per agricultural monitoring catchment, and the other main chemical elements being analysed for every third year.

In addition, an analysis programme for organic micropollutants and a limited number of inorganic trace elements is performed in eight intakes per agricultural monitoring catchment every third year. Most organic micropollutants will only be analysed for once during the programme period in Vejle and Nordjylland Counties, however.

Pesticides and pesticide degradation products are analysed for four times per year in the same eight intakes per agricultural monitoring catchment.

6.5.3 Monitoring at the Rabis Bæk site

Groundwater monitoring at the Rabis Bæk site started in the 1980s under the NPo research programme. The monitoring is primarily intended to describe the trend in the main chemical elements of the groundwater in

the upper unconfined aquifers. The monitoring programme is summarized in Table 6.5.

As previously, the 112 active intakes at the Rabis Bæk groundwater monitoring site are analysed for a limited number of main chemical elements six times annually from two intakes per well and once annually from the other intakes. In addition, aggressive carbon dioxide and methane are analysed for once during the programme period in selected intakes, i.e. intakes where these substances have previously been detected.

The monitoring at the Rabis Bæk site is to be correlated with the monitoring at the six redox wells.

6.5.4 Monitoring at the redox wells

The four redox wells established by the regional authorities under NOVA-2003 are to be supplemented with a further two wells. The four existing redox wells are located one in each of the four counties: Storstrøm County (Sibirien), Ribe County (Grindsted), Aarhus County (Kasted) and Nordjylland County (Albæk). The two new redox wells are to be located in Frederiksborg County (preferably at Skuldelev) and in Vestsjælland County (preferably in Jyderup Forest) (see Table 6.6). The two counties are free to locate the redox wells elsewhere in the county if this is scientifically preferable and the Topic Centre for Groundwater and Wells agrees.

The redox wells contain at least 15 small intakes to facilitate monitoring of the stability and variation in the redox zones. The two new redox wells are to be designed in the same way as the four existing wells. The intakes are placed rather closely above each other to enable sampling from well-defined levels in the aquifers. The wells at the Rabis Bæk site are also used for monitoring the redox zone.

The redox wells (96 intakes) are analysed six times annually for a limited number of variables appropriate for describing conditions concerning the redox zones in the groundwater. Analysis is not planned in the two new redox wells during the first year.

The analysis programme in the redox wells encompasses a limited number of main chemical elements (see Table 6.6 and Annexes 6.1 and 6.4). On the first occasion ammonium, hydrogen sulphide and methane will be analysed for in all intakes. Thereafter they will only be analysed for in the intakes in which they can be expected to be present.

6.6 Main changes relative to NOVA-2003

Under NOVA-2003 the full monitoring programme was carried out at 67 groundwater monitoring sites. This has now been cut to 50. At the same time, the number of groundwater monitoring sites at which a limited monitoring programme is carried out has been increased from 3 to 20.

The number of intakes investigated at each groundwater monitoring site with the full monitoring programme has been increased from approx. 17 under NOVA-2003 to 23 under NOVANA (except that the number of intakes is only 17–20 at four of the groundwater monitoring sites). In addition, 22 of these sites have to be suitable for special analyses as compared with approx. 14 under NOVA-2003.

Tabel 6.5 Monitoring programme at the Rabis Bæk groundwater monitoring site indicating analysis type, number of intakes, annual sampling frequency and selection principle. For the parameter list see Annex 6.1.

Rabis Bæk	Number of intakes	Analysis frequency	Selection principle
Main chemical elements:			
Limited programme	16	6	2 intakes per well
Limited programme	96	1	Other intakes
Aggressive carbon dioxide	112	1/6	Depending on initial result
Methane	96	1/6	Depending on initial result
Field measurements	112	Each time	All intakes

Table 6.6 Monitoring programme for redox wells indicating analysis type, number of intakes, annual sampling frequency and selection principle. For the parameter list see Annexes 6.1 and 6.4.

Redox wells	Number of intakes	Analysis frequency	Selection principle
Main chemical elements:			
Limited programme, frequent analysis	96	6	15 per redox well
Field measurements	96	Each time	All intakes
Pesticides and pesticide degradation products	12	6	2 per well
CFC dating	96	1/6	All intakes

To facilitate monitoring of the quality of the youngest groundwater, 329 new shallow wells are being established.

Two additional redox wells have been established bringing the total to six.

The analysis programme for organic micropollutants has been reduced to only encompass pre-existing monitoring wells with young groundwater (later than 1950 according to CFC dating).

The analysis programme for pesticides has been revised and now only includes 34 substances as compared with 45 under NOVA-2003. The substances that have been deleted are those that have only been detected on very few occasions and only once at a concentration exceeding the limit value for drinking water.

Finally, the focus on the size and variation in the groundwater resource has been enhanced under NOVANA. Thus, the intention is to model the size of the groundwater resource at river basin district scale during the programme period.

6.7 Theme-specific assumptions

Technical instructions for groundwater monitoring were drawn up under the preceding programme NOVA-2003. These instructions are largely sufficient to meet the requirements of NOVANA, although certain adjustments will be needed. See the technical instructions for groundwater monitoring published by the Geological Survey of Greenland and Denmark (GEUS, 2004).

Certain tasks will have to be described from the ground up:

- Establishment and/or operation of stations for measuring groundwater level
- Modelling of the water resource in river basin districts
- Establishment of new, shallow wells
- Analysis of sediment samples to determine the redox potential in new wells.

Adjustments required during the programme period as a result of the implementation of the Water Framework Directive are dealt with in Section 6.8.

6.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

Denmark's obligations pursuant to the Nitrates Directive (91/676/EEC) regarding monitoring of nitrate are considered to be adequately met by the present subprogramme.

As implementation of the Water Framework Directive (2000/60/EC) and Groundwater Directive (EU Commission, COM(2003)550) is still ongoing, it can be expected that the subprogramme will need to be adjusted during the programme period.

The possibility cannot be excluded that transposition of the Water Framework Directive and the Groundwater Directive in Danish legislation might necessitate having to increase the extent/frequency of monitoring.

The Water Framework Directive requires Member States to set up monitoring programmes in order to establish a "coherent and comprehensive overview" of the groundwater's "chemical and quantitative status" within each river basin district. It is thus necessary to establish a series of groundwater models based on the subdivision of Denmark into a number of river basin districts. As these river basin districts have not yet been finally delineated, it may be necessary to adjust the subprogramme during the programme period.

As regards the density and frequency of the monitoring of groundwater quantitative status, i.e. the groundwater level, the Water Framework Directive further stipulates that the monitoring should provide a reliable assessment of the quantitative status of all groundwater bodies or groups of bodies. For the time being the term can presumably be equated with "parts of aquifers that are delineated on the basis of flow conditions".

The regional authorities do not run programmes for measuring groundwater level in all regions. Implementation of the Water Framework Directive will necessitate the establishment of a number of stations for measuring groundwater level in each river basin district.

Table 6.7 Comparison of the groundwater monitoring under NOVA-2003 and NOVANA.

Programme element, etc	NOVA-2003		NOVANA	
	Number	Frequency	Number	Frequency
Construction and maintenance:				
Shallow wells			329	1/6
Redox wells	4	1/6	6	1/6
Redox potentiometers	13	1/6	15	1/6
Other maintenance etc.	67	1	50	1
Sampling etc.:				
Groundwater monitoring sites	67	1	50	1
Groundwater monitoring sites, limited programme			20	1
Redox wells	4	1	6	1
Modelling of groundwater monitoring sites	67	1		
Modelling at river basin district scale			12	1
Groundwater level measurement programme			12	1
Main chemical elements:				
Limited programme in groundwater monitoring sites, young groundwater	829	1	623	1
Limited programme in groundwater monitoring sites, old groundwater	199	1	163	1/6
Limited programme in new wells, young groundwater			329	2
Limited programme in groundwater monitoring sites, with limited programme			188	1
Limited programme in the Rabis Bæk site	96	1		
Limited programme in the Rabis Bæk site, frequent (2x8)	16	6	112	6
Limited programme, frequent pesticide analyses	14	4	12	6
Aggressive carbon dioxide	315	1/6	639	1/6
Aggressive carbon dioxide	815	1		
Methane	294	1/6	659	1/6
Methane	836	1		
Hydrogen sulphide	767	1/6	278	1/6
Hydrogen sulphide	363	1		
Other main chemical elements at groundwater monitoring sites, young + old	1,042	1	1,115	1/6
Other main chemical elements at the Rabis Bæk site	112	1	112	1
Limited programme in redox wells	60	6	96	6
Field measurements (excl. redox wells)	1,214	Each time	1,415	Each time
Inorganic trace elements:				
Limited programme, young groundwater, incl. new intakes	735	1	896	1/2
New variables, all screens	918	1/3		
Limited programme 2, old groundwater			151	1/2
Other inorganic trace elements	918	1/6		
Organic micropollutants:				
Aromatic hydrocarbons	815	1/3	569	1/6
Aromatic hydrocarbons, detected	103	1		
Halogenated aliphatic hydrocarbons	839	1/3	569	1/6
Halogenated aliphatic hydrocarbons, detected	79	1		
Ethers	104	1/3	40	1/3
Phenols and chlorophenols, young groundwater	721	1	569	1/3
Phenols and chlorophenols, old groundwater	173	1/6		
Phenols and chlorophenols, frequent pesticide analysis	14	4		
Detergents	735	1/3	569	1/3
Alkylphenols and phthalates	735	1/3	569	1/3
Pesticides and degradation products (45 substances in NOVA-2003 and 34 substances in NOVANA):				
45/34 substances in young groundwater	721	1	569	1
34 substances in new shallow wells			321	1
45/34 substances in old groundwater	173	1/6		
45/34 substances, frequent analysis	14	4	12	6
Groundwater age:				
CFC dating in groundwater monitoring sites	843	1/6	329	1/6
CFC dating in redox wells			96	1/6
Modelling:				
Modelling tools, etc.			12	1/6

6.9 Annexes

Annex 6.1 Main chemical elements encompassed by the subprogramme for groundwater.

Main chemical elements	Frequency						Detection limit	
	Young groundwater	Old ground-water	New wells	Rabis Bæk site	Redox wells	Agricultural monitoring catchments		
Limited programme:								
Potassium	1	1/6	2	6	6	1/3	0.2	mg/l
Chloride	1	1/6	2	6	6	6	1	mg/l
Sulphate	1	1/6	2	6	6	6	0.5	mg/l
Nitrate	1	1/6	2	6	6	6	0.5	mg/l
Nitrite	1	1/6	2	6	6	6	0.005	mg/l
Ammonium	1	1/6	2	6	6	6	0.01	mg/l
Iron	1	1/6	2	6	6	1/3	0.01	mg/l
Manganese	1	1/6	2	6	6	1/3	0.005	mg/l
Other main chemical elements:								
Calcium	1/6	1/6	1/6	-	-	1/3	1	mg/l
Bicarbonate	1/6	1/6	1/6	-	-	1/3	1	mg/l
Fluoride	1/6	1/6	1/6	-	-	-	0.05	mg/l
Magnesium	1/6	1/6	1/6	-	-	1/3	1	mg/l
Sodium	1/6	1/6	1/6	-	-	1/3	1	mg/l
Strontium	1/6	1/6	1/6	-	-	-	0.1	mg/l
Total-N	-	-	-	-	-	6	0.1	mg/l
Total-P	1/6	1/6	1/6	-	-	6	0.01	mg/l
Orthophosphate-P						6	0.005	mg/l
NVOC	1/6	1/6	1/6	-	-	1/3	0.1	mg/l
Aggressive carbon dioxide	1/6	1/6	1/6	-	-	-	2	mg/l
Hydrogen sulphide	1/6	1/6	1/6	6	6	-	0.02	mg/l
Methane	1/6	1/6	1/6	6	6	-	0.01	mg/l
Field measurements:						*		
pH	1	1/6	2	6	6	6	0.01	-
Redox potential (Eh)	1	1/6	2	6	6	6	0.01	mV
Conductivity	1	1/6	2	6	6	6	0.05	mS/l
Oxygen	1	1/6	2	6	6	6	0.1	mg/l
Temperature	1	1/6	2	-	-	-	0.1	°C

* Field measurements in the agricultural monitoring catchments are carried out to the extent practicable.

Annex 6.2 Inorganic trace elements monitored in the subprogramme for groundwater.

Inorganic trace elements	Frequency				Detection limit	Temporarily raised to:
	Young groundwater	New wells	Old ground-water	Agricultural monitoring catchments		
Aluminium (Al)	½	½	-	½	0.07 µg/l	0.1 µg/l
Antimony (Sb)	½	½	-	½	0.05 µg/l	
Arsenic (As)	½	½	½	½	0.03 µg/l	0.04 µg/l
Barium (Ba)	-	-	½	-	1 µg/l	
Lead (Pb)	½	½	-	½	0.025 µg/l	
Boron (B)	½	½	-	½	10 µg/l	
Cadmium (Cd)	½	½	-	½	0.004 µg/l	0.005 µg/l
Cobalt	½	½	½	½	0.1 µg/l	
Iodide	½	½	½	½	1 µg/l	
Copper (Cu)	½	½	-	½	0.04 µg/l	0.1 µg/l
Chromium (Cr)	½	½	½	½	0.04 µg/l	0.05 µg/l
Nickel (Ni)	½	½	½	½	0.03 µg/l	0.05 µg/l
Selenium (Se)	-	-	½	-	0.05 µg/l	0.1 µg/l
Zink (Zn)	½	½	½	½	0.5 µg/l	

Annex 6.3 Organic micropollutants encompassed by the subprogramme for groundwater.

Organic micropollutants	Frequency		Detection limit
	Young groundwater	Agricultural monitoring catchments	
Aromatic hydrocarbons:			
Benzene	1/6	1/3 *	0.04 µg/l
Naphthalene	1/6	1/3 *	0.02 µg/l
Toluene	1/6	1/3 *	0.04 µg/l
Xylenes (p-xylene, m-xylene and o-xylene)	1/6	1/3 *	0.02 µg/l
Halogenated aliphatic hydrocarbons:			
Tetrachloroethylene	1/6	1/3 *	0.02 µg/l
Tetrachloromethane	1/6	1/3 *	0.03 µg/l
Trichloroethylene	1/6	1/3 *	0.02 µg/l
Trichloromethane (chloroform)	1/6	1/3 *	0.02 µg/l
1,1,1-trichloroethane	1/6	1/3 *	0.02 µg/l
1,2-dibromoethane	1/6	1/3 *	0.02 µg/
Vinyl chloride	1/6	1/3 *	0.05 µg/l
Phenols and phthalates (plasticizers):			
Phenol	1/3	1/3 *	0.05 µg/l
Nonylphenol	1/3	1/3 *	0.05 µg/l
Nonylphenolethoxylates (mono- and diethoxylates)	1/3	1/3 *	0.05 µg/l
Dibuthylphthalates (DBP), DEHP and DNP	1/3	1/3 *	0.1 µg/l
Chlorophenols:			
2,4-dichlorophenol	1/3	1/3 *	0.03 µg/l
2,6-dichlorophenol	1/3	1/3 *	0.03 µg/l
Pentachlorophenol	1/3	1/3 *	0.02 µg/l
Ethers:			
MTBE (methyl tertiary-butyl ether)	1/3	-	1 µg/l
Detergents:			
Anionic detergents	1/3	1/3	3 µg/l
LAS (specific analysis)	1/3	1/3	3 µg/l

* In the agricultural monitoring catchments Horndrup Bæk (Vejle County) and Bolbro Bæk (Nordjylland County) the frequency is 1/6.

Annex 6.4 Pesticides and pesticide degradation products encompassed by the subprogramme for groundwater.

Pesticides and degradation products	Frequency				Detection limit
	Young groundwater	New wells	Redox wells	Agricultural monitoring catchments	
1. Aminomethylphosphonic acid (AMPA)	1	1	6	4	0.01 µg/l
2. Atrazine	1	1	6	4	0.01 µg/l
3. Bentazone	1	1	6	4	0.01 µg/l
4. 4-CPP	1	1	6	4	0.01 µg/l
5. 2,4-D	1	1	6	4	0.01 µg/l
6. 2,6 DCPP	1	1	6	4	0.01 µg/l
7. Desaminodiketometribuzin	1	1	6	4	0.02 µg/l
8. Desethylatrazine	1	1	6	4	0.01 µg/l
9. Desethyldesisopropylatrazine	1	1	6	4	0.01 µg/l
10. Desethylterbuthylazine	1	1	6	4	0.01 µg/l
11. Desisopropylatrazine	1	1	6	4	0.01 µg/l
12. Dichlobenil	1	1	6	4	0.01 µg/l
13. 2,6-Dichlobenzamide (BAM)	1	1	6	4	0.01 µg/l
14. 2,6-Dichlorobenzoic acid	1	1	6	4	0.01 µg/l
15. Dichlorprop	1	1	6	4	0.01 µg/l
16. Diketometribuzin	1	1	6	4	0.02 µg/l
17. Dinoseb	1	1	6	4	0.01 µg/l
18. Diuron	1	1	6	4	0.01 µg/l
19. DNOC	1	1	6	4	0.01 µg/l
20. Glyphosate	1	1	6	4	0.01 µg/l
21. Hexazinon	1	1	6	4	0.01 µg/l
22. Hydroxyatrazine	1	1	6	4	0.01 µg/l
23. Hydroxysimazine	1	1	6	4	0.01 µg/l
24. Hydroxyterbuthylazine	1	1	6	4	0.01 µg/l
25. Isoproturon	1	1	6	4	0.01 µg/l
26. MCPA	1	1	6	4	0.01 µg/l
27. Mechlorprop	1	1	6	4	0.01 µg/l
28. Metamitron	1	1	6	4	0.01 µg/l
29. Metribuzin	1	1	6	4	0.01 µg/l
30. 4-nitrophenol	1	1	6	4	0.01 µg/l
31. Pendimethalin	1	1	6	4	0.01 µg/l
32. Simazine	1	1	6	4	0.01 µg/l
33. Terbuthylazine	1	1	6	4	0.01 µg/l
34. Trichloroacetic acid (TCA)	1	1	6	4	0.01 µg/l

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7 Watercourses

7.1 Introduction

The subprogramme for watercourses is carried out jointly by the regional authorities, Copenhagen Municipality and the Ministry of the Environment, with the regional authorities performing the sample collection and the primary data processing and reporting and the Topic Centre for Inland Surface Waters collecting, processing and reporting the data at the national level.

The monitoring in the subprogramme for watercourses encompasses the status of watercourses and their riparian areas and the transport of nutrients and organic matter to lakes and marine waters. The occurrence of hazardous substances is also investigated in watercourses. Monitoring of nature in watercourses and riparian areas is an integral part of the subprogramme.

7.2 Background and status

7.2.1 Water quality and nutrient and organic matter transport

Nutrients and organic matter have been the focus of the national monitoring since the start of the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment in 1989, mainly because nitrogen, phosphorus and organic matter are the main causes of the poor status of many Danish water bodies. Phosphorus and organic matter loading of the aquatic environment have been reduced considerably at the national level because urban wastewater is now treated much more effectively than was previously the case. In recent years, nitrogen loading has also decreased, partly due to improved wastewater treatment, but mainly due to a reduction in loading from agricultural sources. In many areas, however, agricultural losses remain the main source of both nitrogen and phosphorus transport in watercourses and hence also of nitrogen and phosphorus transport to lakes and fjords.

The results of the monitoring performed since 1989 at watercourse stations in catchments differing in natural and anthropogenic conditions – the catchment loading category (CLC) network – have proven useful for documenting the trend in nutrient and organic matter transport in watercourses. The catchment loading category network has also documented how the magnitude of and trend in nutrient and organic matter transport in catchments affected by either wastewater or agriculture differ from that in uncultivated rural catchments. Correspondingly, the network of stations in watercourse outlets to the sea – the so-called marine loading (ML) network – has documented changes in the total input of nitrogen, phosphorus and organic matter to Danish coastal waters. In recent years it has been possible to demonstrate the trend with increasingly greater statistical certainty, in part because the period over which the trend is measured becomes longer each year, but also because statistical analysis methods require data for a certain time span in order to be able to reliably demonstrate a trend. It is important to maintain an adequate station network able to reliably demonstrate trends in the future.

Under NOVA-2003, special catchment analyses have been performed in selected agricultural monitoring catchments to determine relationships between catchment characteristics and nutrient and organic matter losses. Henceforth, there is a need for nutrient and organic matter transport in each catchment nationwide to be correlated with GIS-related information on such factors as land use and livestock herds. Improved coupling to the important factors will strengthen the scientific foundation for the decision-making process and provide more precise "screws" to turn.

7.2.2 Hazardous substances and heavy metals

Under NOVA-2003, heavy metals, pesticides and other hazardous substances have been monitored in five large watercourses. In addition, pesticides have been monitored in 25 small agricultural catchments. It transpired that a number of substances can be detected in the watercourses, but it is not known whether the flora and fauna are adversely affected. The occurrence of pesticides has proven to be almost identical in large watercourses and small agricultural watercourses. As many of the substances have never been detected in levels exceeding the detection limit, the list of substances analysed for has been reduced considerably under NOVANA.

7.2.3 Watercourse quality

The national watercourse monitoring programme has hitherto mainly encompassed studies of watercourse quality based on the composition of the macroinvertebrate community. The results have only slightly improved our knowledge of watercourse ecological status, the trend therein and the reasons for the trend. NOVA-2003 therefore included an extended biological monitoring programme aimed at describing relationships between anthropogenic pressures and watercourse ecological status, especially the significance of the physical conditions in the watercourses. The extended biological monitoring programme encompassed a number of small watercourses in agricultural areas because the ecological status of such watercourses is often unsatisfactory.

Under NOVANA the monitoring has to meet obligations pursuant to the Water Framework Directive and the Habitats Directive. Greater emphasis will therefore be placed on increasing the number of biological, physical and chemical quality parameters monitored. Moreover, certain species and natural habitat types of relevance to the Habitats Directive will be incorporated.

The subprogramme for watercourses is designed to fulfil to the greatest extent possible Denmark's obligations pursuant to the Water Framework Directive and Habitats Directive, as well as the obligations pursuant to the international marine conventions concerning the North Sea (OSPAR) and the Baltic Sea (HELCOM). The monitoring also fulfils the obligations pursuant to the Nitrates Directive, the Exchange of Information Decision and participation in the EEA monitoring network Eurowaternet.

In addition, the monitoring programme has to fulfil the aquatic environment monitoring requirements pursuant to the Action Plan on the Aquatic Environment (Ministry of the Interior Official Document No. 46 of 19 October 1987). Likewise it has to help meet the need for species and natural habitat monitoring as well as monitoring of the effects of nature restoration projects in the river Skjern and the wetlands established pursuant to Action Plan on the Aquatic Environment II.

7.3 Objectives

The overall objectives of the subprogramme are to:

- Describe **sources of pollution** and other pressures and their effects on the status of watercourses and riparian areas
- Document the overall **effect** of national **action plans** and measures directed at the aquatic environment and nature – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Document that the quality objective is attained for selected watercourses pursuant to the Water Framework Directive and Habitats Directive
- Fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve the aquatic environment and nature, including helping to develop various tools.

7.4 Strategy

The subprogramme for watercourses is designed around the overall objective of determining water, nutrient and organic matter transport to lakes and marine waters and to follow the trend in watercourse quality. The monitoring programme also has to describe the relationship between inputs from the watercourse catchments and the nutrient concentrations in the watercourses. The overall structure resembles that of NOVA-2003, but some changes have been made, among other reasons as a consequence of the international evaluation and the statistical optimization project.

7.4.1 International evaluation

The panel responsible for the international evaluation was generally satisfied with both the subprogramme for watercourses and that for springs/springbrooks. The subprogramme for springs/springbrooks has nevertheless been discontinued as it was concluded that the yield from continued monitoring will be relatively small. The evaluation panel further recommended using the experience gained with hazardous substances under NOVA-2003 to focus the future monitoring. This recommendation was implemented by a cross-disciplinary working group working across the boundaries of the various NOVANA subprogrammes.

7.4.2 Statistical optimization

The statistical optimization project revealed that the number of watercourse stations in uncultivated rural catchments is too small and should be increased if possible, but that sampling frequency should be extensified to every second or third year. The number of stations in the other loading categories was appropriate. The number of watercourse stations in uncultivated rural catchments cannot be increased very much, however, as there are not many pristine watercourses of a reasonable size in Denmark.

The project also showed that relevant trends can be demonstrated over a period of 15 years or less for all watercourse stations and loading categories.

A further conclusion was that more marine stations were needed in 1st and 2nd order coastal sections if the precision was to be sufficiently good in the individual coastal sections. This would have considerably increased the cost of the programme, however, especially because it would involve smaller and smaller watercourses, which only account for a small part of the total riverine load. This need has consequently not been met, and it would probably be better use of resources to develop better tools for calculating nutrient and organic matter loading from unmonitored catchments.

Finally, the project showed that the number of stations at which the watercourse fauna is assessed using the Danish Stream Fauna Index (DSFI stations) can be reduced relative to the 1,054 stations used in NOVA-2003, and that the investigations can be extensified, for example to every third year. The number of stations has therefore been reduced slightly, and the frequency has been extensified, but only to a certain degree due

to political/administrative requirements that watercourse status has to be reported annually.

The strategy for the two main elements of the subprogramme – "Ecological quality of watercourses" and "Water chemistry and nutrient and organic matter transport" – is described in Section 7.4.3 and 7.4.4.

7.4.3 Ecological quality of watercourses

The ecological monitoring consists of both extensive monitoring (800 stations, every 3rd–6th year) and intensive monitoring (50 stations, every year). At 250 of the extensive stations, moreover, the watercourse fauna is assessed annually. The extensive monitoring is performed at 670 representative reaches that are affected by human activities, as well as at 130 reference reaches. The extensive station network will provide a nationwide picture of the ecological status of watercourses and their riparian areas and the possible reasons in cases where watercourses fail to meet their quality objective. The aim of the intensive programme is to support the extensive network and help determine the natural variation in biotic components and parameters used in the assessment of ecological status.

The stations have been selected so as to continue as many of the time series from the last programme period as possible. A further priority was to ensure the greatest possible coincidence between the ecological stations and the water chemistry stations in the watercourses.

The main emphasis of the programme is on the ecological parameters, i.e. watercourse macroinvertebrates, macrophytes and fish, but it also includes a number of physical and chemical parameters that directly express watercourse status or express factors that affect or explain the status.

While the station network focuses on fulfilling obligations pursuant to the Water Framework Directive, it also meets obligations under the Habitats Directive with respect to certain species and natural habitat types. When locating the stations, a number of other needs have also to be met. Thus stations are placed in the river Skjern to follow up on the restoration project. Pilot studies under Action Plan on the Aquatic Environment II are continued in wetlands in the form of botanical investigations.

Table 7.1 Summary indicating the national and international obligations to be met by the individual station networks of the subprogramme.

Station network	APEA	WFD	Nature monitoring strategy	Marine conventions	River Skjern	APAE II wetlands
Ecological status network		x	x		x	x
Nutrient and organic matter transport – CLC network	x	x			x	
Nutrient and organic matter transport – ML network	x	x		x		

APAE: Action Plan on the Aquatic Environment; WFD: Water Framework Directive; CLC: Catchment loading category; ML: Marine loading.

Table 7.2 Summary of the elements of the subprogramme for watercourses. Parentheses indicate that the element is only monitored at a small number of stations.

Subprogramme element	Ecological status network	Nutrient and organic matter transport network
Water flow and water level	+	+
pH, temperature	+	+
Nutrients	+	+
Organic matter	+	+
Macroions	+	(+)
Heavy metals		(+)
Hazardous substances		(+)
Macroinvertebrates (DSFI)	+	
Macrophytes	+	
Fish	+	
Riparian vegetation	+	
Physical description of watercourses	+	
Soil chemistry/properties	+	
Site description	+	

7.4.4 Water chemistry and nutrient and organic matter transport

The network for monitoring water chemistry and nutrient and organic matter transport consists of 179 stations. Of these, 10 are located in reference watercourses. The stations located near the mouth of a watercourse – the ML network – are included in the calculation of water, nutrient and organic matter inputs to the coastal sections, including inputs to areas encompassed by the marine conventions. Other stations – the CLC network – are used to assess the trend in nutrient and organic matter transport and the relation to catchment characteristics, including agricultural practice and point-source discharges. A number of stations are used in both contexts.

Hazardous substances and heavy metals are monitored at five of the stations in the ML network to estimate inputs of these substances to the sea and to obtain a general overview of their occurrence in the aquatic environment. In addition, a number of specific parameters are monitored pursuant to the Exchange of Information Decision at four specially selected stations for which long time series are available. Furthermore, there are nine other stations with long time series of hydrometry data at which only water flow and water level are measured – the former state hydrometry stations.

The monitoring programme focuses on water flow and nutrient concentrations, which are key parameters in relation to both the Action Plan on the Aquatic Environment and the marine conventions. Hazardous substances and heavy metals are also included to a limited extent, and a number of variables (macroions, DOC) are monitored at the reference stations that could eventually be used as indicators of the effect of climate changes.

7.4.5 Relationship to other subprogrammes

For the Topic Centre for Marine Waters, the main requirement is for calculations of the input to the nine (six in NOVA-2003) level 2+ coastal waters that are both precise and of good temporal resolution. It is therefore important to ensure an adequate number of stations in these catchments when the stations for the ML network are selected. The input calculations for the remaining marine waters do not necessarily need to have the same resolution and precision, and modelling can be used to a much greater extent provided it is scientifically defensible.

The subprogramme for lakes continues to require calculations of inputs and outputs of water, nutrients and organic matter to and from the lakes encompassed by the intensive lake monitoring programme. It therefore has to be ensured that the necessary inlet and outlet stations are included in the subprogramme for watercourses. The lake inlet stations should preferably overlap with the catchment loading category stations, while the lake outlet stations can be marine loading stations. Under NOVA-2003, some of these stations were financially part of the subprogramme for lakes while others were part of the subprogramme for watercourses. This arrangement will be changed such that all the stations will be funded by the subprogramme for watercourses, as is the case with the marine loading stations. Retention in the monitored lakes will be used in the subprogramme for watercourses to facilitate source apportionment of nutrient and organic matter transport to the coastal sections.

Calculations of total point-source loading in each watercourse catchment and coastal section will be used to facilitate source apportionment of nutrient and organic matter transport.

Efforts should be made to ensure the best possible coverage of relevant natural habitat types, relevant special areas of conservation (SACs) and relevant species to facilitate reporting pursuant to the Habitats Directive.

7.5 Programme content

The analysis programme for the various elements of the subprogramme for watercourses are summarized in Tables 7.3 (water chemistry and physical variables) and 7.4 (ecological variables). The sampling frequencies are averages and can be higher or lower at different stations. Likewise, some of the variables may not be monitored at some of the stations. The exact analysis programme at the individual stations is described in Part 3 of the Programme Description.

The sampling and analysis methods are specified in the Technical Instruction.

7.5.1 Variables

7.5.1.1 Water flow

Water flow is measured using a propeller type instrument, typically using a lower frequency (12 times yearly) than with the water chemistry variables. At most of the stations for measuring nutrient and organic matter transport (approx. 140), hydrometric stations have been established for continual registration of water level. Water flow is calculated on a daily basis as either the relationship between discharge and water level at the same station or that between discharge and water flow at a nearby station. In a few cases other methods are used, for example catchment area correction.

Table 7.3 Water chemistry and physical variables monitored under the subprogramme for watercourses.

Variable, etc.	Station type						
	Ecological status – extensive	**Ecological status – intensive**	**Nutrient and organic matter transport – reference**	**Lake inlet/ outlet**	**Nutrient and organic matter transport – other**	**Hydro-metry**	**Exchange of Information Decision**
Number of stations	800	50	10	29	169	9	4
No. of investigation years during the period	1–2	6	2	6	6	6	6
Sampling frequency during investigation years	1	1	18*	19*	18*	12*	12
Water flow	+	+	+	+	+	+	+
Continuous water level		+	+	+	+	+	+
Temperature	+	+	+		+		+
pH	+	+	+	+	+		+
Alkalinity ***	+	+	+		+		+
Nitrate+nitrite-N	+	+	+		+		+
Ammonium-N	+	+	+		+		+
Total-N			+	+	+		+
Ortho-phosphate-P	+	+	+	+	+		+
Total-P			+	+	+		+
BOD_5	+	+	+		+		+
COD							+
Total Fe ***	+	+	+	+	+		+
Suspended solids and loss on combustion			+		+		+
DOC			+				
Ca	+	+	+				
Mg			+				
Na	+	+	+				
SO_4			+				
HCO_3	+	+	+				
Si			+				
Cl	+	+	+				+
Faecal E. coli							+
Conductivity							+
Detergents							+
Hg ****					+		+
Cd ****					+		+
Pb ****					+		
Cu ****					+		
Zn ****					+		
Hazardous substances ****					+		

* Mean for all stations, can vary approx. ± 50% depending on the watercourse's hydrological response. See Part 3 of the Programme Description for details.
** Only once during the period.
*** Not at all stations.
**** Only at five stations. The analysis programme is given in Annexes 7.2 and 7.3.

Table 7.4 Ecological variables.

Variable, etc.	Station type	
	Ecological status – extensive	Ecological status – intensive
Number of stations	800	50
Number of investigation years during the period	1–2	6
Sampling frequency during investigation years	1	1
Macroinvertebrates (DSFI)	+	+
Macrophytes	+	+
Fish	+	+
Riparian vegetation	+	+
Riparian vegetation, but measured in permanent transects		+
Physical characterization of watercourses	+	+
Physical characterization of watercourses, extended		+
Hydrological regime based on water level, water flow and water table height	+	+
Soil chemistry/properties		+
Extended site description		+

DSFI: Danish Stream Fauna Index.

7.5.1.2 Chemical variables

A few substances are monitored using a slightly modified programme (relative to the general routine). **Iron** is only monitored at stations where experience indicates its presence in relatively high concentrations (>0.3 mg/l), and is only measured four times per year. **Alkalinity** is only monitored at stations where experience indicates that it is low (<1.5 mmol/l).

7.5.1.3 Hazardous substances

A number of pesticides and other hazardous substances (Annexes 7.1–7.3) are monitored in five large rivers at a frequency of only 12 times per year. In addition, there is an extensive programme for pesticides in small watercourses. The annual budget for this element is DKK 300,000.

7.5.1.4 Ecological and morphometric/physical variables

Submerged macrophytes, macroinvertebrates and fish are determined quantitatively, while the riparian vegetation is determined semiquantitatively and qualitatively. The intensive ecological monitoring will also encompass (semi)quantitative determination of riparian vegetation in permanent transects perpendicular to the watercourse. Macroinvertebrate sampling is carried out in the spring, while sampling of macrophytes and fish is carried out in late summer.

The physical characterization encompasses morphology of the watercourses and riparian areas, simple measures of deposition and erosion in watercourses and on riparian areas, and the hydrological regime in watercourses. In addition to the routine investigation of watercourse macroinvertebrates, fish and macrophytes as specified in the Technical Instruction, there are a number of species that have to be specifically monitored at the localities where they form part of the basis for selection of Natura 2000 SACs pursuant to the Habitats Directive.

The ecological investigations are performed every third year at 160 stations in large watercourses and every sixth year at the remaining stations. In addition, the watercourse fauna is assessed annually using the DSFI at 250 stations in the extensive ecological network as a supplement to the investigations carried out every sixth year.

7.5.1.5 Other information

Additional information of various kinds is collected for use in analysis, modelling and interpretation of the monitoring data. The frequency with which this information is collected varies depending on its nature and use.

Climate data from the Danish Meteorological Institute (annual) are used in connection with calculation of water balance and nutrient and organic matter transport at the stations in the nutrient and organic matter transport network. The geographic localization and the digital catchment boundaries for the individual stations (updated regularly) are used in connection with GIS-based modelling and aggregation of other information at catchment level. Agricultural data concerning livestock herds and cultivation practice (every third year) and phosphorus status of agricultural soil are used in connection with calculation of leaching in the catchments of the nutrient and organic matter

transport stations that are included in the catchment loading category network. At the stations in the ecological monitoring network, information about bed excavation and weed cutting is collected together with available information about whether the riparian area has been under agricultural production (grazing, crop rotation).

7.5.2 Localization of the stations

7.5.2.1 Extensive ecological status network

The 800 stations in the extensive ecological status network have to comprise a representative section of the Danish watercourses. They have thus been selected so as to cover the range of watercourses as regards geographic distribution, size and type, and degree to which they are affected by anthropogenic pressures. At the same time, consideration has been given to the fact that they have to encompass SACs whose type or basis for selection falls in under the subprogramme for watercourses. Likewise, three stations have been located in the area where the river Skjern is restored, and a number of stations have been located in a number of wetlands established under Action Plan on the Aquatic Environment II and at which investigations focussing on the botanical elements will be carried out towards the end of the programme period.

7.5.2.2 Intensive ecological status network

The 50 stations in the intensive ecological status network are located in such a way that there are around five stations in each of the 12 selected large river systems. Endeavours are made to ensure that both the upper and lower reaches of each river system are represented.

7.5.2.3 Nutrient and organic matter transport network

The 179 stations in the nutrient and organic matter transport network under the subprogramme for watercourses are to some extent included in both the ML network and the CLC network. Many stations are included in both these networks. In addition, there are a number of inlet and outlet stations in the lakes included in the intensive monitoring under the subprogramme for lakes, as well as five watercourse stations under the subprogramme for agricultural catchments.

Total input of water, nutrients and organic matter to the sea is calculated on the basis of data from 110 of the stations in the nutrient and organic matter transport network. These cover the inputs from approx. 49% of Denmark. The Danish coastline is subdivided into nine sections (1st order coastal sections), which are in turn subdivided into 49 smaller sections (2nd order coastal sections). The annual input is calculated for each of the 2nd order coastal sections. In addition, the monthly input is calculated for each 1st order coastal section. The input from the unmonitored fraction of the catchments is calculated by modelling based on the measured data. The methods are specified in the Technical Instruction.

Stations included in the CLC network are classified according to the main sources of pollution in the catchment. The data analysis operates with the following three categories, which are compared with respect to the trends in nutrient and organic matter concentrations and transport:

- Watercourses in uncultivated rural catchments
- Watercourses in catchments with point sources
- Watercourse in agricultural catchments.

Inputs of nitrogen, phosphorus and organic matter are calculated for all stations in the nutrient and organic matter transport network apportioned by source (both point sources and diffuse sources). The source apportionment is calculated on the basis of the measured nutrient and organic matter concentrations and water transport together with data on input from point sources collected under the subprogramme for point sources. The methods are specified in the Technical Instruction.

7.6 Main changes relative to NOVA-2003

The main changes are as follows:

- Monitoring of "springs and springbrooks" has been discontinued
- Intensive measurement of phosphorus transport has been discontinued (maintained in the five watercourses agreed under the subprogramme for agricultural catchments, however)
- Measurement of pesticides in agricultural catchments has been discontinued
- More biological, physical and chemical quality elements are included in the watercourses (macrophytes, fish, physical conditions etc.).

7.7 Theme-specific assumptions

The Topic Centre for Inland Surface Waters is to provide the following calculations to the Topic Centre for Marine Waters:

- Modelled annual input of water, nitrogen and phosphorus to 1st order coastal sections as per 1 July
- Final calculations of the input of water, nitrogen, phosphorus and BOD_5 to 1st order coastal sections and annual inputs to 2nd order coastal sections as per 5 September.

The Topic Centre for Inland Surface Waters is to contribute to reporting of the subprogramme for marine waters and the subprogramme for agricultural catchments.

The Topic Centre for Hydrological Point Sources is to provide calculations of the total input of nitrogen,

phosphorus and BOD_5 to every single 2nd order coastal section.

The Topic Centre for Inland Surface Waters is to provide calculation of the total retention of nitrogen and phosphorus in the lakes in the catchments of each of the 2nd order coastal sections.

The Topic Centre for Inland Surface Waters is to provide data to the Topic Centre for Biodiversity and Terrestrial Nature for the national reporting pursuant to the Habitats Directive.

The above assumptions (information requirements and deadlines) may change if the reporting strategy is changed.

7.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

In general, the subprogramme fulfils the national and international reporting obligations.

The calculations of hazardous substance inputs to the sea are still inadequate relative to the criteria in the HELCOM and OSPAR recommendations.

7.9 Annexes

Annex 7.1 Heavy metals encompassed by the subprogramme for watercourses.

	Sampling frequency	Detection limit	
Cadmium (Cd)	12	0.004	µg/l
Copper (Cu)	12	0.04	µg/l
Lead (Pb)	12	0.025	µg/l
Mercury (Hg)	12	0.0005	µg/l
Zink (Zn)	12	0.5	µg/l

Annex 7.2 Hazardous substances encompassed by the subprogramme for watercourses.

	Sampling frequency	Detection limit
Aromatic hydrocarbons:		
Naphthalene	12	0.02 µg/l
Phenols:		
Nonylphenols	12	0.05 µg/l
Nonylphenol monoethoxylates	12	0.05 µg/l
Nonylphenol diethoxylates	12	0.05 µg/l
Halogenated aliphatic hydrocarbons:		
Trichloroethylene	12	0.02 µg/l
Trichloromethane (chloroform)	12	0.03 µg/l
Chlorophenols:		
Pentachlorophenol (PCP)	12	0.02 µg/l
Polyaromatic hydrocarbons (PAHs):		
Acenaphthene	12	0.01 µg/l
Acenaphthylene	12	0.01 µg/l
Anthracene	12	0.01 µg/l
Benz(a)anthracene	12	0.01 µg/l
Benz(a)pyrene	12	0.01 µg/l
Benz(e)pyrene	12	0.01 µg/l
Benz(ghi)perylene	12	0.01 µg/l
Benz(b+j+k)fluoranthenes	12	0.01 µg/l
Chrysen + Triphenylene	12	0.01 µg/l
Dibenz(a+h)anthracene	12	0.01 µg/l
Dibenzothiophene	12	0.01 µg/l
3,6-dimethylphenanthrene	12	0.01 µg/l
Fluoranthene	12	0.01 µg/l
Fluorene	12	0.01 µg/l
Indeno(1,2,3-cd)pyrene	12	0.01 µg/l
2-methylphenanthrene	12	0.01 µg/l
Perylene	12	0.01 µg/l
Phenanthrene	12	0.01 µg/l
Pyrene	12	0.01 µg/l
Plasticizers:		
Di(2-ethylhexyl)phthalate (DEHP)	12	0.1 µg/l
Anionic detergents:		
Linear alkylbenzenesulphonates	12	3 µg/l

Annex 7.3 Pesticides encompassed by the subprogramme for watercourses.

Pesticides	Sampling frequency	Detection limit
Aminomethylphosphonic acid (AMPA)	12	0.01 µg/l
Atrazine	12	0.01 µg/l
2,6-dichlorobenzamide (BAM)	12	0.01 µg/l
Desethyldeisopropylatrazine	12	0.01 µg/l
Desethylterbuthylazine	12	0.01 µg/l
Desisopropylatrazine	12	0.01 µg/l
Diuron	12	0.01 µg/l
DNOC	12	0.01 µg/l
Glyphosate	12	0.01 µg/l
Hydroxyatrazine	12	0.01 µg/l
Hydroxysimazine	12	0.01 µg/l
Isoproturon	12	0.01 µg/l
MCPA	12	0.01 µg/l
Mechlorprop	12	0.01 µg/l
4-nitrophenol	12	0.05 µg/l
Simazine	12	0.01 µg/l
Terbuthylazine	12	0.01 µg/l
Trichloroacetic acid (TCA)	12	0.01 µg/l

8 Lakes

8.1 Introduction

The subprogramme for lakes is carried out jointly by the regional authorities, Copenhagen Municipality and the State (NERI), with the regional authorities performing the sample collection and the primary data processing and reporting and the Topic Centre for Inland Surface Waters collecting, processing and reporting the data at the national level. The Topic Centre is also responsible for reporting data to a number of Danish and international institutions.

The subprogramme describes the status and trend in ecological and environmental conditions in Danish lakes through investigation of a range of physical, chemical and biological variables in freshwater and brackish lakes.

8.2 Background and status

When the Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment was initiated in 1988, 37 lakes were selected for monitoring (Action Plan on the Aquatic Environment I, Danish EPA, 1988). The monitoring programme for these 37 lakes was intensive with respect to both chemical and biological processes. In addition, the external inputs of water and nutrients were carefully determined, and the sources of the external nutrient inputs were apportioned by type. This intensive programme enabled a highly detailed description of the dynamics of these lakes, including a good description of the causal relationships.

The programme was well suited for documenting the magnitude of nutrient inputs and demonstrating the effect of the pollution-limiting measures implemented, as well as for characterizing the status of the 37 lakes and for documenting the trend therein.

The programme has also helped improve knowledge of the relationship between nutrient input and environmental status, and operational empirical models have been developed for these relationships. Furthermore, the programme has enhanced understanding of the significance of the biological components for lake status and has provided considerable new knowledge that has been widely applied in the general management of Danish lakes.

In connection with revision of the Nationwide Monitoring Programme the number of lakes was reduced from 37 to 31, and various adjustments and cuts have been made to the programme. An attempt to establish a nationwide extensive lake monitoring programme was unsuccessful, however.

The main changes made to the subprogramme for lakes in connection with the current revision of the programme were primarily designed to meet obligations pursuant to the Water Framework Directive and Habitats Directive, even though these changes also satisfy a number of national desires, for example a nationwide station network.

In one respect the subprogramme for lakes has been extended relative to NOVA-2003 (although not relative to the original lake monitoring programme under Action Plan on the Aquatic Environment I) due to a desire to fulfil more obligations. The extension is chiefly on the biological front, mainly as a consequence of the introduction of the monitoring of lake habitats pursuant to the Habitats Directive, but also as a consequence of the requirement for biological monitoring stipulated in the Water Framework Directive. Correspondingly, it has been necessary to include some nationwide extensive programmes to fulfil a number of the requirements in the Water Framework Directive. In contrast, the lake monitoring was previously primarily defined on the basis of requirements in the Danish legislation.

The lake programme received a good assessment in the international evaluation of NOVA-2003 (Nixon *et al*., 2002), even though the extensive elements were lacking at that time.

Even though the 37 lakes (41 lake basins) originally selected for the Nationwide Monitoring Programme until 1997 and the 27 freshwater lakes under NOVA-2003 were representatively selected relative to Danish freshwater lakes in general, the monitoring did not provide a satisfactory nationwide picture of the status and trend for Danish lakes.

It has become apparent that it is very useful to have a relatively high sampling frequency, among other reasons because the effects of changes in nutrient inputs vary during the season. During preparation of NOVANA a statistical optimization project examined the possibilities to optimize the sampling frequencies and number of stations (Larsen *et al*., 2002). This also confirmed the necessity for a relatively high sampling frequency in lakes. Conversely, however, the desire for a nationwide assessment of lake status and the corresponding obligations pursuant to the Water Framework Directive and Habitats Directive mean that the number of lakes encompassed by the extensive programmes has to be relatively high, for which reason sampling frequency has to be lower.

The intensive monitoring programme continues – although in a reduced form – in the new monitoring period, among other reasons to be able to document changes in lake status caused by human activities. The intensive programme is necessary in order to meet a number of international reporting obligations (EU, etc.). Thus the intensively monitored lakes are part of Eurowaternet, and data from the intensively monitored lakes are necessary for calculating national riverine loading of the sea, etc. Under NOVANA, more-

over, these lakes will serve as a necessary part of the monitoring of biological and chemical variables in that the intensively monitored lakes can provide a more dynamic picture of lake ecological status – information that is a precondition for interpretation of the results from the extensively monitored lakes.

Under the NOVANA subprogramme for lakes, *extensive monitoring programmes* have been initiated for the large lakes (>5 ha), for the small lakes (0.1–5 ha) and for the ponds (0.01–0.1 ha). The aim of these extensive monitoring programmes is to document the status of the lakes, especially focussing on the ecological conditions. The extent of the analyses and the sampling frequency decrease with decreasing lake area. The lakes in the extensive monitoring programmes are randomly selected using a so-called stratified random design such that the various lake types and catchment types are covered representatively for the country as a whole. The data from the extensive monitoring programmes enable the status of the large Danish lakes to be assessed every third year and that of the small lakes and of the ponds to be assessed every sixth year. In the longer term it will also be possible to describe the trend in status of the various types of lake.

The extensive programmes will be reported in an integrated manner incorporating necessary results from the intensive programme in the interpretation of the status data from the extensive programmes. Correspondingly, the annual investigations in the intensively monitored lakes also serve as a reference framework for interannual variation, etc. when interpreting the results of the extensive programmes.

NOVANA will also encompass lakes from special areas of conservation (SACs) established pursuant to the Habitats Directive, and data on certain species are utilized in the subprogramme for species and terrestrial natural habitats.

As regards brackish lakes, the monitoring effort has hitherto been inadequate. Under NOVA-2003 just four brackish lakes were included in the intensive monitoring programme for lakes, which was far from sufficient to provide an adequate picture of this type of lake. Under NOVANA the monitoring of brackish lakes is part of the extensive monitoring programme, thereby providing a more adequate picture of the status of the Danish brackish lakes. The greater number of brackish lakes included in the extensive monitoring programmes during the NOVANA period is expected to enhance understanding of the ecological and environmental status of the brackish lakes.

All in all, the general part of the programme has been strengthened so as to enable regional and nationwide reporting of the ecological and environmental status and trend for Danish lakes. This has mainly been achieved through cuts in the intensive lake monitoring. As a consequence, the new subprogramme for lakes accords less importance to the direct description of causal relationships and the detailed study of lake ecosystems.

The subprogramme for lakes is thus directed towards meeting Denmark's obligations pursuant to both national legislation and international directives and agreements. The obligations met by the various parts of the programme – either alone or in combination – are summarized in Table 8.1.

In addition, data from the subprogramme for lakes will continue to be utilized in political-administrative decisions as well as to enhance scientific knowledge both nationally and internationally.

8.3 Objectives

The general objectives of the lake monitoring programme are to provide a comprehensive description of the ecological and environmental status and trend for Danish lakes in which natural and anthropogenic pressures on the lakes can be differentiated.

Table 8.1 Overview of the main requirements and obligations met by the individual monitoring programmes under the subprogramme for lakes, either alone or in combination.

	Large lakes (>5 ha)		**Small lakes (0.1–5 ha)**	**Ponds (0.01–0.1 ha)**
	Intensive (23 each year)	Extensive (204 in 3-year rotation)	Extensive (414* in 6-year rotation)	Extensive (456 in 6-year rotation)
	(23 per year)	(68 per year)	(69* per year)	(76 per year)
Environmental Protection Act	X	X	(X)	
Protection of Nature Act	X	X	X	X
Action Plan on the Aquatic Environment I	X	(X)		
Action Plan on the Aquatic Environment II	X	X		
Water Framework Directive	X	X	X	(X)
Habitats Directive	X	X	X	X
Nature Monitoring, other (Wilhjelm Committee, etc.)	X	X	X	X
Data reporting (national + international)	X	X		

* The final number of lakes will be reduced by approx. 8 per year over the period 2007–2009 to enable more monitoring of hazardous substances.

The objectives of the subprogramme for lakes are to:

- Describe **sources of pollution** and other pressures and their effects on the ecological and environmental status and trend for selected types of Danish lake
- Document the overall **effect** of national **action plans** and measures directed at the aquatic environment and nature – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve the aquatic environment and nature, including helping to develop various tools for the management of Danish lakes.

These general objectives are further elaborated in the four monitoring programmes under the subprogramme for lakes:

- Intensive monitoring programme for large lakes
- Nationwide extensive monitoring programme for large lakes
- Nationwide extensive monitoring programme for small lakes
- Nationwide extensive monitoring programme for ponds.

8.3.1 Objectives of the intensive monitoring programme for large lakes

The main objectives are to provide a detailed description of the ecological and environmental status of a few selected lakes in order to be able to demonstrate effects of both natural and anthropogenic pressures, to obtain knowledge for use in interpreting the extensive monitoring data, etc. and to develop models for impact analysis and scenario analysis, for example for the river basin districts established pursuant to the Water Framework Directive.

The more detailed objectives are to:

- Describe the status and trend for nutrient input, retention and loss, including the interannual and seasonal variation, and determine the causes of changes, for example as a result of changes in lake biological structure or the climate
- Describe the status and trend for key biological variables and relationships and determine the causes of changes, including the significance of changes in nutrient loading (external and internal) and the climate
- Describe the status and trend for biodiversity in lakes, including the occurrence of threatened species
- Describe the transient phase following changes in nutrient loading and identify factors that might contribute to a delayed response
- Assess whether changes in the climate in the form of the expected global warming and increased runoff necessitate stricter requirements as to reductions in nutrient loading
- Describe the status and trend for Danish lakes that are unaffected by human activities in order to more thoroughly describe and assess the reference status of different types of lake as required pursuant to the Water Framework Directive
- Describe the status and trend for habitat types encompassed by the Habitats Directive
- Provide knowledge that can be utilized when analysing data from the extensive monitoring of habitats encompassed by the Habitats Directive, among other reasons to also enable analysis of causal relationships in these extensively monitored water bodies
- Develop and maintain modelling tools for use in interpreting the extensive monitoring programme and reporting under Action Plan on the Aquatic Environment II (nitrogen turnover)
- Develop modelling tools for impact analysis and scenario analysis to assist in both national and regional administration of Danish lakes
- Build up general knowledge of causal relationships that can be utilized in the analysis and reporting of data from the three extensive monitoring programmes
- Establish the scientific basis for the interpretation of results from the intensive monitoring programme and to serve as a reference framework for the extensive monitoring programmes and other national and regional monitoring programmes that encompass lakes.

8.3.2 Objectives of the nationwide extensive monitoring programme for large lakes

The main objectives are to provide a general but representative picture of the ecological and environmental status and trend for the majority of large Danish lakes, in part to fulfil national requirements and in part, together with the intensive monitoring programme, to meet the general lake monitoring obligations pursuant to the Water Framework Directive and Habitats Directive by:

- Providing a differentiated picture of the status and trend for the main types of lake fo
- und in Denmark
- Describing the status and trend for the large lakes in such a manner that the results can be used to ful-

fil the general monitoring obligations pursuant to the Water Framework Directive
- Describing the status and trend for habitats encompassed by the Habitats Directive
- Describing the overall biological structure and the interactions between the key biological elements
- Assessing loading and potential threats.

8.3.3 Objectives of the nationwide extensive monitoring programme for small lakes

The main objectives are to describe the general nationwide ecological and environmental status and trend for a representative section of the small Danish lakes by:

- Describing the overall environmental status and trend on the basis of key chemical and biological variables
- Assessing loading and potential threats.

8.3.4 Objectives of the nationwide extensive monitoring programme for ponds

The main objectives are to describe the status and trend for certain important ecological and environmental aspects based on a representative selection of Danish ponds, including temporary ponds, by:

- Describing the amphibian population and its development
- Describing the macrophytes and their development
- Determining nutrient concentrations on the basis of single samples
- Describing and assessing the significance of the catchment for the quality of the water
- Describing and assessing threats to their ecological and environmental quality.

8.4 Strategy

In the subprogramme for lakes the intensive and extensive monitoring programmes are integrated so as to both ensure a detailed description of a few lake ecosystems, for example for use in determining causal relationships between anthropogenic pressures and status, as well as information of an extensive nature that can provide statistically reliable descriptions of the ecological and environmental status and trend for various Danish lake types. As far as concerns the large lakes, the results of the intensive monitoring programme can be directly utilized to interpret the results of the extensive monitoring of large lakes. Correspondingly, but less directly, the understanding of the lake ecosystems can be transferred to the interpretation of the results of the extensive monitoring programmes for small lakes and ponds, etc.

The monitoring of the large lakes (>5 ha, both freshwater, of which there are more than 600 in Denmark, and brackish) encompasses two different but mutually dependent levels of knowledge:

- A level of knowledge based on the results of intensive monitoring of 23 freshwater lakes aimed at describing the causal relationships between the important elements and processes in the lakes and between external pressures and lake status. Thus the intensive monitoring programme encompasses all important descriptive variables in order to ensure a thorough and comparable description of the ecological and environmental status and trend for these lakes. This level also enables assessment of the effects of long-term pressures such as climate changes and of their interaction with other pressures. Is the effect additive or synergistic, or do the effects counteract each other completely or partly? We must look the facts in the eye and carefully assess whether the measures presently considered sufficient to fulfil the environmental goals will also be sufficient in the future. Only an intensive monitoring programme involving continuation of the time series developed over the past 11 years can provide an adequate foundation for such an assessment. A monitoring programme based solely on extensive measurements would not be able to do so.
- A level of knowledge based on the results of an extensive monitoring programme in a representative selection of lakes in which a few variables are analysed in 204 randomly selected lakes that are monitored in three-year rotation (68 lakes per year over three years). The results can provide a general picture of the status and trend for large Danish lakes.

Under NOVANA the intensive and extensive monitoring programmes have to focus more on biological variables and biodiversity and among other things encompass the collection of data on benthic invertebrates. The results of the national intensive and extensive lake monitoring programmes and the regional supervision of lakes are collated as a national report on the status and trend for Danish lakes and the causes thereof. In Denmark there are a great number of small lakes (0.1–5 ha, approx. 32,000) that have not previously been systematically monitored. These lakes have now been included in an extensive monitoring programme encompassing 414 randomly selected lakes that are monitored in six-year rotation (69 lakes per year over six years). The aim is to be able to provide an assessment of the environmental status of these lakes every sixth year.

As regards ponds (0.01–0.1 ha, approx. 88,000 in Denmark), an extremely extensive monitoring programme will be introduced encompassing 456 ponds monitored in six-year rotation (76 lakes per year over six years). This programme focuses on amphibians and macrophytes and includes a single chemical analysis for general classification of nutrient and acidification

status. The aim is to be able to provide an assessment of environmental status and development in the amphibian and macrophyte populations in these ponds every sixth year.

NOVANA does not include regular monitoring of the occurrence of hazardous substances and heavy metals in lakes. Thus these are only included via special investigations (regional and national). As a result of the public hearing, however, NOVANA was changed such that a minor analysis programme for hazardous substances and heavy metals was included in the subprogramme for lakes. This analysis programme is not directly associated with the intensive programme or one of the extensive programmes. Depending on the aim of the specific analyses the measurements will be made where they are most meaningful. However, the analyses are planned in such a way as to ensure correlation with the other measurements in the lakes.

When drawing up the strategy and implementing it in the form of an actual monitoring programme, great importance was accorded to the inventory of monitoring requirements, as well as to the conclusions and recommendations of the international evaluation of NOVA-2003 and the statistical optimization project. Where possible, the recommendations of the international evaluation panel have been followed.

The lake monitoring programme under NOVA-2003 received a very good evaluation, and it was recommended that the programme be continued relatively unchanged (extent, frequencies, etc.). However, the evaluation panel concluded that there are too few reference lakes among the intensively monitored lakes, and that the number of brackish lakes is too small. Contrary to the recommendation, it has been necessary to reduce the number of intensively monitored lakes so as to be able to prioritize the ecological elements and the extensive monitoring programmes. As a consequence of the recommendations, moreover, the number of reference lakes has been increased, and the brackish lakes have been transferred to the extensive monitoring programmes. In addition, the evaluation concludes that the quality assurance requirements should be improved in the subprogramme for lakes. The Topic Centre for Inland Surface Waters fully agrees, but this will first be effectuated in connection with the Technical Instructions.

The statistical optimization project recommended that the relatively high sampling frequency used in the lake monitoring should be continued. This recommendation has been followed in the remaining lakes in the intensive monitoring programme. In planning the extensive monitoring programmes, however, a low sampling frequency (7, 5 and 1 sample(s) per year) had to be selected in order to attain the desired coverage (area and number) of the most important types of lake in Denmark. This is considered acceptable, though – also in relation to the results of the statistical optimization project – as the strength of the extensive programmes is their relatively high coverage. Details concerning lake dynamics – including seasonal variation – are derived from the intensively monitored lakes.

The statistical optimization project also suggested that changes to the analysis methods might improve interpretation of the data. A working group on multivariate analysis techniques was therefore set up under the Topic Centre for Inland Surface Waters to draw up proposals for new methods (among other things to improve utilization of concomitant measurements). In addition, the Topic Centre is working to develop tools for analysing and disseminating the results of the lake monitoring programme.

8.4.1 Relationship to other subprogrammes

A number of the NOVANA watercourse stations serve as nutrient and organic matter transport monitoring stations in both the subprogramme for lakes and the subprogramme for watercourses.

The subprogramme for lakes utilizes certain results from other subprogrammes. The most important are nutrient background concentrations, which are used in source apportionment of nutrient input to lakes (Topic Centre for Inland Surface Waters) and calculations of nutrient discharges from point sources and sparsely built-up areas for use in source apportionment, scenario analyses, etc. (Topic Centre for Hydrological Point Sources).

The Topic Centre for Air Quality provides estimates of nitrogen and phosphorus deposition on lakes which, together with estimates of groundwater concentrations (Topic Centre for Groundwater and Wells), are necessary for correct calculation of lake nutrient balances.

The subprogramme for lakes also requires that various other data are available to facilitate interpretation of the results. The most important types of data are climate data (temperature, precipitation, evaporation, wind and sun influx), agricultural data and various GIS data sets (for example as available via the Area Information System, AIS) providing information on soil type, land use, etc.

Part of the lake monitoring strategy is the inclusion of all relevant data about the lakes. Thus supplementary data from regional supervision of lakes are also included, as are data generated by the regional authorities in connection with the setting and control of quality objectives. Other investigation data from the regional authorities are of great value in connection with special problems (e.g. the possibilities for lake restoration).

The overall design of the various lake monitoring programmes is summarized in Table 8.2.

Table 8.2 Elements in the intensive and extensive lake monitoring programmes.

Element	Large lakes (>5 ha)		Small lakes (0.1–5 ha)	Ponds (0.01–0.1 ha)
	Intensive n=23	Extensive n=204	Extensive n=414*	Extensive n=456
Physical-chemical conditions:				
- Physical measurements	x	x	x	x
- Water and nutrient balances	x	-	-	-
- Source apportionment	x	-	-	-
- Nutrients	x	x	x	x
- Hazardous substances	x	-	-	x
- Heavy metals	x	-	-	-
Biological conditions:				
- Phytoplankton	x	x	-	-
- Zooplankton	x	x	-	-
- Macrophytes	x	x	x	x
- Benthic invertebrates	x	x	-	-
- Fish	x	x	-	-
- Birds	x	-	-	-
- Amphibians	-	-	-	x
Sediment:				
- Nutrients	x	-	-	-
Loading and threats (GIS etc.)		x	x	x

* The final number of lakes will be reduced by approx. 8 per year over the period 2007–2009 to enable more monitoring of hazardous substances.

Table 8.3 Summary of the four monitoring programmes under the subprogramme for lakes indicating the size range and number of lakes investigated and the monitoring rotation period.

	Area (ha)	Number of lakes	Rotation (yrs)
Intensive monitoring programme for large lakes	>5	23	1
Extensive monitoring programme for large lakes	>5	204	3
Extensive monitoring programme for small lakes	0.1–5	414*	6
Extensive monitoring programme for ponds	0.01–0.1	456	6

* The final number of lakes will be reduced by approx. 8 per year over the period 2007–2009 to enable more monitoring of hazardous substances.

The combined strategy involving a few intensively monitored lakes (detailed investigations of physical-chemical conditions and the most important biological components) and many representatively selected extensively monitored lakes (limited monitoring programme) yields a lake monitoring programme that is well suited for determining relationships between pressures and lake status.

With the selected strategy, NOVANA will be able to provide considerably better regional and nationwide assessment of lake ecological and environmental status than was previously the case.

8.5 Programme content

Over the programme period as a whole (6 years) the subprogramme for lakes will encompass 23 intensively monitored large lakes and 1,074 extensively monitored large lakes, small lakes and ponds (Table 8.3). The intensive monitoring programme for large lakes is carried out every year, while the extensive monitoring programmes are carried out in either three-year rotation (large lakes) or six-year rotation (small lakes and ponds).

The content, analysis frequency and number of lakes encompassed by each of the monitoring programmes are adapted to the purpose of the individual programmes. This has been achieved by collating previous experience with the lake monitoring programme, among other means through the statistical optimization project (Larsen *et al.*, 2002), previous experience with the design of lake monitoring programmes (Søndergaard *et al.*, 1999) and the recommendations of the international evaluation panel (Nixon *et al.*, 2002). The final choice of variables, frequencies, etc. is a compromise between resource consumption and the optimal number of sampling occasions and stations

needed for the programme to demonstrate changes and to achieve the required degree of detail in the various programmes.

Each of the four monitoring programmes is described below indicating the variables measured and the sampling frequency. Details concerning the background, sample collection, analysis methods (e.g. detection limits and analysis methods), data processing and interpretation are available in the Internet-based Technical Instructions for lake monitoring under NOVANA.

8.5.1 Intensive monitoring programme for large lakes

Nutrient dynamics is described in detail for the lakes in the intensive monitoring programme (Table 8.4). Input and output of water, total-N, total-P and total-Fe are determined through water chemistry measurements made with an annual sampling frequency of 12–26 depending on the runoff pattern. The nutrient content of the lake water is described through measurement of both the total and inorganic fractions of nitrogen and phosphorus; in stratified lakes the measurements are also made in the bottom water. The sediment content of total-P is determined once every sixth year to support the analyses of nutrient turnover in the lakes. Buffering capacity and acidification status are described through measurement of pH and alkalinity, which, together with total-Fe, etc., are utilized in the description of nutrient dynamics in the lakes. In addition, the programme includes measurement of oxygen and temperature profiles, conductivity and Secchi depth for use in describing the physical conditions in lake water.

Table 8.4 Intensive monitoring programme for large lakes (>5 ha). Summary of the variables measured and the annual frequency of sample collection in the epilimnion, hypolimnion and in the inlets/outlets. (Hypolimnion samples are only collected if a thermocline has formed, and the frequency given is a rough average for all lakes (the actual frequency in the individual lakes range from 0 to 15)).

Variable	Lake water (frequency)		Inlets/outles
	Epilimnion	Hypolimnion	(No. of samples per year)
Water chemistry and physical analyses:			
pH	19	5	12–26
Alkalinity	19	5	
Nitrite+nitrate-N	19	5	
Ammonium-N	19	5	
Total-N	19	5	12–26
Total-P	19	5	12–26
Dissolved-P	19	5	12–26
Chlorophyll *a*	19		
Total-Fe	19		12–26
Colour value	19		
Cations[2]	1		
Silicate+silica	19		
Suspended matter	19		
Loss on combustion of suspended matter	19		
Secchi depth[1]	19		
Oxygen and temperature profile[1]	19	5	
Water level[1]	19 or continuous		
Conductivity[1]	19	5	
Measurement of water flow[1]			12–26 or continuous
Sediment chemistry:			
Heavy metals and hazardous substances[3]	1/6		
Biological analyses:			
Phytoplankton: Composition, abundance and biomass	19		
Zooplankton: Composition, abundance and biomass	19		
Benthic invertebrates	1		
Birds	1		
Macrophytes: Depth distribution, coverage, dominant species, species list	1		
Reed belt distribution	1/6		
Fish	1/6		

[1)] Field measurements incl. oxygen and temperature depth profiles. Conductivity can also be measured in the laboratory immediately upon return from the field.

[2)] Winter sample.

[3)] Programme not yet finalized (to be carried out in the period 2007–2009)

Table 8.5 Extensive monitoring programme for large lakes (>5 ha). Summary of the variables measured, the annual frequency of sample collection and the number of samples per year. The seven samples are collected monthly from 1 April to 30 September with a single winter sample being collected in November.

Variable	Frequency	No. of samples per year
Water chemistry and physical analysis:		
- Conductivity	1/3 (every third year)	7
- Salinity	1/3	7
- Oxygen and temperature profiles	1/3	7
- pH	1/3	7
- Colour value	1/3	7
- Alkalinity	1/3	7
- Total-N	1/3	7
- Total-P	1/3	7
- Chlorophyll *a*	1/3	7
- Secchi depth	1/3	7
- Sulphate[1]	1/3	1[1]
Phytoplankton:		
- Genus composition	1/3	1
- Biomass	1/3	1
Zooplankton:		
- Group composition	1/3	1
Macrophytes:		
- Depth distribution	1/3	1
- Dominant species	1/3	1
- Species list	1/3	
Benthic invertebrates	1/3	1
Fish	1/6	1
Loading and threats (GIS etc.)	1/3	1

[1)] Only measured in winter samples.

The amount of organic matter in the lake water is measured in two different ways: 1) The total amount of suspended matter is measured together with the loss on combustion, and 2) Chlorophyll *a* is measured as an estimate of the photosynthetic activity (primarily phytoplankton) in lakes. In addition, a number of biological elements are investigated. Phytoplankton and zooplankton abundance and biomass are determined throughout the year, and zooplankton grazing pressure on the phytoplankton is determined. Macrophyte coverage and the density of benthic invertebrates and birds is investigated once annually. Fish and reed belt distribution are investigated once every sixth year.

The intensive measurements in the lakes enable their ecosystems to be described in detail, thereby facilitating interpretation of nutrient turnover, biological status and interactions. They also enable causal relationships to be demonstrated between anthropogenic pressures and the lakes' response, both physical-chemical and biological. At the same time, it is possible to describe the influence of climatic and other natural factors on the lakes and their response to these influences.

8.5.2 The extensive monitoring programme for large lakes

The monitoring programme is carried out in three-year rotation such that the selected lakes are investigated every third year (Table 8.5). Water chemistry and physical conditions are measured monthly during the growth season (April–September) on the basis of a few key variables. A single winter sample is used as a reference for summer nutrient levels and to describe buffering capacity and acidification status as winter samples are better suited for this purpose than summer samples.

The biological elements are measured extensively as follows: Phytoplankton and zooplankton are investigated once in August, macrophytes are investigated once in July/August, and fish are investigated once per six-year period in August/September (to be investigated the first time during the period 2004–2006).

The extensive monitoring programmes do not include direct measurement of nutrient input, but loading and potential threats are determined based primarily on inspection and GIS-based analyses.

By incorporating results from the intensive lake monitoring programme, the extensive programme for large lakes enables the ecological and environmental status of large Danish lakes to be determined in detail every third year. After six years, moreover, it will be possible to interpret possible trends detected.

8.5.3 The extensive monitoring programme for small lakes

The monitoring programme is carried out in six-year rotation such that the selected lakes are investigated every sixth year (Table 8.6). Water chemistry and physical conditions are measured monthly during the summer period (May–September) on the basis of a few key variables. Among other things these measurements provide an impression of the nutrient and acidification status of the small lakes. The biological response is described through concomitant measurement of Secchi depth and chlorophyll *a*. In addition, the programme includes a single annual investigation of macrophyte distribution. Loading and threats are determined based primarily on inspection and GIS-based analyses.

The investigations enable the ecological and environmental status of small Danish lakes to be described, although the random sample is small (<1%). After a longer time series has been established, moreover, the investigations will enable the trend in the status of the lakes to be assessed.

8.5.4 The extensive monitoring programme for ponds

The monitoring programme is carried out in six-year rotation such that the selected ponds are investigated every sixth year (Table 8.7). The programme mainly consists of the investigation of macrophytes and amphibians once during the year of investigation supplemented by a single measurement of the physical-chemical conditions. As with the other extensive programmes, loading and threats are determined based primarily on inspection.

The investigations enable the ecological and environmental status of selected ponds to be described. After a longer time series has been established, moreover, the investigations will enable the trend in the status of the ponds to be assessed.

8.5.5 Localization and selection of the lakes and ponds

Localization and selection of the lakes and ponds for the various monitoring programmes will be carried out in autumn 2003 on the basis of proposals from the Topic Centre for Inland Surface Waters in dialogue with the individual regional authorities.

8.6 Main changes relative to NOVA-2003

There are major principal differences between the subprogramme for lakes under NOVA-2003 and that under NOVANA. Thus instead of only encompassing intensive monitoring of a few lakes as in NOVA-2003, the subprogramme now also encompasses both a reduced version of the intensive monitoring programme and three extensive monitoring programmes. Only minor changes have been made to the investigations themselves, however.

Table 8.6 Extensive monitoring programme for small lakes (0.1–5 ha). Summary of the variables measured, the annual frequency of sample collection and the number of samples per year.

Variable	Frequency	No. of samples per year
Water chemistry and physical analyses:		
- Conductivity	1/6 (every sixth year)	5
- Salinity	1/6	5
- Oxygen and temperature profiles	1/6	5
- Water temperature	1/6	5
- pH	1/6	5
- Alkalinity	1/6	5
- Total-N	1/6	5
- Total-P	1/6	5
- Chlorophyll *a*	1/6	5
- Secchi depth	1/6	5
Macrophytes:		1
- Depth distribution	1/6	1
- Dominant species	1/6	1
- Species list	1/6	1
Loading and threats (GIS etc.)	1/6	1

Table 8.7 Extensive monitoring programme for ponds (0.01–0.1 ha). Summary of the variables measured, the annual frequency of sample collection and the number of samples per year.

Variable	Frequency	No. of samples per year
Water chemistry and physical analyses:		
- Conductivity	1/6 (every sixth year)	1
- Salinity	1/6	1
- Oxygen and temperature profiles	1/6	1
- Water temperature	1/6	1
- pH	1/6	1
- Alkalinity	1/6	1
- Total-N	1/6	1
- Total-P	1/6	1
- Chlorophyll *a*	1/6	1
- Secchi depth	1/6	1
*Hazardous substances**		
Macrophytes:	1/6	1
- Dominant species	1/6	1
- Species list	1/6	1
Amphibians	1/6	1
Loading and threats	1/6	1

* Programme not yet finalized (to be carried out in the period 2007–2009.

Table 8.8 Overview of the main requirements and obligations indicating whether the Topic Centre for Inland Surface Waters considers these to be fulfilled for lakes, and whether there are matters that remain to be resolved. The latter are briefly described.

	Fulfilled	Matters to be resolved	
Environmental Protection Act	x		
Protection of Nature Act	x		
Action Plan for the Aquatic Environment I	x		
Action Plan for the Aquatic Environment II	x		
Water Framework Directive (surveillance part)	x	Yes	The final requirements are not yet known
Habitats Directive	x		
Nature Monitoring, other (Wilhjelm Committee etc.)	x	Yes	Coverage of ponds, etc. is less than desired by the Wilhjelm Committee
Data reporting (national + international)	x	Yes	Lake coverage by the intensive monitoring has been reduced considerably
Statistical optimization	x		
International evaluation	x		

The main changes relative to NOVA-2003 are:

- The number of intensively monitored lakes has been reduced from 31 (originally 37) to 23
- The actual catchment analyses have been deleted from the intensive monitoring programme
- Fish fry investigations have been deleted from the intensive monitoring programme
- Bird and benthic invertebrate investigations have been added to the intensive monitoring programme
- The biological elements, including a measure of biodiversity, have been accorded greater priority
- New extensive programmes encompassing a large number of lakes have been established
- The reporting strategy has been changed significantly in that the focus has been switched from reporting of the individual lakes to reporting of the lakes within a catchment or of a particular type.
- A special programme has been added for investigation of hazardous substances and heavy metals in lakes.

8.7 Theme-specific assumptions

The subprogramme for lakes utilizes data from the subprogrammes for point sources, for watercourses, for background monitoring of air quality and atmospheric deposition and for groundwater. As far as concerns the subprogramme for watercourses, a precondition for the subprogramme for lakes is that a number

of the watercourse stations can be used as lake inlet and outlet stations.

8.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

The subprogramme for lakes naturally encompasses a number of compromises. The Topic Centre for Inland Surface Waters nevertheless believes that it is possible to fulfil the obligations detailed in the inventory of monitoring requirements pursuant to both EU directives and Danish legislation.

The final evaluation of the subprogramme relative to the general monitoring obligations pursuant to the Water Framework Directive must await Parliament's final decision about implementation of the Water Framework Directive.

Table 8.8 summarizes the Topic Centre for Inland Surface Water's assessment of the final subprogramme in relation to the main requirements and obligations.

The amount of monitoring data to be reported nationally and internationally was reduced as a consequence of the cuts in the intensive programme. In some cases, though, for example general state-of-the-environment reports, it is possible to compensate for this using results from the extensive monitoring programmes. In contrast, this is not possible in cases where calculations of nutrient loading, nutrient balances, etc. are a precondition, for example HELCOM and Eurowaternet.

In the light of the Water Framework Directive and Habitats Directive the number of intensively monitored lakes cannot be reduced further, among other reasons because they comprise a necessary reference framework for interpreting the data from the extensive monitoring programmes in relation to these directives.

After the public hearing a monitoring programme for hazardous substances and heavy metals was added to the subprogramme for lakes, but the details of the investigations have not yet been finalized (the budget in 2002 prices is DKK 1.2 million over the six-year NOVANA period).

All in all, the Topic Centre for Inland Surface Waters believes that within the framework permitted, the design of the subprogramme fulfils as many requirements and obligations as possible. This has been at the expense of the more detailed understanding of lake dynamics and trends, just as the possibilities to build up knowledge within the framework of the subprogramme have diminished.

[Tom side]

9 Marine waters

9.1 Introduction

The monitoring of Danish marine waters focuses on three elements:

1. Eutrophication, incl. physical conditions and modelling
2. Species and habitats
3. Hazardous substances and biological effect monitoring.

Monitoring of environment and nature (ecological status) in the Danish fjords and marine waters is carried out cooperatively by the regional authorities and the National Environmental Research Institute (NERI). Generally speaking, the regional authorities are responsible for monitoring the fjords and coastal waters, while NERI is responsible for monitoring the open marine waters.

9.2 Background and status

The monitoring of the Danish marine waters is primarily motivated by a number of environmental problems such as oxygen deficit, the occurrence of harmful algal blooms (HABs) or hazardous substances, a decline in submerged aquatic vegetation or coastal fish populations and changes in the biological structure of the fjords. The majority of these problems became clearly apparent at the end of the 1970s and early 1980s. During the 1980s and 1990s, a number of monitoring activities and research projects showed that several of these problems were to some extent due to the input of pollutants such as nutrients and hazardous substances.

The Danish open marine waters lie in the transitional zone between the brackish Baltic Sea and the saline North Sea. This creates many different marine ecosystems ranging from small closed coves with standing water of low salinity to open marine waters of high salinity and high throughflow. There is considerable variation from the inner parts to the outer parts of fjords, from the coastal marine waters and onwards out into the open marine waters. These areas are characterized by sudden changes in temperature and salinity due to changed wind and current conditions. Ecological quality is also strongly affected by human activities. The high population density and intensive exploitation of the countryside result in pollutant discharges and losses to the sea. At the same time, the high level of commercial fishery places pressure on the marine ecosystems. In addition, there are pressures from other marine activities such as ship traffic, sand and gravel extraction, construction work and oil and gas extraction.

The monitoring programme is designed to take into account the great variation in physical, chemical and biological conditions in the sea and in the various pressures upon it.

Actual monitoring of fishery and the pressures it places on marine ecosystems is outside the scope of the monitoring programme. It is generally accepted that fishery is one of the main pressures, cf. Figure 9.1. Over the past 100 years, fishery utilizing bottom gear and various types of net have changed the species composition and distribution of commercial species of fish. The size of the populations has changed. Sometimes this is due to overfishing, while other times changed hydrographic conditions have played the major role. In the areas where trawl fishery is carried out the composition of the benthic invertebrate community has changed, as has the structure of certain habitats. The Danish Institute for Fisheries Research, which is responsible for ensuring that fishery is carried out in a scientifically defensible and sustainable manner, performs various forms of monitoring of all the commercially important fish species, both in the open marine waters and in a number of coastal waters. These monitoring activities are not encompassed by NOVANA.

Large-scale monitoring of ecological status in the Danish open marine waters did not start until 25 years ago. In parts of the open marine waters and in some coastal waters the monitoring started in the mid 1970s and has been regularly expanded during the 1980s. Systematic monitoring of coastal waters in all counties was first introduced in connection with the 1988 Nationwide Monitoring Programme under the Action Plan on the Aquatic Environment. At the same time, monitoring of the open marine waters was intensified.

9.2.1 Inventory of monitoring requirements

The monitoring of ecological status in the Danish open marine waters is need-controlled, cf. Part 1 of the Programme Description. Thus the monitoring programme

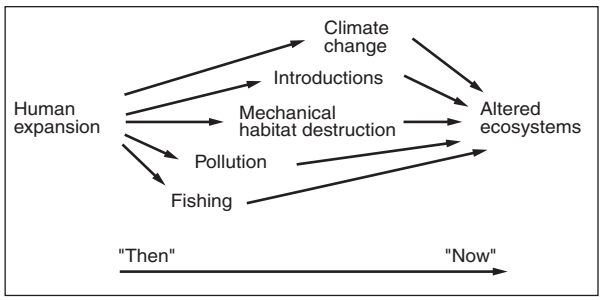

Figure 9.1 Summary of the factors that affect ecological status in Danish marine waters. The subprogramme for marine waters mainly focuses on pollution, which in the Danish marine waters primarily encompasses nutrients and hazardous substances, and to a much lesser extent on the other pressures. After Jackson *et al.*, 2001.

and reporting of the results are founded on the monitoring requirements inventoried by the Danish EPA and the Danish Forest and Nature Agency.

Denmark has a number of international obligations (e.g. pursuant to HELCOM, OSPAR and the North Sea Conferences) and is subject to many EU obligations (e.g. pursuant to the Water Framework Directive and the Habitats Directive). At the national level several action plans (first and foremost the Action Plans on the Aquatic Environment) have been adopted concerning protection and monitoring of ecological status in the marine waters around Denmark.

Together, the international obligations in the form of conventions and directives comprise a large number of obligations that largely concern the same features and are a result of negotiated compromises. Furthermore, it is not always obvious which of the obligations is the most stringent and which thereby represents the minimum requirement that Denmark must meet.

In the national perspective the Action Plans on the Aquatic Environment are important. It was Action Plan on the Aquatic Environment I that led to the establishment of a coordinated, nationwide monitoring programme. The requirements of the Action Plans on the Aquatic Environment regarding monitoring of ecological status in the Danish open marine waters are very general in character compared with EU directives and marine conventions.

9.2.2 Scientific status

Since the last revision of the marine monitoring programme in 1997, new knowledge has been obtained through a number of national and EU-financed research projects. The results of these research programmes together with the knowledge and experience gained from the monitoring performed during the period 1988–2001 comprise the scientific background for the revision of the programme content.

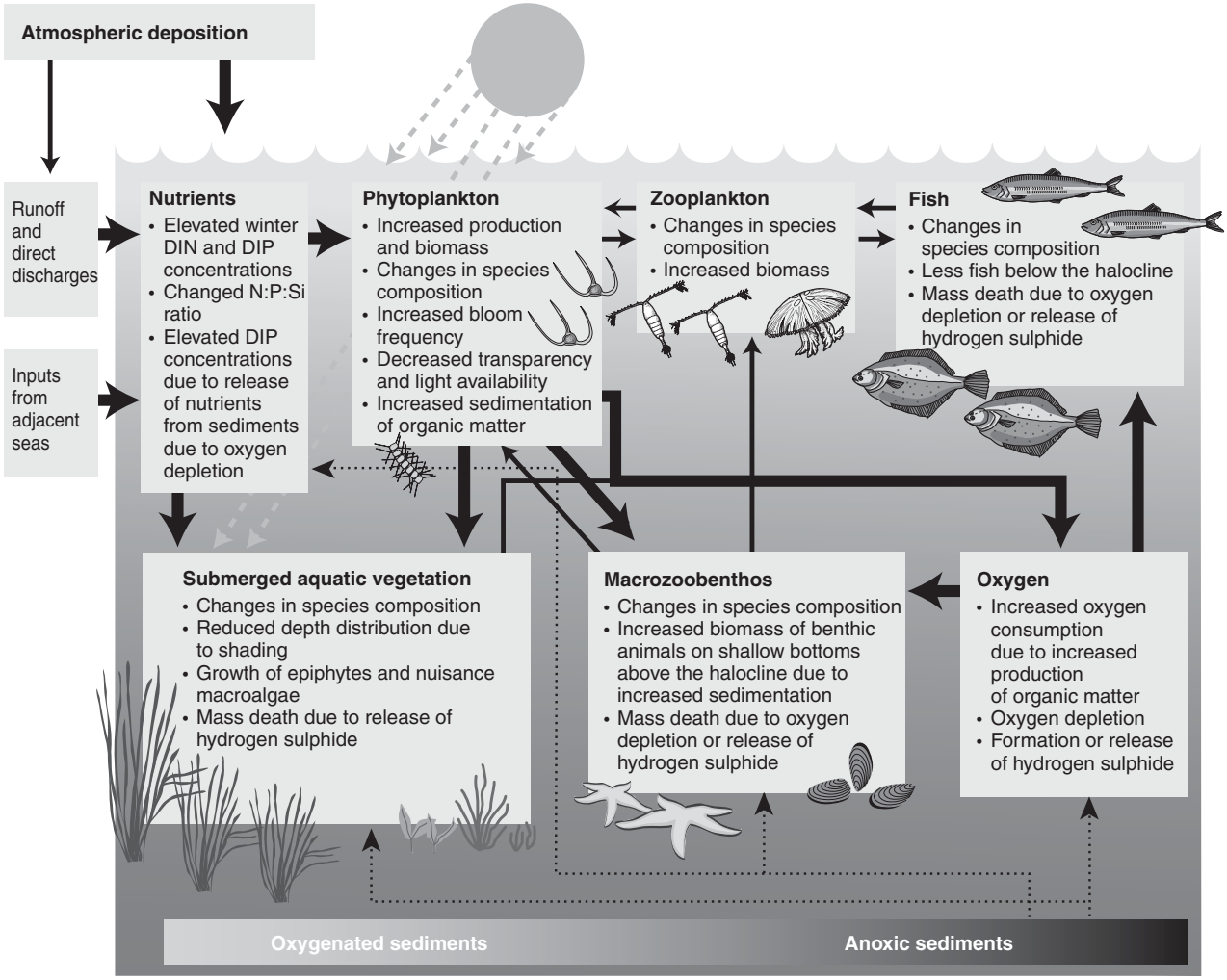

Figure 9.2 Conceptual model of marine eutrophication. The arrows indicate interactions between the various ecological components. A pristine ecosystem in Danish open marine waters was probably characterized by: (1) a short pelagic food chain (phytoplankton → zooplankton → fish), (2) a natural composition of plankton and benthic invertebrates, and (3) a natural distribution of submerged aquatic vegetation. Enhanced nutrient levels result in changes in marine ecosystem structure and function as indicated by the thick lines. The broken lines indicate the release of hydrogen sulphide (H_2S) and phosphorus, a release that is correlated with oxygen deficit. After Ærtebjerg *et al.*, 2003.

The monitoring hitherto undertaken has focused on nutrients, plankton, submerged aquatic vegetation and benthic invertebrates. Experience from the Nationwide Monitoring Programme 1988–97 and NOVA-2003 shows that the indicators and quality elements employed are generally good at describing the state and trend in the marine waters. Monitoring of the occurrence and effects of hazardous substances including heavy metals has been part of the programme since 1998. Experience so far is relatively limited, but it is generally accepted that the selected substances, matrices and frequencies are appropriate.

9.2.2.1 Eutrophication

The greatest and most obvious effect of human activity on the marine environment is probably eutrophication. Eutrophication, which means "well-nourished", results from nutrient pollution. The effects of eutrophication are well documented for the Danish marine waters and the adjoining marine waters in the Baltic Sea as well as in the southern part of the North Sea. The monitoring programme focuses on a number of chemical and biological indicators and quality elements that respond to changes in nutrient levels, and on a number of physical conditions of relevance for the chemical and biological conditions.

The concentration and turnover of nitrogen, phosphorus and silicon are decisive for the biological system in marine waters. Phytoplankton growth is generally limited by nutrient input from the end of winter to late autumn. Enhanced input of nutrients therefore leads to a higher concentration of planktonic algae. This increase in the concentration of planktonic algae subsequently gives rise to a number of negative effects on the aquatic environment. Analyses of data from Danish fjords and coastal waters have shown that there is a close correlation between changes in the biological system and the concentration of nutrients (Borum *et al.*, 1990; Sand Jensen *et al.* 1994; Kaas *et al.*, 1996; and Nielsen *et al.*, 2001). In turn, nutrient levels are significantly correlated to the magnitude of the inputs (Kaas *et al.*, 1996).

Nutrient conditions in the open waters are affected by the ability of fjords and coastal waters to retain and convert nutrients input from the land. The fjords therefore act as nutrient filters in relation to land-based discharges. Mass balances for nine Danish fjords indicate that due to these processes, many fjords comprise an effective nitrogen filter for the open marine waters. In contrast, seven of the nine fjords exported phosphorus to the adjoining marine waters (Kaas *et al.*, 1996). The seasonal variations are great, however, and it is therefore necessary to assess the filter effects – i.e. the mass balances – at more frequent intervals.

Previous investigations in connection with monitoring and research have shown that nutrient concentrations vary considerably throughout the year and that the sampling frequency should therefore be sufficiently high to cover this variation.

Sediment processes affect nutrient conditions in the water and hence the availability of nutrients for the primary producers. Nitrogen is lost through denitrification in the sediment etc., and both nitrogen and phosphorus are removed by "burial" of organic matter in the sediment. Upon mineralization of the sedimented organic matter, inorganic phosphorus and nitrogen are released that can migrate into the overlying water column. Nutrient turnover and the magnitude of the fluxes depend on the type of sediment and the presence of submerged aquatic vegetation (e.g. eelgrass and macroalgae) and other algae (microalgae and algal mats) as well as of bioturbating animals. Oxygen conditions also affect nutrient release, and poor oxygen conditions or oxygen deficit enhance the release of phosphorus. In the shallow Danish fjords and coastal waters, phosphorus release from the sediment is consequently often high during the summer half year.

Part of the organic matter that the plants produce will be input to the seabed as living or dead material. Here the organic matter will be metabolized through a number of metabolic processes, thereby releasing the bound nutrients. Degradation of the organic matter involves the consumption of oxygen, and the greater the amount of matter input to the seabed, the greater the amount of oxygen consumed for degradation. Oxygen deficit (hypoxia/anoxia) occurs regularly in Danish marine waters. Generally, the occurrence of oxygen deficit depends on a high input of organic matter to the sediment, while the actual situation is largely determined by the meteorological conditions. Oxygen deficit typically occurs in periods with warm, calm weather, where the bottom water receives only little new oxygen because the water masses are stratified or because the water exchange is low.

Phytoplankton comprise an important element in aquatic ecosystems. Variations in the amount and composition of phytoplankton decisively influence biological structure in marine waters. The biomass of phytoplankton determines the percentage of the light absorbed by the phytoplankton and hence available for production of organic matter. The phytoplankton biomass thus helps determine the potential primary production. In addition, the phytoplankton biomass is a measure of the amount of food that is available for zooplankton. The phytoplankton biomass is the result of the balance between growth, i.e. primary production, and loss due to grazing and sedimentation. Phytoplankton are grazed by zooplankton, and in shallow waters also by mussels and other benthic filter feeders. A study of Danish fjords shows that plankton biomass is mainly regulated by nitrogen availability and the amount of benthic grazers, and that a 25% reduction in chlorophyll concentration is achieved each time the nitrogen concentration is halved (Kaas *et al.*, 1996). Phytoplankton species composition is a major determinant of biological state in that food chain composi-

tion and nutrient turnover are affected when the structure of the phytoplankton community changes.

Phosphorus also plays a role for the phytoplankton, especially in the spring, when phosphorus is usually the limiting nutrient for phytoplankton production and biomass in fjords and other closed waters.

In coastal and open marine waters as well as in some fjords, zooplankton grazing is a major cause of phytoplankton loss. Zooplankton community structure and biomass thus provide information on phytoplankton regulation and nutrient and carbon turnover, and hence are important elements for the understanding of causal relationships. The role of mesozooplankton in marine ecosystems has long been known, but the significance of microzooplankton has only become fully acknowledged over the past decades. In contrast to the mesozooplankton, the growth rates of microzooplankton correspond to those of phytoplankton. In principle, therefore, changes in phytoplankton biomass and species composition should be reflected in the microzooplankton biomass.

Submerged aquatic vegetation (SAV) is well suited as an indicator of the state of and changes in the surrounding environment because its lifetime is relatively long and its occurrence is affected by the physical and chemical conditions in the environment. Its growth is mainly regulated by light and nutrients, while the loss of plant biomass is mainly due to physical disturbances and in some cases grazing and disease. For example, the depth distribution and coverage of the plants in deep water are highly reflective of the light conditions in the water column and hence also of the nutrient inputs (Sand-Jensen *et al.*, 1994 and Nielsen *et al.*, 2001).

The benthic macrofauna is a key part of the marine ecosystem that filters and degrades material produced in the water column. It also comprises an important food resource for higher trophic levels such as fish. In shallow waters the benthic fauna metabolizes a large part of the pelagic production. This is particularly the case for the filter feeders, which are potentially able to control the pelagic phytoplankton in many areas (Cloern, 1996 and Kaas *et al.*, 1996). Furthermore, the benthic fauna in shallow waters is very easily affected by stochastic events such as oxygen deficit and ice winters, with considerable resultant variation in biomass. These fluctuations in biomass are of great significance for the ecosystems' biological structure and hence for the impact of eutrophication in these waters.

Modelling and quantification of water and nutrient transport were not integrated in monitoring and assessment of the environmental state of the inner Danish marine waters until the NOVA-2003 programme. Previously, i.e. in the period up to 1997, water and nutrient transport were largely estimated through qualified assessments and correlation-based analyses. Knowledge of the hydrographic conditions in the Danish open marine waters has been enhanced by research programmes such as Hav90, which have also resulted in the development and establishment of hydrographic models for the Danish open marine waters.

Calculations of water and nutrient transports are a precondition for the assessment of environmental status, both in the more open marine waters, where monitoring frequencies are relatively low, and in the coastal waters, where the land-based inputs are modest in relation to inputs from the adjoining marine waters. The necessary information about inputs to Danish open marine waters from adjoining marine waters and the significance of foreign sources can only be obtained by modelling. Boundary conditions are calculated to enable the Counties to assess the influence of the more distant open marine waters on ecological status in the coastal waters. In some areas close to the coast it is difficult for models to correctly calculate the boundary data. In NOVANA this issue will be accorded special attention, both in connection with the call for tenders for the model complex and in the actual operational phase.

Under the NOVA-2003 programme, modelling of nutrient retention in selected fjords became an integral part of the monitoring. The modelling is carried out with the aim of: (1) Determining water and nutrient exchange with adjoining waters, (2) supporting assessment of the fjord's state and biological events in relation to natural variations in the physical conditions, and (3) correlating nutrient exchange with local inputs and internal turnover.

The activities hitherto carried out have provided information on the retention of nutrients in the fjords and on the exchange of nutrients between the fjords and the adjoining coastal waters. These activities continue under the NOVANA programme. At the same time, the focus on the more open coastal waters will be increased as models are now to be established and run for the more "open" coastal waters.

9.2.2.2 Biodiversity and habitats

A new aspect to the subprogramme for marine waters is the special focus on biodiversity and protected habitats and species. As part of the assessment of environmental conditions the predecessors to the NOVANA programme focussed on the biological conditions, especially phytoplankton, zooplankton, macroalgae in coastal waters and on stone reefs and soft-bottom macrofauna. It will be possible to utilize the information contained in these data in the future assessments of marine biodiversity. Similarly, part of the routine eutrophication monitoring concerning both biological quality elements and supporting variables could support the general assessment of biodiversity in the Danish open marine waters.

As regards the monitoring of marine biodiversity the programme will provide information on the most important groups of organisms:

- Phytoplankton (species composition, abundance and biomass)
- Zooplankton (micro- and mesozooplankton – species composition, abundance and biomass)
- Submerged aquatic vegetation (macroalgae on hard substrate and rooted angiosperms (eelgrass) – species composition and coverage)
- Fauna on soft bottom (species composition, abundance and biomass)
- Fauna on hard substrate (semiquantitative studies of species composition and abundance)
- Fish (species composition and size distribution).

Monitoring of sea birds and marine mammals is not included in the subprogramme for marine waters, but rather in the subprogramme for species and terrestrial natural habitats.

In Denmark there are 76 marine Natura 2000 sites that have in part been designated because of the habitats they contain. An annex to Part 3 of the Programme Description lists the basis for designating the individual sites. The protected marine habitats are:

1. Reefs
2. Submarine structures made by leaking gasses (so-called "bubble reefs")
3. Large shallow inlets and bays
4. Coastal lagoons (excl. brackish lakes and ponds)
5. Mudflats and sand flats not covered by seawater at low tide
6. Estuaries (river mouths)
7. Sandbanks which are slightly covered by sea water all the time
8. Marine caves.

Pursuant to the Habitats Directive Denmark is required to monitor all special areas of conservation (SACs) except those considered unimportant and which are solely designated because the habitat type occurred in a Natura 2000 site that has been designated for some other reason. The expected extent of the monitoring of marine habitats is summarized in Table 9.1. The monitoring is based on a representative selection of habitats. Thus not all sites are included, neither all special areas of conservation, nor all the habitats for which the sites were designated.

In principle, the monitoring of the localities included in the monitoring programme should encompass the quality elements upon which the conservation objective is based as well as those elements known to respond to changes in pressures from human activities in the site or catchment in question.

As conservation objectives have not yet been established, the monitoring activities have been designed around the fact that discharges and inputs of nutrients are the factors of greatest significance for changes in the ecological status of both the SACs and the habitat types within the individual SACs. Marine biodiversity and the status of the individual habitat types will be assessed partly through the specific subprogramme for species and terrestrial natural habitats and partly by using data from the eutrophication monitoring.

9.2.2.3 Hazardous substances and biological effect monitoring

Hazardous substances and heavy metals were not included in the Nationwide Monitoring Programme until 1998. However, heavy metals have been monitored in biota at four stations in the open marine waters since 1979 in connection with Denmark's international obligations, and two background level studies have been carried out in 1985 and 1990 in which the concentrations of heavy metals and selected organic compounds were measured. Several Danish Counties have investigated heavy metals and hazardous substances in the coastal waters, but systematic nationwide monitoring has not previously been carried out.

Charting of the geographic distribution and temporal trends in the occurrence of hazardous substances and heavy metals in the marine environment is usually based on measurements of the concentration in biota (e.g. in fish or mussels) or in sediment. This provides information on the inputs of pollutants to the water body over a longer period of time, while a corresponding single measurement of the concentration in the water phase only provides a snapshot of the concentration.

Table 9.1 Expected extent of monitoring of marine habitats in the NOVANA programme 2004–2009.

Habitat type		Number of SACs	NOVANA	Coverage
1.	Reefs	54 (+2)	49	97%
2.	Submarine structures made by leaking gasses, so-called "bubble reefs"	6	2	33%
3.	Large shallow inlets and bays	38	30	79%
4.	Coastal lagoons (excl. brackish lakes and ponds)	42	21	58%
5.	Mudflats and sand flats not covered by seawater at low tide	25	20	80%
6.	Estuaries	4	3	75%
7.	Sandbanks which are slightly covered by sea water all the time	40 (+3)	21	51%
8.	Marine caves	1	0	0

In accumulation areas both current and previous pollution levels can be investigated by analysing segments (layers) of a sediment column representing the preceding time interval, where the column's length (depth) depends on the sedimentation rate in the area. The picture can be disturbed by bioturbation, however, i.e. disturbance of the sediment by burrowing animals. In order to date the various layers of the sediment and calculate the degree of bioturbation it is necessary to date the sediment itself. This can then be used to examine the temporal trends for other substances in the sediment, e.g. nutrients and hazardous substances.

Several foreign and Danish investigations have demonstrated effects of organic tin compounds from hull paints in marine waters. For example, imposex has been detected in several species of whelk and periwinkle (*Littorina littoralis*) in Danish open marine waters.

NOVANA also encompasses a further three forms of effect measurements:

- Effects on reproduction/gender distribution and abnormalities in eelpout fish fry (which integrates the effects of many groups of substances)
- Measurement of the activity of detoxification enzymes in fish (eelpout) as a measure of pressure from substances such as PAHs and PCBs
- Investigation of cell damage in mussels. In the Danish monitoring programme it will thereby be possible to correlate effects on mussels with current concentrations as the mussel is the organism that has been used to assess pressure from hazardous substances in various areas under the NOVA-2003 programme.

9.3 Objectives

The overall objectives of the subprogramme are to:

- Describe **sources of pollution** and **water and nutrient transports** and their effects on the state and trend in the Danish coastal waters and open marine waters
- Document the overall **effect** of national **action plans** and measures aimed at the aquatic environment and nature – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Help fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve the aquatic environment and nature, including helping to develop various tools.

In extension of the overall objectives, separate subobjectives have been formulated for the monitoring of coastal waters and open marine waters, respectively.

The subobjectives for the coastal waters are to:

- Determine the quantitative trend in a number of important physical, chemical and biological quality elements, among others plankton, macroalgae, eelgrass, benthic invertebrates (including hazardous substances and biological effect monitoring), fish (including selected hazardous substances and biological effect monitoring), water chemistry (including hazardous substances) and sediment chemistry (including selected hazardous substances)
- Determine the quantitative relationships between inputs of nutrients and biological effects, including determining the significance of variations in climate and biological structure
- Eventually establish quantitative relationships between discharges, concentrations and effects of selected hazardous substances in biota in selected areas
- Provide up-to-date information on oxygen deficit
- Describe the transport of nutrients to and through selected Danish fjords and coastal waters, among other reasons with a view to establishing budgets for these substances
- Assess long-term changes caused by human activities, including the input of hazardous substances and changed climate and habitat quality.

The subobjectives for the open marine waters are to:

- Determine the quantitative trend in a number of important physical, chemical and biological variables, among others plankton, macroalgae, benthic invertebrates (including hazardous substances), fish (including hazardous substances), water chemistry and sediment content of hazardous substances
- Determine quantitative relationships between inputs of nutrients and biological effects, including determining the significance of variations in climate and biological structure
- Provide up-to-date information on oxygen deficit
- Describe the transport of nutrients to and through the open marine waters, among other reasons with a view to establishing budgets for these substances
- Assess long-term changes caused by human activities, including changed climate and habitat quality.

The main differences in the subobjectives for the monitoring of coastal waters and open marine waters are:

- That the quantitative relationships between discharges and concentrations and effects of hazardous substances will only be established for selected areas in the coastal waters, and
- That the above-mentioned relationships will only be established for selected substances.

9.4 Strategy

Based on the inventory of monitoring requirements, previous experience, the international evaluation of NOVA-2003 (see below) and the statistical optimization project (see below), the monitoring programme activities focus on three main areas: 1) Eutrophication and physical conditions, 2) Biodiversity and habitats, and 3) Hazardous substances and biological effect monitoring.

As the Danish open marine waters lie in the transitional zone between the brackish Baltic Sea and the saline North Sea and encompass many different areas ranging from small closed coves to open marine waters, the monitoring strategy has to take into account the large variation in the physical, chemical and biological conditions. This necessitates differentiating between coastal waters and open marine waters, while concomitantly taking into account differences between the coastal waters themselves.

In some cases spatial and temporal coverage will be suboptimal, for example due to logistical reasons and due to resource limitations.

The programme is therefore structured in such a way that it is performed as a stratified task encompassing coastal waters and open marine waters and concomitantly covering the three programme areas, cf. Table 9.2.

Modelling is a central element in connection with the processing of the collected data and assessment of the state of nature and the environment, both in coastal waters and in general for the open marine waters. The efforts concentrate on three activities: (1) Calculation of water and nutrient transports in the open parts of the inner Danish marine waters as well as calculation of boundary data for selected coastal waters, (2) Calculation of dominant currents, and (3) Modelling of level 2+ coastal waters. These modelling activities together with the generally increased focus on modelling create the basis for stronger coupling between monitoring and management of the Danish coastal waters than hitherto.

One of the main foundation stones for revision of the programme was the international evaluation of the NOVA-2003 programme. The evaluation of the marine subprogramme concluded that:

- The objectives and subobjectives adequately meet the obligations and needs, both national and international
- The subprogramme for marine waters contributes to the overall objective of the NOVA-2003 programme
- Coordination with other subprogrammes is sufficiently close, especially with the subprogrammes for watercourses and background monitoring of air quality and atmospheric deposition
- The strategy involving stratification (intensive/extensive areas and stations) is appropriate
- The methods are relevant for the objectives and subobjectives
- The monitored indicators and supporting variables are relevant and appropriate
- The balance between modelling and actual monitoring is appropriate.

The international evaluation is fundamentally positive about the monitoring hitherto performed in the Danish open marine waters. It is recommended, though, that the number of variables should be optimized. The reason for this is that data were collected during the NOVA-2003 period that have not been assessed and reported, and that monitoring was performed that was not justified by obligations. This has been taken into consideration in that measurement of TOC (total organic carbon) has been discontinued, and the number of sediment chemistry variables has been reduced in the present programme.

Another foundation stone for revision of the programme was the statistical optimization project. Among other things, this concluded that all the frequencies with which monitoring of the water column have previously been carried out have been appropriate. At the end of the NOVANA period it will thus be possible to draw statistically reliable conclusions about interannual variations. The relatively high sampling frequencies for pelagic quality elements and indicators have therefore been maintained.

The subprogramme for marine waters depends on data from the subprogrammes for point sources, watercourses and background monitoring of air quality and atmospheric deposition, cf. Section 9.7.

Table 9.2 Overall content of the monitoring of ecological status in Danish marine waters.

	Level 1		Level 2		Level 2+	
	Coastal	Open	Coastal	Open	Coastal	Open
Eutrophication, including physical conditions	-	-	E2	E2	E2+	E2+
Biodiversity and habitats	B1	B1	B2		-	-
Hazardous substances, etc.	HS1		HS2		-	-

Table 9.3 Quality elements encompassed by the eutrophication monitoring during the period 2004–2009.

Physical-chemical conditions in the water column:	• Profile measurements (pressure, temperature, conductivity, light attenuation and fluorescence • Nutrients (total-N, nitrite+nitrate, ammonium, total-P, orthophosphate P, inorganic silica (silicate), chlorophyll *a*) • Oxygen concentration • Secchi depth
Plankton:	• Phytoplankton (species composition and biomass) • Primary production (particulate production) • Micro- and mesozooplankton (species composition and biomass)
Submerged aquatic vegetation:	• Macroalgae • Eelgrass • Area distribution, including shoot density and biomass
Benthic invertebrates:	• Species composition, abundance and biomass • Biomass of filter feeders
Sediment:	• Internal loading (nitrite+nitrate, ammonium, orthophosphate, oxygen) • Pigments (chlorophyll *a*)

9.5 Programme content

This section describes the measurement and analysis programme, the selection of quality elements and supporting variables, sampling frequency etc., and indicates at which types of area and station the quality elements etc. are to be measured. The frequencies are indicated in the tables as 1–47 (which means that sampling is carried out between 1 and 47 times per year) or 1/6 (sample collection once during the programme period, 2/6 (sample collection twice during the programme period) and 3/6 (sample collection three times during the programme period).

The selection of quality elements (indicators, supporting variables etc.) was based on a combination of knowledge concerning the elements and structures that best characterize the Danish marine ecosystems, the resilience and measurability of these elements and structures, and the costs associated with carrying out the measurements.

Sampling and analysis methods are described in the technical instructions for marine monitoring (see Andersen *et al.*, 2004). The technical instructions follow the guidelines stipulated for monitoring under the international marine conventions: HELCOM's "Manual for Marine Monitoring in the COMBINE Programme of HELCOM", and OSPAR's "Joint Assessment and Monitoring Programme". These guidelines are binding for the activities encompassed by NOVANA.

9.5.1 Eutrophication and physical conditions

The eutrophication monitoring encompasses the quality elements listed in Table 9.3. For further information about sample collection methods, analysis methods and other processing of the collected samples see the technical instructions (Andersen *et al.*, 2004).

9.5.1.1 Marine model complex for open marine waters

In NOVA-2003, water and nutrient transports were quantified using 3D-modelling. In addition, boundary data were calculated for selected fjords and coastal waters. This activity continues in NOVANA through the following measures:

- Under the regional authorities' monitoring programme a project is to be designed and submitted for tender aimed at:
  - Calculating hydrodynamic boundary data for selected coastal waters
  - Calculating water and nutrient transports in the inner Danish marine waters and along the west coast of Jutland
  - Calculating inputs of water and nutrients to the inner Danish marine waters from selected, large fjord systems
  - Calculating the dominant currents (direction and strength)
- Operation of three measurement buoys (maintenance and data transfer)
- Operation of three intensive marine stations.

The modelling task was submitted for tender in 2003. Evaluation of the incoming tenders had not been completed at the time of preparation of this report (8.1.2004). Regarding the modelling task it is presupposed that:

- Assimilation of both buoy data and data from ship-based measurements is an integral part of the project
- An external evaluation of the model and its output will be carried out in 2006
- Boundary data for the 11 proposed level 2+ coastal waters will also be measured at the 11 proposed boundary stations, and the need for continued operation of these boundary stations is to be assessed in connection with the above-mentioned mid-term evaluation
- The costs are to be shared between the regional authorities in a pre-agreed manner
- Within the framework of the state programme the Topic Centre for Marine Data is to be responsible for a number of specific tasks, including: 1) Helping to prepare calls for tender, 2) Helping to evaluate tenders and participation in contract negotiations, 3) Participation in steering committees and the mid-term evaluation, and 4) Validation. These activities are believed to be a necessary supplement to the part of the model complex submitted for tender.

The model is to be a three-dimensional hydrodynamic model established for the Danish open marine waters. The primary calculation network stretches from the Arkona Basin in the western Baltic Sea via the Darss and Drogden Sills through the inner Danish marine waters to Skagen.

The model calculates the temporal trend in current conditions, water level, salinity and temperature in the open marine waters in three dimensions taking into account variations in density and bottom topography.

It is presupposed that data for sea level, salinity and temperature along the open boundaries and the influx of fresh water to the inner Danish marine waters and the Baltic Sea will be procured in good time if this improves the quality of the model calculations.

Nutrient transports are calculated on the basis of nutrient measurements at intensive and extensive stations in the open marine waters and corresponding measurements from other national and international monitoring programmes in the model area. Measurements of total nitrogen (total-N), inorganic nitrogen (DIN), total phosphorus (total-P) and inorganic phosphorus (DIP) are employed. Alternatively, the nutrient transports can be calculated by direct modelling of the nutrient concentrations in the model area.

The three intensive marine stations, which are part of the overall marine model complex, have provisionally been placed in the Kattegat west of Læsø, in Hjelm Bay at Darss Sill and in the Øresund at the Drogden Sill.

To support the model calculations, hydrographic data are collected from six automatic monitoring buoys. It is expected that the buoys will be positioned in the following areas: 1) Hjelm Bay, at Darss Sill, 2) The Little Belt, at the Little Belt Bridge, 3) Kattegat, at Læsø Rende (west of Læsø), 4) Kattegat, east of Læsø, 5) The Great Belt, and 6) Øresund at Drogden Sill. The first three buoys are an integral part of the NOVANA programme. The measurement buoy east of Læsø is Swedish and run by the Swedish Meteorological and Hydrological Institute, while the buoys in the Great Belt and Øresund are run by the Royal Danish Administration of Navigation and Hydrography. The three latter buoys are expected to be in operation during the period 2004–2009.

9.5.1.2 Coastal water modelling (level 2+ areas)

The purpose of modelling the 11 level 2+ coastal areas is:

- To determine water, salt and nutrient exchange with the adjoining marine waters
- To quantify the physical conditions such that the state of the coastal waters and the biological events within them can be assessed in relation to the natural variations in the physical conditions
- To correlate nutrient exchange with local input and internal turnover
- To model any special physical conditions pertaining.

The morphology of level 2+ coastal waters has to be described sufficiently to determine the fjord volume and area as a function of depth. The bottom topography has to be determined for important transects (e.g. fjord outlets and basin borders).

The overall model for the inner marine waters has to calculate boundary data for various coastal waters. In addition, profile measurements etc. are to be made at the boundary stations in level 2+ areas. The transport of water, salt and nutrients across the area's boundary(ies) with the adjoining marine waters is calculated using time intervals of one day or less such that the transports are reported on a daily basis. Net mass balances are established for the fjords, and the nutrient retention estimated.

9.5.1.3 Stratification of the eutrophication monitoring

The monitoring of eutrophication is performed in a stratified manner for coastal waters and open marine waters, respectively, and encompasses four activities:

- E2 activities in level 2 areas in coastal waters (previously termed "representative areas")
- E2 activities at level 2 stations in open marine waters (previously termed "marine stations")
- E2+ activities in level 2+ areas in coastal waters (previously termed "type areas")
- E2+ activities at level 2+ stations in open marine waters (previously termed "intensive marine stations").

9.5.1.4 E2 activities in coastal waters

The general monitoring of eutrophication in level 2 coastal waters, which will be carried out in 34 areas, is the backbone of the monitoring of the effects of eutrophication. In 11 of these areas supplementary activities and modelling will be carried out (see under E2+ activities in coastal waters).

The monitoring programme for level 2 coastal waters is summarized in Table 9.4. The level 2 areas encompassed by the monitoring programme are summarized in Table 9.5 together with the activities in the individual areas.

9.5.1.5 E2 activities in open marine waters

The general monitoring of eutrophication conditions in the open marine waters, which is the responsibility of the National Environmental Research Institute, encompasses the activities summarized in Table 9.6.

The monitoring encompasses five monitoring cruises in the inner Danish marine waters, where there are 26 permanent stations. In addition, a single winter monitoring cruise is carried out in the North Sea and the Skagerrak.

Table 9.4 Monitoring programme for eutrophication in level 2 areas in coastal water indicating the number of areas, number of stations per area, number of subsamples (depths) per station and annual frequency of sample collection and analysis.

	Areas	Stations	No. per station	Frequency
			n	
Physical-chemical conditions in the water column:				
• Profile measurements, chlorophyll *a*, nutrients and oxygen	23 + 12	0–1	1-4	20–33
Plankton:				
• Species composition and biomass	11	1	1	13–26
• Micro- and mesozooplankton	2[1]	1	1	18–19
Submerged aquatic vegetation:				
• Macroalgae	23	2–14	1	3/6
• Eelgrass	29	5–14	1	2/6 and 1
Benthic invertebrates:				
• Species composition, abundance and biomass	25	35–50	1 HAPS	1

[1)] Zooplankton are part of the analysis programme in two level 2 coastal waters and in seven level 2+ coastal waters.

Table 9.5 Level 2 areas indicating the variables to be monitored in the individual areas. PM: Profile measurements; WC: Water chemistry; PHP: Phytoplankton; PP: Primary production; ZP: Meso- and microzooplankton; IL: Internal loading; MA: Macroalgae; EG: Eelgrass; AD: Areal distrubution, biomass and shoot density; AP: Aerial photography; FF: Filter feeders; BI: Benthic invertebrates. (St.: Station; Trans.: Transect).

Level 2 areas	PM+WC	PHP	PP	ZP	IL	MA	EG	AD	AP	FF	BI
	St.	St.	St.	St.	Area	Trans.	Trans.	Area	Area	Area	Area
Bornholm	+	-	-	-	-	+	-	-	-	-	-
Dybsø Fjord	+	-	-	-	-	-	+	-	-	-	-
Flensborg Fjord	+	-	-	-	-	+	+	-	-	-	+
Hevring Bay	-	-	-	-	-	-	-	-	-	-	+
Hjelm Bay	+	-	-	-	-	-	-	-	-	-	-
Horsens Fjord *	+	+	+	+	+	+	+	+	-	+	+
Isefjord *	+	+	+	-	-	+	+	+	-	-	+
Kalundborg Fjord	+	-	-	-	-	+	+	-	-	-	-
Karrebæksminde Bay	+	-	-	-	-	+	+	-	-	-	+
Køge Bay *	+	+	+	+	+	+	+	+	-	+	+
Little Belt, northern part	-	-	-	-	-	+	+	-	-	-	+
Little Belt, southern part	+	+	+	+	-	+	+	-	-	-	+
Limfjorden, central part	+	+	-	-	-	+	+	-	-	-	+
Limfjorden, eastern part	+	-	-	-	-	-	+	-	-	-	+
Limfjorden, western part	+	+	-	-	-	+	+	-	-	-	+
Mariager Fjord	+	+	+	-	-	-	+	-	-	-	+
Nissum Fjord	+	+	-	-	-	-	+	-	-	-	+
Nivå Bay	+	-	-	-	-	-	+	-	-	-	+
Odense Fjord *	+	+	+	-	+	+	+	+	-	+	+
Præstø Fjord *	+	+	+	+	+	-	+	+	-	+	+
Randers Fjord	+	-	-	-	-	(+)	+	-	-	-	-
Ringkøbing Fjord *	+	+	+	+	+	-	+	+	+	+	+
Roskilde Fjord *	+	+	+	+	+	+	+	+	-	+	+
Sejerø Bay	+	-	-	-	-	+	+	-	-	-	-
Zealand, northeastern coast	+	-	-	-	-	+	-	-	-	-	+
Skive Fjord/Lovns Broads *	+	+	+	+	+	+	+	+	+	+	+
Småland marine waters	+	-	-	-	-	+	+	-	-	-	-
South Funen Archipelago *	+	+	+	-	+	+	+	+	-	+	+
Wadden Sea, northern part	+	+	-	-	-	-	-	-	-	-	+
Wadden Sea, southern part *	+	+	+	-	-	-	+	+	-	+	+
Vejle Fjord	+	-	-	-	-	+	+	-	-	-	+
Øresund, central part	+	-	-	-	-	+	+	-	-	-	+
Åbenrå Fjord	+	-	-	-	-	+	+	-	-	-	-
Aarhus Bay *	+	+	+	+	+	+	+	+	+	(+)	+

* Areas where supplementary activities and modelling (E2+ activities in coastal waters) will be carried out.

Table 9.6 Monitoring programme for eutrophication at level 2 stations in open waters indicating the number of stations, number of subsamples (depths) per station and annual frequency of sample collection and analysis.

Sample type	No. of stations	No. per station	Frequency
Physical-chemical conditions in the water column:			
• Profile measurements, chlorophyll *a*, nutrients and oxygen	26	3–23 depths	5
• Profile measurements, chlorophyll *a*, nutrients and oxygen	50	3–23 depths	1
Plankton:			
• Primary production	1	1	4
• Mesozooplankton	1	1	4
Benthic invertebrates:			
• Species composition, abundance and biomass	24	5–10 HAPS *	1
Sediment:			
• Pigments	9	5	2

* 5 HAPS per station; 10 HAPS at HELCOM stations.

Table 9.7 Monitoring programme for eutrophication in level 2+ areas in coastal waters indicating the number of areas, number of stations per area, number of subsamples (depths) per station and annual frequency of sample collection and analysis.

	Area	Stations	No. per station	Frequency
		n		
Physical-chemical conditions in the water column:				
• Profile measurements, nutrients and oxygen[1]	11	1	1–2	+ 20–24[1]
• Profile measurements, nutrients and oxygen[2]	9[3]	1–2	1–2	11–47
Plankton:				
• Primary production	11	1	1	18–25
• Micro- and mesozooplankton	7	1	1	14–25
Sediment:				
• Internal loading	9	3	1	8–10 x 2/6[4]
Submerged aquatic vegetation:				
• Areal distribution, biomass, shoot density	11	1	1	2/6 and 1
• Aerial photography	3	1	1	2/6
Benthic invertebrates:				
• Biomass of filter feeders	9[5]	1	1	

[1)] This activity is a supplementary activity at the level 2 station.

[2)] This activity, which is new compared with the activities carried out in level 2 coastal waters, encompasses boundary data etc. and any extra basin station.

[3)] There are no further stations in the form of boundary stations and extra basin stations in Isefjord and Aarhus Bay.

[4)] In Aarhus Bay, internal loading is determined once during the programme period.

[5)] In Aarhus Bay, a simple determination is made of the distribution of filter feeders.

Some of the 26 and 50 pelagic stations are also included in Norwegian, Swedish and German monitoring activities. The cruises are coordinated between the countries, and procedures have been agreed on for the informal exchange of data.

9.5.1.6 E2+ activities in coastal waters

The 11 coastal waters, which are designated E2+ coastal waters, are summarized in Table 9.5. All of these 11 areas are monitored as stated for level 2 (see Section 9.5.1.4 and Table 9.4). The **supplementary** monitoring programme for level 2+ activities in coastal waters is described in Table 9.7 as regards the number of stations per area, number of samples to be collected per station, and the annual frequency for sample collection and analysis.

Boundary data for level 2+ coastal waters is to be obtained by placing an intensive station on or near the boundary. In principle, one of the supplementary stations with sampling up to 47 times per year should be a boundary station.

In the seven level 2+ areas that are actual fjords (Horsens Fjord, Isefjord, Odense Fjord, Præstø Fjord, Ringkøbing Fjord, Roskilde Fjord and Skive Fjord/Lovns Broads) the modelling will mainly focus on retention of nutrients and exchange with adjoining open marine waters. The other four level 2+ areas (Køge Bay, the South Funen Archipelago, the southern part of the Wadden Sea and Aarhus Bay) are so open that the modelling will mainly focus on the importance of the adjoining open marine waters.

9.5.1.7 E2+ activities in open marine waters

The monitoring programme for level 2+ marine stations is summarized in Table 9.8. These activities are not a supplement to level 2 activities since the regional authorities do not carry out such monitoring in the open marine waters.

The 11 level 2+ marine stations are summarized in Table 9.9.

The measurements at the 11 level 2+ marine stations will be performed by the following regional authorities: Regional Municipality of Bornholm (Bornholm East), Ribe County (Esbjerg), Vestsjælland County (Gniben), Viborg County (Hanstholm), Nordjylland County (Hirtshals 1 and 2 and Aalborg Bay), Frederiksborg County and Copenhagen County (Ven), Vejle County (Little Belt), Ringkjøbing County (North Sea near Ringkøbing Fjord) and Funen County (Great Belt).

The activities at three intensive marine stations encompassed by the marine model complex (see Table 9.10) are in principle identical with activities at the 11 level 2+ marine stations.

There is some overlap between the stations run by NERI, cf. Table 9.6, and the 11 level 2+ marine stations. Thus the actual frequencies are higher than those summarized in Table 9.9. The stations included in NERI's activities are Ven, Aalborg Bay, Gniben and the Great Belt. In addition, Norway, Sweden and Germany monitor a number of the stations, among others Bornholm East, Ven, Hirtshals 1 and Hanstholm.

9.5.1.8 Activities specifically associated with modelling of the open marine waters

In addition to operation of the model, the modelling of boundary data and of water and nutrient transports in the open marine waters entails a number of specific activities. These activities include maintenance and servicing of three measurement buoys and the operation of three intensive marine stations. At the three marine stations, profile and nutrient measurements are made with the aim of collecting boundary data for calculation of water and nutrient transports in the inner Danish marine waters. The specific activities are summarized in Table 9.10.

Table 9.8 Monitoring programme for eutrophication at level 2+ stations in open marine waters indicating the number of stations, number of subsamples (depths) per station and annual frequency of sample collection and analysis.

	Stations	Subsamples	Frequency
Physical-chemical conditions in the water column:			
• Profile measurements, nutrients and oxygen	9	1.25–9	17–47
• Profile measurements, nutrients and oxygen	2	3–10	6–28
Plankton:			
• Primary production	3	1	20–23
• Species composition and biomass	5	1	5–26
• Micro- and mesozooplankton	3	1	5–23

Table 9.9 Level 2+ marine stations indicating the variables to be monitored at the individual stations. PM: Profile measurements; WC: Water chemistry; PHP: Phytoplankton; ZP: Meso- and microzooplankton.

Stations	PM + WC	PHP	PP	ZP
Bornholm, east of	1	1	-	1
Esbjerg, west of	1	1	-	-
Gniben	1	1	1	1
Hanstholm	1	-	-	-
Hirtshals 1	1	-	-	-
Hirtshals 2	1	-	-	-
Ven	1	1	1	-
Little Belt, northern part	1	-	-	-
North Sea, near Ringkøbing Fjord	1	-	-	-
Great Belt	1	-	-	-
Aalborg Bay	1	1	1	1
Total	11	5	3	3

Table 9.10 Activities associated with the model complex etc. indicating the number of stations, number of subsamples (depths) per station and average frequency of sample collection and analysis.

	Stations	Subsamples	Frequency
Modelling	-	-	1
Measurement buoys, maintenance and service	3	-	10
Intensive marine stations (CTD, total-N, DIN, total-P, DIP)	3	2–4	44
Large fjords (DM, total-N, total-P, DIN, DIP) – Limfjorden	1	-	44
Large fjords (DM, total-N, total-P) – Randers Fjord and Isefjord	"2"	-	1

9.5.2 Biodiversity and habitats

The monitoring activities aimed at monitoring biodiversity and habitats focus on the monitoring of protected marine habitats and of fish in seven coastal waters. In addition, the activities will be able to make considerable use of data from the monitoring of eutrophication, first and foremost data regarding the biological conditions.

For further information on sample collection methods and analysis methods see the technical instructions (Andersen *et al.*, 2004).

9.5.2.1 B1 activities in coastal waters and open marine waters

The level 1 monitoring of biodiversity and marine habitats encompasses the following elements: Vegetation and fauna on stone reefs and "bubble" reefs, soft-bed fauna and fish.

Monitoring of vegetation and fauna on stone reefs and "bubble" reefs at this level will encompass 13 reefs per year. Given the selected sample collection frequency (every third year), a total of 39 reefs will be encompassed. In addition, a further 12 reefs are monitored at level 2, i.e. every year (see below).

The monitoring of the benthic invertebrate fauna has to cover as many coastal waters as possible. It is believed that the majority of the designated coastal habitats will be encompassed by the monitoring. This applies first and foremost to the following habitat types: Large shallow inlets and bays, coastal lagoons, mudflats and sand flats not covered by seawater at low tide, and estuaries.

Fish will be monitored in the following seven areas: Løgstør Broads in the central part of Limfjorden, Ringkøbing Fjord, Randers Fjord, Horsens Fjord, Odense Fjord, the South Funen Archipelago, and Frederiksværk Broads (the northern part of Roskilde Fjord).

The monitoring programme for B1 activities in coastal waters and open marine waters is summarized in Table 9.11.

The monitoring of vegetation and fauna on stone reefs and "bubble" reefs is the responsibility of NERI. Aarhus County monitors the submerged aquatic vegetation at SACs 186 (Ebeltoft Cove) and 231 (Kobberhage) every second year during the programme period.

The distribution of the other level 1 activities (extensive soft-bottom macrofauna and fish) among the various regional authorities is shown in Table 9.12.

Table 9.11 Monitoring programme for biodiversity and habitat types at level 1 stations in coastal waters and open marine waters indicating the number of areas, number of stations, number of subsamples (depths) per station and frequency of sample collection and analysis.

B1	Areas	Stations	No. per station	Frequency
Submerged aquatic vegetation:				
• Stone reefs and "bubble" reefs	3 x 13	3.75	-	2/6
Benthic invertebrates:				
• Species composition, abundance and biomass	1	845	1 van Veen	1/6
• Hard-bottom fauna (semiquantitative) at stone reefs	3 x 13	3.75	-	2/6
Fish:				
• Species composition and size distribution	7	-	-	1/6

Table 9.12 Marine "nature activities" in level 1 coastal waters apportioned by regional authority (County).

County	Soft-bottom fauna No. of stations	Fish No. of areas
Nordjylland County	54	-
Viborg County *	30	0.5
Aarhus County	150	1
Ringkjøbing County *	48	1.5
Ribe County	30	-
Vejle County	75	1
Sønderjylland County	50	-
Funen County	75	2
Vestsjælland County	75	-
Storstrøm County	66	-
Roskilde County	42	-
Frederiksborg County	50	1
Copenhagen County	75	-
Regional Municipality of Bornholm	0	-
Copenhagen Municipality	25	-
Total	845	7

* The monitoring of fish in the central part of Limfjorden (Løgstør Broads) is the responsibility of Ringkjøbing County and Viborg County.

9.5.2.2 B2 activities in open marine waters

The monitoring at this level, which is carried out at 12 stone reefs and 12 "bubble" reefs in the open marine waters, encompasses submerged aquatic vegetation (macroalgae) and semiquantitative monitoring of the hard-bottom fauna.

9.5.2.3 Supplementary activities

As previously mentioned, information from routine eutrophication monitoring concerning both biological quality elements and supporting variables is to be used to support the general assessment of status and trend for biodiversity in the Danish open marine waters. The B1 and B2 activities are estimated to be insufficiently comprehensive to allow assessment of the general status and trend in marine biodiversity. Information on phytoplankton and zooplankton will be provided by the eutrophication monitoring. It is presupposed that sea birds and marine mammals will be encompassed by the subprogramme for species and terrestrial natural habitats. As regards monitoring of the marine habitats, the situation is almost identical. Thus a scientifically defensible geographic distribution can only be achieved by incorporation of elements from the eutrophication monitoring.

9.5.3 Hazardous substances and biological effect monitoring

The selection of hazardous substances and heavy metals is based on Denmark's obligations pursuant to a number of EU directives and the international marine conventions including the North Sea Conferences. As the majority of hazardous substances and heavy metals accumulate in biota and sediment, these are selected as investigation media in order to obtain an integrated measure of pressure on the environment. At the same time, this ensures more accurate concentration measurements due to the higher concentrations compared with the water phase.

For further information on sample collection methods and analysis methods, see the technical instructions (Andersen *et al.*, 2004).

9.5.3.1 Sediment

Many hazardous substances and heavy metals have affinity for particles and will therefore sediment out of the water phase to become deposited in a sedimentation area. A number of groups of substances have been selected for monitoring in sediment based on their physical properties. Efforts should be made to ensure that the sampling stations for analysis of organotin compounds and biological effect monitoring are the same or are located as close to each other as possible. The list of substances to be monitored in sediment is shown in Table 9.14.

9.5.3.2 Biota

When using biota to investigate the occurrence of hazardous substances and heavy metals it is necessary to take into account that the bioconcentration factor (BCF) varies with species and substance group. Thus in order to be able to compare concentrations of hazardous substances in biota only a few organisms have been selected for inclusion in the programme, and sampling has to be carried out within a limited period of time.

The selected animal species and the tissues to be analysed in the monitoring programme are indicated in Table 9.15. Common mussels have been selected because they are widely distributed throughout the fjords and coastal waters. At the same time, they are sedentary and hence express local environmental pressures. In addition, they filter large amounts of water and hence have considerable potential to accumulate heavy metals and hazardous substances. Among fish, one of the most sedentary is the eelpout. As the earlier measurements were often carried out on flounder, however, it has been decided to continue with this species in most areas.

Wherever possible, flounder and common mussels are used. The other organisms are selected in areas where it is not possible to find the preferred species.

The monitoring of the concentration of heavy metals and hazardous substances in mussels encompasses a basic programme and a supplementary programme. The basic programme is summarized in Table 9.16 and the supplementary programme in Table 9.17.

The list of hazardous substances to be monitored in fish is shown in Table 9.18.

Table 9.13 Monitoring programme for biodiversity and habitats at level 2 stations in open marine waters indicating the number of stations, number of subsamples (depths) per station and frequency of sample collection and analysis.

B2	No. of stations	No. per station	Frequency
		n	
Submerged aquatic vegetation:			
• Stone reefs and "bubble" reefs	12	4.3	1
Benthic invertebrates:			
• Hard-bottom fauna (semiquantitative)	12	4.3	1

Table 9.14 List of hazardous substances etc. to be monitored in sediment.

- Normalization (cf. the Technical Instructions): TOC, Li, Al, DM and GLT
- As, Cr, Zn, Ni, Cu, Cd, Hg and Pb
- TBT, DBT, MBT og TPhT
- Polybrominated biphenyls: PCB No. 28, 31, 52, 101, 105, 118, 138, 153, 156 and 180
- Brominated flame retardants: BDE No. 47, 99, 100, 153 and 154
- Pesticides: DDT, DDE, lindane and HCB
- Hexachlorobutadiene
- PAHs: Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(e)pyrene, benzo(ghi)perylene, benzo(b+j+k)fluoranthenes, chrysene and triphenylene, dibenz(a,h)anthracene, dibenzothiophene, 3,6-dimethylphenanthrene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylphenanthrene, perylene, phenanthrene and pyrene
- 1-methylnaphthalene, 2-methylnaphthalene, dimethylnaphthalenes, naphthalene and trimethylnaphthalenes
- Coplanar PCBs: PCB No. 26, 77 and 169
- Dioxin/furans: 1234678-HpCDF, 1234789-HpCDF, 234678-HpCDD, 123478-HxCDF, 123678-HxCDF, 123789-HxCDF, 234678-HxCDF, 123478-HxCDD, 123678-HxCDD, 123789-HxCDD, OCDD, OCDF, 12378-PeCDF, 23478-PeCDF, 12378-PeCDD, 2378-TCDF and 2378-TCDD
- Phthalates: DEHP, DNP, di-n-octylphthalate, dibutylphthalate and diethylphthalate
- Nonylphenols, nonylphenol-monoethoxylates and nonylphenol-diethoxylates
- Musk xylenes, if screening indicates the necessity (in which case phthalates are omitted)
- Persistent fluor compounds, if screening indicates the necessity (in which case phthalates are omitted)

Table 9.15 Selected organisms and tissues to be analysed for hazardous substances and heavy metals.

Species	**Tissue**
Common mussel (*Mytilus edulis*)	All soft tissue
Soft-shelled clam (*Mya arenaria*)	All soft tissue
Flounder (*Platichthys flesus*)	Hg in muscle, all other substances in liver
Eelpout (*Zoarces viviparus*)	Hg in muscle, all other substances in liver
Plaice (*Pleuronectes platessa*)	Hg in muscle, all other substances in liver

Table 9.16 List of hazardous substances etc. encompassed by the basic monitoring programme in mussels.

- Dry matter, fat content, length/weight of shells and soft tissue
- Zn, Ni, Cu, Cd, Hg and Pb
- TBT, DBT, MBT and TPhT
- Polybrominated biphenyls: PCB No. 28, 31, 52, 101, 105, 118, 138, 153, 156 and 180
- Brominated flame retardants: BDE No. 47, 99, 100, 153 and 154
- Pesticides: DDT, DDE, lindane and HCB
- PAHs: Acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(e)pyrene, benzo(ghi)perylene, benzo(b+j+k)fluoranthenes, chrysene and triphenylene, dibenz(a,h)anthracene, dibenzothiophene, 3,6-dimethylphenanthrene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylphenanthrene, perylene, phenanthrene and pyrene
- 1-methylnaphthalene, 2-methylnaphthalene, dimethylnaphthalenes, naphthalene and trimethylnaphthalenes

Table 9.17 List of hazardous substances etc. encompassed by the supplementary monitoring programme in mussels.

- Coplanar PCBs: PCB No. 26, 77 and 169
- Dioxin/furans: 1234678-HpCDF, 1234789-HpCDF, 234678-HpCDD, 123478-HxCDF, 123678-HxCDF, 123789-HxCDF, 234678-HxCDF, 123478-HxCDD, 123678-HxCDD, 123789-HxCDD, OCDD, OCDF, 12378-PeCDF, 23478-PeCDF, 12378-PeCDD, 2378-TCDF and 2378-TCDD
- Phthalates: DEHP, DNP, di-n-octylphthalate, dibutylphthalate and diethylphthalate
- Musk xylenes, if screening indicates the necessity (in which case phthalates are omitted)
- Persistent fluor compounds, if screening indicates the necessity (in which case phthalates are omitted)

Table 9.18 List of hazardous substances etc. to be monitored in fish.

- Dry matter, fat content, length/weight and age
- Zn, Ni, Cu, Cd, Hg and Pb
- Polybrominated biphenyles: PCB No. 28, 31, 52, 101, 105, 118, 138, 153, 156 and 180
- DDT, DDE, lindane and HCB

9.5.3.3 Biological effect monitoring

This part of the monitoring programme investigates the effects of organic tin compounds (antifouling agents) from hull paints through monitoring of the occurrence of imposex in the common whelk (*Buccinum undatum)* or, in areas where *Buccinum* is absent or scarce, in the dwarf whelk (*Hinia reticulata).*

Investigations of cell damage in mussels, which are also recommended by ICES, are already used in a monitoring context in several European countries. In the Danish monitoring programme it will therefore be possible to correlate effects on mussels with the actual concentrations as the common mussel is the organism utilized in the present monitoring programme (NOVA-2003) to assess the pressure from hazardous substances in various areas.

Effects on reproduction/gender distribution and abnormalities in eelpout fry integrate effects of many groups of substances. The eelpout is a very suitable fish as it is relatively sedentary and gives birth to living young. It has been used for monitoring purposes in Germany and Sweden, where effects have also been demonstrated – probably attributable to hazardous substances – on reproduction and gender distribution and abnormalities in the fry. Measurement of detoxification enzyme activity in fish (eelpout) as a measure of pressure from substances such as PAHs and PCBs is expected to be encompassed by the monitoring requirements pursuant to agreements under OSPAR and HELCOM. The Swedish monitoring programme has utilized this marker and in recent years has shown that the activity of the enzyme is enhanced in fish from the Baltic Sea despite the fact that the concentrations of known hazardous substances have generally decreased. This could indicate that new substances are present that also cause this effect.

9.5.3.4 HS1 activities in coastal waters

The monitoring programme for HS1 activities in coastal waters is summarized in Table 9.19.

The distribution of the above-mentioned activities among the various regional authorities is shown in Table 9.23.

9.5.3.5 HS1 activities in open marine waters

The monitoring programme for HS1 activities in the open marine waters is summarized in Table 9.20.

9.5.3.6 HS2 activities in coastal waters

The monitoring programme for HS2 activities in the coastal waters is summarized in Table 9.21.

The distribution of the above-mentioned activities among the various regional authorities is shown in Table 9.23.

9.5.3.7 HS2 activities in open marine waters

The monitoring programme for HS2 activities in the open marine waters is summarized in Table 9.22.

Table 9.23 summarizes the distribution of the hazardous substance and biological effect monitoring activities among the regional authorities and NERI.

Table 9.19 Monitoring programme for hazardous substances and biological effect monitoring at level 1 stations in coastal waters indicating the number of stations, number of subsamples (depths) per station and frequency. It should be noted that in a few cases no decision has yet been made as to the number of areas (only as to the total number of stations).

	Stations	Subsamples	Frequency
Sediment:			
• Hazardous substances	35	1–2	1/6
Mussels:			
• Hazardous substances (supplementary substances)	25	1–3	3/6
Biological effect monitoring:			
• Molluscs (imposex/intersex)	13	3	3/6

Table 9.20 Monitoring programme for hazardous substances and biological effect monitoring at level 1 stations in open marine waters indicating the number of stations, number of subsamples (depths) per station and frequency of sample collection and analysis. These activities are carried out by the National Environmental Research Institute.

	Stations	Subsamples	Frequency
Sediment:			
• Hazardous substances	15	Variable	1/6
Mussels:			
• Hazardous substances (supplementary substances)	1	Variable	2/6
Biological effect monitoring:			
• Molluscs (imposex/intersex)	14	Variable	3/6

Table 9.21 Monitoring programme for hazardous substances and biological effect monitoring at level 2 stations in coastal waters indicating the number of stations, number of subsamples (depths) per station and frequency. It should be noted that in a few cases no decision has yet been made as to the number of areas (only as to the total number of stations). In cases where the temporal trend from the NOVA-2003 programme continues, attempts are made to keep three subsamples.

	Stations	Subsamples	Frequency
Mussels:			
• Hazardous substances (basic)	28	1–3	
Fish:			
• Hazardous substances	4	10	1
Biological effect monitoring:			
• Mussels (cell damage)	4	3	1
• Fish (reproductive success and detoxification enzymes)	5	2	1

Table 9.22 Monitoring programme for hazardous substances and biological effect monitoring at level 2 stations in open marine waters indicating the number of areas, number of stations, number of subsamples (depths) per station and frequency. These activities are carried out by the National Environmental Research Institute.

	Areas	Stations	Subsamples	Frequency
Mussels:				
• Hazardous substances	3*	3*	3*	1
Fish:				
• Hazardous substances	1	1	10	1
Biological effect monitoring:				
• Mussels (cell damage)	2	1	-	1
• Fish (reproductive success and detoxification enzymes)	2	1	-	1

* Temporal trend station.

Table 9.23 Monitoring programme for hazardous substances in sediment, mussels and fish and for biological effect monitoring. IMP: imposex/ intersex; MUS: Cell damage in mussels; FRSD: Fish – reproductive success and detoxification enzymes.

County	Sediment	Mussels		Fish	Biological effect monitoring		
		Basic	Suppl.		IMP	MUS	FRSD
Nordjylland County	2	2	2	-	1	-	-
Viborg County	1	1	-	-	-	-	-
Aarhus County	2	3	3	-	2	1	1
Ringkjøbing County	2	2	2	-	1	-	-
Ribe County	1	2	2	1	2	1	-
Vejle County	1	2	2	-	1	1	1
Sønderjylland County	8	3	3	-	2	-	-
Funen County	2	2	2	-	2	1	1
Vestsjælland County	1	2	1	1	1	-	-
Storstrøm County	1	2	2	1	-	-	1
Roskilde County	2	4	3	-	-	-	-
Frederiksborg County	1	1	1	-	-	-	-
Copenhagen County[1]	0.5	1	1	-	-	-	-
Regional Municipality of Bornholm	-	-	-	-	-	-	-
Copenhagen Municipality[1]	0.5	1	1	1	1	-	-
NERI	15	1	1	1	14	2	2
Total	40	29	26	5	27	6	6

[1)] Copenhagen County and Copenhagen Municipality cooperate on the sediment monitoring in a common area.

9.5.4 Timetable and frequency of sample collection

With some of the quality elements the sampling and analysis frequency is less than once annually. Table 9.24 indicates the years in which the analyses in question are to be carried out together with the sampling frequency.

9.6 Main changes relative to NOVA-2003

The main changes relative to the NOVA-2003 programme are described in the following section.

9.6.1 Eutrophication and hydrography etc.

The most obvious change is that the monitoring of eutrophication in coastal waters has been concentrated in fewer areas and at fewer stations. Stratification of the subprogramme has been strengthened such that level 2+ activities (corresponding to type areas) now supplement level 2 activities (corresponding to representative areas). The frequencies have only been changed to a minor degree as the statistical optimization project concluded that the current frequencies will enable reasonably statistically certain conclusions to be drawn about interannual variation over the NOVANA period.

The main changes in the monitoring of eutrophication in the Danish open marine waters can be summarized as follows:

- The number of "representative" areas has been reduced from 40 (34+6) to 34 (23+11)
- The number of fjords and coastal areas in which modelling is performed has been increased from 6 to 11
- The number of intensive marine stations has been reduced from 16 to 14 (11+3)
- The monitoring of sediment chemistry now focuses solely on internal loading
- Measurement of TOC and POC in the water phase has been discontinued
- Monitoring of vegetation has been reduced slightly due to the reduced number of areas
- The monitoring of the benthic fauna in the open parts of the North Sea has been discontinued
- Summer monitoring cruises in the Skagerrak and the North Sea have been discontinued.

As something new, moreover, the model complex under NOVANA is being financed by the regional authorities collectively. In addition, associated activities such as the three measurement buoys and the three intensive marine stations are included in the budget for the model complex. This prevents these buoys and stations – as under NOVA-2003 – comprising a relatively great burden for those regional authorities who actually carry out these specific activities.

9.6.2 Biodiversity and habitats

Specific monitoring of marine habitats is a new activity relative to the NOVA-2003 programme. Only stone reefs have previously been systematically monitored.

Actual species monitoring is not included in the subprogramme for marine waters. Fish are included, though, although only in six areas. The description of marine biodiversity thus has to be based on monitoring of the marine habitats and on the biological variables encompassed by the eutrophication monitoring.

Table 9.24 Summary of the annual sampling frequency in the monitoring programme for marine waters 2004–2009.

Quality element	Number of samples per year											
	2004		2005		2006		2007		2008		2009	
Water chemistry variables:												
Water column												
- Water chemistry and profile measurements etc.	1–47		1–47		1–47		1–47		1–47		1–47	
Sediment												
- Internal loading [1)]	-		8/10		8/10	or	8/10		8/10			
Biological variables:												
Phytoplankton												
- Primary production	4–25		4–25		4–25		4–25		4–25		4–25	
- Species composition + biomass	4–25		4–25		4–25		4–25		4–25		4–25	
Mesozooplankton												
- Species composition + biomass	4–25		4–25		4–25		4–25		4–25		4–25	
Microzooplankton												
- Species composition + biomass	4–25		4–25		4–25		4–25		4–25		4–25	
Submerged aquatic vegetation												
- Macroalgae (level 2 coastal waters)	-		1		-		1		-		1	
- Eelgrass (level 2 coastal water) [2)]	1		1		1		1		1		1	
- Areal distribution, biomass and shoot density (2+) [3)]	-		1		-		1		-		-	
- Aerial photography (2+)	1	or	1		-		1	or	1		-	
- Intensive, stone reefs	1		1		1		1		1		1	
- Extensive, stone reefs	1	or	1	or	1		1	or	1	or	1	
Benthic invertebrates												
- Species, abundance, biomass	1		1		1		1		1		1	
- Extensive programme (soft-bed)	1		-		-		-		-		-	
- Biomass of filter feeders	1		1		1		1		1		1	
- Intensive, stone reefs	1		1		1		1		1		1	
- Extensive, stone reefs	1	or	1	or	1		1	or	1	or	1	
- Biological effects, molluscs (imposex)	-		1		-		1		-		1	
- Biological effects, mussels	1		1		1		1		1		1	
Fish												
- Species composition	-		-		1		-		-		-	
- Biological effects	1		1		1		1		1		1	
Hazardous substances and heavy metals:												
Fish												
- Biota	1		1		1		1		1		1	
Mussels												
- Sample type, basic	1		1		1		1		1		1	
- Sample type, supplementary	-		1		-		1		-		1	
Sediment												
- Sample type, basic	-		-		-		-		1		-	

[1)] In Aarhus Bay, internal loading is measured in one single year.

[2)] In Randers Fjord, eelgrass and rooted vegetation are monitored in the inner part on two occasions during the monitoring period.

[3)] In Odense Fjord, areal distribution, biomass and shoot density are monitored during all six years of the programme period.

9.6.3 Hazardous substances and biological effect monitoring

The main changes in the monitoring of heavy metals and hazardous substances concern the number of areas, stations, subsamples and frequency, as summarized below:

Number of stations:	• The number of stations has been increased for sediment and mussels, with the change being financed through lower frequencies and fewer subsamples • Two state fish stations have been transferred to the regional authorities' programme
Number of subsamples:	• Sediment – changed from 2–4 to 1–2 • Mussels – changed from 3 to 1–3
Frequencies:	• Sediment – changed from 2/6 to 1/6.

In addition, the list of substances has been adjusted slightly and the monitoring of biological effects has been changed considerably in that mussels and fish have been added to the programme:

Mussels:	• Cell damage in mussels
Fish (eelpout):	• Effects on reproduction/ gender distribution and abnormalities in fish fry • Measurement of the activity of detoxification enzymes in fish
Imposex:	• The frequency has been reduced from 6/6 to 3/6 • The number of stations in the regional authorities' programme has been increased from 21 to 11x3.

The main differences in the activities carried out by the regional authorities during the two programme periods are summarized in Table 9.25.

9.7 Theme-specific assumptions

The subprogramme for marine waters depends on information and data from a number of other subprogrammes, first and foremost concerning inputs of pollutants.

As regards the hydrological point sources it is assumed: (1) that inputs of nitrogen, phosphorus and organic matter will continue to be calculated as hitherto, (2) that to the extent it is possible to adapt the measurement programme, the direct discharges of hazardous substances should be calculated for those coastal waters where the monitoring encompasses hazardous substances and biological effect monitoring, and (3) that marine dumping of seabed material and the offshore industry are included when reporting the subprogramme for point sources.

As regards the subprogramme for watercourses it is assumed: (1) that inputs of nitrogen, phosphorus and organic matter will continue to be calculated as hitherto, (2) that the methodological problems (water versus particles) will be solved, and (3) that if screening investigations are carried out, efforts will be made to ensure coordination as regards the stations in the subprogramme for watercourses and the subprogramme for marine waters.

Finally, as regards the monitoring and calculation of atmospheric deposition it is assumed: (1) that the deposition of nitrogen on the sea will continue to be calculated as hitherto, (2) that measurement of irradiance will be added as a new activity at the stations at Anholt and Keldsnor, which are the backbone of the subprogramme, and (3) that at least one air measurement station encompassing monitoring of hazardous substances will be located coastally.

9.8 Consequences of the subprogramme in relation to the inventory of monitoring requirements

The present subprogramme is based on the inventory of monitoring requirements and meets the majority of the requirements and obligations. It does not meet 100% of the requirements, however, either because (1) A number of the obligations cannot yet be included in the monitoring programme for scientific reasons because the monitoring or analysis methods have not yet been developed or (2) The obligation is costly in the sense that the collected information is modest relative to the costs in association with sailing, sample collection or analysis.

The extent to which the monitoring meets the objectives is summarized in Table 9.26 for 1) Eutrophication incl. physical conditions and modelling, 2) Biodiversity and marine habitats, and 3) Hazardous substances and biological effect monitoring. A more detailed assessment of this is available in an annex to Part 3 of the Programme Description.

Table 9.25 Comparison of the regional authorities' activities in the NOVA-2003 and NOVANA programmes.

Aktiviteter	NOVA-2003		NOVANA	
	n	Frequency	n	Frequency
Level 1 coastal waters:				
Physical-chemical conditions in water – HS	7	2/6 and 3/6	0	0
Sediment: HS[1]	10	2/6	35	1/6
Benthic invertebrates – extensive soft-bed	0	0	845	1/6
Benthic invertebrates – biological effect (imposex)	21	1	13 × 3	3/6
Benthic invertebrates – HS (supplementary)	12	3/6	25	3/6
Fish – species composition, etc.	0	0	7	1/6
Level 2 coastal waters:				
Profile measurements	38[2]	12–28, 47	34	20–33
Plankton	11	17–28	6 + 11	19–25
Sediment: internal loading etc.	8	2/6–2	0	0
Submerged aquatic vegetation – macroalgae	≈34	3/6	23	3/6
Submerged aquatic vegetation – eelgrass	≈34	1 and 3/6	29	1
Benthic invertebrates	23	1	23	1
Benthic invertebrates – biological effect monitoring	0	0	4	1
Benthic invertebrates – HS	12	1	30	1
Fish – biological effect monitoring	0	0	4	1
Fish – HS[3]	3	1	4	1
Level 2+ coastal waters:				
Profile measurements (level 2)	5 * 3[4]	47	11	+ 20–24
Profile measurements (other)	-	-	9	11–47
Plankton etc.	5	26	11	16–25
Sediment: internal loading	5	2/6–2	9	8–10 × 2/6
Submerged aquatic vegetation (areas, biomass, aerial photos etc.)	5	2/6	11	2/6 and 1
Filter feeders	5	1	9	1
Level 2+ open marine waters:				
Profile measurements (k)	16[5]	6–47	11	6–47
Plankton etc.	5	3–26	4	5–28
Sediment: processes and pools	3	2/6–2	0	0
Model complex, open marine waters:				
Model, communication etc.	0	0	1	Cont.
Buoys	3	Cont.	3	Cont.
Intensive marine stations	3	44	3	44

[1)] Number of subsamples (mean) changed from 3+ in NOVA-2003 to 2 in NOVANA.

[2)] Includes both representative and type areas, sensu NOVA-2003.

[3)] Two former state stations have been transferred to the regional authorities' programme.

[4)] In the NOVA-2003 programme the type areas encompassed three stations.

[5)] Incl. three intensive marine stations required by the hydrographic model of Danish marine waters.

Table 9.26 Assessment of the extent to which the monitoring meets the obligations and requirements described in the inventory of monitoring requirements.

	Coastal waters	Open marine waters
Eutrophication	+	–
Biodiversity and marine habitats	+	+ / –
Hazardous substances and biological effect monitoring	+ / –	+

9.9 Annexes

Annex 9.1 Heavy metals – marine waters.

	Fish		Mussels		Sediment	
Variable	**Frequency**	**Detection limit**	**Frequency**	**Detection limit**	**Frequency**	**Detection limit**
Heavy metals:						
Arsenic (As)					1/6	200 µg/kg DM
Lead (Pb)	1	40 µg/kg ww	1	40 µg/kg ww	1/6	200 µg/kg DM
Cadmium (Cd)	1	5 µg/kg ww	1	5 µg/kg ww	1/6	10 µg/kg DM
Copper (Cu)	1	200 µg/kg ww	1	200 µg/kg ww	1/6	200 µg/kg DM
Chromium (Cr)	1				1/6	200 µg/kg DM
Mercury (Hg)	1	10 µg/kg ww	1	10 µg/kg ww	1/6	10 µg/kg DM
Nickel (Ni)	1	200 µg/kg ww	1	200 µg/kg ww	1/6	200 µg/kg DM
Zink (Zn)	1	500 µg/kg ww	1	500 µg/kg ww	1/6	500 µg/kg DM

Annex 9.2 Pesticides and hazardous substances – marine waters.

	Fish		Mussels		Sediment		Water phase	
Variable	**Freq.**	**Detect. limit**	**Freq.**	**Detect. limit**	**Freq.**	**Detect. limit**	**Freq.**	**Detect. limit**
Pesticides:								
DDT	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
DDE	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
Gamma-lindane (HCH)	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
Aldrin[1]			S	0.5 µg/kg ww				
Dieldrin[1]			S	0.5 µg/kg ww				
Endrin[1]			S	0.5 µg/kg ww				
Isodrin[1]			S	0.5 µg/kg ww				
Diuron							1/6[2)]	0.002 µg/l
Irgarol							1/6[2)]	0.002 µg/l
Atrazine							1/6[2)]	0.002 µg/l
Simazine							1/6[2)]	0.002 µg/l
Sea-Nine							1/6[2)]	1.0 µg/l
Zink-pyrethion							1/6[2)]	1.0 µg/l
Aromatic hydrocarbons:								
Dimethylnaphthalenes			S	0.5 µg/kg ww	1/6	1 µg/kg DM		
1-methylnaphtalene			S	0.1 µg/kg ww	1/6	0.5 µg/kg DM		
2-methylnaphtalene			S	0.1 µg/kg ww	1/6	0.5 µg/kg DM		
Naphthalene			S	0.1 µg/kg ww	1/6	0.5 µg/kg DM		
Trimethylnaphthalenes			S	0.5 µg/kg ww	1/6	1 µg/kg DM		
Phenols:								
Nonylphenols					1/6	1 µg/kg DM		
Nonylphenol-monoethoxylates					1/6	2 µg/kg DM		
Nonylphenol-diethoxylates					1/6	2 µg/kg DM		
Halogenated aliphatic hydrocarbons:								
Hexachlorobutadiene					1/6	2 µg/kg DM		
Halogenated aromatic hydrocarbons:								
Hexachlorobenzene (HCB)	1	0.6 µg/kg ww	S	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
Pentachlorobenzene[1]					1/6	0.1 µg/kg DM		
1,2,4-trichlorobenzene[1]					1/6	0.1 µg/kg DM		
Trichlorbenzenes[1]					1/6	0.1 µg/kg DM		
Polychlorinated phenyls:								
PCB # 28	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
PCB # 31	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
PCB# 52	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
PCB # 101	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		
PCB # 105	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM		

PCB # 118	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM
PCB # 138	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM
PCB # 153	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM
PCB # 156	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM
PCB # 180	1	0.6 µg/kg ww	1	0.1 µg/kg ww	1/6	0.1 µg/kg DM
PCB #26 (coplanar)			S	x µg/kg ww	1/6	x µg/kg DM
PCB #77 (coplanar)			S	x µg/kg ww	1/6	x µg/kg DM
PCB #169 (coplanar)			S	x µg/kg ww	1/6	x µg/kg DM
Polyaromatic hydrocarbons (PAHs):						
Acenaphthene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Acenaphthylene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Anthracene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Benz(a)anthracene			1	0.2 µg/kg ww	1/6	1 µg/kg DM
Benz(a)pyrene			1	0.2 µg/kg ww	1/6	1 µg/kg DM
Benz(e)pyrene			1	0.2 µg/kg ww	1/6	1 µg/kg DM
Benz(ghi)perylene			1	0.5 µg/kg ww	1/6	1 µg/kg DM
Benzo(b+j+k)fluoranthenes			1	0.1 µg/kg ww	1/6	1 µg/kg DM
Chrysene + triphenylene	NB: reverse in NOVA		1	0.5 µg/kg ww	1/6	0.1 µg/kg DM
Dibenz(a+h)anthracene			1	1 µg/kg ww	1/6	2 µg/kg DM
Dibenzothiophene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
3,6-dimethylphenanthrene			1	0.5 µg/kg ww	1/6	1 µg/kg DM
Fluoranthene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Fluorene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Indeno(1,2,3-cd)pyrene			1	1 µg/kg ww	1/6	2 µg/kg DM
2-methylphenanthrene			1	0.5 µg/kg ww	1/6	1 µg/kg DM
Perylene			1	0.2 µg/kg ww	1/6	1 µg/kg DM
Phenanthrene			1	0.1 µg/kg ww	1/6	0.5 µg/kg DM
Pyrene			1	0.2 µg/kg ww	1/6	0.5 µg/kg DM
Plasticizers:						
Di(2-ethylhexyl) phthalate (DEHP)			S	5 µg/kg ww	1/6	1 µg/kg DM
Diisononylphthalate (DNP)			S	5 µg/kg ww	1/6	1 µg/kg DM
Di-n-octylphthalate			S	5 µg/kg ww	1/6	1 µg/kg DM
Dibuthylphthalate			S	5 µg/kg ww	1/6	1 µg/kg DM
Organotin compounds:						
Dibutyltin			1	1 µg/kg ww	1/6	2 µg/kg DM
Monobutyltin			1	5 µg/kg ww	1/6	10 µg/kg DM
Tributyltin (TBT)			1	1 µg/kg ww	1/6	2 µg/kg DM
Triphenyltin (TPhT)			1	5 µg/kg ww	1/6	10 µg/kg DM
Brominated flame retardants:						
BDE #47			1	0.02 µg/kg ww	1/6	0.065 µg/kg DM
BDE #99			1	0.02 µg/kg ww	1/6	0.065 µg/kg DM
BDE #100			1	0.02 µg/kg ww	1/6	0.065 µg/kg DM
BDE #153			1	0.04 µg/kg ww	1/6	0.125 µg/kg DM
BDE #154			1	0.04 µg/kg ww	1/6	0.125 µg/kg DM
Octabromodiphenylether[1]					1/6	x µg/kg DM
BDE #209[1]					1/6	x µg/kg DM
Dioxins and furans:						
Dioxins and furans			S	x µg/kg ww	1/6	x µg/kg DM

Freq.: Frequency.
S: Supplementary programme, performed 2/6 for the state programme and 3/6 for the regional authorities' programme.
x: Detection limit not yet set.
[1)] Included if the analysis can be included in one of the other analysis packages at no extra cost.
[2)] Carried out as screening.

10 Species and Terrestrial Natural Habitats

10.1 Introduction

The decision to implement NOVANA means that monitoring of the Danish terrestrial environment will be initiated on 1 January 2004 integrated with monitoring of the aquatic environment. The monitoring will be carried out collaboratively by the regional authorities and the State.

10.2 Background and status

While aquatic environment data have been collected at the national level in a planned, systematic manner for a number of years, no nationwide monitoring programme has previously existed for the terrestrial environment.

This does not mean that no information is available about the terrestrial environment, but the existing knowledge is fragmented and spread throughout many different institutions and organizations, without any overview being available. With NOVANA, more comprehensive and systematic monitoring of the terrestrial environment is finally being initiated.

The former lack of an actual national terrestrial environment monitoring programme influences the present subprogramme during the first six-year period of NOVANA. Major parts of the Danish terrestrial environment have only been charted pursuant to Section 3 of the Protection of Nature Act – and at such a general level that the information could not serve as the basis for planning NOVANA. As a consequence, part of the programme for the period 2004–2009 therefore has to aim at procuring the background knowledge that is lacking. The monitoring encompasses registration of the current status of the natural habitat types and, in the course of time, also of the trend in their status. No baseline is used in assessing the current status, which is instead assessed on the basis of the criteria stipulated for favourable conservation status, independent of the trend in the status of the natural habitat types prior to the monitoring programme. The trend in the status is assessed on the basis of the measurement series generated through annual measurements at the intensive stations and measurements every sixth year at the extensive stations.

The terrestrial environment part of NOVANA stems from the obligations under the Rio Convention to prepare a national strategy for conserving biodiversity. The Convention defines biodiversity on the following three levels:

1. Ecosystem diversity
2. Species diversity
3. Genetic diversity.

Of these, NOVANA addresses the first two through monitoring of ecosystems/natural habitats and through monitoring of individual species. At present, however, it is not possible to design a realistic monitoring programme able to address the level "genetic diversity".

The main European legislation of relevance for nature protection is the Birds Directive and the Habitats Directive. Together these encompass a large number of natural habitats and species that are threatened in the European Union. The EU Member States are therefore required to implement national measures to ensure that the encompassed species and natural habitats achieve so-called "favourable conservation status". The Special Protection Areas (SPAs) established pursuant to the Birds Directive and the Special Areas of Conservation (SACs) established pursuant to the Habitats Directive together comprise the European Natura 2000 network. The Danish Forest and Nature Agency has prepared an inventory of monitoring requirements that assesses monitoring needs pursuant to international and national obligations.

In the present subprogramme these requirements have been subdivided according to ecosystem level and species level. Using the terminology of the Habitats Directive, where "ecosystems" are termed "natural habitats", the NOVANA subprogramme for species and terrestrial natural habitats aims to address both levels.

The subprogramme has been designed around the inventory of monitoring requirements. As both the national and international needs are comprehensive, a large number of aspects need to be covered. The individual elements are thus planned in such a way that it will not be possible to reduce data collection without exceeding the lower limit for what is scientifically defensible.

10.3 Overall strategy for monitoring of species and terrestrial natural habitats

The Habitats Directive defines the term "favourable conservation status" for both natural habitats and species (see Annex 1 of Part 3 of the Programme Description). According to the directive, conservation objectives have to be drawn up for both at the national and locality levels (Natura 2000 SACs).

In addition, several regional authorities have drawn up proposals for nature quality objectives for use in future Regional Plans. It is expected that these will eventually be harmonized with the objectives pursuant to the Habitats Directive.

Table 10.1 Reporting deadlines for the various elements of the subprogramme for species and terrestrial natural habitats.

Programme element	State	State	Regional authorities
	International	National	
Habitats Directive, species	2006	Annual	Annual
Habitats Directive, natural habitats	2006	Annual	Annual
Birds Directive[1]	Tentatively 2006	Annual	Annual
Birds Directive[2]	Annual		
Tønder Marsh Act		Annual	
Wadden Sea – TMAP	Annual	Annual	
National Red Lists	2004	Regular revision	
Cormorant breeding populations		Annual	

[1)] The deadline for submission of the status report pursuant to the Birds Directive has not yet been fixed, but it would be appropriate if it coincided with the reporting deadlines for the Habitats Directive.
[2)] A number of special censuses of staging and overwintering migratory birds contribute to coordinated European censuses and are reported annually to Working Groups under Wetlands International.

The two parts of the subprogramme are planned so as to satisfy a number of international obligations. This also means that reporting by the State has to follow deadlines that will often be determined by deadlines for international reporting. In some cases this will influence the agreements drawn up between the State and the regional authorities concerning the timetable for performing, data submission and reporting of the individual elements of the monitoring programme by the regional authorities.

These deadlines are summarized in Table 10.1. As far as State reporting is concerned the deadlines for most elements are predetermined, and the new NOVANA subprogramme will have to fit in with these. In addition, fixed national reporting of NOVANA will take place each year. As far as concerns the regional authorities, data submission and reporting will take place annually.

Both parts of the subprogramme utilize a number of methods that have been tested in pilot projects run jointly by the State and the regional authorities in 2001–02. Once NOVANA has been initiated, moreover, results will be produced that will help strengthen the basis for planning and statistical optimization of the subprogramme. Where possible, existing data will be incorporated in the assessment of the status and trend regarding natural habitats.

It is considered essential that the experience gained is regularly incorporated so that any necessary adjustments can be agreed upon and implemented as early as possible, It is expected that this will be incorporated in the reports submitted by the regional authorities, especially at the beginning of the period, during which time there will naturally be less actual monitoring data to consider.

10.4 Monitoring of terrestrial natural habitats

10.4.1 Objectives

The overall objectives are to:

- Describe **sources of pollution** and other pressures and their effects on the status and trend regarding terrestrial natural habitats
- Document the overall **effect** of national **action plans** and measures directed at terrestrial natural habitats – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Help fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve terrestrial natural habitats, including helping to develop various tools.

The Habitats Directive requires Member States to designate special areas of conservation (SACs) in order to conserve the natural habitat types listed in Annex I of the directive. Approximately 60 of these occur in Denmark, of which 14 are priority natural habitat types. Of these approximately 60 natural habitat types, eight are marine, seven are freshwater (both lakes and watercourses), and 44 are terrestrial, of which 13 are priority natural habitat types. In all, 10 of the terrestrial natural habitat types are forest habitat types (three priority natural habitat types). Forest habitats are not encompassed by the present subprogramme.

The NOVANA programme for terrestrial natural habitats aims to monitor 18 of the 35 non-forest terrestrial natural habitat types. This monitoring encom-

passes all 10 of the priority terrestrial habitat types. Nature monitoring in forests is part of NOVANA, but has not yet been planned (see Part 1 of the Programme Description, Section 4.1.3). In the first phase of the programme the terrestrial natural habitat types will be charted. The forest habitat types will be charted by the Danish Forest and Nature Agency, with the National Environmental Research Institute providing knowledge- and need-based guidance. The natural habitat types are to be identified and the sites delineated. In addition, an initial assessment will be made of their nature content to facilitate selection of sites for monitoring stations. Based on the charting of forest habitat types a programme will be drawn up for nature monitoring in forests. Final selection of monitoring station sites is expected to be completed by the end of 2005. Charting of the forest habitat types is expected to be completed in 2006, such that monitoring can begin in 2007.

10.4.2 Strategy

10.4.2.1 Introduction

The monitoring of natural habitats in Denmark thus encompasses 1) their range 2) their structure and function and 3) their typical species – in accordance with the Habitats Directive's definition of favourable conservation status.

Natural habitats in Denmark are exposed to a large number of pressures. Some of these are anthropogenic, others are attributable to natural variation. The most important anthropogenic pressures are:

- **Eutrophication**. Pressures from nutrient inputs encompass inputs via atmospheric deposition and inputs via direct fertilization and via fertilization of adjacent land. The main pressures are inputs of nitrate, ammonia and phosphorus
- **Hydrology**. Pressures caused by lowering of the water table due to drainage and water abstraction
- **Changed land use** as a result of changes in management practice. The most important change is cessation of the grazing of permanent grasslands, which leads to non-forest natural habitats becoming overgrown
- **Attenuation of natural dynamics** through regulation (e.g. restriction of the flooding of meadows and reduction of breaches in sand dunes through planting)
- **Habitat fragmentation** as a result of which small natural habitats may become separated by too great a distance to allow species to spread naturally.

The effects of such pressures are reflected in the structure and function of the individual ecosystems/natural habitats, including the size of the nutrient pools, water table, etc. Terrestrial natural habitat monitoring under NOVANA thus aims not only to provide information about status and trends, but also to provide the necessary insight into both the natural and the anthropogenic pressures to be able to carry out appropriate management.

The natural habitats will be monitored both inside and outside the SACs. The SACs have been designated with the aim of covering the largest and most valuable occurrences of natural habitat types in Denmark. In addition, the SACs are relatively overrepresented by state-owned land. It will therefore be necessary to take into account any systematic differences in size distribution, management practice, pressures, etc. between the natural habitats inside and outside the SACs when making nationwide assessments of the natural habitat types.

Sets of criteria for favourable conservation status have been established for the individual natural habitat types. It is intended that these criteria should be measurable and hence usable as monitoring variables. This sets natural limits on the minimum number of variables that can be used to assess the status of natural habitats.

Due to economic constraints on the monitoring, the highest sampling frequency is annual. Thus it is meaningless to include variables that require more frequent measurements in order to be interpretable. Consequently, many functional elements will not be included in the monitoring programme.

Nitrogen deposition will be determined by modelling at a limited number of measurement stations on the basis of measured air concentrations. At the other stations, deposition will be determined using modelled air concentrations. The terrestrial natural habitat monitoring does not encompass measurements of sulphur and basic cation deposition.

The programme's needs and limitations are examined in greater detail in Annex 1 of Part 3 of the Programme Description.

10.4.2.2 Distribution of natural habitat types: Charting and area monitoring

For a natural habitat to have favourable conservation status its total area has to be stable or increasing. It is therefore necessary to incorporate monitoring of the area of natural habitat types into the subprogramme.

The general charting of natural areas in Denmark carried out pursuant to Section 3 of the Protection of Nature Act is based on the five main categories of natural habitat stipulated in the Act, however, i.e. 1) Lakes and watercourses, 2) Heathland and dunes, 3) Mires, 4) Coastal meadows and salt swamps and 5) Freshwater meadows and dry grasslands. The definitions of the natural habitat types applied in Section 3 of the Protection of Nature Act differ significantly from the definitions used in the Habitats Directive, and it is consequently not possible to use this charting to calculate the area and range of the natural habitat types encompassed by the Habitats Directive. The occurrence of the natural habitat types encompassed by the Habitats Directive will thus have to be charted in connection with NOVANA.

In addition to charting the habitats within the SACs, it can also be necessary to carry out some charting outside the SACs to ensure representative habitat monitoring. This can be done at a more extensive level, however.

The various habitat types differ considerably as regards what the charting will entail. Some types of habitat are congregated in large contiguous areas (e.g. the dune types), where they are woven together in a complicated mosaic structure. It is not practicable to chart these structures, and it is instead necessary to make an overall assessment of the percentage of the area covered by each habitat type. Other types (e.g. dry grasslands) are dispersed throughout the whole country as many small habitats of which a large proportion lies outside the SACs.

In 2000, NERI started to cooperate with the regional authorities and the Danish Forest and Nature Agency to chart the occurrence of natural habitats within the SACs. As a consequence, coverage of just under half of the terrestrial natural habitats in the non-forest SACs have already been determined.

In the initial phase of NOVANA the subprogramme thus needs to include completion of the charting work already initiated. The approach to be used involves the digitilization of the location and range of the natural habitats on orthophotographs on the basis of the regional authorities' knowledge of their occurrence supplemented by observations recorded in the field. Charting will be carried out just once in the first instance and is expected to be completed by the end of 2005.

10.4.2.3 Intensive monitoring

The aim of the network of intensive stations is primarily to enable description of the trends and relationship between pressures, status and trend. Data from the intensive stations are also to be used to calibrate and validate models and for generalizing input data so that the same models can be used at the extensive stations.

In order for the subprogramme to provide the coverage required pursuant to the Habitats Directive it would be best to locate the intensive stations in the SACs.

The selection of monitoring variables at the intensive stations is based on the conservation objectives set for the site together with a knowledge of the main pressures. Measurements are made of both physical-chemical and biotic variables (vegetation, phytochemistry, soil chemistry, water chemistry and selected fauna groups).

10.4.2.4 Extensive monitoring

The extensive monitoring shall provide the best possible representative picture of the current status of natural habitats at the national level and describe the trends. The extensive monitoring focuses on the composition of the vegetation and on selected information about soil conditions, nutrient status, acidification status and hydrology. In order to ensure representativeness it is expected that the extensive monitoring will be carried out both within and outside the SACs.

The data from the extensive monitoring should be suitable for assessing conservation status pursuant to the Habitats Directive.

10.4.2.5 Effect monitoring

Effect monitoring is monitoring aimed at determining the effects of specific nature management measures. Effect monitoring therefore entails more intensive registration of pressures than intensive monitoring. The planned activities provide the possibility to determine effects if any nature management etc. was carried out at the selected stations.

10.4.2.6 Monitoring of small biotopes

The NOVANA programme includes monitoring of structural landscape development in arable land with special emphasis on the trend with regard to small biotopes. This part of the programme is based on the nationwide monitoring carried out by Roskilde University since 1981.

10.4.2.7 Choosing between intensive and extensive monitoring

Close coupling is established between the intensive and extensive monitoring, among other means through the use of models. One of the preconditions for being able to implement this coupling is that the data collected through the extensive monitoring also serve as data for the intensive monitoring.

For each of the natural habitat types encompassed by the programme an appropriate number of intensive and extensive stations will thus have to be selected. This has to be done taking into consideration both the variation within the individual natural habitat types and the statistical variation between stations within the same natural habitat type. The total variation will determine the number of stations needed. Initially it is estimated that at least 10 intensive stations will be needed for each natural habitat type.

Selection of the correct location for the stations will be made jointly by the regional authorities and the Topic Centre.

10.4.2.8 Exchange within the subprogramme and with other subprogrammes

The monitoring of terrestrial natural habitats will contribute more to the monitoring of species than the converse. The areas where the two parts of the subprogramme can support each other are:

- Joint reporting in relation to the Habitats Directive
- The data on typical species collected during the terrestrial natural habitat monitoring will contribute to the extensive monitoring of the range of species encompassed by the species monitoring
- The data on conservation status and pressures on natural habitat types collected during the terrestrial

natural habitat monitoring will contribute to interpretation of the results from the species monitoring
- The species monitoring will contribute to future planning of management measures for habitats at the locality level
- Information on drainage and water abstraction.

The Topic Centre for Inland Surface Waters and the Topic Centre for Marine Waters are responsible for monitoring of habitats in the limnic and marine environments. The data will be incorporated in the national reporting pursuant to the Habitats Directive.

Under NOVANA, atmospheric deposition of nitrogen on land will be calculated for the individual stations by modelling. A network of measurement stations will be established for model validation for use in monitoring of both the aquatic and terrestrial environments. The new network will be established so as to match the coming location of the intensive stations. It is important that the station network for measuring atmospheric deposition meets the needs of all the NOVANA subprogrammes (see Section 4.2.11 in Part 1 of the Programme Description "The Nationwide Air Quality Monitoring Programme (LMP IV)").

In the agricultural monitoring catchments it will be possible to couple the interview data on agricultural practice – including data on grazing intensity and emission and deposition calculations – to effects on nature and the environment. Where possible, it will also be relevant to couple data on water abstraction and water table to the selection of stations for monitoring the terrestrial environment. With several of the wet natural habitats it will be relevant to coordinate with the Topic Centre for Inland Surface Waters.

10.4.3 Programme content

10.4.3.1 Selection of natural habitat types

Due to economic constraints it has not been possible for the subprogramme to encompass comprehensive monitoring of all the 35 types of non-forest natural habitat found in Denmark, and we have therefore had to prioritize between them. In selecting the natural habitat types for monitoring attempts have been made to:

- Ensure representative monitoring of the 10 priority non-forest terrestrial natural habitat types
- Ensure representative monitoring of natural habitat types that are considered to be particularly exposed to negative pressures
- Ensure representative monitoring of natural habitat types protected under the Protection of Nature Act.

The monitoring will therefore focus on the main habitat categories, i.e. coastal meadows, heaths, dunes, dry grasslands and mires, and will provide representative coverage of the following natural habitat types encompassed by the Habitats Directive (The Natura 2000 code is shown; priority natural habitat types are indicated by an asterisk):

1330 Atlantic salt meadows *(Glauco-Puccinellietalia maritimae)*
1340* Inland salt meadows
2130* Fixed coastal dunes with herbaceous vegetation ("grey dunes")
2140* Decalcified fixed dunes with *Empetrum nigrum*
2190 Humid dune slacks
2250* Coastal dunes with *Juniperus* spp.
4010 Northern Atlantic wet heaths with *Erica tetralix*
4030 European dry heaths
6120* Xeric sand calcareous grasslands
6210* Semi-natural dry grasslands and scrubland facies on calcareous substrates *(Festuco-Brometalia)* (* important orchid sites)
6230* Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe) [1)]
6410 *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils *(Molinion caeruleae)*
7110* Active raised bogs [2)]
7140 Transition mires and quaking bogs
7150 Depressions on peat substrates of the *Rhynchosporion*
7210* Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
7220* Petrifying springs with tufa formation *(Cratoneurion)*
7230 Alkaline fens.

[1)] 6210 is only a priority habitat type if the site is rich in orchids
[2)] and adjoining areas of degenerated raised bogs still capable of natural regeneration (7120).

To a large extent these natural habitat types also meet the need for monitoring of the habitats encompassed by the Protection of Nature Act. In addition, the subprogramme will be able to provide basic data on a number of other natural habitat types encompassed by the Habitats Directive that will occur in mosaic with the selected natural habitat types at the monitoring stations. The natural habitat types that are expected to be included in the mosaic are:

1210 Annual vegetation of drift lines
1220 Perennial vegetation of stony banks
1230 Vegetated sea cliffs of the Atlantic and Baltic Coasts
1310 *Salicarnia* and other annuals colonizing mud and sand
1320 *Spartina* swards (*Spartinion maritimae*)
2120 Shifting dunes along the shoreline with *Ammophila arenaria* ("white dunes")
2160 Dunes with *Hippophaë rhamnoides*
2170 Dunes with *Salix repens* ssp. *argentea* (*Salicion arenariae*)
2180 Wooded dunes of the Atlantic, Continental and Boreal region
2310 Dry sand heaths with *Calluna* and *Genista*

2320 Dry sand heaths with *Calluna* and *Empetrum nigrum*
2330 Inland dunes with open *Corynephorus* and *Agrostis* grasslands
5130 *Juniperus communis* formations on heaths or calcareous grasslands
7120 Degraded raised bogs still capable of natural regeneration.

In addition to the 10 forest habitat types, the Annex II terrestrial natural habitat types that are not expected to be encompassed by the present subprogramme are:

2110 Embryonic shifting dunes
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
8220 Siliceous rocky slopes with chasmophytic vegetation.

10.4.3.2 Extensive and intensive stations

The difference between extensive and intensive stations is firstly, that intensive stations are monitored every year while extensive stations are monitored every sixth year, and secondly, that more chemical variables are measured at intensive stations than at extensive stations. The distribution of stations among the individual natural habitat types follows the following general rules:

1. Ten intensive stations is considered to be the minimum necessary to document interannual variations and describe the selected causal relationships. In the case of natural habitat types that are characterized by great heterogeneity and/or are subjected to a very varied range of pressures, the number of intensive stations is greater
2. The number of extensive stations in each individual natural habitat type lies between 0 and 100. In the case of natural habitat types that are very rare in Denmark or which exhibit very little variation, no extensive stations have been established. In general, the number of stations depends on the number of individual habitats of each type and on the natural and anthropogenic variation within the natural habitat type.

The basis for the selection of monitoring stations is presented in Annex 1 of Part 3 of the Programme Description. The distribution of the intensive stations is based on the existing knowledge, whereas the final distribution of the extensive stations will be based on the results of the habitat charting.

The preliminary distribution of stations among the natural habitat types encompassed by the subprogramme is shown in Table 10.2.

Table 10.2 Distribution of intensive and extensive stations among the natural habitat types encompassed by the subprogramme. The final decision on the number and location of the extensive stations awaits the results of the habitat charting.

Habitat type	Intensive stations	Extensive stations
1330 (incl. 1340)	10	75
2130	15	75
2140	10	50
2190	10	50
2250	10	0
4010	10	50
4030	15	100
6120	10	0
6210	15	100
6230	15	100
6410	10	50
7110	10	11
7140	10	50
7150	10	10
7210	10	10
7220	10	50
7230	15	75

10.4.3.3 Selection of variables

The variables have been selected so as to fulfil the objectives of the monitoring programme as best possible. The objective accorded highest priority is monitoring of the conservation status of natural habitat types encompassed by the Habitats Directive. Under the directive, favourable conservation status depends on the habitat's area and range, the structure and functions necessary for its long-term maintenance, and the range and population dynamics of its typical species.

For each of the natural habitat types encompassed by the Habitats Directive a set of indicators of favourable conservation status has been developed that defines favourable biological status for the habitat type in question and the physical-chemical environment that has to be present in order for favourable status to be maintained (see Table 10.3). These indicators describe a number of measurable variables and for each parameter a criterion that has to be fulfilled. The indicators are selected with the aim of fulfilling the definition of favourable conservation status given in the Habitats Directive and of encompassing the main known pressures affecting the individual habitat types.

Part 3 of the Programme Description contains a detailed description of the selected.

Eutrophication (and acidification), cessation of extensive farming, changes in hydrology, attenuation of natural dynamics and habitat fragmentation constitute the main pressures on habitat area and range, structure and function and typical species. With certain habitat types, invasive species can also pose a threat.

Air concentrations of ammonia are measured annually at approx. 10 intensive stations.

The pH level is relatively stable throughout the growth season with little interannual variation. Measurement of pH is relevant for all natural habitat types and will be carried out at both the intensive and the extensive stations at six-year intervals.

Measurements of conductivity are performed in fen and raised bog communities and in coastal meadows using annual measurements at the intensive stations and six-year intervals at the extensive stations.

The C/N ratio is measured every sixth year at all stations.

The phosphorus index, which is well suited for assessing the impact of any fertilization, is measured every sixth year at relevant stations.

Measurements of nitrate/ammonium vary markedly with water table conditions and the amount of precipitation and consequently also vary through the growth season and from year to year. The measurements are carried out in fen and raised bog communities and in coastal meadows using annual measurements at the intensive stations and six-year intervals at the extensive stations.

Nitrogen analyses of shoots, mosses and lichen can provide important information about the nitrogen load from the air at the locality. Such measurements are made annually at the intensive stations in heaths, dunes and some types of mire.

The water table varies considerably over the year – especially when the hydrology is natural – and from year to year depending on precipitation and input from the surroundings. The water table is only measured at selected intensive stations.

The structure and composition of the vegetation is investigated in all natural habitat types.

Table 10.3 Example of criteria for favourable conservation status for a natural habitat type. Each row in the table is an indicator specified through a property, a measurable parameter and a criterion that has to be fulfilled.

Indicator	Property	Measurable parameter	Criterion	Remarks
Area	Area	Ha	The area has to be stable or increasing	Calculation of area is based on reproducible methods
Structure and function	Eutrophication	Average Ellenberg indicator value for nitrogen on species list; C/N; N content of lichen/moss	Ellenberg N <3.5. C/N <xx, N% in leaves <y%. All figures stable or decreasing	
	Natural nutrient balance	The available nutrient pool (seen in dynamic relationship with the other pools and in exchange with the surroundings)	Inputs of nutrients must not cause short-term or long-term changes in structure, function or species composition	Critical load for N deposition currently estimated to be 10–15 kg N/ha/yr
	Balance between lichen, grass and plant dominated vegetation and thicket/trees	Coverage of bushes and trees	Stable or decreasing	Designed so that the indicator does not exclude the preservation of old valuable thickets
	Hydrology	Water table measured in July–August	Water table must not exceed – 20 cm	
Typical species	Typical species	Population index for each typical species	Long-term maintenance at a stable or increasing level	Calculated on a species basis, e.g. DAFOR scale. Fluctuations are natural. In special cases a decreasing level can be accepted and stipulated as an objective.

The Interpretation Manual of European Union Habitats describes characteristic species for each natural habitat type. Investigation of the occurrence and the population dynamics of these species is included in the assessment of whether the conservation status of the individual habitat type is favourable.

Information will be collected about C/N in soil and biomass analyses, and factors such as vegetation height, degree of cover of woody plants and invasive species, dry/wet areas of raised bogs, heather beetle damage, etc. will be assessed in the relevant natural habitat types.

10.4.3.4 Establishment of stations

Each station is assigned to a single natural habitat type. As many natural habitat types occur in mosaics, the area covered by a station may encompass several natural habitat types. This applies for example to humid dune slacks, which occur as patches in areas with grey dunes and dune heathland. In the case of natural habitat types such as dry grasslands and mires, attempts are made to select stations that encompass several habitats of the type in question located in close proximity to each other. By establishing large stations, transport costs for fieldwork are minimized and the possibilities for making use of common station data are maximized. The final decision on location of the stations will aim to ensure good representation of the natural habitat type and its geographic and biological range of variation. Final selection of the stations will be carried out by NERI in cooperation with the regional authorities.

10.4.3.5 Charting and area monitoring

The habitat charting is expected to be completed by the end of 2005. The charting only encompasses the 18 natural habitat types in which it is planned to establish monitoring stations. Outside the SACs, the natural habitats will be charted in a more extensive manner based on random analyses. The charting will initially be based on maps and existing knowledge and will be supplemented by field visits to identify and delineate the natural habitats.

10.4.3.6 Data processing and reporting

Data processing and reporting will be carried out annually for all intensive stations and those extensive stations encompassed by the year's monitoring activities. In practice, data will thus be reported annually from the pool of extensive stations as these are expected to be monitored in a cycle that involves a proportion of the stations each year. Data processing encompasses dealing with the samples, input/transfer of results and quality assurance of the data. Reporting encompasses adapting data to and reporting them in agreed formats.

10.4.4 Consequences of the natural habitat programme in relation to the inventory of monitoring requirements

The Habitats Directive concerns conservation of natural habitat types and species. The Directive stipulates the term "natural habitat types" in relatively great detail as defined in the Interpretation Manual of European Union Habitats. Approximately 60 of the natural habitat types encompassed by the Directive occur in Denmark, of which 13 are "priority" terrestrial natural habitat types (i.e. habitat types in danger of disappearance and for the conservation of which the Community has particular responsibility (indicated by an asterisk (*)).

The Protection of Nature Act encompasses the following categories of terrestrial natural habitat: heathland, dunes, mires, coastal meadows and salt swamps, freshwater meadows and dry grasslands. Dunes are not covered by Section 3 of the Act, however. Forests are covered by other legislation.

Attempts have been made to maintain a connection between the Habitats Directive and the Protection of Nature Act by grouping the directive's natural habitat types under the habitat categories used in the Protection of Nature Act. In the present subprogramme this has been concretized through the monitoring of the 35 Habitat Directive non-forest terrestrial natural habitat types found in Denmark. In drawing up the programme, emphasis has been placed on the 10 of these that are priority natural habitat types.

The design of the monitoring accords priority to meeting international obligations, in particular pursuant to the Habitats Directive, while concomitantly providing relevant knowledge in relation to national legislation and objectives. The subprogramme will help accrue knowledge of relevance for the Rio Convention on Biodiversity and to international fora such as the OECD. Moreover, the Habitats Directive natural habitat types found in Denmark provide good representation of the habitats protected under the Protection of Nature Act and are among the most important habitats for organisms encompassed by the Danish Red List of animals, plants and fungi in need of protection.

It is difficult to assess how good the coverage provided by the data collected under NOVANA is because the occurrence of the individual natural habitat types in Denmark has not yet been fully charted. To some extent, coverage (both inside and in some cases outside the SACs) can be assessed from the basis for selection of the 254 SACs in Denmark. It should be taken into consideration, though, that the basis for selection of the sites cannot be used as the basis for a complete assessment of the coverage provided by the subprogramme as:

- The individual habitats vary considerably in size from under 1 ha to several km^2

- In many cases there are several separate habitats of one natural habitat type within a SCA even though the habitat type is only included once in the basis for selection
- The percentage of the total area of a given natural habitat type in Denmark accounted for by the selected habitats varies from 20% to more than 50%.

In all, 44 of the terrestrial natural habitat types encompassed by the Habitats Directive occur in Denmark (Table 10.4). Of these, 10 are forest habitats that are not included in NOVANA at present. Of the remaining 34 habitat types, monitoring stations are planned at 18. The subprogramme will thus enable a nationwide assessment of these habitat types. To some extent data will also be collected for the other 17 non-forest natural habitat types (through the random establishment of field plots at the stations), but it is as yet uncertain whether it will be possible to provide a nationwide assessment for these habitat types.

The overall assessment is therefore that the present monitoring programme for the selected natural habitat types adequately fulfils the monitoring obligations pursuant to the Habitats Directive.

10.5 Monitoring of species

10.5.1 Objectives

The overall objectives are to:

- Describe **sources of pollution** and other pressures and their effects on the status and trend in the population dynamics of selected species of plants and animals
- Document the overall **effect** of national **action plans** and measures directed at the aquatic environment and nature – including whether the **objectives** are attained, and whether the **trend** is in the desired direction
- Help fulfil Denmark's **obligations** under EU **legislation**, international conventions and national legislation
- Help strengthen the **scientific foundation** for future international measures, national action plans, regional administration and other measures to improve the aquatic environment and nature, including helping to develop various tools.

The species monitoring contains the following elements:

- Monitoring of the status and trend for selected plant and animal species encompassed by Annexes II and IV of the Habitats Directive
- Monitoring of birds pursuant to the Birds Directive (Annex I for breeding species - and regularly occurring migratory species. The most important of the regularly occurring migratory species are 28 species of national responsibility (species of which more than 20% of the total population occurs in Denmark)
- Monitoring of certain species of national responsibility that can be monitored within the framework of the remaining extensive monitoring of species (vascular plants, moths)
- A special programme for monitoring birds in the Wadden Sea in cooperation with Germany and Holland (Trilateral Monitoring and Assessment Program – TMAP)
- A special programme for Tønder Marsh focussing on breeding birds
- Monitoring of the cormorant breeding population
- Preparation of national Red Lists.

10.5.2 Background and status

For each of the species encompassed by Annex II of the Habitats Directive – and for which SACs have been designated (Table 10.5) – NERI has provided the scientific framework for final political/administrative stipulation of individual criteria for favourable conservation status at both the locality and national levels. The scientific framework for stipulation of these criteria concomitantly comprises a specification of the variables that should be included in the monitoring programme.

In 2000, for use in connection with Denmark's first national reporting to the EU Commission pursuant to the Habitats Directive (which has to take place every sixth year), NERI prepared a status report for the priority natural habitat types and the species encompassed by Annexes II, IV and V. The data thereby collected were considered adequate to enable a solid assessment of the conservation status of 30 species and inadequate for 49 species. To the extent that the data material enabled conservation status to be assessed, this was found to be "favourable" for 14 species, "unfavourable" for 22 species and "unknown" for 17 species, while 13 species were assessed as "extinct". At the same time it was concluded that the group of 79 species assessed could not unequivocally be considered as representative of Denmark's flora and fauna.

Table 10.4 Summary of the subprogramme's coverage of the 44 terrestrial natural habitat types encompassed by the Habitats Directive that occur in Denmark. For each habitat type the table indicates the number of times it is included in the basis for selection of the 254 Danish SACs, and the provisional number of planned intensive and extensive monitoring stations. The number of planned stations can exceed the number of occurrences of the habitat included in the basis for selection of the Danish SACs, either because there are several stations in the same SAC or because there are stations outside the SACs. The priority natural habitat types, on which emphasis is placed in planning the subprogramme, are indicated by an asterisk (*). (*) 6210 is only a priority habitat type if the site in question is rich in orchids.

Habitat type	No. of habitats included in the basis for SAC selection	Intensive stations	Extensive stations
1210	42	0	0
1220	32	0	0
1230	26	0	0
1310	35	0	0
1330 and *1340	50	10	75
2110	23	0	0
2120	36	0	0
*2130	39	15	75
*2140	35	10	50
2160	16	0	0
2170	20	0	0
2180	11	0	0
2190	27	10	50
*2250	10	10	0
2310	7	0	0
2320	12	0	0
2330	10	0	0
4010	28	10	50
4030	64	15	100
5130	34	0	0
*6120	13	10	0
(*)6210	73	15	100
*6230	81	15	100
6410	25	10	50
6430	49	0	0
*7110	16	10	11
7120	17	0	0
7140	32	10	50
7150	20	10	10
*7210	12	10	10
*7220	40	10	50
7230	112	15	75
8220	4	0	0
8330	1	0	0
9110	33	-	-
9120	11	-	-
9130	65	-	-
9150	8	-	-
9160	51	-	-
9170	3	-	-
9190	35	-	-
*91D0	42	-	-
*91E0	98	-	-

Table 10.5 Species encompassed by Annex II of the Habitats Directive that occur in Denmark. The table shows the number of special areas of conservation (SACs) designated for each species in 1998 and 2002 (revised basis for selection).

Species	Number of SACs		Species	Number of SACs	
	1998	2002		1998	2002
Great crested newt	35	55	European great diving beetle	2	2
Otter	34	57	Green shield-moss	2	2
Harbour porpoise	17	1	Weatherfish	2	2
Common seal	12	21	Dipping beetle	2	3
Hermit beetle*	10	11	Allis shad	2	1
Brook lamprey	9	37	Thick shelled river mussel	2	2
Fen orchid	9	11	Bechstein's bat[1]	2	(1)
Sea lamprey	8	12	Barbastelle[1]	1	(1)
Pond bat	8	10	Least moonwort	1	1
River lamprey	7	13	Freshwater pearl mussel	1	1
Marsh Fritillary	6	8	Lady's-slipper orchid	1	1
Fire-bellied toad	6	6	Atlantic salmon	1	4
Houting*	5	5	Slender naiad	1	1
Grey seal	5	8	Roger's bristle-moss	1	(1)
Marsh saxifrage	5	7	Narrow mouthed whorl snail	1	8
Twaite shad	5	7	Desmoulin's whorl snail	1	12
Spined loach	5	6	Greyer's whorl snail	0	1
Slender green feather-moss	4	5	Dichelyma moss	0	0
Floating water-plantain	4	6	Messia moss	0	0
Green club-tailed dragonfly	3	3	Pseudoscorpion Anthreno-chernes stellae	0	1
Large white-faced darter	3	6			

[1] Bechstein's bat, the Barbastelle and Roger's bristle-moss were deleted from the Reference List for the Continental Biogeographical zone in Denmark (which lists the Annex II species naturally occurring in Denmark) after the Natura 2000 Continental Region pSCI representativity assessment seminar in November 2002.

Due to the rather sparse knowledge, one of the objectives of the species monitoring programme under NOVANA is to establish more reliable data material for such assessments.

The occurrence and population dynamics of the individual species in Denmark are affected by many factors. The most important anthropogenic pressures are:

- Eutrophication
- Habitats becoming overgrown due to changes in management practice
- Drainage/abstraction
- Fragmentation.

Registration of these factors in the present subprogramme is limited, but data on them are obtained through other subprogrammes. Moreover, the species monitoring is planned in such a way that the collected data provide the basis for analysing the significance of the individual factors.

At present the range of approx. 800 species has been charted in Denmark through the so-called Atlas mapping of occurrence studies (10 x 10 km grid), which have examined groups such as birds, amphibians and certain insects (butterflies, hoverflies). These studies can serve as the baseline for monitoring of the majority of the species.

10.5.3 Strategy

10.5.3.1 Introduction

The occurrence of a species can be described through its:

- Range and
- Population size.

Both range and population size are elements of the Habitats Directive's definition of favourable conservation status.

Monitoring of population size is often very resource-heavy, while monitoring of range can be carried out for fewer resources and at a more extensive level. In the present programme, species monitoring is subdivided into:

1. Intensive monitoring
2. Extensive monitoring, and
3. Effect monitoring (which aims to investigate the effects of concrete nature management measures).

These three monitoring categories are described below.

10.5.3.2 Intensive monitoring

Intensive monitoring is monitoring of population size.

The methods depend on the species in question. In many cases, monitoring of population size can be carried out by simple counting. In other cases, when either the populations are large or the species in question live hidden, it can be necessary to employ methods such as transect surveys or so-called capture-recapture analysis.

Intensive monitoring also encompasses relatively general registration of relevant background information about the surrounding environment for use in assessing the status of the population. To some extent the necessary data are expected to be provided by the habitat part of the subprogramme.

As a general rule, intensive monitoring is carried out annually, but could be carried out every second, third or sixth year in order to meet administrative needs after discussion in the Steering Committee for the Topic Centre for Biodiversity and Terrestrial Nature.

10.5.3.3 Extensive monitoring

Extensive monitoring is monitoring of range.

Extensive species monitoring is directed at the variable "range" in the Habitats Directive's definition of favourable conservation status and aims to provide sufficient information to be able to assess to what extent a species' range in Denmark is decreasing, stable or increasing (explained further in Annex 1 of Part 3 of the Programme Description).

As a general rule, extensive monitoring is carried out every sixth year, but can be "intensified" by increasing the frequency as necessary.

In the case of the species and populations that are monitored extensively, very general background information can also be included.

10.5.3.4 Effect monitoring

As far as concerns species monitoring under NOVANA, effect monitoring is monitoring of effects of concrete nature management measures on populations. In order to provide the necessary data, one or more populations are monitored intensively, and factors in the surrounding environment are registered more frequently using a more comprehensive set of variables that encompasses both variables that are changed by a management measure, and other variables in the catchment that can influence the result.

Effect monitoring is carried out annually (in those cases where it needs to be carried out over a relatively long period of time).

10.5.3.5 Choosing between intensive and extensive monitoring

In principle, the choice between intensive and extensive monitoring in NOVANA depends on the targets set for the species in question – possibly at a specific locality. If specific targets have been set, intensive monitoring is applied; otherwise extensive monitoring is applied.

In many cases it is not possible to carry out intensive monitoring, however. For example, species such as otter, the priority beetle species the hermit beetle, bats and whorl snails can only be monitored extensively as methodological constraints render the monitoring of their population size unrealistic.

Conversely, there are species for which extensive monitoring can be rendered intensive without any major increase in resource consumption. An example is the Lady's-slipper orchid, which presently only occurs in Denmark in two small, restricted populations. When "charting" these populations it would be relatively easy to concomitantly register the number of individuals.

Intensive monitoring is carried out in accordance with the conservation objectives for species at the locality level in those SACs where the species in question is included in the basis for selection of the SACs (see Table 10.5).

Extensive monitoring is carried out in the case of species that do not have to be monitored intensively. In principle, extensive monitoring is carried out every sixth year. In certain cases it can be appropriate to increase the frequency, however (see Annex 1 of Part 3 of the Programme Description).

Effect monitoring is only carried out in special cases. At present, it is not intended that any effect monitoring should be carried out under NOVANA by the regional authorities. This can be incorporated as needed following consideration by the Steering Committee for Terrestrial Nature and the Programme Management Board.

The distribution of the Habitats Directive Annex II and IV species between intensive and extensive monitoring is described in Annex 1 of Part 3 of the Programme Description. Initial analyses carried out by NERI indicate that this group of species is at least to some extent representative of species diversity in Denmark.

The distribution of the Birds Directive Annex I species between intensive and extensive monitoring is also described in Annex 1 of Part 3 of the Programme Description.

The species encompassed by Annexes II and IV of the Habitats Directive and Annex I of the Birds Directive comprise a number of groups of which several species can be recorded together as one entity. This makes it most practical to group the monitoring according to the following programme elements:

- Mammals
- Birds

- Amphibians
- Fish
- Insects
- Snails and mussels
- Plants and mosses.

The monitoring of these species groups/species is described in more detail in Annex 1 of Part 3 of the Programme Description.

10.5.3.6 Exchange within the subprogramme and with other subprogrammes

The monitoring of terrestrial natural habitats will contribute more to the monitoring of species than the converse. The areas where the two parts of the subprogramme can support each other are:

- Joint reporting in relation to the Habitats Directive
- The data on typical species collected during the terrestrial natural habitat monitoring will contribute to the extensive monitoring of species range in the species monitoring
- The data on conservation status and pressures on natural habitat types collected during the terrestrial natural habitat monitoring will contribute to interpretation of the results from the species monitoring
- The species monitoring will contribute to future planning of management measures for habitats at the locality level.

Part of the data needed in the species monitoring is obtained through the subprogrammes for watercourses and for lakes (freshwater fish and monitoring of ponds). These data will be utilized in the national reporting pursuant to the Habitats Directive and in the extensive monitoring of species range.

10.5.4 Programme content

10.5.4.1 General principles for the monitoring of species

Based on the inventory of monitoring requirements the species monitoring has been planned so as to encompass a total of approx. 170 species as outlined below:

- Monitoring of Habitats Directive Annexes II and IV species (34 and 21 species, respectively). The 21 Annex IV species only include species that are not included in Annex II. This part of the programme also encompasses 30 species of vascular plants designated as species of national responsibility in the national Yellow List, as well as 10 species of moth that are also designated as species of national responsibility
- Monitoring of birds under the Birds Directive (Annex I, regularly occurring migratory species and species of national responsibility (37 and 28 species, respectively)
- Monitoring of species of national responsibility (moths and vascular plants)
- Trilateral Monitoring and Assessment Program (TMAP) under the Trilateral Wadden Sea Cooperation (the present subprogramme encompasses the monitoring of birds in the Wadden Sea)
- The preparation of national Red Lists
- Monitoring of Tønder Marsh focussing on breeding birds
- Monitoring of the cormorant breeding population.

The various special programmes (preparation of Red Lists, TMAP and Tønder Marsh) are part of the monitoring that has been carried out for a number of years by the State. The majority of these programmes are specialized and will continue to be run by the State under NOVANA. Similarly, the State has hitherto also monitored two species encompassed by Annex II of the Habitats Directive (grey seal and common seal) and certain birds encompassed by the Birds Directive (the cormorant breeding population and moulting, staging and overwintering migratory bird populations). These programmes, which require specialized methods such as aerial counts, will also continue to be run by the State under NOVANA.

The monitoring is carried out as either intensive monitoring, extensive monitoring or effect monitoring. The type of monitoring that is to be carried out for the individual species is examined below for species encompassed by the Habitats Directive, bird species encompassed by the Birds Directive and species of national responsibility. As a general rule the monitoring is extensive, but with the following exceptions:

- Species encompassed by Annex II of the Habitats Directive are monitored intensively in the SACs designated for the species in question
- Species for which the type of monitoring is determined by methodological considerations. For example, otter, bats and whorl snails can only be monitored extensively, while other species (Lady's-slipper orchid and a number of birds) can be monitored intensively through counting without raising resource consumption.

10.5.4.2 Intensive monitoring

By intensive monitoring is understood monitoring of population size. The monitoring is performed using the following methods:

1. Total counting (e.g. the Lady's-slipper orchid and the fen orchid)
2. Transect surveys (certain aquatic bird species)
3. Capture-recapture (houting).

Intensive monitoring is planned in cases where:

1. The species is included in the basis for selection of SACs and SPAs, and

2. The necessary operational methods and possibilities to monitor the species intensively exist.

Due to consideration 2, only extensive monitoring is planned for several species encompassed by Annex II of the Habitats Directive and Annex I of the Birds Directive (Great crested newt, otter, lamprey and bats as well as a number of rather common birds. Conversely, some species are so relatively easy to count that intensive monitoring is planned, but at a lower frequency.

Intensive monitoring can be carried out annually or every second, third or sixth year depending on administrative needs. As a general rule, intensive monitoring is carried out annually (see Annex 1 of Part 3 of the Programme Description).

Intensive monitoring also encompasses registration of certain background information. In certain cases (e.g. watercourses and ponds), the necessary information (e.g. water quality) is provided by other NOVANA subprogrammes.

10.5.4.3 Extensive monitoring

Extensive monitoring of a species is carried out as an investigation of the species' range in Denmark. The aim is to obtain monitoring data that will eventually enable a methodologically reliable analysis of whether the species' range is stable, increasing or decreasing in Denmark.

As the term "extensive monitoring" is new in a species monitoring context, a relatively thorough discussion of the topic is provided in Annex 1 of Part 3 of the Programme Description.

10.5.4.4 Effect monitoring

Effect monitoring is initially only being carried out on a restricted basis in connection with nature restoration projects (Tønder Marsh, River Skjern and Vest Stadil Fjord).

10.5.5 Consequences of the species programme in relation to the inventory of monitoring requirements

In the species monitoring programme the monitoring is concretized in the following elements:

- Monitoring of species encompassed by Annexes II and IV of the Habitats Directive[1]
- Monitoring of species encompassed by Annex I of the Birds Directive (breeding species) and of regularly occurring migratory species pursuant to the same Directive (species of national responsibilty)
- Monitoring of species of national responsibility (moths and vascualar plants)[2]
- A special programme for monitoring the Wadden Sea in cooperation with Germany and Holland (Trilateral Monitoring and Assessment Program – TMAP)[3]
- Preparation of national Red Lists
- Monitoring of Tønder Marsh
- Annual censuses of the population of breeding cormorant.

While the monitoring programme accords priority to fulfilling the obligations under the two directives, it also aims to fulfil the obligations under a number of international conventions. Several of these are built into the lists of species encompassed by the directives. An example is the group of 13 species of bat in Annex IV of the Habitats Directive. Bats are placed in Annex IV because they are encompassed by the Bonn Convention on migratory species.

The same applies for example to the inclusion of 28 species of water birds that are Danish species of national responsibility. In accordance with the Birds Directive these species are monitored as regularly occurring migratory species, but are concomitantly encompassed by the Bonn Convention on migratory species (African-Eurasian Migratory Water Birds Agreement – AEWA) and the Ramsar Convention.

Finally, the preparation of national Red Lists aims at fulfilment of the Rio Convention on Biodiversity.

It has not been possible to include monitoring of the harbour porpoise in the programme as monitoring of this species would take approx. 1/3 of the programme's total resources. However, it will be possible to incorporate monitoring of the harbour porpoise at a later date if a less resource-heavy method becomes available than the one presently used.

As with the habitat part of the subprogramme it has been necessary to set the monitoring frequency at six years. This means that as in the case of the natural habitat types, many years will pass before the monitoring will allow assessment of general trends.

It has not been possible to include monitoring of invasive species in the subprogramme.

The extent to which the two parts of the subprogramme for species and terrestrial natural habitats fulfil international and national obligations is summarized in Table 10.6.

[1] The Habitats Directive's annexes encompass species specified below:
Annex II encompasses animal and plant species of Community interest whose conservation requires the designation of special areas of conservation.
Annex IV encompasses animal and plant species of Community interest in need of strict protection.
Annex V encompasses animal and plant species of Community interest whose taking in the wild and exploitation may be subject to management measures.
Monitoring obligations for species are thus entailed by Annexes II and IV, but not by Annex V.

[2] There are no direct international obligations to monitor species of national responsibility, and they are therefore only monitored to an extent that can be kept within the economic constraints of the species monitoring in general and concomitantly with it (see below).

[3] The NOVANA subprogramme for species and terrestrial natural habitats covers the nature part of the TMAP. Other parts of the TMAP are covered by the subprogramme for marine waters.

Table 10.6 Fulfilment of international and national obligations by the two parts of the subprogramme for species and terrestrial natural habitats.

Obligations	Monitoring of terrestrial natural habitats	Monitoring of species
INTERNATIONAL:		
Habitats Directive	Fulfilled[1]	Fulfilled[2]
Birds Directive	None	Fulfilled[3]
Ramsar Convention	None	Fulfilled
HELCOM	None	Fulfilled[4]
Bonn Convention	None	Fulfilled[5]
Wadden Sea – TMAP	None[6]	Fulfilled
NATIONAL:		
Protection of Nature Act	Fulfilled	None
Tønder Marsh Act	None	Fulfilled

[1)] Nationwide data are collected for a total of 18 of 44 terrestrial natural habitat types. Of these, 10 are forest habitats that are not presently included in the planned monitoring programme. At 16 of the remaining 34 habitat types, where no actual monitoring stations are planned, certain data will be collected via transects at monitoring stations.

[2)] The programme covers the relevant Annex II and IV species except the harbour porpoise. With most species, though, monitoring is extensive, i.e. only range is monitored, not population size.

[3)] The programme covers the breeding bird species encompassed by Annex I of the directive as well as regularly occurring migratory species (in particular species of national responsibility).

[4)] It is expected that an agreement will be reached under HELCOM concerning the provision of monitoring data for water birds at a later date. In this case it will be possible to fulfil the obligation with the data collected under NOVANA.

[5)] The planned programme covers the reporting obligations pursuant to the African-Eurasian Migratory Water Birds Agreement under the Bonn Convention (AEWA) at a level corresponding to previous fulfilment of the obligation.

[6)] Monitoring of salt meadows is presently being planned under the Trilateral Monitoring and Assessment Program (TMAP). It will be possible to meet this obligation through the monitoring of Habitats Directive habitat type 1330 (Atlantic salt meadows).

[Tom side]

11 Nationwide Air Quality Monitoring Programme (LMP IV)

11.1 Introduction

This subprogramme – the Nationwide Air Quality Monitoring Programme (LMP IV) – concerns monitoring of the quality of the ambient air, focusing on towns and the air pollutants that are detrimental to health. The subprogramme is carried out by the National Environmental Research Institute (NERI) in cooperation with the regional/local authorities.

11.2 Background and status

The Nationwide Air Quality Monitoring Programme was started in 1981 as a collaboration between the Ministry of the Environment and the regional and municipal authorities. The programme is coordinated by the Ministry of the Environment and has been adjusted during the four programme periods in order to ensure the best possible fulfilment of relevant international (EC/EU) and national obligations within the allocated financial framework.

Under the first programme, LMP I (1981–86), monitoring was performed in the towns Copenhagen, Næstved, Odense, Fredericia, Esbjerg, Randers and Aalborg. The main emphasis was on SO_2, total suspended particles (TSP) and particle-bound heavy metals, etc. In addition, an atmospheric dispersion model (OML) was developed, tested and applied for determining the dispersion of air pollution from point sources.

Under the second programme, LMP II (1987–91), monitoring was performed in the towns Copenhagen, Odense, Fredericia, Esbjerg, Aarhus and Aalborg. The main emphasis was on the measurement of pollution from traffic, especially NO/NO_2 and lead, because LMP I had shown that road traffic was one of the main sources of air pollution in Danish towns.

Under the third programme, LMP III (1992–99), monitoring was performed in the towns Copenhagen, Odense and Aalborg. The programme was extended to also encompass the measurement of ozone and campaign measurements of CO. Finally, meteorological measurement stations were established in the towns for use in the analysis/interpretation of measurement data and for use in modelling.

The programmes were designed to meet Denmark's obligations pursuant to EC/EU directives that have been implemented in Danish legislation, as well as national requirements for information about air pollution in Danish towns. The latter include the effect of measures to limit air pollution, e.g. reduction in the sulphur content of fossil fuels, reduction in the lead content of petrol and introduction of catalytic converters on petrol cars.

In the coming years it will remain necessary to follow the air pollution situation and the effect of future measures. Possible future measures could include stricter particle emission norms for diesel cars and pollution norms for diesel busses and lorries.

In order to enhance our knowledge of pollution from traffic, NERI has been developing models for calculating pollution from traffic. It will be possible to use the models for practical traffic planning.

On 27 September 1996 the EU Council adopted a new Framework Directive on Ambient Air Quality that has to be implemented together with the subsequent more specific daughter directives. The first directive, which encompasses SO_2, NO/NO_2, lead and particles (PM_{10}), was adopted on 22 April 1999. Under the provisions of the directive, $PM_{2.5}$ also has to be measured at some selected measurement stations. Directives were adopted for benzene and CO in 2001 and for ozone in 2002. The necessary laws and administrative regulations ensuing from the Framework Directive have to be implemented in Member States within 18 months of adoption of the directives. The Danish EPA is responsible for this in Denmark.

The present subprogramme (LMP IV) is designed to meet the obligations pursuant to the daughter directives for SO_2, NO/NO_2, lead, particles ($PM_{10}/PM_{2.5}$), benzene, CO and ozone. Further directives will be adopted for As, Cd, Ni, Hg and PAH. As regards Hg and PAH, this will probably necessitate extending the subprogramme. Adoption of this fourth daughter directive is expected in early 2005. Under LMP IV, monitoring is performed in the towns of Copenhagen, Aarhus, Odense and Aalborg. Measurements made by Copenhagen Municipality at H.C. Andersens Boulevard (station number 1103) are also included in the subprogramme. An agreement concerning this is drawn up annually between NERI and Copenhagen Municipality.

11.3 Objectives

The overall objectives of the subprogramme are to fulfil the EU directives on air quality through:

- **Measurement** and **assessment** of air pollution in Denmark with the emphasis on air pollutants that are detrimental to health in order to be able to assess air quality in relation to Danish limit values (which are in accordance with EU directives)
- **Dissemination** of knowledge and information about air quality in Danish towns
- **Assessment of the effect** on air quality (status and trend) of Danish and international measures to limit air pollution in Denmark.

11.4 Strategy

The strategy behind the design of the present subprogramme (LMP IV) is to ensure optimal fulfilment of obligations pursuant to EU directives and national requirements concerning monitoring of urban air quality and to build upon the experience gained through the three previous programme periods.

Furthermore, the strategy is to ensure the best possible coordination between the present subprogramme and the subprogramme for background monitoring of air quality and atmospheric deposition (see Chapter 3). Parts of each subprogramme are therefore performed at the same measurement stations and wherever possible the same methods are used in each subprogramme.

11.4.1 Continued time series

The air quality measurements hitherto made in Danish towns have shown that long time series are vital for documenting trends. Among other reasons this is due to the fact that air pollution varies markedly with the meteorological conditions, which in turn vary from year for year. The best time series exist for Aalborg, where the measurement station has been at the same location since 1982. In this case even relatively small tendencies can be demonstrated, e.g. TSP, particulate sulphur and nitrogen oxides.

11.4.2 Station types and location

The subprogramme utilizes the following types of measurement station/assessment:

1. Local measurement stations (street stations), at which NO/NO_2, CO and TSP (PM_{10} pursuant to the first daughter directive) are measured. In addition, $PM_{2.5}$ is measured at a few selected localities. Selected TSP samples are analysed for lead, sulphur, cadmium, etc. using PIXE. Benzene is also measured. Data collection and transmission to NERI are performed as hitherto from the automatic monitors, with the individual participants in the subprogramme concomitantly having the possibility to download current data into their own data systems. The measurement stations are located in busy streets.
2. Urban background measurement stations, at which wind direction, wind speed, temperature, relative humidity and global insolation, NO/NO_2, particles and O_3 are measured. In addition, limited measurement of SO_2 is performed to allow the trend to be followed. The stations have data equipment like that at the local measurement stations.
3. Preliminary assessment is carried out in a number of towns in which continual measurements are not performed, but where knowledge of air pollution levels relative to the new limit values is inadequate. A preliminary assessment relative to Article 5 of the Framework Directive is particularly necessary for NO_2 and particles. As far as possible the preliminary assessments are performed using simple methods, for example passive samplers or by model calculations based on existing air quality data from earlier measurements, surveys, traffic data and existing emission data.

Existing traffic censuses made by the municipal authorities will also be utilized when assessing the air quality measurements. Urban background measurement stations will be continued/established in the vicinity of the stationary measurement stations, in most cases on the roofs of nearby buildings. The number of SO_2 measurements will be reduced to a level just sufficient to allow the trend to be followed. They will only encompass measurements of SO_2 with high time resolution at a few selected measurement stations (Copenhagen, Aarhus/Aalborg and Lille Valby).

The measurements made at the urban background measurement stations are also intended to provide the data necessary to determine urban background pollution, which gives an impression of the general level of pollution in urban areas. This can account for a significant proportion of the air pollution (especially with NO_2), even in the busiest streets. In order to be able to relate air pollution to the traffic conditions in the streets it is necessary to know the level of urban background pollution.

Of particular importance is a knowledge of the urban background levels of O_3, the latter being decisive for the formation of NO_2 in urban air. In order to be able to assess the trend in NO_2 pollution, for example as a consequence of the introduction of catalytic converters or rerouting of road traffic, it is necessary to know the background concentration of O_3 in urban air.

The meteorological measurements are necessary, especially in towns, to improve interpretation of the air pollution measurements. The trends in air pollution levels should be compared with the changing meteorological conditions before they can be related to trends in emissions. For this purpose it is necessary to use air quality models such as the Operational Street Pollution Model (OSPM).

Finally, the measurement station at Keldsnor is being retained for measurement of O_3 and NO/NO_2 pursuant to the Ozone Directive.

11.4.3 Assessment in relation to limit values

The current Framework Directive does not stipulate limit values, but these have been/will be specified in the daughter directives. Specific requirements are stipulated as to the quality of the measurement programmes and their comparability between Member States. Thus strict requirements are stipulated as to the quality of the data (among others quality assurance programmes and accredited laboratories) and their representativeness (measurement strategy).

For the country as a whole, the measurements made hitherto have shown that the level of NO_2 pollu-

tion in ambient air in Denmark is now below the existing limit value. In addition, they show that the NO_2 level in the large towns is close to or exceeds the limit value. It seems that the NO_2 level has remained virtually unchanged since the early 1980s with a weak decreasing trend. The measurements reveal that the NO_2 concentration has fallen slightly since 1995 due to catalytic converters on petrol cars and falling O_3 concentrations. The available measurements also show exceedances of the annual mean value for NO_2 (40 $\mu g/m^3$) that has to be met by 1 January 2010.

Particle (TSP) pollution has tended to decrease since the early 1980s, but it is doubtful whether Denmark can meet the new stricter limit values for PM_{10}.

The ozone concentration has exceeded the alert threshold a few times a year since 1991. Finally, preliminary measurements appear to show that the level of benzene pollution was higher than expected due to the emissions from petrol cars. In recent years, however, the benzene level has fallen due to the lower benzene content of petrol.

Few data are available concerning PAH pollution. In contrast, the data on heavy metals are comprehensive, and everything indicates that Denmark will be able to meet the coming limit values for these.

11.4.4 Measurements and model calculations

The monitoring concept utilized in LMP III based on street stations, urban background stations, meteorological stations on building roofs and measurement campaigns has also proven to be well suited for monitoring of air quality in urban areas and for determining atmospheric processes and hence as input for air quality models. The combination of measurements and model calculations is utilized for the assessment of air quality required pursuant to Article 6 of the Framework Directive.

Methods have previously been established for calculating air pollution from point sources (the OML model – Operational Meteorological Air Quality Model). Such model calculations are necessary for quantitative determination of the contribution made by the individual sources of air pollution and for assessing the contribution from planned sources.

Correspondingly, there is a need to apply modelling to other types of air pollution sources, e.g. in connection with traffic planning. This developmental work has been carried out by NERI in the form of the OSPM model. Among other things, the model requires the above-mentioned measurements or calculations of background air pollution as well as meteorological data. The model calculations can be used for several purposes:

- Determining the contribution from various types of source, including the various transport categories
- Determining the geographic distribution of air pollution. Air pollution in a street can vary markedly just from one side of the street to the other depending on the wind direction
- Assessing the future trend in air pollution and the effect of planning measures (scenario calculations)
- Interpreting and controlling the measurement results.

The model calculations are used by NERI to assess air quality in relation to sources and meteorological conditions. In addition, the models are used to assess air quality in areas for which no measurements are available, including areas where the level of pollution is considerably below the limit values. In some cases, however, it is necessary to carry out exploratory measurement campaigns. The models can be used by the local authorities in cooperation with NERI in those towns where this is required pursuant to the EU daughter directives. In addition, the municipal and regional authorities can use the models in connection with traffic planning, etc. and environmental approval of enterprises.

11.4.5 Presentation of current data

NERI has developed a data transmission system that among other things can be used by the municipal authorities to download data from local measurement stations. In connection with LMP III this system was provided to all municipal authorities requesting it. This has not yet led to the dissemination of data to the general public, however, except in Greater Copenhagen. The system is now used by NERI for disseminating current and historical data to a wider audience via the Internet and text TV.

11.5 Programme content

The subprogramme consists of the following elements:

11.5.1 Initial assessment

The initial assessment comprises the subdivision of Denmark into zones and the assessment of air quality with the aim of determining the number of measurement stations needed in Denmark in order to comply with the Framework Directive and their location. The zonation and assessment have to be revised as needed, typically every fifth year. This was last done in Denmark in 2001.

11.5.2 Measurements

Measurement of air quality pursuant to the Framework Directive and the first three daughter directives:

- Measurements at existing stationary measurement stations in the four largest urban areas to determine the content of sulphur dioxide (SO_2), nitrogen ox-

ides (NO_2/NO_x), particles (PM_{10}), lead, benzene, CO and ozone (O_3)
- Measurements at two existing stationary measurement stations in background areas to determine the content of nitrogen oxides (NO_2/NO_x), particles (PM_{10}) and ozone (O_3).

Measurement of air quality pursuant to the forthcoming fourth daughter directive:

- Measurements at existing stationary measurement stations in the four largest urban areas to determine the content of the heavy metals arsenic, nickel and cadmium, of mercury and of PAHs.

Measurement of air quality pursuant to the expected revision of the daughter directive on particles:

- Measurements at a few of the existing stationary measurement stations in the subprogramme for background monitoring of air quality and atmospheric deposition to determine the content of particles – $PM_{2.5}$ or $PM_{1.0}$ – depending on the outcome of the revision of the daughter directive.

In addition, meteorological parameters are measured in the vicinity of the air measurement stations in the four largest urban areas, which is necessary for assessment of the air quality measurements.

The measurement data are used to validate and improve tools (models) for the assessment of air pollution in Danish towns.

The location of the measurement stations used by the Nationwide Air Quality Monitoring Programme (LMP IV) is shown in Figure 11.1 and Table 11.1, and the measurements made at the individual measurement stations are summarized in Table 11.2.

11.5.3 Model calculations

NERI's assessment of air quality is carried out through a carefully considered combination of air quality models and the above-mentioned measurements in order to:

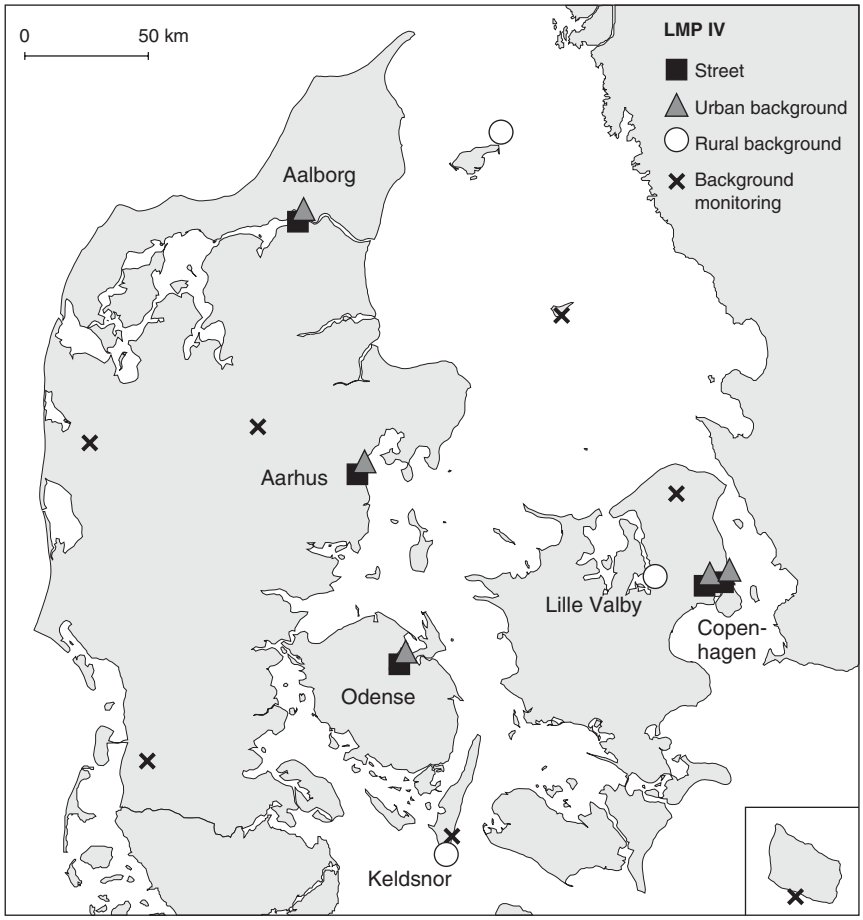

Figure 11.1 Measurement stations used by the Nationwide Air Quality Monitoring Programme (LMP IV). The stations used by the subprogramme for background monitoring of air quality and atmospheric deposition are also shown.

Table 11.1 Measurement stations used by the Nationwide Air Quality Programme (LMP IV).

Station	Location	Type
Copenhagen/1103	H.C. Andersens Boulevard	Street
Copenhagen/1257	Jagtvej	Street
Copenhagen/1259	H.C. Ørsted Institute	Urban background
Aarhus/6153	Banegårdsgade	Street
Aarhus/6159	Valdemarsgade	Urban background
Odense/9155	Albanigade	Street
Odense/9159	Odense Town Hall	Urban background
Aalborg/8151	Vesterbro	Street
Aalborg/8159	Vesterbro 14	Urban background
Lille Valby/2090	-	Rural background
Keldsnor/9055	-	Rural background

- Perform a generalized assessment of air quality such that it encompasses towns other than those with measurement stations
- Determine the contribution to air pollution from traffic, other Danish sources and long-range transboundary transport, including the trend in these, in the towns encompassed by the measurement programme. This is to be done regularly in connection with the annual reporting. The assessment can be generalized to other towns through the use of air quality models
- Identify and quantify the relationships between sources (emissions) and pressures (concentrations)
- Perform scenario calculations and prognoses of air pollution in Denmark.

11.5.4 Dissemination of information

The public is regularly informed about the quality of the ambient air via the Internet (NERI's website), text TV, local radio, etc.

In addition, information/alerts are issued to the public in cases of exceedance of certain limit values or alert thresholds for O_3, NO_2 and SO_2. The information/alert is issued in cooperation with the Danish EPA via the Internet (NERI's website), text TV, local radio and in the form of press releases.

11.6 Theme-specific assumptions

Overall responsibility for the subprogramme lies with the Danish EPA, which serves as Chairman for the subprogramme Steering Committee. The Agency draws up the necessary administrative documents in connection with implementation of the Framework Directive and deals with Denmark's obligations in relation to the EU Commission.

NERI is the national reference centre for air quality in relation to the European Environment Agency and therefore handles with Denmark's obligations in this respect, including data exchange and quality control, both nationally and in relation to European standards, including reporting to the EU Commission.

A Steering Committee for the Nationwide Air Quality Monitoring Programme (LMP IV) has been established comprised of representatives from the Danish EPA (Chairman and Secretary), NERI (project management), the participating regional authorities and the municipal organizations. A special terms-of-reference has been drawn up for the Steering Committee.

NERI is a Danish reference laboratory for air quality and is accredited to perform the measurements in the subprogramme. The Institute performs the measurements and calculations in cooperation with the participating parties and in addition performs the quality control.

11.7 Consequences of the subprogramme in relation to the inventory of monitoring requirements

The present subprogramme is considered to meet all requirements and obligations pursuant to current directives and associated Danish air quality legislation.

Monitoring obligations pursuant to the fourth daughter directive cannot be met by the present subprogramme as far as concerns PAH and Hg (it is presently unknown whether Denmark will be required to monitor for Hg).

Table 11.2 Summary of the measurements made at the individual measurement stations used by the Nationwide Air Quality Monitoring Programme (LMP IV).

Station	SO_2	NO_x	CO	O_3	Benzene	PM_{10}	$PM_{2.5}$	PIXE	Wind speed	Wind direction	Temperature	Global insolation	Relative humidity
Copenhagen/1103	x	x	x	x		x	x	x					
Copenhagen/1257		x	x		x	x	x	x					
Copenhagen/1259		x	x	x		x	x	x	x	x	x	x	x
Aarhus/6153		x	x			x		x					
Aarhus/6159		x	x	x		x		x	x	x	x	x	x
Odense/9155		x	x			x		x					
Odense/9159		x	x	x					x	x	x	x	x
Aalborg/8151		x	x			x		x					
Aalborg/8159		x	x	x		x		x	x	x	x	x	x
L. Valby/2090		x		x		x		x					
Keldsnor/9055		x		x		x		x					

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