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HELCOM Guidelines for the annual and periodical compilation and reporting of waterborne pollution inputs to the Baltic Sea (PLC-Water)

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HELCOM Guidelines for the annual and periodical compilation and reporting of waterborne pollution inputs to the Baltic Sea (PLC-Water)

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Overview of tables

1. Introduction

Since the establishment of the Convention for the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) in 1974, the Commission for the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Commission or HELCOM for short) has been working to reduce the inputs of nutrients to the sea. Through coordinated monitoring, HELCOM has, since the mid-1980s been compiling information about the magnitude and sources of nutrient inputs into the Baltic Sea. By regularly compiling and reporting data on pollution inputs, HELCOM is able to follow the progress towards reaching politically agreed nutrient reduction input goals.

In 2007, the HELCOM Baltic Sea Action Plan (BSAP) was adopted by the Baltic Sea coastal countries and the European Union (HELCOM 2007). The BSAP has the overall objective of reaching good environmental status in the Baltic Sea, by addressing eutrophication, hazardous substances, biodiversity, and maritime activities. The BSAP was updated in 2021 (HELCOM Baltic Sea Action Plan – 2021 update). The new BSAP identifies a complex of measures which are to be implemented by Contracting Parties to the Helsinki Convention by 2030 and aims to achieve good environmental status of the Baltic Sea by the end of this period. The BSAP establishes maximum allowable inputs (MAI) of nutrients as key environmental targets to achieve good status in terms of eutrophication derived through modelled calculations by the Baltic Nest Institute (BNI) in Sweden. The Action Plan also adopts nutrient input ceilings (NIC) for all Baltic Sea countries and other contributors to the total input of nutrients as a prerequisite for achieving MAI.

Since MAI and NIC are based on the best available scientific information and are subject to review when new scientific knowledge is available, the 2021 BSAP calls for targeted regional studies to improve the quality of the assessment data particularly on natural background losses, atmospheric deposition, retention, transboundary loads and other aspects. The BSAP also requests all Contracting Parties to implement all nutrient input reduction measures necessary to achieve the NICs by 2027 at the latest.

In the 2021 Baltic Sea Action Plan the HELCOM Contracting Parties agreed on the continuous follow-up of the implementation of maximum allowable inputs and nutrient input ceilings which assumes annual assessment of MAI and assessment of progress towards NICs every two years. This follow-up requires that Contracting Parties timely provide sufficient and consistent data on nutrient loads to the Baltic Sea. It requires maintaining and enhancing monitoring programmes and networks striving for harmonized methods to estimate nutrient inputs. Since large amount of nutrients are transported to the Baltic Sea through national borders, strengthening cooperation with river basin management authorities, including non-HELCOM countries, is the way to improve knowledge on transboundary inputs and develop adequate measures for their minimization.

Finally, the 2021 BSAP calls HELCOM countries to submit an account listing, as detailed as possible, the planned and implemented measures in different sectors and catchments alongside an estimation of their effectiveness to HELCOM by 2023 in order to demonstrate whether National Net Nutrient Input Ceilings can be achieved with these measures. This information is to be a part of PLC work on assessment of the effectiveness of measures to reduce input of nutrients.

The present document contains a revised and updated version of the guidelines that was prepared as part of the project *Eighth Baltic Sea Pollution Load Compilation* (PLC-8). It provides the Contracting Parties of the Helsinki Commission a guidance in their national monitoring programmes and reporting of pollution inputs in order to compile harmonized data and produce reliable region-wide PLC assessments. The Guidelines concern monitoring of either airborne or waterborne input of contaminants, since the assessment products are intended to demonstrate a holistic approach, including assessment of total inputs as well as identification of major pathways and sources of pollutants. The updated Guidelines also include procedures for the reporting of data for HELCOM pollution load compilation (PLC) and releasing of PLC products based on reported data. The Guidelines are aligned with EU quality assurance standards and OSPAR methodologies.

1.1. Aim of PLC assessments

In Article 3 and Article 16 of the Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (Helsinki Convention), the Contracting Parties agreed to undertake measures to prevent and eliminate pollution of the marine environment of the Baltic and to provide pollution load data, as far as available. Compilations of pollution load data (PLC) have been an integral part of the HELCOM assessment system since 1987, focusing on annual and periodic assessments of inputs of nutrients and selected hazardous substances.

The PLC assessments aim to follow up on the implementation of the Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention) by its Contracting Parties, in particular paragraphs 1 and 2 under Article 6 of the Convention:

- *The Contracting Parties undertake to prevent and eliminate pollution of the Baltic Sea Area from land-based sources by using, inter alia, Best Environmental Practice for all sources and Best Available Technology for point sources. The relevant measures to this end shall be taken by each Contracting Party in the catchment area of the Baltic Sea without prejudice to its sovereignty.*
- *The Contracting Parties shall implement the procedures and measures set out in Annex III. To this end they shall, inter alia, as appropriate co-operate in the development and adoption of specific programmes, guidelines, standards or regulations concerning emissions and inputs to water and air, environmental quality, and products containing harmful substances and materials and the use thereof.*

The 2013 Monitoring and Assessment Strategy and the 2021 Baltic Sea Action Plan adopted by HELCOM Ministerial Meeting 2021 (HELCOM Baltic Sea Action Plan 2021 – updated), specified by the decisions of HELCOM Heads of Delegations created demands for a number of PLC products:

- HELCOM core pressure indicator on progress towards fulfilment of Maximum Allowable Inputs of nutrients (MAI);
- assessment of progress towards implementation of National Nutrient Input Ceilings;
- quantification of sources and pathways of nutrients to the Baltic Sea;
- assessment of nutrients input by major rivers;
- assessment of effectiveness of measures to reduce input of nutrients;
- assessment of input of selected hazardous substances.

The PLC products serve to follow up implementation of HELCOM BSAP and other agreements but also those Contracting Parties that are EU Member States for their river basin management plans under WFD and programmes of measures under MSFD.

The PLC utilizes monitoring data obtained in accordance with the requirements of the HELCOM Recommendations on waterborne pollution input assessment and on monitoring of airborne pollution input. It also integrates the data reported by the Contracting Parties under the Convention on Long-range Transboundary Air Pollution and its protocols as well as data obtained in the frame of the EU and national monitoring programmes.

Contracting Parties to the Helsinki Convention report data on input of nutrients into the Baltic Sea annually and periodically. Annually reported data are mainly utilized to assess nutrient load on sub-basins of the Baltic Sea and progress towards Maximum Allowable Inputs of nutrients (MAI) and nutrient input ceilings (NIC). Annually reported data on input of selected hazardous substances are used to follow up the implementation of respective measures in the BSAP and identify regional priorities with respect to contamination of the Baltic Sea by hazardous substances. They might be published as environmental fact sheets or be a part of indicators of pollution of the Baltic Sea by hazardous substances.

Periodically reported data are used for the apportionment of sources and pathways of nutrients and respectively effectiveness of measures to reduce input of nutrients from different sources.

The objectives of annual and periodic waterborne pollution input compilations (PLC-Water) are to:

- Compile information on the waterborne inputs of nutrients via rivers and direct discharges to the Baltic Sea as well as from different sources in the Baltic Sea catchment area on the basis of harmonized monitoring and modelling methods;
- Compile information on the waterborne inputs of selected hazardous substances via rivers and direct discharges to the Baltic Sea;
- Follow-up the long-term changes in the pollution input from various sources by normalizing data and making trend analysis with standardized methodologies;
- Assess progress towards fulfilling MAI and NIC;
- Identify the main sources of pollution to the Baltic Sea in order to support prioritization of measures;
- Assess overall the effectiveness of measures undertaken or planned to reduce the pollution inputs into the Baltic Sea catchment area;
- Assess total nutrient inputs from different countries to the different Baltic Sea sub-basins to identify progress towards nutrient input ceilings;

Evaluation of effectiveness of measures requires specific reporting which is not a part of the current Guideline.

National data on inputs of nutrients are stored in the HELCOM PLC water database and publicly available after quality assurance, in accordance with HELCOM information policy.

1.2. Aims of the PLC guidelines

The aims of these guidelines are to:

- Provide a framework and guide HELCOM Contracting Parties in national monitoring, quantification and reporting on total waterborne inputs of nitrogen, phosphorus and selected hazardous substances and their sources to the Baltic Sea to obtain a harmonized and comparable dataset covering the whole Baltic Sea region.
- Enhance the comparability, consistency, and quality of the PLC data and, as much as possible, ensure harmonization of monitoring practices and source quantification methods between the Contracting Parties.
- Ensure transparency of applied methodologies, in cases when their full harmonization can’t be achieved due to climatic, topographical, hydrological etc. specificity of territories, and thus guarantee consistency of regional databases.
- Provide practical guidance on the use of HELCOM tools for annual and periodic reporting, including templates and detailed explanation on how to fill in templates, upload and insert data in the PLC database and how to perform and follow-up quality assurance of inserted data.

To fulfil the evolving data requirements of HELCOM and its Contracting Parties, these guidelines according to HELCOM Recommendation 37-38/1 (2016a) should be regularly reviewed and updated by experts, endorsed by respective HELCOM WG and adopted by HELCOM Heads of Delegations.

1.3. PLC data reporting requirements

The PLC monitoring and reporting requirements reflect the data needs of HELCOM for supporting the implementation of the Helsinki Convention and the Baltic Sea Action Plan (HELCOM 2007 and HELCOM 2021), while bearing in mind also the monitoring and reporting needs of those HELCOM Contracting Parties that are also EU Member States.

According to **HELCOM Recommendation 37-38/1** "Waterborne pollution input assessment (PLC-WATER)" (HELCOM, 2016) data is to be reported by Contracting Parties to the Commission both on an annual and periodical basis:

- Annually, total inputs of nutrients and hazardous substances to the sea should be reported by quantifying inputs from monitored rivers, unmonitored areas, and point sources discharging directly to the sea (Table 1.1).
- Periodically (every six years unless otherwise decided by HELCOM), comprehensive waterborne pollution input assessment should be carried out to quantify, in addition to the total inputs to the sea (annual reporting), also waterborne discharges from point sources, losses from diffuse sources as well as natural background losses into inland surface waters within the Baltic Sea catchment area located within the borders of the Contracting Parties (Tables 1.1 and 1.2).

The parameters to be reported have been agreed upon by the Contracting Parties as either mandatory or voluntary (Tables 1.1 and 1.2). Further, the limits of quantification/detection (LOQ/LOD) for the different parameters are taken into account when evaluating if they must be reported. See the list of definitions in Annex 1 for explanations of the terms measured, calculated and estimated.

Table 1.1 lists the annual reporting obligation and Table 1.2 the additional reporting requirements besides the annual reporting during the periodic assessment.

The annual reporting requirements are further specified in Chapter 12 and more details on the additional reporting requirements for the periodical reporting requirements are given in Chapter 13. The specific annual reporting formats are included in Annex 2 and the periodical reporting formats in Annex 3.

Table 1.1. Variables to be reported within PLC-Water (annually).

Parameters	Point sources discharging directly to the Baltic Sea[7]			Monitored rivers*	Unmonitored areas[5]	Transboundary at the border of the Contracting Party[10]
	Municipal Effluents*	Industrial Effluents*	Aqua-culture*			
BOD_5[3]	+	+[9]	+	v	v	v
TOC				v		
TP	+	+	+	+	+	+
P_{PO4}	+[8]	v		+	+	v
TN	+	+	+	+	+	+
N_{NH4}	+	v		+	+	v
N_{NO2}[4]	v	v		+	+	v
N_{NO3}[4]	v	v		+	+	v
Hg[11]	+[2]	+[9]		+[1]	+[1]	v
Cd[11]	+[2]	+[9]		+[1]	+[1]	v
Zn[11]	+[2]	+[9]		v	v	v
Cu[11]	+[2]	+[9]		v	v	v
Pb[11]	+[2]	+[9]		+[1]	+[1]	v
Ni[11]	+[2]	+[9]		v	v	v
Cr[11]	+[2]	+[9]		v	v	v
Flow	+	+	+[6]	+	+	+

Footnotes:

\+ mandatory

v voluntary

1 Except for rivers where heavy metal concentrations are below the limit of quantification (LOQ). If all measurements are below LOQ, then the value should be reported as zero and information provided about number of samples below the LOQ. (Those countries who do not use LOQ should replace it with limit of detection (LOD)).

2 Hazardous substances are mandatory for municipal wastewater treatment plants (MWWTP) larger than 20,000 population equivalents (PE).

3 If BOD_7 is measured, it will be stored in the HELCOM PLC-Water database, and for PLC assessments a conversion factor $BOD_5 = BOD_7 /1.15$ will be used for converting to BOD_5.

4 Can be monitored and reported as the sum of oxidized nitrogen ($NO_{2,3}$-N).

5 Diffuse sources entering directly to the sea include inputs from scattered dwellings and rainwater overflows.

6 For aquaculture where it is relevant (outlet for discharges).

7 Point sources discharging directly to the Baltic Sea should preferably be reported individually but can be reported as a sum for every Baltic Sea sub-basin for municipal effluents, industrial effluents, and aquaculture, respectively.

8 Should be measured or calculated.

9 If monitoring of the parameter is required in the permit conditions of the industrial plant

10 Surface water retention of total nitrogen (TN) and total phosphorus (TP) on transboundary inputs in the receiving catchment should be reported if updated data/information is available compared to former reported/used data.

11 Might be measured as dissolved concentration as in accordance to EU Water Framework Directive (Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy), heavy metals on the list of priority substances must be determined as dissolved concentrations, i.e. the dissolved phase of a water sample obtained by filtration through a 0.45 µm filter or any equivalent pre-treatment.

* In those cases where the recorded concentrations are below the LOQ, the estimated concentration should be calculated using the equation: Estimate = ((100%-A) x LOQ)/100 where A= percentage of samples below LOQ, and if >50% of the observations are <LOQ then use LOQ/2 as the estimation to avoid 0 inputs (cf. Chapter 11.7). This is

according to one of the options listed in the guidance document on monitoring adopted by EU under the IE Directive. (Those countries who do not use LOQ should replace it with LOD in the equation.)

Table 1.2. In addition to the annual reporting in Table 1.1, the following data and information are also to be reported periodically for PLC-Water every sixth year unless otherwise decided by HELCOM.

Parameters	Monitored areas			Unmonitored areas			
	Point sources[1]	Diffuse sources[2]	Natural background	Point sources[3]	Diffuse sources[2]	Natural back-ground losses	Retention (monitored and unmonitored, respectively)[4]
TP	+	+	+	+	+	+	+
TN	+	+	+	+	+	+	+
Hg[5]	v			v			
Cd[5]	v			v			
Pb[5]	v			v			
Flow	+			+			

Footnotes:

+ mandatory

v voluntary

[1] Reported for MWWTPs, industries and aquaculture separately.

[2] Nutrient losses from diffuse sources can be estimated either as the total for all sources or as losses divided by individual source/pathways.

[3] The point sources from unmonitored areas are to be reported individually although they can be aggregated separately for MWWTPs, industries and aquaculture (in monitored areas point sources are to be reported individually).

[4] Preferably a separate retention value should be estimated for each pathway, otherwise a single value can be provided. See Chapter 9 for calculation of retention.

[5] Might be measured as dissolved concentration as in accordance to EU Water Framework Directive (WFD) (Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy), heavy metals on the list of priority substances must be determined as dissolved concentrations, i.e. the dissolved phase of a water sample obtained by filtration through a 0.45 µm filter or any equivalent pre-treatment.

2. Framework and approach of waterborne pollution load compilation

2.1. Overall framework

The guidelines focus mainly on nutrients but also include quantification of total waterborne inputs of selected hazardous substances e.g. cadmium, lead, mercury, chrome, copper, nickel and zinc (Table 1.1).

The overall structure of the guidelines is shown in Figure 2.1, reflecting the general framework and approach used for quantifying total waterborne inputs to the Baltic Sea and for quantifying importance of different nutrient sources. The different topics are described in separate chapters with cross-reference to each other to avoid repetitions. The reporting requirements are described in separate chapters on annual (Chapter 12) and on periodical reporting (Chapter 13), respectively. The details related to reporting sheets can be found in the Annexes 2 and 3.

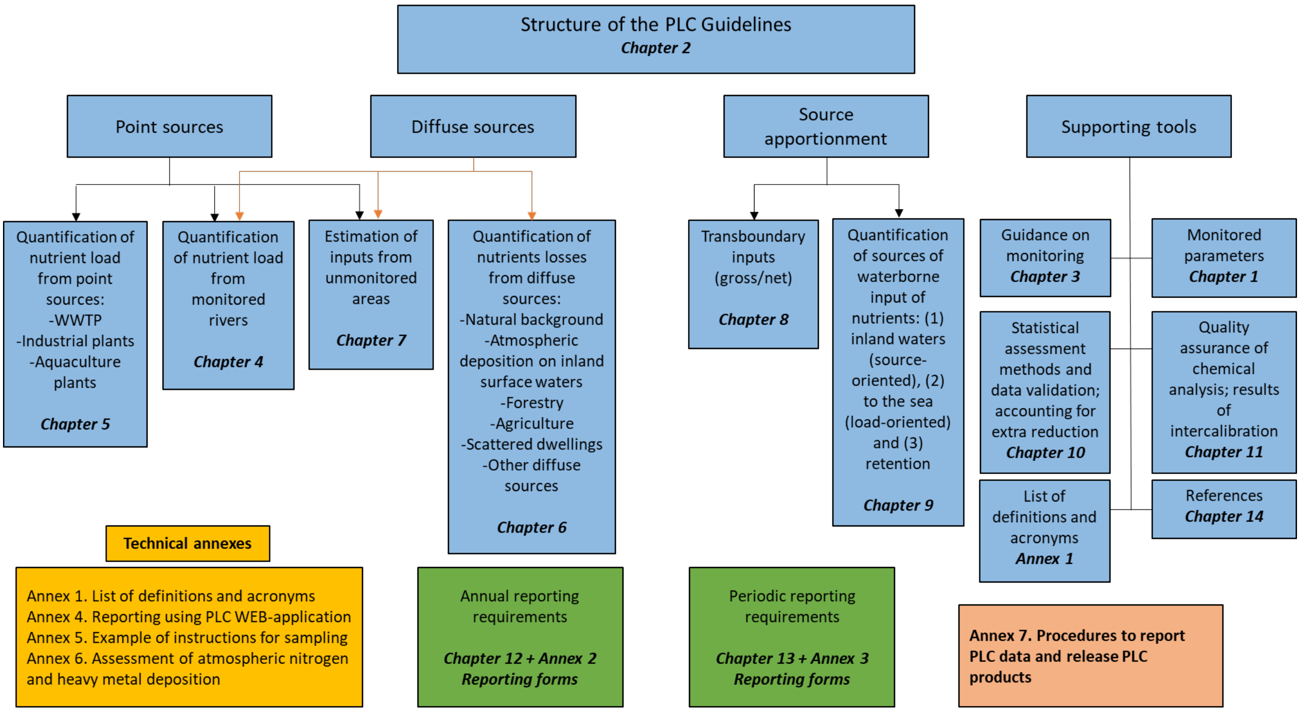


Figure 2.1 Structure of the pollution load compilation (PLC) guidelines illustrating where different topics are considered.

The main definitions and abbreviations used in the guidelines are listed in the Annex 1. Procedures for the reporting of data for HELCOM pollution load compilation (PLC) and releasing of PLC products based on reported data are included in Annex 7.

2.2. Quantification of total inputs to the Baltic Sea

Contracting Parties are obliged annually to quantify and report total waterborne inputs from point and diffuse sources entering to the Baltic Sea from their catchment (**HELCOM Recommendation 37-38/1** "Waterborne pollution input assessment (PLC-WATER), HELCOM, 2016a). Transboundary waterborne nutrient inputs reaching the Baltic Sea should be included in the total waterborne inputs, and the transboundary part of Contracting Parties waterborne inputs should be quantified to allow for the follow up on the progress towards reaching the nutrient input ceilings adopted in the updated BSAP (HELCOM Baltic Sea Action Plan – 2021 update).

The total waterborne input is the sum of total riverine inputs from monitored (see Chapter 4) and unmonitored areas (see Chapter 7) plus the input from point sources discharging directly to the Baltic Sea (also called direct discharges) and is quantified for nutrients and selected hazardous substances per Contracting Party and per Baltic Sea sub-basin as:

$$TI_x = \sum I_x \text{ monitored rivers} + \sum I_x \text{ unmonitored areas} + \sum I_x \text{ point sources discharging directly to the sea} \quad (2.1)$$

where

TI_x is total waterborne inputs (I) of the substance x from a country.

The goal is to provide as precise as possible estimates of the total waterborne inputs of nutrients and selected hazardous substances to the Baltic Sea sub-basins including transboundary waterborne inputs.

2.3. Quantifying sources of waterborne nutrient inputs to the Baltic Sea

Contracting Parties are obliged to periodically (every six years or when decided necessary) quantify and report nutrient discharges from point sources, and nutrient losses from natural and anthropogenic diffuse sources into inland surface waters within monitored and unmonitored catchment areas of the Baltic Sea located within their borders. Further, the Contracting Parties are obliged to periodically quantify and report the sources of the total nutrient inputs entering the Baltic Sea taking into account the retention in inland surface waters. Quantification of sources of inputs is explained in Chapters 5 and 6, and quantification of transboundary loads in Chapter 8.

Two source quantification approaches are described in Chapter 9:

- Quantifying the total gross loads from point sources, diffuse sources and natural background losses into inland surface waters within the whole Baltic Sea catchment area is important to get a comprehensive overview of the total loading originating in the Baltic Sea catchment area and the nutrient sources behind these inputs. This is called the “source-oriented approach”.

- Quantifications of the sources of the total waterborne nutrient inputs to the sea are used for assessing the main sources of waterborne nutrient inputs to the sea, and to evaluate the resulting effects of land-based measures for reducing waterborne nutrient inputs (to the sea) taking into account the importance of inland surface water retention. This is called the “load-oriented approach”.

Examples of different point and diffuse sources and pathways for nutrients (and heavy metals) to inland surface waters and waterborne inputs to the sea are shown in Figure 2.2. The Contracting Parties are not obliged to quantify all the pathways, only the (major) point and diffuse sources described in Chapters 5 and 6. Figure 2.3 illustrates how different sources add nutrients to inland surface waters and how retention in the waters of the catchment area removes and/or retains nutrients.

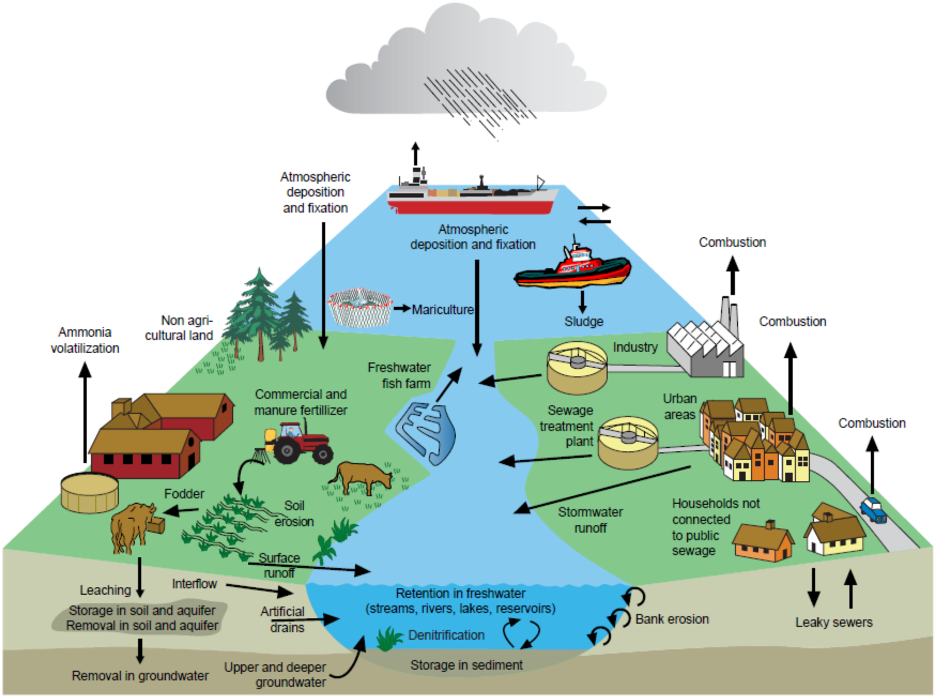


Figure 2.2 Sources and pathways of nutrients (and heavy metals) to the marine environment. Some of the arrows are only of relevance for one of the nutrients e.g. combustion and ammonia volatilization (nitrogen). For the atmospheric compartment, atmospheric deposition on surface inland waters is included in inputs from diffuse sources and only airborne inputs on inland surface waters are included in the PLC guidelines. (Airborne emissions and deposition to the sea are covered in EMEPs annual reports and fact sheets on airborne inputs, cf. Annex 6).

Retention is the removal of e.g. nutrients in surface waters of river systems including lakes, flooded riverbanks and wetlands caused by biological, chemical and physical processes (Figure 2.3). As a proportion of the nutrients entering inland surface water is retained or removed, retention must be taken into account when e.g. evaluating sources for total waterborne inputs to sea and quantifying net contribution of riverine transboundary inputs. Chapter 9 includes a sub-chapter on retention in inland surface waters.

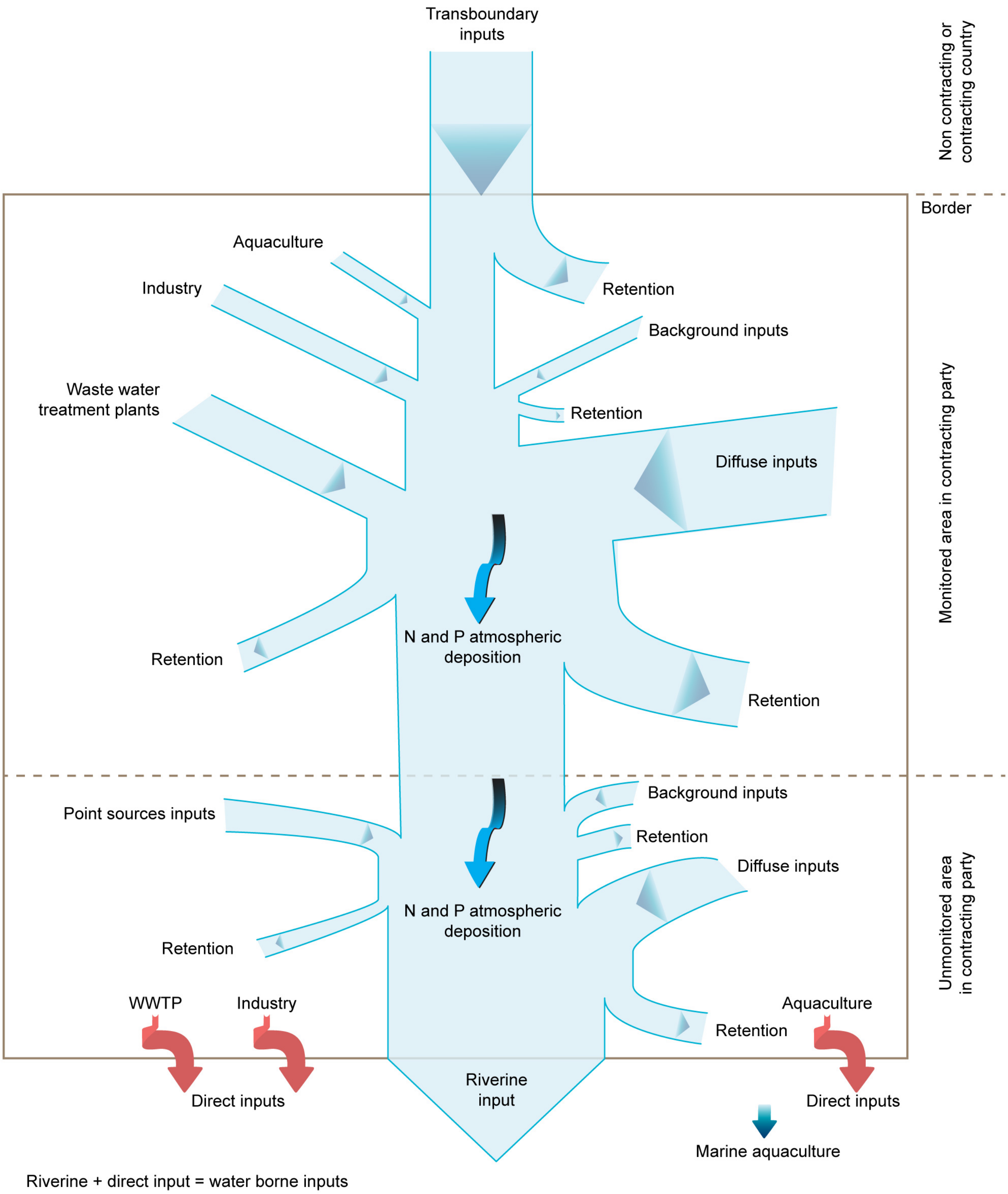


Figure 2.3 Illustration of inputs to and removal processes (retention) from a river system (inland surface waters), which includes transboundary inputs, monitored and unmonitored areas, and direct inputs to the sea. For definitions, see Figure 2.4 and Annex 1.

2.4. Supporting tools

The guidelines also include the following chapters:

- An overview of the parameters to monitor (Chapter 1)
- Guidance on how to take and handle water samples in rivers, and to monitor river flow and discharge from some point sources (Chapter 3)
- Data validation and assessment methodologies for MAI and NIC includes statistical methods on estimating uncertainty on nutrient inputs, normalization, trend analysis and test for break points, and how to handle data gaps and outliers. Further it includes assessment methodology on evaluating progress towards MAI and NIC, and how to account for extra reduction in the evaluation (Chapter 10)
- Minimum quality assurance expected by the Contracting Parties, inter-laboratory comparison test, recommended limits of quantification (Chapter 11)
- List of definitions and acronyms, detailed instructions on reporting sheets and on reporting and making quality assurance using the PLC WEB-application, a short description of used methodology to quantify atmospheric deposition in the Baltic Sea etc. (Annexes 1-6).

Some of the statistical methods included in the guidelines serve as guidance for assessment in the PLC work including progress towards fulfilling MAI and NIC. They will be performed in a uniform way within the HELCOM PLC data processing framework, and Contracting Parties are not required to make these calculations (further specifications are given in Chapter 10).

2.5. Basic definitions

Figure 2.4 illustrates the definitions of catchment areas, monitored areas, unmonitored areas, direct and indirect point sources and transboundary inputs (see the list of definitions and acronyms contained in the Annex 1).

Monitored areas are the catchment area upstream of the river monitoring station. The chemical monitoring decides the monitored area in cases where the locations of chemical and hydrological monitoring stations do not coincide (see Chapter 4.2).

Unmonitored areas are any part of sub-catchment(s) located downstream of the (riverine) chemical monitoring point within the catchment and further all unmonitored catchments; e.g. unmonitored part of monitored areas.

Catchment area is any area of land where precipitation collects and drains off into a common outlet such as into a river, bay or other body of water. The catchment to the Baltic Sea is divided in catchment areas to each Baltic Sea sub-basin (Figure 2.5) and each of these catchments are divided in several sub-catchments (Figure 2.6).

Sub-catchment is a portion of a catchment as e.g. the corresponding catchment to each monitoring station or the unmonitored area river of a catchment.

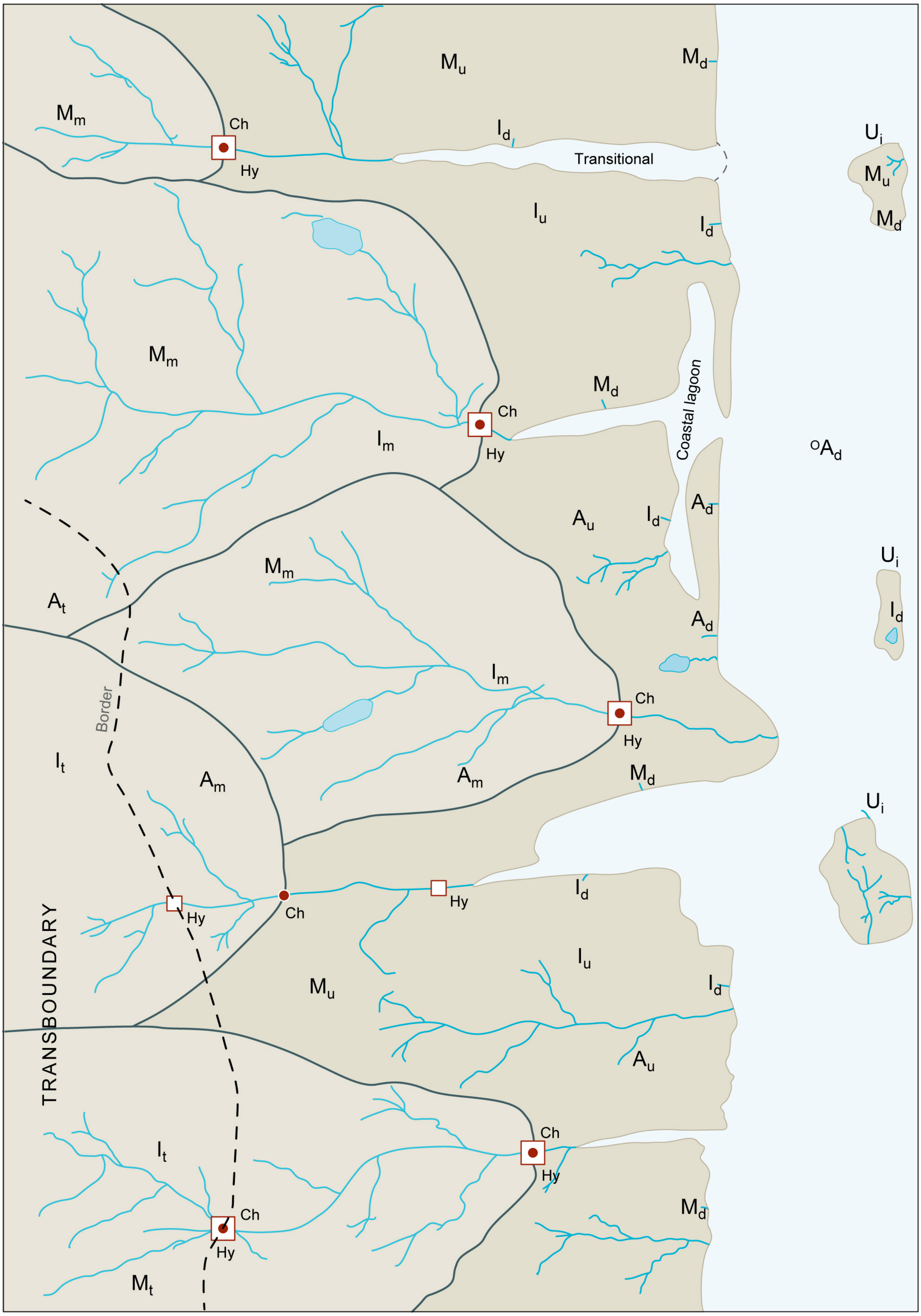
Sub-basin are the sub-division units of the Baltic Sea: the Kattegat (KAT), The Sound (SOU), Western Baltic (WEB), Baltic Proper (BAP), Gulf of Riga (GUR), Gulf of Finland (GUF), Archipelago Sea (ARC) Bothnian Sea (BOS) and Bothnian Bay (BOB). The whole Baltic Sea is abbreviated BAS (Figure 2.5).

Direct point sources are municipal wastewater treatment plants, industrial plants and aquaculture plants discharging directly into the Baltic Sea. Further, it includes marine aquaculture plants situated and discharging in marine waters.

Indirect point sources are municipal wastewater treatment plants, industrial plants and aquaculture plants discharging (defined by location of the outlet) into the monitored or unmonitored part of the catchment area through one or several outlets.

A river that has its outlet to the Baltic Sea at the border between two countries is considered a **border river**. For these rivers, the inputs to the Baltic Sea are divided between the countries in relation to each country's share of total load.

A transboundary river has its outlet to the sea situated in one country but is receiving transboundary inputs from one or several upstream countries. Chapter 8 includes a list of the transboundary rivers where Contracting Parties should quantify the proportion of transboundary inputs. In some cases, a river is both border and transboundary, e.g. as Nemunas.



Mm
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Mm
Md
Coastal lagoon
Ch
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Hy
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Au
Id
Ad
Ui
At
Mm
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Ad
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Border
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Id
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Mu
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Figure 2.4 Illustration of some key definitions used in these guidelines – see also Annex 1 "List of definitions and acronyms". Sub-catchment to monitoring stations shown with black bold curved lines. **I=Industry, M=MWWTPs municipal wastewater treatment plants, A=aquaculture, U_i = unmonitored island, Hy=hydrographic monitoring station, Ch=Chemical monitoring stations, u=unmonitored, m=monitored, t=transboundary, d= direct inputs (point sources).**

2.6. Division of the Baltic Sea catchment area

In order to take into account the harmonization process within HELCOM and the assessment products dealing with pollution inputs and their effect in the marine environment, the Baltic Sea is divided into the sub-basins listed in Table 2.1. An overview of the entire Baltic Sea catchment area and the catchment areas to the sub-basins of Baltic Sea are presented in Figure 2.5.

Table 2.1. Sub-catchment of the Baltic Sea catchment area for which data have to be reported for annual and periodical inputs, evaluation of sources and effectiveness of measures. In the assessment of progress towards MAI and NIC, the reported waterborne data for The Sound and Western Baltic are aggregate as one sub-basin Danish Straits = DS, and for Archipelago Sea they are integrated as a part of the Bothnian Sea (BOS) (figure 2.5).

No.	Sub-basins	Abbreviation
1	Bothnian Bay	BOB
2	Bothnian Sea	BOS
3	Archipelago Sea	ARC
4	Gulf of Finland	GUF
5	Gulf of Riga	GUR
6	Baltic Proper	BAP
7	Western Baltic	WEB
8	The Sound	SOU
9	The Kattegat	KAT

To enable for assessments the input figures must be collected and reported separately for the catchment to each sub-basin by each Contracting Party. A GIS shape file of the sub-basins of the Baltic Sea and sub-catchments of the Baltic Sea catchment area can be downloaded via the HELCOM Map and Data Service.

In relation to the assessment of progress towards maximum allowable inputs of nutrients (MAI) and nutrient input ceilings (NIC) set by the BSAP the following sub-basins are reported aggregated:

- Archipelago Sea included as a part of Bothnian Sea (BOS)
- The Sound and Western Baltic as Danish Straits (DS)

The main part of the catchment to the Baltic Sea is monitored and it is mainly minor rivers and areas close to the sea that are unmonitored (Figures 2.6 and 2.7).

The distribution of monitored and unmonitored areas as well as spatial borders of sub-catchments might be changed in case of changing of national monitoring programmes or location of monitoring stations. Spatial data on monitored and unmonitored sub-catchments are to be updated concurrently with periodic reporting. Requirements for the spatial data are given in Chapter 13.

Upstream parts of the catchments located within the borders of countries without the river outlet to the sea are transboundary sub-catchments. There are also rivers which are borders between countries; these border rivers also divide the river basin to sub-catchments. (Figure 2.8)

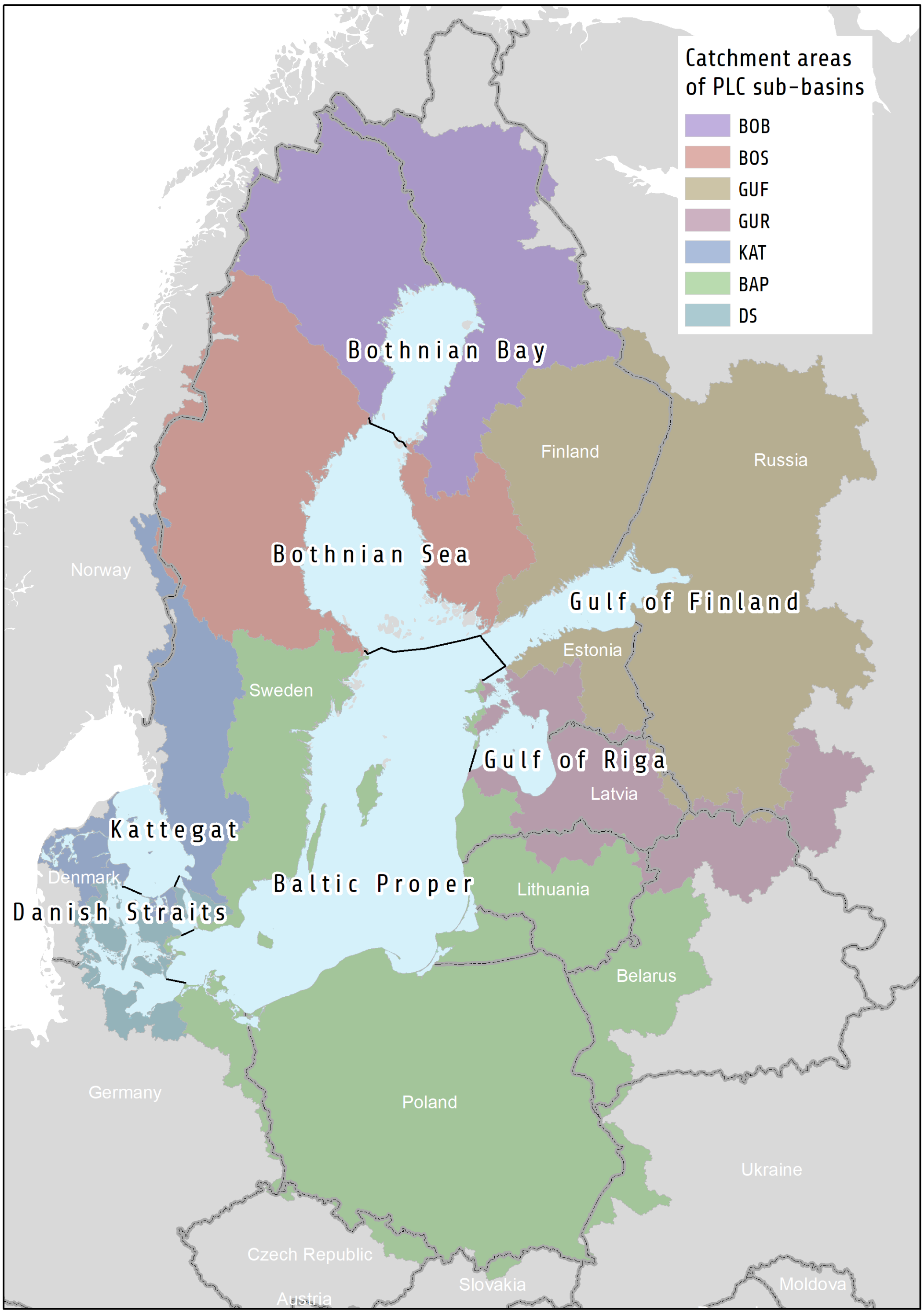

Figure 2.5 Subdivision of the Baltic Sea catchment area to sub-basins for the HELCOM PLC assessment.

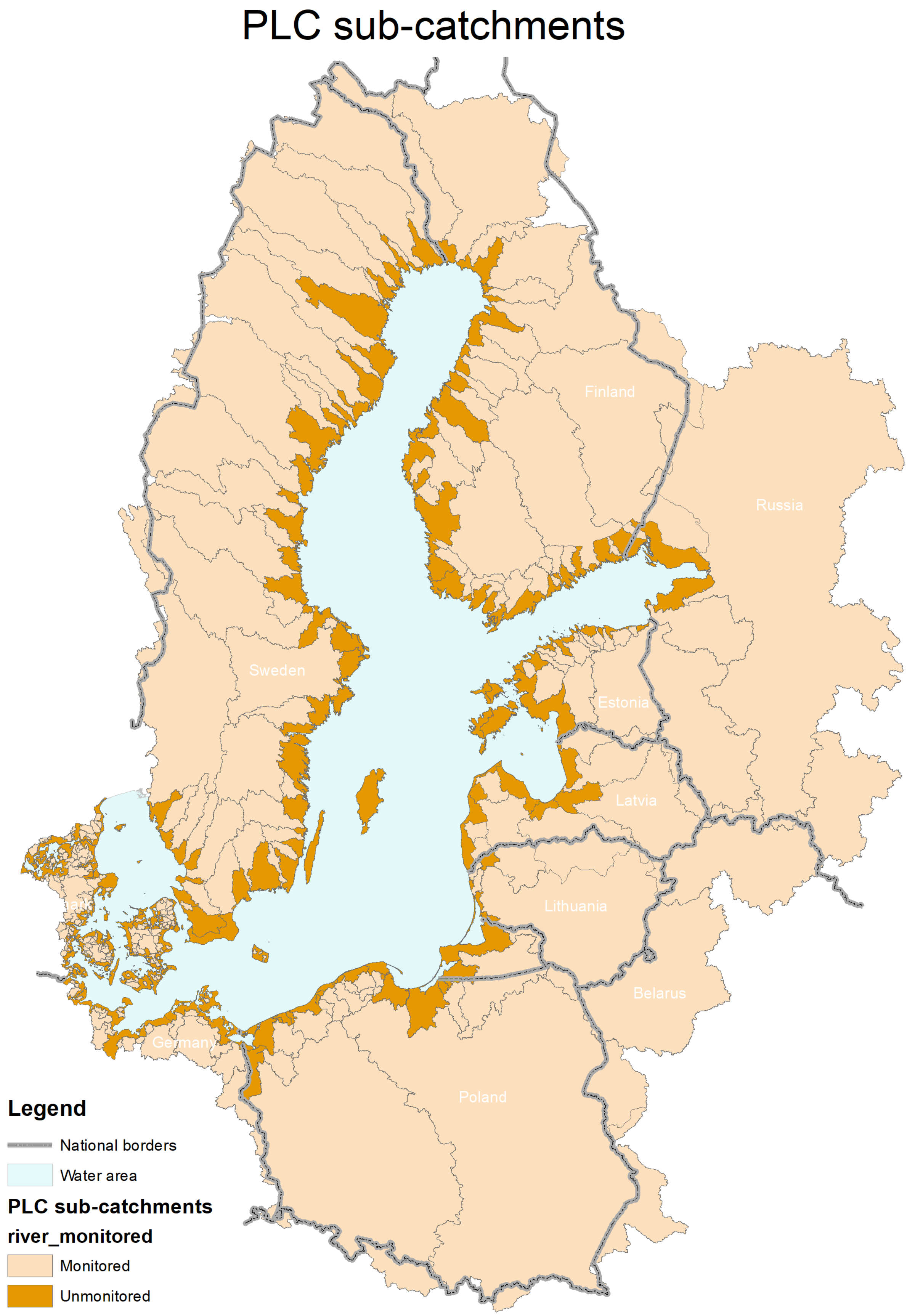

Figure 2.6 Monitored and unmonitored areas in the HELCOM countries. The figure includes transboundary catchments and the catchment area located outside the HELCOM countries.

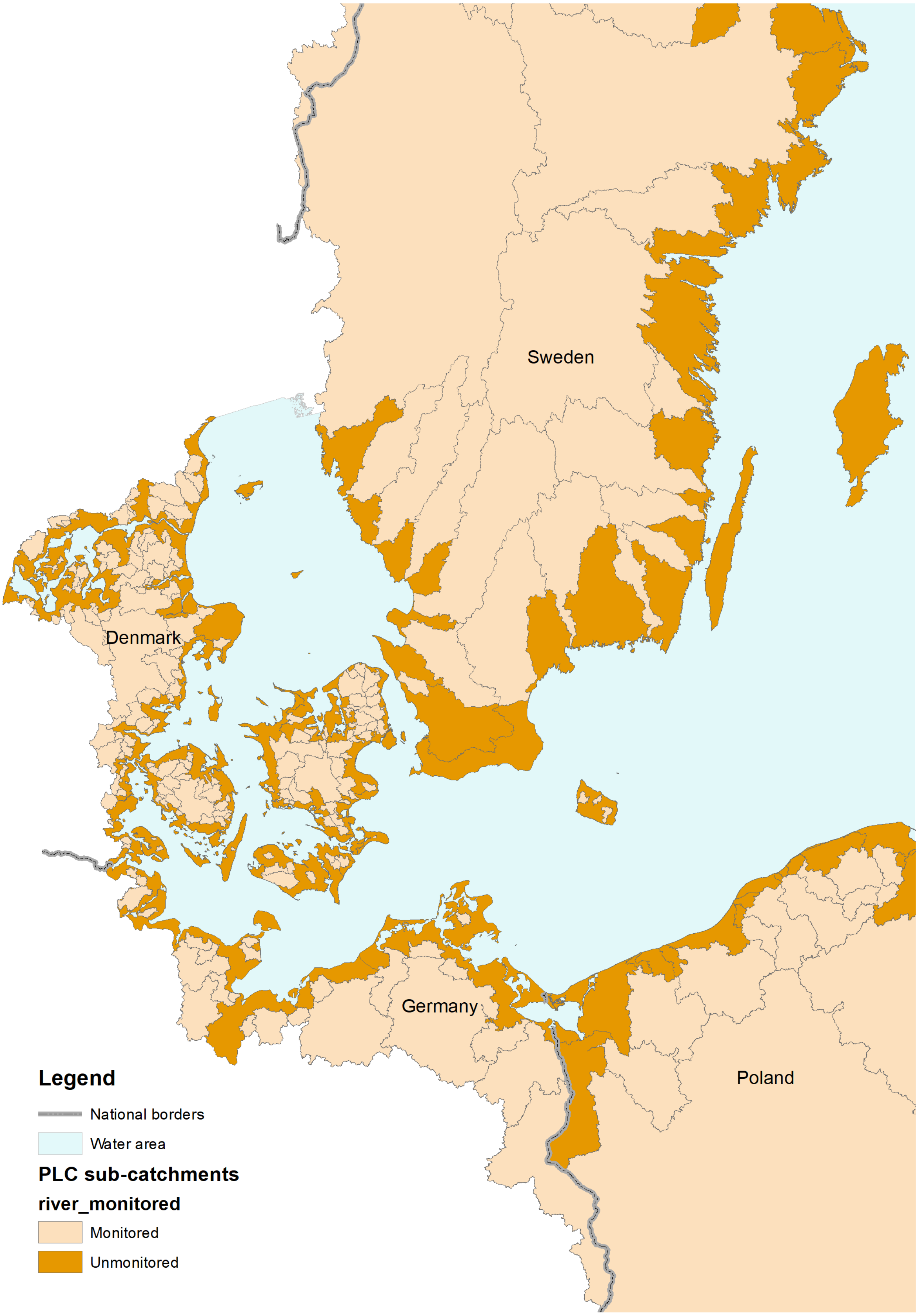

Figure 2.7 Close up of Danish, German, western Poland, and southern Swedish monitored and unmonitored areas.

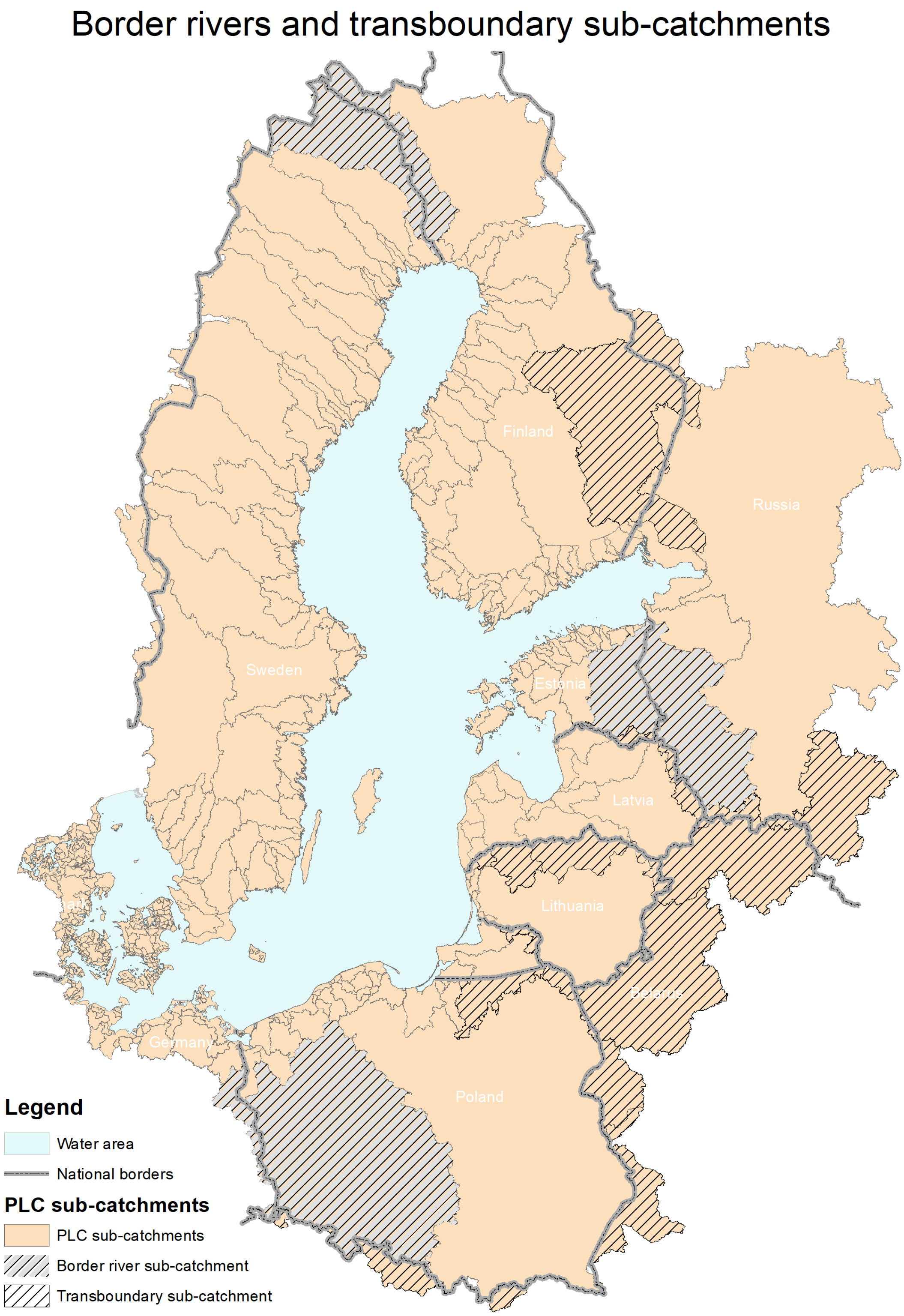

Figure 2.8 Border rivers and transboundary sub-catchments. In some cases, transboundary load was included in the load of downstream countries. For example load to river Neva from some parts of Russian through the territory of Finland was included in total transboundary load from Finland; load from Latvia to river Narva was included in total load from Russian; loads from the territory of Norway were included in loads from respective sub-catchments of Sweden etc.

3. Guidance on monitoring

This chapter gives guidance on how to monitor riverine and wastewater flow as well as how to take and handle water samples in rivers, municipal wastewater treatment plants and industrial plants.

3.1. Flow measurements

3.1.1. Riverine flow measurements

For rivers with riverine water level and flow (velocity) measurements , the location of permanent hydrological stations (if any), measurement equipment, and frequency of water level and flow measurement should at least follow the World Meteorological Organization (WMO) Guide to Hydrological Practices (WMO-No. 168, 2008) and national quality assurance (QA) standards. See also Chapter 3.1.2. on requirements of monitoring water flow.

Rivers with long-term mean flow rates > 5 m^3s^{-1} should be monitored regularly (at least 12 times per year). For part of the Baltic Sea catchment, it is necessary also to include rivers with long-term mean flow rates < 5 m^3s^{-1} in the regularly monitoring, to reduce the proportion of unmonitored area. In general, the frequency of flow measurement should as a minimum correspond to the sampling frequency for the determination of the load and be carried out at least 12 times per year.

Preferably the discharge (or at least the water level) should be monitored (quantified) continuously and close to where chemical samples are taken. If the discharges are not monitored continuously the measurements must cover low, mean and high river flow rates, i.e. they need not necessarily to be done at regular intervals, but should as a minimum reflect the main annual river flow pattern. A relation between discharge and water level should be established based on the regular discharge measurement in order to calculate daily flow in the river. Continuously controlled and regularly calibrated equipment (e.g. current meters), maintained and carefully performed measurements together with an accurate calculation can diminish errors. The presence of aquatic weeds and effect of weed cutting should be included when establishing relationships between discharge and rivers flow, as should changes in elevation of the riverbed or changes in slope of the river.

Several different stream flow-monitoring principles are applied, two often used methods are mentioned, and some more are mentioned under 3.1.2. One of the most common ones is the mechanical current meter. In the latest 10-15 years also acoustic Doppler current profilers (ADCP) have been applied using Doppler effect to determine water velocity by sound pulse. The ADCP has some advantage regarding monitoring during flooding, close to estuaries with change current direction and in rivers with a lot of aquatic weeds. Compared to a mechanical current meter ADCP can make more discharge measurements with reduced time, including more detailed profiles of water velocity. On the other hand, close to the bottom and the water surface the velocity profiles are extrapolated rather than monitored using the ADCP principle.

It is important to have an overlapping time series in case of change of measuring principles/type of flow monitoring instruments for ensuring a consistent time series.

3.1.2. Wastewater flow measurements

The accuracy of the wastewater flow measurements in municipal sewage systems and industrial plants are in many cases of a considerably lower quality than can be expected. Measurement errors of more than 20% are not unusual. However, the accuracy can be improved by increasing the awareness of the types of errors, by elimination of these errors and by continuous maintenance of the measurement system and its accuracy. A relative error of less than 5%, which can be achieved by most of the methods used in open and closed systems, should be the target in each case.

An open flow measurement system includes channels, flumes and weirs, e.g. Venturi- and Parshall channels/flumes and Thompson (V-notch) weirs. In closed systems the measurement takes place in pipes using different kind of flow meters, e.g. ultrasonic (Acoustic -Doppler) and electromagnetic meters. Most of these available methods are reliable if properly used and can be recommended for the wastewater flow measurement. In this chapter only some general instructions related to the flow measurement and improvement of its accuracy are presented. More detailed information can be obtained from numerous standards (e.g. ISO-/DIN-standards) as well as guidelines and handbooks (e.g. WMO-No. 168, 2008) that deal with flow measurement methods, the theory and prerequisites of them, as well as possible sources of error, calibration methods etc.

A flow measurement system should be chosen so that continuous measurement and registration of wastewater flow can be carried out. In addition to the instant flow recorder the system should have a totalizer to give the cumulative flow. Otherwise, the system should be chosen based on good accuracy and reliability.

The whole flow measurement system (waterways plus measurement devices) should be planned carefully as well as built and installed exactly according to dimensions, prerequisites and guidelines of the chosen system/method. Old systems should be checked thoroughly from time to time. Observed errors should be corrected; if this is not possible, a new accurate system should be applied.

The measurement system/equipment should be calibrated on-site (in the real measurement conditions). The calibration should be carried out by using an independent method/system that is accurate (relative error preferably less than ± 2%). The accuracy of the calibration should be possible to estimate in each calibration. The calibration should be repeated e.g. once per 1-2 years. If the system is stable the calibration frequency can be reduced and vice versa.

In order to maintain continuously a good accuracy and reliability of the measurement system, waterways and devices have to be cleaned and the function of them checked regularly. For example, in the case of Venturi-channels and overflow weirs, the correctness of the water level measurement should be checked daily.

The above-mentioned principles for selection of flow measurement systems, and for calibration and control of systems are valid for treated and untreated wastewater. However, the untreated wastewater outflow is often not measured with stationary measurement systems. In these cases, the flow has to be estimated, e.g. on the basis of the water consumption.

3.2. Sampling strategy for water samples: site selection and sampling frequency

3.2.1. Riverine water sampling

The sampling strategy for water samples should be designed on the basis of historical records and cover the whole flow cycle (low, mean and high river flow). It is important to cover periods of expected high river flow if continuous monitoring is not performed. It is known that in general there is a positive (but not necessarily linear) correlation between periods of high river flow and high concentrations, especially for substances transported in connection with particles as suspended solids, e.g. some nutrient species and some heavy metals. Sampling should therefore be done at different high flow conditions as hysteresis effects may occur. For all monitored rivers a minimum of 12 samples should be collected over a year in order to estimate the annual input load (Rönnback et al. 2009, Ekholm et al 1995, and Rekolainen et al. 1995). The samples do not need to be collected at regular intervals, but at a frequency that appropriately reflects the expected river flow pattern e.g. covers high flow after spring snow melt, high flows in autumn, drought periods etc. This is particularly important if only 12 samples are taken annually and there is a marked annual variation in the flow pattern. If more samples are taken (e.g. 18, 26 or more) and/or the flow pattern does not show significant annual variation, the samples can be more evenly distributed over the year. Overall, for substances transported in connection with suspended solids, lower bias and better precision is obtained with higher sampling frequency (Kronvang & Bruhn 1996) – see also Chapter 10.4.

The monitoring site should be in the river stretch where the water is well mixed (such as at a weir or immediately downstream of a weir) and, therefore, of uniform quality. Pooled sampling strategy (i.e. several sub-samples are collected to make one pooled sample) is recommended where the concentration of sampled substances can change markedly within a short period, and these sub-samples can be taken either flow- or time-proportional. Otherwise, discrete samples can be collected. The representativeness of the sampling points in the cross-section must be checked. The Standard ISO 5667-6 should be used. Guidelines for carrying out sampling are contained in Annex 5.

3.2.2. Wastewater sampling

There are several ISO-standards dealing in detail with the sampling of wastewater already applied by Contracting Parties e.g. ISO 5667-10. Therefore, in this chapter only the main principles of sampling are presented.

In order to get representative samples, they should be taken at points where the effluent has a high turbulent flow to ensure good mixing. If the water is not mixed properly the suspended solids and other substances may be unequally distributed in the water column, which may cause a remarkable error. The chosen sampling location should be regularly cleaned to avoid excess contamination by sludge, bacterial film etc. from the walls. Sampling frequency should be optimized taking into account the variation of flow and concentration.

3.2.2.1. Municipal wastewater treatment plants

The EC Urban Wastewater Treatment Directive (UWWTD) calls for measurements at the outlet of municipal wastewater treatment plants, with a minimum frequency of sampling according to the number of PE (Population Equivalent) connected; the monitoring of pollutants is required for municipal wastewater treatment plants with more than 2,000 PE connected (Table 3.1).

Table 3.1. Number of PE (Population Equivalent) connected and number of samples required regarding nutrients.

Number of PE connected	Number of samples
< 2,000 PE	4 samples or theoretical quantification when no sampling
2,000 – 9,999 PE	4 samples[1]
10,000 – 49,999 PE	12 samples
≥ 50,000 PE	24 samples

For storm water treatments plants, 4-12 samples should be taken per year.

[1] If one out of the four samples fails to comply with the requirements of the Urban Wastewater Treatment Directive, 12 samples should be taken in the year that follows.

3.2.2.2. Industrial plants

In self-controlled large point sources (e.g. pulp, paper and metal processing mills, and larger plants producing chemicals) sampling and analyses should be made 2-7 times per week. At smaller point sources a sampling frequency of 1-4 times per month, or even only a few times per year at very small sources, can be considered acceptable. Samples from treated and untreated wastewater should always be taken as composite samples, which are prepared either automatically or manually. In both cases 24-hours-flow-weighted composite samples[2] should be the target at a well-defined point in the outlet of the industrial plant. At plants with very small wastewater discharges the sampling period of the composite samples can be less than 24 hours (e.g. 8-12 hours).

For measurements at the outlet of industrial plants, the number of samples should be

- 12 times per year if water consumption is more than 500 m^3 per day,
- 4 times per year if water consumption is 50-500 m^3 per day, and
- 2 samples a year if 5-50 m^3 water consumed per day.

[2] According to the Urban Wastewater Treatment Directive (UWWTD, Council Directive 91/271 EEC, Annex 1) alternative methods may be used if it can be demonstrated that equivalent results are obtained.

4. Quantification of load from monitored rivers

The annual load for all monitored rivers should be determined and reported every year. For every monitored river the annual load should be calculated for the measurement site, to have a calculated figure for the monitored part of the catchment. The load from the unmonitored part of the river catchment area can either be estimated for each river individually, or estimated as a part of the countries' unmonitored areas including coastal areas for each Baltic Sea sub-basin.

For transboundary rivers the receiving (HELCOM) country with the river mouth has the obligation to carry out measurements at the most downstream situated monitoring station of the catchment area and to report total inputs entering the sea for the monitored and unmonitored area (see Chapter 8). Furthermore, measurements of the transboundary inputs entering to the HELCOM country should be carried out at the border and reported to the PLC database. The Contracting Parties are also encouraged to cooperate with the upstream country in order to accommodate data collection. Surface water retention within Contracting Parties receiving transboundary inputs must be calculated to estimate net transboundary inputs entering the Baltic Sea by Contracting Party/country. The Contracting Party receiving transboundary input has the responsibility to quantify the retention within its country on the transboundary inputs (see Chapter 9).

The quantification, division and reporting of loads at the mouths of border rivers discharging into the Baltic Sea must be coordinated by the relevant countries ensuring it is clear how the total load should be shared between these countries.

4.1. Methods for calculation of the load from monitored rivers

The objective is to obtain the total load from monitored rivers into the Baltic Sea. The calculation should be made based on water quality monitoring data and hydrological observations (see Chapter 5). Additional information on methodologies is available in the WMO, Guide to Hydrological Practices, vol. 1, 2008: Practices (WMO-No. 168, 2008).

By definition, monitored rivers have river flow and concentration measurements. When both hydrological and chemical measurements are performed at the same station (hydro-chemical monitoring station), one of the calculation methods recommended below should be applied. If the hydrological and chemical observations are not performed at the same station, the river flow should be calculated to the nearest chemical station prior to the load calculation, e.g. using the method proposed in Chapter 4.2.

The following annual load calculation methods (presented in the order from most recommended to least recommended) should be used:

a) *Daily river flow and daily concentration (interpolated)*

This method utilizes linear interpolated concentration values (C_t) for days where pollutants have not been measured. If daily river flow (monitored) on day t (Q_t) is not available, it should be estimated by linear interpolation between days with monitored river flow data.

Concentrations C to day t of a substance are denoted:

$$C_t \; t = 1,2,\ldots,n.$$

When the linear interpolation is made (for concentrations and/or discharge), the last measurements from the previous year and the first measurements from the following year should be used when available.

When daily concentrations and discharges have been calculated, then the annual load is estimated by:

$$L = 0{,}0864 * \sum_{t=1}^{n}(Q_t * C_t) * 0.001 \quad (4.1)$$

$\sum$ = denotes summation;

n = number of days;

L = annual load (tons a-1 for nutrients, kg a-1 for hazardous substances);

Ct = concentration day t (mg l-1 for nutrients, and µg l-1 for hazardous substances);

Qt = river flow (l s-1).

The factor 0.0864 are number of seconds per day divided by 1,000,000. By further multiplying with 0.001 or $1*10^{-3}$ the annual load for nutrient ends up in tons a^{-1}.

b) Mean monthly concentration and monthly river flow

Annual load is calculated as:

$$L = \sum_{t=1}^{12}(W_i * C_i) * 10^{-6} \quad (4.2)$$

L = Annual load (tons a^{-1} for nutrients, kg a^{-1} for hazardous substances);

W_i = volume of monthly river flow (m^3) in month i;

C_i = mean monthly concentration (mg l^{-1}) in month i.

c) Daily river flow and daily concentration regression

Annual load is calculated as:

$$L = 0{,}0864 * \sum_{i=1}^{n}(Q_i * C_{ri}) * 0.001 \quad (4.3)$$

Concentration is calculated from regression:

$$C_{ri} = \frac{a}{Q_i} + b + c * Q_i \quad (4.4)$$

L = Annual load (tons a^{-1} for nutrients, kg a^{-1} for hazardous substances);

Q_i = daily river flow day i (measured) (l s^{-1});

C_{ri} = the regression value of the concentration for day in (mg l^{-1});

0.0864 is a conversion factor of units together with the factor 0.001 to get loads in tons a^{-1} for nutrients

a, b, c = coefficients typical of each quality parameter, observation station and time series;

n = number of days per year.

This calculation using daily regression should only be applied if there is a good relationship between the specific compound and the daily river flow.

4.2. Methods for estimating the water flow for rivers where chemical and hydrological stations are not located at the same place

For rivers where chemical and hydrological stations are not located at the same location there are different methods to estimate the water flow at the chemical monitoring station for use in load calculations. For instance, there are sophisticated models using Geographic Information system (GIS). However, most such models are region-specific and have to be tested before they can be applied to other regions. A simpler methodology that might be applied when the proportion of catchment area between the hydrological and chemical stations is low, and no tributaries is entering between the chemical and hydrological stations, is to extrapolate (area proportional) the water flow from the hydrologically monitored part to the unmonitored catchment area. When extrapolating to catchment with hydrological monitoring stations, knowledge about the hydrological behavior of water flow of a comparable monitored catchment area should be taken into account.

If there is no developed model or experience in modelling water flow, the following extrapolation method might be used:

- The annual river flow ($m^3\ s^{-1}$) should be calculated for the catchment area covered by the chemical station by multiplying the specific flow ($m^3\ s^{-1}\ km^{-2}$) at the hydrological monitoring station with the area of the chemically monitored catchment.

This method can be used for calculating monthly or annual flow, but not for daily values. For the estimation of the annual loads the same equations as in Chapter 4.1 should be used. If other methodologies are applied, information about the used methodology should be reported (cf. Annexes 2 and 3).

5. Quantification of load from point sources

This chapter covers calculation and estimation methods to quantify the load from point sources (MWWTP, industrial plants and aquaculture plants) into recipient water bodies. It should be noted that if a point source has several outlets, located in different sub-catchments, the load should be presented separately for each outlet. Details on wastewater sampling and flow measurement are provided in Chapter 3, and on reporting requirements in Chapter 12 and 13.

5.1. Municipal Wastewater Treatment Plants (MWWTP)

The wastewater outflow should be measured continuously (at least for plants > 10,000 PE) in order to calculate the total volume in a certain time period (day, month, and year). For MWWTP larger than 100,000 PE, release data provided to the EU Pollutant Release and Transfer Register (E-PRTR) [3] could also be reported for the use in PLC and needs not to be recalculated (for more information see Chapter 5.2 Industrial plants (INDUSTRY)). Furthermore, the wastewater samples should be taken frequently as flow-weighted composite samples. If that is not possible, the monitoring programme has to be optimized (see Chapter 3 for details concerning wastewater monitoring and sampling). Annual discharges should be calculated as the product of annual total quantity of wastewater and flow-weighted concentrations; the three ISO standard methods below (a, b and c) are examples of such quantification procedures. Where there is no reliable monitoring method, the load may be derived from per capita load estimates (d).

a) Continuous flow measurements and sampling (e.g. 24 hours flow-weighted composite samples 7 times/week)

The annual load is the cumulative load of continuously monitored time periods and can be calculated as follows:

$$L = \sum_{i=1}^{n} \mathrm{Qi} * \mathrm{Ci} * 10^{-6} \tag{5.1}$$

L = annual load (tons a^{-1} for nutrients, kg a^{-1} for hazardous substances;
Q_i = wastewater volume of period i (m^3);
C_i = flow weighted concentration of period i (mg l^{-1} for nutrient and µg l^{-1} for hazardous substances);
n = number of days in the year.

When concentration is in µg l^{-1} (hazardous substances) equation 5.1 must be divided with 1,000,000.

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[3] E-PRTR = The European Pollutant Release and Transfer Register is the Europe-wide register that provides easily accessible key environmental data from industrial facilities in European Union Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland. It replaced and improved upon the previous European Pollutant Emission Register (EPER).

b) Continuous flow measurement and non-continuous sampling every second day, once a week or twice a month (preferably as 24-hour composites)

The annual load can then be calculated as follows:

$$L = \frac{\sum_{i=1}^{n} Q_i * C_i}{\sum_{i=1}^{n} Q_i} * Q_t * 10^{-6} \quad (5.2)$$

L = annual load (tons a^{-1} for nutrients, kg a^{-1} for hazardous substances);
Q_i = wastewater volume of period i (m^3);
C_i = concentration of sample i (mg l^{-1} for nutrient and µg l^{-1} for hazardous substances);
Q_t = total wastewater volume of the year in m^3;
n = number of sampling periods.

c) Flow measurement only on sampling days and sampling rather seldom i.e. 1–12 times per year

In this case the annual load can be calculated by multiplying the average load of sampling days by 365, as follows:

$$L = \frac{\sum_{i=1}^{n} Q_i * C_i}{\mathrm{n}} * 365 * 0.001 \quad (5.3)$$

L = annual load (tons a^{-1} for nutrients, kg a^{-1} for hazardous substances);
Q_i = wastewater volume on sampling day i (m^3);
C_i = concentration on sampling day i (mg l^{-1} for nutrient and µg l^{-1} for hazardous substances);
n = number of sampling days.

d) Load estimate of small MWWTPs (<2,000 PE) and for untreated sewage discharges without reliable monitoring

If no reliable monitoring has been done for small MWWTP (<2,000 PE) or for untreated sewage discharges and only population data (PE) are available, the load may be derived on the basis of the below per capita load estimates:

- BOD_5 1 PE = 60 g O_2/day (70 g O_2/day for BOD_7)
- TN 1 PE = 12 g N/day
- TP 1 PE = 2.7 g P/day

However, countries should use their own estimates if more specific data on the local conditions are available. These estimates, including the calculation methods used, must be reported (see Chapter 12 on annual reporting).

During storm events, combined sewers[4] may not be able to treat all wastewater in the wastewater treatment plant due to heavy loads of rainwater. This may lead to either an overflow[5] in the sewage system or that the water is discharged directly to surface water via a bypass[6]. These portions need to be quantified and the related nutrient and/or hazardous substance loads estimated.

5.1.1. Separately treated drainage water from paved areas

When the drainage water from paved areas etc. are treated separately (i.e. not included in a combined sewage system), the nutrient load via the drainage water should be included among the diffuse sources as this kind of sources often do not have a distinct outlet.

5.2. Industrial plants (INDUSTRY)

Ideally, all industrial plants should have a monitoring programme. Practically it is necessary to ensure that at least the industrial plants exceeding the E-PRTR capacity and pollutant threshold values (in Annex I and II to the Regulation (EC) No 166/2006 on the establishment of a European Pollutant Release and Transfer Register) have an adequate monitoring programme. The aim of E-PRTR is to provide comparable and transparent figures, and that the reported figures are as complete as possible.

Wherever possible, the annual discharges from industrial plants should be calculated as the product of the total quantity of wastewater in a period multiplied with the corresponding flow-weighted concentrations and summed up annually. The three ISO standard methods (a, b and c) in Chapter 5.1 are examples of such quantification procedures. For industrial plants discharging less than the E-PRTR threshold value into waters, relevant standard discharge coefficients should be used in cases where no monitoring data is available. The determination of such coefficients should be based on experience with discharges from larger plants that have monitoring programmes, taking into account of differences in the degree of internal treatment at the plants.

According to minimum reporting of E-PRTR should include plants/facilities, which have a significant impact on the environment. The significance is demonstrated by covering facilities that:

1. undertake one or more of the activities and exceed the production capacity as listed in Annex I of the E-PRTR Regulation;
2. <u>and</u> exceed threshold values set for the release of substances according to Annex II of the E-PRTR Regulation.

Plants/facilities that fulfil these criteria have to report the annual release data to the relevant national authority, which further provides the data to European Commission and the European Environment Agency for compilation and dissemination on the E-PRTR website

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[4] Combined sewage system includes both wastewater and drainage water from paved areas etc. Control of overflows is regulated with HELCOM Recommendation 23/5-Rev.1.

[5] Overflows are discharges from combined sewerage system to the water body during rainfall when the flow (mixture of sewage and rainfall runoff) in the system is over-loading the designed volume of the system. Control of overflows is regulated with HELCOM Recommendation 23/5-Rev.1.

[6] Bypasses are discharges from a sewerage system to the water body to prevent station treatment plant overflow damages during breaks in electricity supply or emergency repairing works. Use of bypasses is regulated with HELCOM Recommendation 28E/5.

(https://ec.europa.eu/environment/industry/stationary/e-prtr/legislation.htm). The data reported to E-PRTR could also be reported for the use in PLC and needs not to be recalculated. For completeness and the PLC assessments, any other plant with industrial effluents entering the Baltic Sea and national catchment areas should be included in PLC reporting.

Non-EU countries applying other rules are invited to strive for good correlation to these criteria and to measurements and analytical methods complying with international standards. Source identification and reporting details are in the Annexes 2 and 3 of these guidelines.

5.3. Aquaculture

The term aquaculture refers to the cultivation of both marine and freshwater species (e.g. fish and shellfish) in either land-based systems that discharge either to rivers and inland lakes, through direct point sources or production systems in coastal and open marine areas. In general, fish farms are the main concern regarding aquaculture as a nutrient source to the sea. On the contrary, shellfish cultures could be seen as having a net export of nutrients from the water, as the nutrient supply is from the water, and by harvesting the produced shellfish nutrients are actually removed from the system. Also, some freshwater aquaculture plants can net retain e.g. phosphorus.

The main source for nitrogen, phosphorus and organic matter (measured as BOD) discharges from aquaculture is the feed supplied into the farming system. Cultivation of mussels and other species that do not use artificial feed are not covered in this guideline. Discharges of nitrogen, phosphorus and BOD are derived from uneaten feed, undigested nitrogen, phosphorus and organic matter (faeces), and excretion via gills and urine. Measures aimed at the reduction of discharges from freshwater and marine fish farming in particular are regulated in HELCOM Recommendation 25/4 "Measures aimed at the reduction of discharges from freshwater and marine fish farming" (HELCOM 2004).

According to HELCOM Recommendation 37-3 (HELCOM, 2016c) on sustainable aquaculture in the Baltic Sea region the HELCOM recommends "to make better use or establish and maintain national databases of aquaculture or water permits and monitoring data in co-operation with the aquaculture sector. A better assessment of the nutrient loads from aquaculture should be based on data collected and reported to the HELCOM PLC database…". Further in order to fulfil the objectives in the Recommendation on the actions that should be taken "the Contracting Parties should provide information according to HELCOM Guidelines for the annual and periodical compilation and reporting of waterborne pollution inputs to the Baltic Sea (PLC-water)".

Discharges from aquaculture plants into rivers or lakes can be determined by:

1. Monitoring at the outlets from these plants;
2. Through calculations. Calculations can be based either:
   (a) on records of fish (or other farmed organism) production and feed used, or
   (b) by using feed conversion rates (FCR) combined with chemical analyses of feed and fish and taking into account removal of nutrients (and organic matter) by natural processes and sludge removal (for more information, see HARP NUT Guideline 2, OSPAR (2018)

Quantification of discharges from fish farming plants may be based on aggregated information extracted from national registers of annual figures for relevant parameters from each individual plant. Such statistics are usually collected as part of the requirements in the discharge permits. For the quantification of discharges, the distinction is made between two main production types:

1. Plants without treatment (e.g. plants where the sludge is not collected or where the sludge is collected, but discharged to the aquatic environment without treatment); and
2. Plants with treatment (e.g. plants with permanent removal of sludge), where the N and P contents (and organic matter) in the sludge removed are quantified.

The quantification of discharges from aquaculture plants is described in the following three approaches:

1. Approach 1 is based on calculations from production parameters. The starting point is that information is available on both production and feed consumption at plant level. The quantification method is based on mass balance equations. Valid for both marine and freshwater aquaculture plants.
2. Approach 2 is based on calculations from production parameters, but only information on either production or feed is available at national level. Valid for both marine and freshwater aquaculture plants.
3. Approach 3 is based on monitoring the discharge. It is feasible for ponds or other land-based production systems where the discharges are distinct point discharges (such as end of pipe/channel). The quantification of losses is also based on mass balance equations, but in this case on monitoring results. The method is valid only for freshwater aquaculture plants.

5.3.1 Approach 1 (marine and freshwater plants)

This approach forms a basis for the estimation of nitrogen, phosphorus and BOD (organic matter) discharges from aquaculture plants (Cho *et al.* 1991).

a) For plants without treatment (sludge removal):

Phosphorus (P) or nitrogen (N) discharge to water body in ton a^{-1} ($L_{P/N}$)

$$L_{P/N} = (0.01*(IC_i-GC_f) - M - T)*0.001 \quad (5.4)$$

where

I = amount of feed used for feeding of fish in kg a^{-1}

C_i = P or N content in feed in %

G = net growth of fish including dead fish in kg a^{-1}

C_f = P or N content in fish in %

M = nutrient losses due to metabolism in fish in kg a^{-1}

T = nutrient removal processes on the fish farm not related to sludge removal (e.g. nutrient turnover, denitrification etc.) in kg a^{-1}

BOD discharge to water body in ton a^{-1} (L_{BOD})

$$L_{BOD} = (P_L - D) *0.001 \quad (5.5)$$

where

P_L = Internal fish farm loss from fish production

$$= (686-1671*F_k + 1544*F_k^2 - 354*F_k^3)*G \quad (5.6)$$

F_k = I/G, feed quotient, i.e. feed used for producing fish during a year

I = amount of feed used for feeding of fish in t a^{-1}

G = net growth of fish including dead fish in t a^{-1}

D = area-decomposition/turnover of BOD = E_d * A (5.7)

E_d =specific decomposition/turnover in kg m^{-2} a^{-1}

= (6.4 * F_k – 4.2) * 0.365 (5.8)

A = water covered surface area in the fish farm (estimate of the sedimentation basin surface area and of the plant lagoon, if present) in m^2

b) For plants with treatment (sludge removal):

Phosphorus (P) or nitrogen (N) discharge to water body in ton a^{-1} ($L_{P/N}$)

$$L_{P/N} = (0.01*(IC_i-GC_f) - M - T - S)*0.001 \quad (5.9)$$

where

I = amount of feed used for feeding of fish in kg a^{-1}

C_i = P or N content in feed in %

G = growth of fish in kg a^{-1}

C_f = P or N content in fish in %

M = nutrient losses due to metabolism in fish in kg a^{-1}

T = nutrient removal processes on the fish farm not related to sludge removal (e.g. nutrient turnover, denitrification etc.) in kg a^{-1}

S = amount of P or N removed with the sludge in kg a^{-1}

BOD discharge to water body in ton a^{-1} (L_{BOD})

$$L_{BOD} = ((P_L - D) * (1 - S))*0.001 \quad (5.10)$$

where

P_L = Internal fish farm loss from fish production = $(686-1671*F_k+1544*F_k^2-354*F_k^3)*G$ (5.11)

F_k = I/G, feed quotient, i.e. feed used for producing fish during a year

I = amount of feed used for feeding of fish in t a^{-1}

G = net growth of fish including dead fish in t a^{-1}

D = area-decomposition/turnover of BOD = E_d * A (5.12)

E_d = specific decomposition/turnover in kg m^{-2} a^{-1}

= (6.4 * F_k – 4.2) * 0.365 (5.13)

A = water covered surface area in the fish farm (estimate of the sedimentation basin surface area and of the plant lagoon if present) in m^2

S = reduction factor for nutrient removal processes on the fish farm not related to sludge removal.

The net growth (G) of one year in equations 5.4, 5.5., 5.9 and 5.10 is calculated as the sum of i, ii, and iii below + the difference between the standing stock by the end of the year and the beginning of the year:

i. organisms taken out of the water for slaughter (alternatively the sum of slaughter weight and slaughter offal) or sold alive ($t\ a^{-1}$)

ii. dead organisms collected during the year ($t\ a^{-1}$), and

iii. escaped organisms ($t\ a^{-1}$).

The total nitrogen and phosphorus content in the feed may be obtained from the feed manufacturers. In order to facilitate national calculations, average figures based on the typical feed used in the catchment area may be used, but if the type(s) of feed in each individual fish farm is known ideally that information should be used. The indicative figures in Table 5.1.a and 5.1.b may be used if the above-mentioned figures are not available. If "moist/semi-moist feed" (higher content of water than "dry feed")[7] is used, the quantity of moist/semi-moist feed should be converted to the comparable amount of dry feed, as an expression of the total quantity of feed used. The total phosphorus and nitrogen content in the produced organisms can be obtained as a standard figure for each catchment area. If such figures are not available, the figures in Table 5.1 may be used.

Table 5.1.a Content of total nitrogen and total phosphorus in fish (trout) and fish feed.

	Total phosphorus content (%)	**Total nitrogen content (%)**
Fish (fresh)	0.4	2.5
Dry feed [1]	Approx. 0.9	7.0 (for big fish) 7.5 (for small fish, fingerling, and fry)
Semi-moist feed [2]	0.5	5.0
Moist(fresh) feed [3]	0.45	2.5

[1] Dry matter >80 %
[2] Dry matter 35-80 %
[3] Dry matter <35 %

[7] The water content in this feed category varies, but a general guidance can be: semi-moist feed (35-80% is dry matter), moist feed (< 35% is dry matter), while a dry feed has > 80% dry matter.

Table 5.1.b Content of total nitrogen and total phosphorus from freshwater fish farms. The percentages are of the fish wet weight.

	Total phosphorus content (%)	Total nitrogen content (%)
Fish (fresh) up to 800 grams	0.43	2.75
Fish (fresh) over 800 g (and brood stock)	0.414	2.95
Dry feed	Max. 1.0	Max. 9.0

The calculation of treatment yield requires that the nitrogen and phosphorus content in the sludge is calculated/measured regularly (e.g. based on requirements in the discharge permits) as a basis for quantification of the fraction that is removed by the sludge. If such figures are unavailable and, in the case of regular removal of sludge, an average removal of 10% N and 40% P due to decantation may be considered.

5.3.2 Approach 2 (marine and freshwater plants)

If national registers on feed use and production on individual plants are not available, national sales statistics could be used. If only statistics on production or feed used is available, an assumption of the feed conversion ratio (FCR) should be made. FCR is the ratio between weight of feed used (dry feed basis) and weight gain of the organism (production), expressed as:

$$FCR = \frac{\text{Feed used (t a}^{-1}\text{)}}{\text{Production (ta}^{-1}\text{)}} \quad (5.14)$$

The FCR is, among other things, species dependent and varies by water temperature, as the fish metabolism is temperature dependent. Hence, it is preferred to use FCRs specific for the actual catchment or region based on estimates obtained from literature or determined from experimental work. If literature values are used, the report should include a literature reference. If no values from literature or experimental work are available the following standard figures are recommended:

- FCR=1.1 for big fish over 0.8 kg (although use 3.0 for mother fish),
- FCR=0.8-1.0 for fish between 30 g and 800 g,
- FCR=0.6 for fingerlings.

The figures are obtained from salmonid fish production under optimal growth conditions. Other figures should be used for other fish. When FCR is available for the catchment/region to be reported on, the missing figures of the feed used or production may be estimated from the above-mentioned equation (equation 5.14). Approach 1 can then be followed for the quantification of the discharge.

5.3.3. Approach 3 (freshwater plants only)

For land-based aquaculture systems such as artificial ponds, basins and raceways, the nitrogen and phosphorus discharges may be quantified by monitoring the nitrogen and phosphorus concentrations and the water flow in the inlet(s) and outlet(s) of the production system, followed by a mass balance calculation of the increased discharge. The discharge of nitrogen and phosphorus (and organic matter) from a production system may vary considerably over both the short and long timescale and depend, *inter alia*, on operational factors such as standing stock, application of feed, feed quality, time of feeding, time of cleaning operations, the presence of different purification tools and their effectiveness (e.g. plant lagoons are less effective during a cold winter), as well as on the natural variation in the inlet(s) water quality. The effluent monitoring strategy must reflect this variation.

All fish farming (or other aquaculture) plants with an annual production of more than 200 tons should, ideally, take as a minimum 12 contemporary samples a year in the inlet(s) and the outlet(s) for measurements of nitrogen and phosphorus concentrations.

In order to ensure a reliable quantification, sampling of water for analyses of nitrogen and phosphorus (and organic matter) should be flow-proportional over at least 24 hours and be carried out using automatic samplers.

Further, at least flow in inlet(s) and outlet(s) should be monitored on sampling days, but ideally monitored continuously providing daily water intake and outflow.

Good international laboratory practices, aiming at minimizing the degradation of samples between collection and analysis should be applied. The water flow should be registered continuously. Flow measurements should preferably be performed according to international standards (e.g. ISO standards).

The annual load of inlet(s) and outlet(s) may be calculated as follows:

$$L = \frac{\sum_{i=l}^{n} Q_i * C_i}{\sum_{i=l}^{n} Q_i} * Q_t * 10^{-6} \qquad (5.15)$$

L = annual load (tons a^{-1} for nutrients and kg a^{-2} for hazardous substances;

Q_i = wastewater volume of the period I (m^3);

C_i = concentration of sample I (mg l^{-1} for nutrients or µg l^{-1} for hazardous substances);

Q_t = total wastewater volume of the year;

n = number of sampling periods.

The total load of nitrogen, phosphorus or organic matter (or hazardous substances) from the production system is calculated by deducting the corresponding loads in the inlet(s) from the total nitrogen or phosphorus load in the outlet(s).

If flow and concentrations in inlet(s) to and outlet(s) from aquaculture plants are monitored regularly the method *"Daily river flow and daily concentration (interpolated)"* in Chapter 4.1 should be used (Eq. 4.1).

6. Quantification of nutrients losses from diffuse sources

Diffuse sources of nutrients are defined as any source of nutrients not accounted for as a point source. Within the periodic PLC-Water, quantifications of natural background and major diffuse anthropogenic nutrient losses to inland surface waters and to the sea are required (Chapter 13). In the annual reporting, the diffuse inputs are included in the total inputs from monitored rivers and unmonitored areas (Chapter 12).

6.1. Quantification of the natural background nutrient losses

Natural background losses are defined as losses of nutrients that would occur from areas unaffected by human activities. Procedures for the periodic quantification of natural nitrogen and phosphorous background losses into inland surface waters are described below.

Natural nutrient background losses need to be quantified for the entire national Baltic Sea catchment area and therefore cover:

- Losses from currently unmanaged land;
- Losses from currently managed land that would occur irrespective of anthropogenic, e.g. agricultural, activities.

Hence, the natural background losses are a part of the total diffuse losses. The Contracting Parties can use different approaches or a combination of the approaches to estimate natural background losses:

- Monitoring of small unmanaged catchment areas without or with very minor inputs from point sources, and/or
- Use of models including estimation method.

The methods used by Contracting Parties need to be described in a background document.

When natural background losses are estimated using monitoring data from small unmanaged catchment areas without or with very minor inputs from point and anthropogenic diffuse sources the following suggestions are given:

- Using representative catchments in natural conditions (soils), natural vegetation
- Using a representative number of catchments
- Using catchments with negligible impact from point and anthropogenic diffuse sources

It should be taken into account that monitoring values include recent (anthropogenic influenced) atmospheric deposition both on land and on water surfaces. For this reason, and because unmanaged catchment areas nowadays hardly occur, it is preferable to estimate background losses by modelling based on monitoring.

When background losses are estimated by models the assumptions in Table 6.1 should be used.

Table 6.1. Model assumption modelling natural background losses.

Model assumptions	Description of the assumption
Household and industrial wastewaters	*none/negligible*
Hydrological conditions	*Kept as today*
Agriculture	*None*
Forestry	*None*
N-deposition	*0-5 kg/ha/a*
P-deposition	*0-0.05 kg/ha/a*

Natural background losses of nutrients have been reported by the Contracting Parties. The figures given in Table 6.2 relate to the period 1995-2018.

Table 6.2. Annual natural background losses and flow-weighed concentrations of nutrients as reported by Contracting Parties.

Country	Total Nitrogen in kg ha^{-1}	Total Nitrogen in mg l^{-1}	Total Phosphorus in kg ha^{-1}	Total Phosphorus in mg l^{-1}	Comments
Denmark		0.61-1.48		0.021-0.089	Sub-catchment depending
Estonia		1.21		0.04	
Finland	0.62-2.07	0.169-0.752	0.023-0.072	0.0051-0.034	Sub-catchment depending
Germany	<0.1-14 (median 0.2)		<0.001-1.4 (median 0.028)		Sub-catchment depending
Latvia	2.6-10.4	0.78-2.25	<0.1-0.5	0.035-0.082	Sub-catchment depending
Lithuania		0.58		0.0339	
Poland		0.96-1.9		0.04-0.11	Depending on soil and slope conditions
Sweden		0.11-8.5		0.003-0.11	Depending on different land use areas
Russia	2.1		0.15		Same for the entire catchment

6.2. Quantification of nutrient losses from diffuse anthropogenic sources

Diffuse anthropogenic nitrogen and phosphorus losses from the following sources should be considered in the quantifications:

- Agricultural land;
- Managed forestry and other managed land;
- Atmospheric deposition directly on inland surface waters;
- Scattered dwellings;
- Rainwater constructions (e.g. paved surfaces without a distinct outlet).

Whereas point sources are discharging into inland surface waters or directly to the sea with a defined outlet, losses from diffuse sources may be delivered via a number of different pathways into inland surface waters (in monitored and unmonitored areas). Small, dispersed point source discharges e.g. from point sources in agriculture (e.g. farmyards) should also be dealt with as diffuse sources as long as they do not have a distinct and monitored outlet (in which case, they would instead be treated as a point source). The pathways to inland waters are characterized by different flow characteristics and include very different processes (see Figure 2.2). Depending on the land use, losses of phosphorus and nitrogen can vary substantially. PLC-Water defines and considers the following seven diffuse pathways:

- Surface run-off;
- Erosion;
- Groundwater;
- Tile drainage;
- Interflow[8];
- Atmospheric deposition on inland surface waters;
- Scattered dwellings;
- Rainwater constructions.

A large number of removal, storage or transformation processes may influence the final quantities of nitrogen and phosphorus entering inland surface waters. Knowledge about these processes of transformation and retention within inland surface waters is necessary to quantify and to predict nutrient losses into river systems in relation to their sources.

The different loss processes and pathways are very complex and variable including in time and region. The significance of their effects also varies between nitrogen and phosphorus. It is therefore difficult to quantify diffuse losses in a consistent and accurate way. The PLC-Water guidelines do not include a specific methodology for quantifying diffuse sources or delivery pathways. However, countries quantifying nutrient diffuse losses should as a general rule quantify direct losses into surface water bodies (not at root zone or other media). Surface water bodies ideally should be the same as in the national River Basin Management Plans. There are many different methodologies, e.g. OSPAR HARP-NUT Guideline 6 on diffuse sources (OSPAR Commission 2007; updated 2010). Models and approaches to quantify diffuse sources are varying and range from complex process-based models via more conceptual models, using export coefficients, to more simple calculations. Depending on the chosen approach the demand of both manpower to execute model calculations and demand for complex data varies. Vice versa the best model is only as good as the available data it is run with, which implies that the choice of calculation tool should be based on the quality (and quantity) of the available data.

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[8] Substance transport within the vadose zone, i.e. unsaturated soils above the groundwater table.

In the absence of comprehensive measurements, it is necessary to apply calculation methodologies (e.g. various modelling techniques).

6.2.1. Documentation on used estimation methods for diffuse sources

Processes and pathways differ widely, therefore many different methods exist to estimate the losses from diffuse sources, and it is vital that the Contracting Parties comprehensively describe the methodology used for various sources to ensure transparency and to enable assessments. It is important that the documentation include how e.g. the following important factors have been taken into consideration:

- Seasonal variation;
- Retention (see Chapter 9);
- Monitoring data as support to model or values from look-up tables or expert judgement; and
- Estimates based on source-oriented (sources are estimated) or load-oriented approach (only total diffuse anthropogenic sources) – see also Chapter 9.

Many different source-apportionment models exist, with varying capabilities to model the nutrient flow under various conditions, and with very different demands on supporting data. Some examples on models commonly used by the Contracting Parties are given in the Table 6.3. More examples are given in documentation from the EUROHARP project, in which thorough descriptions, as well as comparisons and assessments of commonly used models can be found (e.g. Schoumans and Silgram 2003, and in 10 articles in Journal of Environmental Monitoring Vol. 11, pages 503–609 e.g. Hejzlar et al. 2009, Kronvang et al. 2009, Schoumans et al. 2009a, Schoumans et al. 2009b, and Silgram et al. 2009).

Important issues that need to be considered before a model is chosen are e.g.:

- The purpose with the modelling (only source-apportionment or also scenarios on remedial measures);
- Coverage of important pathways for the nutrients in the prevailing conditions;
- Supporting data availability and quality compared to model needs;
- Source availability regarding man-power or financial support compared to what is expected for data and model handling; and
- Result assessment.

Other important issues are temporal and spatial resolution (vertical and horizontal), high resolution generally implicate higher requirements on supporting data as well as higher labour demands, but maybe one of the most important issues is the applicability of the various models to the specific prevailing conditions that are to be modelled. If there are resources enough, it might be suitable with an ensemble modelling, i.e. several models are used and assessed together, to get more reliable estimates. More detailed concerns on various issues prior to start modelling may be found in e.g. Schoumans and Silgram (2003).

Process-orientated, dynamic models normally require large amounts of input data at a very detailed temporal and spatial scale to describe relevant processes as accurately as possible. These types of models have the potential to provide dynamic responses at a fine temporal and spatial resolution.

Empirical and quasi-empirical approaches, e.g. in data oriented models, typically require less input data/less detailed input data. However, many data-based models have the limitation that they may not be able to describe dynamics in the modelled fluxes and the empirical functions may be limited to the specific catchment and climatic region in which they were developed.

For documenting a model, the issues listed above should be described including a description of the process involved in the model and results of sensitivity and uncertainty analysis. Table 6.3 provides an overview example of source-apportionment models applied in the PLC-7 project by countries and the main input and outputs, and further details are in Svendsen (ed) in press.

Table 6.3. Examples of source-apportionment models that are being used by the Contracting Parties to estimate various nutrient sources and nutrient retention in different scales and a selection of their main input data and output data. More detailed information on input data requirements and output data can be found for example in the PLC 7 methodology report (Svendsen (ed), in press). Please note that at the time this table is composed, Latvia is in the process of adapting the SWAT model. Current estimates of Latvian nutrient losses are based on complex and comprehensive calculations.

	model name (CP)	VEMALA (FI)[1)]	HYPE (SE)[1)]	SWAT (LT, PL)	EstModel (EE)	MoRE (DE)	ILLM (RU)	DK-QNP (DK)
	model type	process oriented	process oriented	process oriented	data oriented	data oriented	data oriented	data oriented
indata		**catchment information**						
indata		basin boundaries						
indata		soil types						
indata		nutrient observations [2)]						
indata		flow data (hydrology)						
indata		land cover and land use	land cover and land use	land cover and land use	land cover	land cover and land use	land cover and land use	land cover and land use
indata		meteorological data	meteorological data	meteorological data	-	meteorological data	meteorological data	meteorological data
indata		**nutrient sources**						
indata		point sources						
indata		fertilizer usage						
indata		atmospheric deposition	atmospheric deposition	atmospheric deposition	atmospheric deposition	atmospheric deposition	atmospheric deposition	-
indata		field slope (for erosion)	field slope (for erosion)	field slope (for erosion)	-	erosion (USLE)	-	-
indata		**agricultural data**						
indata		crop type						
indata		yields	yields	yields	-	yields	-	National nitrogen surplus
indata		soil content P	soil content P	-	-	soil content P	soil content P	
indata		-	-	elevation	-	elevation	-	-
resolution outdata	**nutrient loads**							
resolution outdata	spatial	Sub-catchment <100 km²	Sub-catchment	Sub-catchment	Sub-catchment	Sub-catchment	per river-branch	Sub-catchment
resolution outdata	temporal	Daily	daily	annually	annually	Annually	Annually	monthly
resolution outdata	**Runoff**							
resolution outdata	spatial	Sub-catchment >100 km²	Sub-catchment	Sub-catchment	Sub-catchment	Sub-catchment	per river-branch	Sub-catchment
resolution outdata	temporal	daily	daily	daily	annually	annually	annually	monthly
resolution outdata	**Retention**							
resolution outdata	spatial	waterbody	Sub-catchment	River-branch	Sub-catchment	Sub-catchment	per river-branch	Sub-catchment
resolution outdata	temporal	daily	annually	monthly	annually	annually	annually	monthly

1) ensemble modelling: several models are used to achieve a comprehensive description
2) for validation and calibration

Additional information on the different models can be found here:

VEMALA	A National-Scale Nutrient Loading Model for Finnish Watersheds—VEMALA | SpringerLink
HYPE	https://hypeweb.smhi.se/
MoRE	https://isww.iwg.kit.edu/english/MoRE.php
SWAT	http://swat.tamu.edu/software/
EstModel (model)	https://estmodel.app/
ILLM	http://helcom.ru/media/Annex%203a_eng.PDF

7. Methods for estimation of inputs from unmonitored areas

Unmonitored areas consist of unmonitored rivers, unmonitored parts of monitored rivers and coastal areas including unmonitored islands (see Figure 2.4). In unmonitored areas there are no available data on the requested water chemical determinants or on flow measurements in rivers.

There are different methods to estimate the load from unmonitored areas:

- Using modelling results; or
- Extrapolating the knowledge about neighbouring rivers under similar conditions.

If models are available, they should be used. Chapter 6.2 includes examples of models quantifying inputs from diffuse sources and Chapter 6.1 for quantifying natural background losses. Often information on point sources is available and must be added to the estimated inputs from diffuse sources.

The following method should only be used if more sophisticated methods are not available and if the unmonitored part of the catchments only constitutes a minor share of the total catchment:

Assuming unmonitored area has climate, topography, geology, soil type, land use (especially proportion of agricultural land) etc. that are similar with a monitored area, also similar load in the output (river) then a rough calculation takes into account only the different surface areas of the basins, e.g.:

$$L_n = L_m \frac{A_n}{A_m} \tag{7.1}$$

L_n = input from unmonitored area A_n;

L_m = known input coming from monitored area A_m;

A_n = area of unmonitored catchment;

A_m = area of monitored catchment.

If possible, discharges from large point sources should be taken into account separately, as the discharges from these rarely are equal per area unit in the monitored area and unmonitored area. In some regions/countries the discharge from point sources is monitored and/or estimated also in unmonitored areas. Then the equation 7.1 above is changed to:

$$L_n = DL_m \frac{A_n}{A_m} + PL_U \tag{7.2}$$

Ln = estimated input coming from unmonitored area A_n;

DL_m = known diffuse inputs coming from monitored area A_m (estimated as monitored load minus discharge from point sources, taking into account retention);

PL_u = monitored or estimated point source discharge from unmonitored areas;

A_n = area of unmonitored catchment;

A_m = area of monitored catchment.

Retention in surface waters within the unmonitored catchment should be taken into account when quantifying DL_m and PL_u.

Flow from unmonitored areas can be estimated with the methods described in Chapter 4.2 or from models described in Chapter 6.2. For estimates of heavy metal inputs from unmonitored areas corresponding methods as for nutrients could be applied.

If alternative load calculation methods are used, they must be described in detail (see the Annexes 2 and 3).

8. Transboundary rivers

8.1. Introduction

The follow-up system for the NICs require knowledge about transboundary riverine inputs from non-HELCOM Contracting Parties as well as between Contracting Parties to follow up on the progress towards reaching the nutrient reduction requirements. The new NICs are specific for each Contracting Parties' net inputs defined as their "own" share of the nutrient inputs to the Baltic Sea taking into account retention within surface waters. Further, expected reductions in riverine inputs have also been allocated to non-Contracting Parties. Transboundary inputs between HELCOM Contracting Parties were taken into account when allocating the reductions requirements. The 2021 BSAP points out that continuous cooperation with river basin management authorities will ensure that river basin management plans, including for transboundary rivers, consider the environmental targets as set by the BSAP – as well as by international agreements such as the 1992 UNECE Convention on Transboundary Waters and Lakes.

Therefore, it is important to address transboundary inputs between Contracting Parties and non-Contracting Parties and between two or more Contracting Parties (including border rivers) for PLC assessments. Quantifying transboundary inputs between countries are used both evaluating progress towards the NICs between countries and the importance of these inputs as a source to the receiving countries (source apportionment) and for following any development in transboundary inputs. For assessing the importance of measures taken in upstream loading countries on the net inputs to the Baltic Sea, retention in downstream countries surface waters must be taken into account (see Chapter 9). The importance of transboundary inputs also holds true for hazardous substances for proper estimates of the origin of the pollutants even though at the moment there are no reduction targets for this kind of substances.

A **transboundary river** is a river that crosses one or more country (political) borders. Hence, the inputs of nutrients and contaminants to the Baltic Sea from these rivers are caused by sources in at least two countries. In several cases the upstream countries are not HELCOM contracting parties. The country where the river outlet is located is responsible to report not only the total river input, but also the transport of water and constituents at the points where the river cross borders.

A **border river** is a river with its outlet to the Baltic Sea at the border between two countries. For these rivers, the countries share the responsibility to monitor the inputs of the river.

About 7% of the total catchment draining to the Baltic Sea (total area is 1.73 million km^2) is situated in non-Contracting Parties, but also a proportion of the catchment area within Contracting Parties contributes with transboundary riverine inputs to other Contracting Parties (see Figure 2.5). All big rivers draining to the Baltic Sea are transboundary or border rivers.

It is necessary to monitor the inputs at the borders and to estimate retention in the rivers to attribute contributions from different countries to the input to the Baltic Sea. The Nutrient input ceilings (NIC) of the Baltic Sea Action Plan were calculated and are followed up based on estimating the contributions from different countries to the Baltic Sea via nine of the transboundary rivers. Further, the relative importance of transboundary inputs is also estimated in the periodical source apportionments.

This chapter includes an overview of the rivers that are identified as transboundary and border rivers. Further, it details the transboundary rivers that are accounted for NIC of the BSAP.

8.2. Estimating the inputs to the Baltic Sea from upstream countries

The riverine transboundary inputs to the Baltic Sea from an upstream country is estimated by reducing the observed inputs at the border between the upstream country *a* and the receiving country *b* with the retention of nutrients in the river during passage in country *b* as:

$$TNT_{a,b,n} = (1 - TNR_{b,n})\, TNB_{a,b,n} \qquad (8.1)$$

$TNT_{a,b,n}$ = transboundary input of the nutrient from country *a* via country *b* to the Baltic Sea for river *n;*

$TNR_{b,n}$ = river nutrient retention coefficient (expressed as a value between 0 and 1) in country *b* on transboundary inputs from country *a* in river *n;*

$TNB_{a,b,n}$ = nutrient input at the border between country *a* and country *b* in river *n.*

In the annual reporting the Contracting Parties are providing data on the nutrient inputs at the border ($TNB_{a,b,n}$) and the amount of nutrient retained in the river downstream (i.e., the retention coefficient times the load at the border: $TNR_{b,n}$ * $TNB_{a,b,n}$).

Retention coefficients used to estimate the NIC in the BSAP are shown in Table 8.3.

8.3. Necessary information for quantifying transboundary input

The downstream HELCOM Contracting Party whose territory includes the river mouth is responsible to collect data, and to compile, quantify and report on the annual transboundary inputs. For periodical reporting all data on apportionment of sources for sub-catchments should be reported by countries on which territories these sub-catchments are. The downstream country is encouraged to cooperate with the upstream country in order to quantify inputs and river flow at the border using the methods described in the PLC guidelines and to ensure that all relevant transboundary inputs are quantified and reported to the PLC-Water database. Further, Contracting Parties should also report on retention in the catchment receiving the transboundary input. For border rivers, the involved Contracting Parties should agree on the responsibilities above and report accordingly to HELCOM.

Necessary information to be used for estimating transboundary riverine inputs includes:

- At the river mouth: water flow and loads of total nitrogen, total phosphorus, fractions of nutrients and heavy metals (Table 1.1) to the Baltic Sea (divided in monitored and unmonitored part of the river if applicable);
- At the border: annual water flow and loads of total nitrogen, total phosphorus and, if available, also fractions of nutrients and heavy metals (Table 1.1). Preferably, this is based on monitoring. If the reported information has been modelled, then information on how the estimates were obtained should be reported. The general rule is that downstream Contracting Party reports inputs from both upstream Contracting and non-Contracting Parties. However, if a river has a Contracting Party upstream of a non-Contracting Party, that Contracting Party should report the export of water and nutrients across the border;
- For monitoring stations in transboundary/border rivers the name of the river and the location of the monitoring point(s) (geographical coordinates) should be reported;
- Size of sub-catchments in the up- and downstream countries;

- Estimate of nitrogen and phosphorus retention in each river during passage in the downstream Contracting Party or non-Contracting Party. The Contracting Party with the mouth is responsible to report retention of load from non-Contracting Party surface waters catchment of the transboundary river; and
- In periodic assessment of nutrient source quantifications and for the background information report: population in the catchment, point and diffuse sources, information on land use, livestock, fertilizer application etc. (all in both the up- and downstream countries).

8.4. Overview of transboundary rivers to take into account in reporting and assessments

In the PLC database, there are 26 monitored rivers classified as transboundary and/or border rivers. These rivers are reported to the database in several sub-catchments: one sub-catchment for each country part of the river (with usual SC encoding) and one sub-catchment for the whole river (encoded RC). In case of border rivers, there are two whole river sub-catchments (RC) as both border countries monitor and report the whole river export.

De facto there are 16 of the 26 rivers where reporting of transboundary and/or contributions occurs (information on these are summarized in Table 8.1). For the remaining 10 rivers (summarized in Table 8.2), only whole river inputs are reported.

In the BSAP NIC, nine boundary and/or transboundary rivers were singled out. The information used to estimate national contributions to these rivers in the reference period 1997-2003 is presented in Table 8.3.

Table 8.1 List of transboundary and border rivers that should be included in annual and periodical PLC reporting. CP = Contracting Party, BY = Belarus, CZ = Czech Republic, DE = Germany, DK = Denmark, EE = Estonia, FI = Finland, LT = Lithuania, LV = Latvia, NO = Norway, PL = Poland, RU = Russia, SE = Sweden, SK = Slovakia, UA = Ukraine, BAP = Baltic Proper, BOB = Bothnian Bay, BOS = Bothnian Sea, GUF = Gulf of Finland, GUR = Gulf of Riga, KAT = Kattegat.

River name	Transboundary/ border river between which CP's/countries	CP responsible for reporting	Total catchment and proportion of catchment in involved countries	Other comments
Narva (GUF):	Border between EE and RU. Transboundary contributions from LV and BY	EE, RU	Total area: 58,126 km^2 EE: 30.2% LV: 6.3% RU: 63.0% BY: 0.5%	No reporting/quantification of Belarussian inputs expected
Pärnu (GUR):	Transboundary river EE/LV	EE	Total area: 6,752 km^2 EE: 99.7% LV: 0.3%	
Torne älv (BOB)	Border river between SE and FI Transboundary contribution from NO	FI, SE	Total area: 40,112 km^2 SE: 63.9% FI: 35.0% NO: 1.2%	It is agreed that 55 % of the inputs of N and P entering the sea via the river is from SE and the remaining 45 % from FI. Sweden includes Norwegian inputs in their net inputs
Nemunas (BAP):	Transboundary LT/BY/PL/RU/LV	LT	Total area: 97,920 km^2 RU: 1.6 % LV: 0.1 % BY: 47.1 % PL: 2.6 % LT: 48.6 %	

Sventoji (BAP)	Transboundary LT/LV	LT	Total area 480 km^2 LT: 84.4% LV: 15.6%
Barta (BAP):	Transboundary river LV/LT	LV	Total area: 2,016 km^2 LT: 37.1% LV: 62.9%
Daugava (GUR):	Transboundary river LV/BY/RU/LT/EE	LV	Total area: 87,900 km^2 EE: 0.2% LT: 2.2% RU: 31.6% BY: 38.2% LV: 27.7%
Gauja (GUR)	Transboundary river LV/LT	LV	Total area: 8,950 km^2 LV: 87.5% EE: 12.5%
Lielupe (GUR):	Transboundary river LV/LT	LV	Total area: 17,814 km^2 LV: 50.4% LT: 49.6%
Salaca (GUR)	Transboundary LV/EE	LV	Total area: 3,471 km^2 LV: 91.9 % EE: 8.1 %

Venta (BAP):	Transboundary river LV/LT	LV	Total area: 11,692 km^2 LT: 44.3% LV:55.7%	
Oder (BAP):	Transboundary river PL/CZ/DE	PL	Total area: 118,840 km^2 CZ: 6.1% DE: 4.7% PL: 89.2%	It is agreed that the German contributions currently are 3.7% for TN and 8.5% for TP of total inputs.
Vistula (BAP):	Transboundary PL/BY/UA/SL	PL	Total area: 194,424 km^2 BY: 6.5% UA: 5.7% SL: 1.0% PL: 86.7%	
Neva (GUF)	Transboundary river RU/FI/BY	RU	Total area: 281,000 km^2 BY: 0.3% FI: 20.2% RU:79.5%	No reporting/quantification of Belarussian inputs expected
Pregolya (BAP)	Transboundary river RU/PL/LT	RU	Total area: 15,500 km^2 LT: 0.6% PL: 51.1% RU:48.3%	No reporting of LT contribution expected

Seleznevka GUF)	Transboundary RU/FI	RU	Total area: 642 km^2 RU: 40% FI: 60%

Table 8.2 List of transboundary rivers where only inputs from the whole river is reported and allocated to the first mentioned country. FI = Finland, NO = Norway, RU = Russia, SE = Sweden, BOB = Bothnian Bay, BOS = Bothnian Sea, KAT = Kattegat.

River name	**CP's/countries**	**CP reporting**	**Proportion of catchment in upstream country (%)**
Kemijoki (BOB):	FI/RU	FI	6.0
Oulujoki (BOB):	FI/RU	FI	5.9
Dalälven (BOS)	SE/NO	SE	4.0
Göta älv (KAT):	SE/NO	SE	16.8
Indalsälven (BOS):	SE/NO	SE	7.3
Lule älv (BOB):	SE/NO	SE	2.6
Pite älv (BOB)	SE/NO	SE	0.7
Skellefte älv (BOB):	SE/NO	SE	0.2
Ume älv (BOS)	SE/NO	SE	0.6
Ångermanälven (BOS)	SE/NO	SE	4.8

Table 8.3 Data set and retention values used in estimation of transboundary inputs in the reference period 1997-2003 for the BSAP NIC calculations. If nothing else is stated, retention was calculated by Per Stålnacke within the project BONUS RECOCA. Nitrogen retention estimated from this study was published (Stålnacke et al., 2015) while phosphorus retention estimates are not properly published although more information is available in BONUS RECOCA Deliverable reports. For country and basin abbreviations see e.g. Table 8.1 caption. TN = total nitrogen, TP = total phosphorus.

River	Upstream country	Data set	TN Retention	TP Retention
Nemunas	BY	Lithuanian border loads from Nemunas and Neris	0.11[1]	0.22[1]
Barta	LT	Both Lithuania and Latvia monitor close to the border and averaged data should be used. Latvian data is available from 2001	0.047	0.4
Venta	LT	Both Lithuanian and Latvian monitoring (from 2001), but both stations are at some distance from the border. Average stations give approximate loads at the border. Prior 2001 that border loads = 1.228 * LT loads	0.16	0.48
Lielupe	LT	Lithuanian monitoring in Musa and Nemunelis used. Add unmonitored area (3037 km^2) to monitored (5693 km^2), i.e., multiply with (5693+3037)/5693 = 1.53.	0.15	0.6
Daugava	LT	Contribution not monitored, estimate by using annual area specific loads from Musa and Nemunelis. Area in LT is 1821 km^2, i.e. multiply Musa and Nemunelis loads with 1821/5693 = 0.32 to get border loads	0.38	0.43
Daugava	BY	Latvian monitoring data at the border	0.38	0.43
Daugava	RU	BY monitoring data is available 2004-16. TN not monitored but estimated by multiplying DIN with a factor of 1.76 deduced from comparing Latvian and Belarussian monitoring data at the Latvian-Belarussian border. For 1995-2003, border loads are assumed to be TN 34% and TP 56% of the loads at the BY-LV border based on average ratio 2004-2010. 2017 is estimated as TN 23% and TP 18% of the BY-LV border load based on average ratio for 2014-2016.	0.38 (in BY) 0.62 (total)	0.43 (in BY) 0.68 (total)
Neva	FI	Finnish border load data	0.3[2]	0.7[2]
Oder	DE	It has been estimated by German modeling that the German contribution to Oder during the reference period was 2337 ton/y and 101 ton/y of TN and TP, respectively. These result to 3.6 % (TN) and 2.5% (TP) of total Oder loads. It is estimated that the current proportions are 3.7% (TN) and 8.5% (TP)	0	0
Oder	CZ	Polish border load data, 1995-2010 previously supplied, 2012-2017 reported to PLC, 2011 estimated 9.5% of total Oder loads	0.3	0.64
Vistula	BY	Estimated as 6% of total Vistula loads based on 2012-2017 data reported to PLC	0.32	0.55
Vistula	UA	Polish load data from Bug, 1995-2010, 2012-2017 reported to PLC, 2011 estimated as 7.5% of the total Vistula loads	0.32	0.55
Pregolya	PL	Polish data time-series provided 1995-2010, 2012-2017 reported to PLC, 2011 estimated as 49% of total Pregolya loads	0.25	0.58

[1]Retention figures supplied by LT

[2]Retention figures supplied by FI

9. Quantification of sources of waterborne inputs to inland waters and to the sea

Quantifying the total gross loads from point sources, diffuse sources and natural background losses into inland surface waters within the whole Baltic Sea catchment area (defined as the source-oriented approach) is important to get a comprehensive overview of the total loading originating in the Baltic Sea catchment area. This is also a prerequisite for the estimation of retention and source apportionment. The quantification of gross loads together with retention is also important for evaluating effectiveness of measures for reducing waterborne pollution to the sea. The quantification of input sources to inland surface waters is described in Chapter 9.1.

Quantification of sources of waterborne riverine inputs to the sea (defines as the load-oriented approach) is a tool to evaluate the contribution from different inland point and diffuse sources of the total riverine input of nitrogen and phosphorus actually entering the Baltic Sea (see Chapter 4 for a description on how to quantify riverine inputs). The objective is to divide riverine input to the sea into different sources (anthropogenic and natural background losses). This apportionment is done based on the total nitrogen and phosphorus inputs to the sea taking into account the retention in inland surface waters (see Chapter 9 for information on retention). The quantification of sources of waterborne inputs to the sea is described in Chapter 9.2.

Retention in inland surface waters is the connecting link between the “Source-orientated Approach” and the “Load-orientated Approach” and is delineated in Chapter 9.3. See also Figure 2.3.

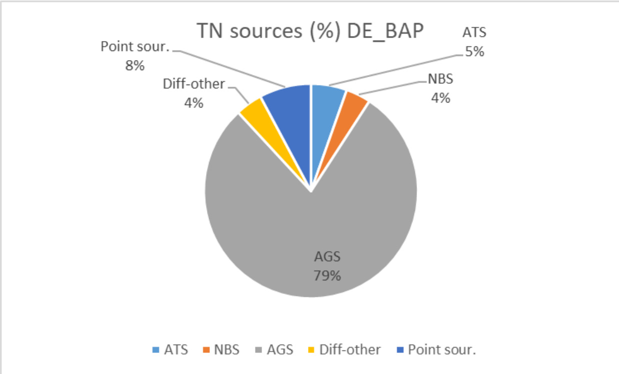
9.1. Source-oriented approach: Quantification of sources of waterborne inputs into inland surface waters

The source-oriented approach aims to quantify all inputs from point sources, diffuse sources and natural background losses into inland surface waters within the Baltic Sea catchment area. Quantifying these inputs is important for assessing e.g. the effectiveness of pollution reduction measures and the extent of retention of pollutants in the catchment area.

Quantification of losses from point sources is described in Chapter 5 and quantification of diffuse sources and natural background losses are described in Chapters 6 and 7.

Quantification of loads using the source-oriented approach is carried out only periodically for PLC projects, ideally every sixth year in accordance with the **HELCOM Recommendation 37-38/1** “Waterborne pollution input assessment (PLC-WATER)”. The information and data that have to be reported are summarized in the Annexes 2 and 3.

Figure 9.2 provides two examples of applying source-oriented approach to assess the importance of total nitrogen and total phosphorus sources into the inland surface waters in the German catchment to the Baltic Sea in 2017.



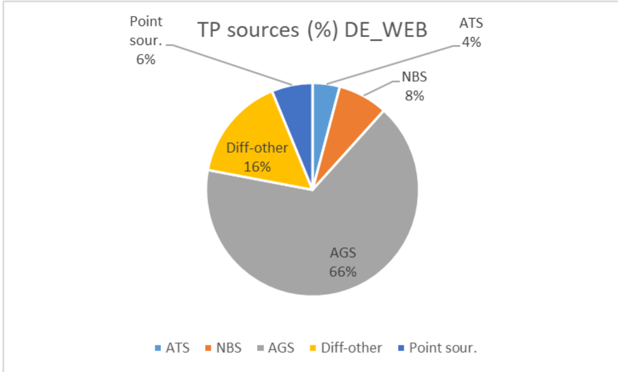


Figure 9.1 Examples on the importance of different total nitrogen (TN) (left) and total phosphorus (TP) (right) *sources to inland surface waters* in the German catchment to Baltic Proper (for TN) and to Western Baltic (TP) in 2017. Total nitrogen amounts to 7,329 tons and total phosphorus to 247 tons. AGS = agricultural sources; ATS = atmospheric sources; NBS = natural background sources; diff-other = sum of other diffuse sources (scattered dwellings and storm waters) Point sour. = sum of point sources (wastewater treatment plants and industry).

9.2. Load-oriented approach: Quantification on sources of waterborne inputs to the sea

According to the **HELCOM Recommendation 37-38/1** "Waterborne pollution input assessment (PLC-WATER)" the sources of waterborne inputs to the sea (riverine load apportionment) should be quantified for the periodic pollution input compilations. It should be done for the monitored rivers and reported individually per monitored river. For unmonitored areas, riverine load apportionment figures should be reported per Contracting Party for each Baltic Sea sub-basin.

Point and diffuse sources behave differently in relation to meteorological/hydrological factors: Discharges from point sources are normally comparatively constant during the whole year, while losses from diffuse sources vary strongly with the meteorological and/or hydrological conditions. Thus, in order to reduce temporal variability of diffuse sources it may be suitable to base the source apportionment on flow normalized data. In addition, quantification of natural background losses to inland surface waters is necessary for calculating the total nutrient loading entering the inland surface waters (see Chapter 6.1).

Part of the loading entering the inland surface waters is retained in lakes, rivers and flooded riparian zones before it is discharged into the Baltic Sea (surface water retention). Thus, to divide the riverine net export into its sources, the retention processes must be taken into account (see Chapter 9.3 for more information on retention).

It is preferable to quantify and report each source separately (e.g. wastewater treatment plants, industry, aquaculture, natural background losses, atmospheric deposition, agriculture, scattered dwellings, storm waters etc.). As a minimum the following sources categories must be reported: point sources, anthropogenic diffuse sources and natural background sources. The possible sources categories are in the Annex 2.

Figure 9.2 provides two examples of applying load-oriented approach to assess the importance of Swedish total nitrogen and total phosphorus waterborne input sources to the Baltic Sea in 2017.

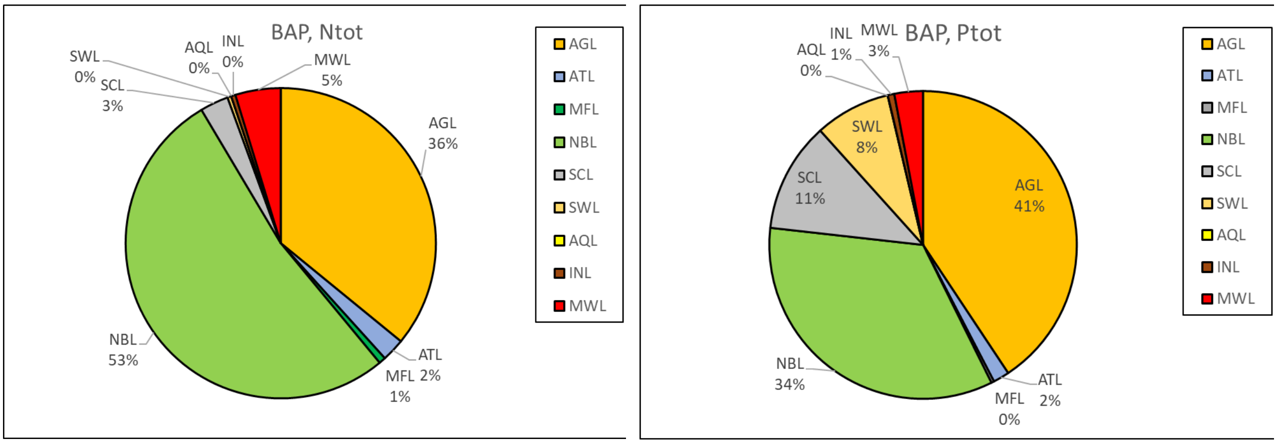


Figure 9.2 Examples on the importance of different Swedish total nitrogen (TN) (left) and total phosphorus (TP) (right) *sources in the waterborne inputs* to Baltic Proper in 2017 (load-oriented approach). Total nitrogen amounts to 22,110 tons and total phosphorus to 451 tons. AGL = agricultural load; ATL = atmospheric load; MFL = Managed forest load; NBL = natural background load; SCL = scattered dwelling load, SWL = storm waters load; AQL = aquacultural load; INL_ industrial load, MWL = municipal wastewater treatment plant load.

9.2.1. Calculation principles for riverine load apportionment

The recommended procedure for large river catchments is to first divide the catchment into sub-catchments, and then estimate the nutrient input and calculate retention using a mass balance approach or by using a numerical model tool in each sub-catchment. In this way both the total retention and the retention of individual nutrient sources in inland surface waters at the river outlet can be achieved. A simpler approach may be used for smaller river catchments and unmonitored areas. Methodologies to calculate retention are described in Chapter 9.3.

As a minimum the riverine source apportionment should cover the following three source categories: point sources, losses from anthropogenic diffuse sources and natural background sources. If possible, it is recommended to divide these main sources into further categories in accordance with the sources listed in Chapters 5 and 6. The possible sources categories are in the Annex 3.

If models for quantifying net inputs entering the Baltic Sea sub-basin from each source are not available, a simplified approach can be used. This starts out by expressing the riverine load apportionment (L_{river}) in the following equation:

$$L_{river} = D_P + LO_D + LO_B - R_p - R_d - R_B \qquad (9.1)$$

where:

D_p = discharges from point sources ($t\ a^{-1}$);

LO_D = losses from anthropogenic diffuse sources ($t\ a^{-1}$);

LO_B = natural background losses ($t\ a^{-1}$);

R_p = retention for point sources ($t\ a^{-1}$);

R_D = retention for diffuse sources ($t\ a^{-1}$), and

R_B = retention for background load ($t\ a^{-1}$).

Also an aggregated value for total retention might be used. See Chapter 9.3 for a description on how to calculate retention.

The following equation can then be used for calculating nitrogen and phosphorus losses from diffuse sources (**LO_D**):

$$LO_D = L_{river} – D_P - LO_B + R_p + R_d + R_b\,. \qquad (9.2)$$

In equations 9.1 and 9.2 flow normalized data can be used to reduce temporal variability of diffuse sources.

9.3. Retention

9.3.1 Introduction

Retention of nitrogen and phosphorus in *inland surface waters* (lakes, rivers including flooded riparian zones) is a process removing nitrate through denitrification or storing nitrogen and phosphorus for shorter or longer time periods in sediments and vegetation thus reducing or delaying the nutrient transport in river basins. In some cases, retention is negative due to the release of nutrients from lake and river sediments. In general, phosphorus retention is influenced by sedimentation and other physical and chemical processes, while nitrogen retention to a large extent is influenced by biological processes.

Quantification or estimation of retention in inland surface waters is a prerequisite to enable quantification of sources of nutrients to marine areas from different parts of river basins. A geographically detailed estimate of retention will make a reliable source apportionment of the inputs to the sea possible, which in turn will enable efficient water protection measures. Ideally, if individual evaluation of all different measures and sources are expected, retention should be estimated separately for all categories of nutrient sources in a river system, also taking into account the distance to the coast.

If the loads from agriculture are expressed as losses from the root zone, the retention estimates will also include soil retention, i.e. removal processes that occur in soil and groundwater. These guidelines only deal with retention of phosphorus and nitrogen in *inland surface waters*, which is also the reporting obligation for the annual PLC reporting.

9.3.2. Quantification

The total retention in the river catchment (R) is the sum of retention for each source category, expressed as:

$$R = R_p + R_D + R_B \qquad \textit{(9.3)}$$

where:

R_p = retention for point sources ($t\ a^{-1}$);

R_D = retention for diffuse sources ($t\ a^{-1}$);

R_B = retention for background load ($t\ a^{-1}$).

It is generally difficult to distinguish retention from the different sources in equation 9.3. The calculation can be simplified if it is assumed that retention is proportional to the total load of each source and that the retained fraction is the same for all sources. Then only the total retention is needed. Further, the procedure outlined above requires measurements at one or several monitoring sites of the selected river in order to determine riverine load (actual or normalized riverine load). It also requires data on nitrogen and phosphorus point source discharges and natural background losses in the river catchment area. If there is a significant degree of uncertainty in the retention estimate, more than one retention methodology or a sensitivity analysis should be applied to get a range for the quantification of diffuse sources entering inland surface waters.

The following main quantification approaches can be used:

A. Mass balance approach
B. Modelling approach

A. Mass balance approach

This approach is based on monitoring data from inland waters, used to calculate mass balances for selected parts of the river system. The method can be applied to:

- the whole river catchment
- lakes (by using results on lakes retention from a part of the catchment for lakes in the remaining part and the scale for the whole catchment by area proportion)
- sub-catchments covering the whole catchment

Basically, the methodology is the same irrespective of the size of the calculation unit. The retention is calculated as the difference between the input and output of the considered water body, preferably on an annual basis, according to the equation:

$$(Ia + lb + Ic + In) - U = R \qquad (9.4)$$

where:

Ia to In are input sources;

U = Output; and

R = retention.

Estimates of diffuse inputs based on a longer period (more than one year) will result in a retention estimate for the corresponding period.

Estimation with equation 9.4 can be simplified by ignoring small input sources. Another simplification can be made by analyzing only a few sub-catchments representing different parts of the river system and transferring the results to the whole river. If possible, retention in big lakes should always be assessed separately.

The simplest way of calculating total retention in a catchment is to make a mass balance for the whole river system and calculate retention as the difference between the sum of all inputs at source (gross load) from the load calculated at the river mouth station (net load). A major problem with this approach is that it only provides an average retention figure for the whole river system. Retention may differ between sources positioned in different parts of the catchment, and thus the source apportionment at the coast will not be precise. For small rivers this difference may be less important. When applying the mass balance approach to larger river catchments the calculations become more complicated and the use of numerical models may be necessary.

B. Modelling approach

A modelling approach is often applied when retention is calculated in a river system for the whole catchment or for sub-catchments. The retention is calculated with empirical or dynamical models covering from mass balance models to algorithms describing the relationship between retention and river characteristics. The selected model should preferably be able to calculate retention of individual sub-catchments as well as for the whole river system.

There are several, both freely available and commercial, models that can be used to calculate retention. They all need input data on point and diffuse nutrient sources as well as river and lake characteristics. Some available models are described in the Table 6.3. They have variable applicability depending on e.g. the scale and climatological conditions of the study catchment. In the EUROHARP project several models compiling retention have been compared regarding their retention estimates and the results are published in Hejzlar et al. (2009).

For the PLC-7 assessment Table 9.1 summarizes retention methodologies used by the countries. More information about the applied methodologies is the PLC-7 methodology report (Svendsen (ed.) al. in press).

Table 9.1. Summary of the applied inland surface waters retention methodology by countries in the PLC-7 source apportionment assessment. More information in Svendsen (ed.), in press.

Country	Method applied
Denmark	Calculated for all large lakes individually with a national model. Retention estimates for nearly 6,000 small ponds and lakes based on results from 16 monitored lakes), for streams wider than 2 m and for restored wetlands
Estonia	Retention in surface waters is calculated using Michaelis-Menten equation approach (Michaelis & Menten, 1913).
Finland	National statistical modelling with mass balance approach using incoming and outflowing load in a sub-catchment, and load from point sources, agriculture, forestry, scattered dwellings, natural leaching and atmospheric deposition of N on lakes. Retention assumed negligible in unmonitored areas.
Germany	The MoRE model provides riverine retention based on the MONERIS retention coefficients for TN and TP (Behrendt & Opitz, 1999)
Latvia	Following Behrendt & Opitz (1999) with retention coefficient for TN and TP depending on discharge, areas on surface waters in the catchment
Lithuania	Using SWAT model including processes in river channels as sedimentation, resuspension, turn-over of nutrients, diffusion etc.
Poland	Retention coefficients in monitored rivers calculated based on the mass-balance methodology.
Russia	Follows principles in Behrendt & Opitz (1999) method – see more in Svendsen (ed.) in press
Sweden	Using SMED-HYPE model in the 39,600 sub-catchments. Takes into account river and lake nutrient processes. SMED-HYPE is built upon HYPE model – but using the land use leaching and local river retention.

9.3.3 Available retention data

Several studies have been made in different Baltic Sea countries to estimate nutrient retention. One example is the RECOCA project (2009-2012) in which total and inland surface water nutrient retention of the major river catchments around the Baltic Sea were calculated. Total retention, including both soil and water retention, were estimated using a regional mass balance model (Hong et al. 2012). The results show quite high retention values for the largest catchments of the Baltic Sea (50-86% for total nitrogen and 85 to nearly 100% for phosphorus). Nutrient retention in inland surface waters was also calculated for all major river catchments around the Baltic Sea using the MESAW model (Stålnacke et al. 2003).

Retention estimates of transboundary inputs should only contain retention in inland surface waters. Inputs and retention coefficients of transboundary inputs were compiled during the revision of MAI and NICs for the BSAP (see the Tables 8.3 and 9.2).

Table 9.2. Nitrogen and phosphorus inland surface water retention coefficients (%) in Baltic Sea drainage areas. Nitrogen retention is from Stålnacke et al. (2015) and phosphorus retention from Stålnacke et al. (2011).

	Retention coefficient			
	Nitrogen			Phosphorus
River basin	**Total surface water**	**Lake**	**In-stream**	**Total surface water**
Alterälven	0.15	0.134	0.014	0.29
Aurajoki	0.02	0,000	0.019	0.34
Botorpströmmen	0.54	0.526	0.021	0.53
Dalälven	0.41	0.343	0.102	0.24
Daugava	0.38	0.255	0.164	0.43
Delångersån	0.54	0.522	0.029	0.43
Emån	0.44	0.417	0.043	0.52
Eurajoki	0.6	0.594	0.024	0.53
Forsmarksån	0.26	0.25	0.012	0.42
Gauja	0.13	0.079	0.06	0.45
Gavleån	0.45	0.435	0.032	0.47
Gideälven	0.29	0.26	0.038	0.37
Göta älv	0.72	0.673	0.132	0.28
Helge å	0.38	0.354	0.044	0.42
Iijoki	0.4	0.348	0.074	0.26
Iilolanjoki	0.21	0.202	0.012	0.00
Indalsälven	0.48	0.427	0.098	0.14
Isojoki	0.05	0.032	0.022	0.32
Kalajoki	0.28	0.249	0.043	0.42
Kalix älv	0.23	0.159	0.082	0.14
Karvianjoki	0.3	0.267	0.038	0.39
Kasari	0.04	0.008	0.037	0.48
Kelia	0.03	0.009	0.018	0.34
Kemijoki	0.37	0.272	0.134	0.29
Kiiminkijoki	0.26	0.224	0.04	0.36
Kiskonjoki	0.36	0.349	0.02	0.32
Kokemäenjoki	0.54	0.493	0.1	0.39
Koskenkylänjoki	0.32	0.302	0.02	0.43
Kuivajoki	0.22	0.203	0.024	0.29
Kymijoki	0.7	0.657	0.114	0.41
Kyrönjoki	0.14	0.098	0.045	0.45
Lagan	0.54	0.515	0.052	0.35
Laihianjoki	0.04	0.019	0.018	0.61
Lapuanjoki	0.23	0.192	0.041	0.48
Lestijoki	0.06	0.037	0.021	0.35
Lielupe	0.15	0.073	0.082	0.60
Ljungan	0.42	0.374	0.07	0.30
Ljungbyån	0.11	0.087	0.021	0.80
Ljusnan	0.35	0.291	0.087	0.27
Lögdeälven	0.2	0.179	0.025	0.29

Luleälv	0.51	0.459	0.095	0.11
Lyckebyån	0.34	0.323	0.019	0.42
Mörrumsån	0.63	0.616	0.038	0.43
Motala ström	0.73	0.708	0.074	0.47
Mustijoki	0.13	0.117	0.018	0.37
Närpiönjoki	0.07	0.049	0.021	0.43
Narva	0.56	0.49	0.14	0.48
Neman	0.3	0.158	0.172	0.48
Neva	0.74	0.652	0.262	0.42
Nissan	0.42	0.399	0.036	0.29
Norrström	0.6	0.564	0.093	0.46
Nyköpingsån	0.62	0.603	0.043	0.64
Odra	0.3	0.138	0.188	0.64
Öreälven	0.15	0.123	0.036	0.32
Oulojki	0.59	0.545	0.095	0.30
Paimionjoki	0.14	0.125	0.022	0.45
Pärnu	0.06	0.013	0.052	0.51
Perhonjoki	0.23	0.208	0.033	0.45
Pite älv	0.39	0.35	0.066	0.16
Porvoonjoki	0.13	0.108	0.024	0.43
Pregolia	0.25	0.195	0.072	0.58
Pyhäjoki	0.38	0.359	0.039	0.46
Råneälven	0.2	0.164	0.042	0.37
Rickleån	0.44	0.422	0.027	0.38
Rönneå	0.31	0.291	0.029	0.47
Salaca	0.19	0.16	0.038	0.39
Siikajoki	0.19	0.157	0.041	0.41
Simojoki	0.38	0.355	0.036	0.26
Sirppujoki	0.1	0.087	0.014	No estimate
Skellefteälv	0.57	0.536	0.068	0.19
Töreälven	0.25	0.244	0.015	0.36
Torne älv	0.37	0.29	0.119	0.30
Ume älv	0.43	0.363	0.099	0.15
Uskelanjoki	0.07	0.048	0.02	0.55
Vantaanjoki	0.26	0.242	0.028	0.46
Venta	0.16	0.1	0.068	0.48
Vironjoki	0.18	0.167	0.013	0.25
Viskan	0.44	0.42	0.03	0.19
Vistula	0.32	0.12	0.229	0.55
Ångermanälven	0.48	0.413	0.107	0.16
Ähtävänjoki	0.4	0.378	0.042	0.78
Ätran	0.43	0.408	0.037	0.27
Coast DE & Arkona Basin	0.07	0.036	0.032	0.83
Coast DE & Bornholm Basin	0.23	0.174	0.065	0.48
Coast DE & Fehmarn Belt	0.29	0.237	0.065	0.69

Coast DK & Arkona Basin	0.04	0.018	0.026	0.08
Coast DK & Bornholm Basin	0.02	0,000	0.016	0.22
Coast DK & Central Kattegat	0.14	0.071	0.07	0.22
Coast DK & Fehmarn Belt	0.22	0.195	0.035	0.74
Coast DK & Northern Kattegat	0.21	0.195	0.017	0.88
Coast DK & Samsø Belt	0.07	0.007	0.061	0.72
Coast DK & Southern Kattegat	0.04	0,000	0.036	0.84
Coast DK & The Sound	0.81	0.806	0.014	0.14
Coast EE & Baltic Proper	0.13	0.094	0.043	0.56
Coast EE & Gulf of Finland	0.08	0.031	0.049	0.36
Coast EE & Gulf of Riga	0.11	0.068	0.047	0.31
Coast FI & Baltic Proper	0.19	0.153	0.039	0.59
Coast FI & Bothnian Bay	0.2	0.149	0.063	0.34
Coast FI & Bothnian Sea	0.28	0.223	0.068	0.29
Coast FI & Gulf of Finland	0.23	0.193	0.047	0.38
Coast LT & Baltic Proper	0.07	0.046	0.026	0.21
Coast LV & Baltic Proper	0.16	0.118	0.047	0.40
Coast LV & Gulf of Riga	0.22	0.178	0.05	0.62
Coast North of Northern Kattegat	0.84	0.838	0.014	No estimate
Coast PL & Baltic Proper	0.26	0.213	0.065	0.26
Coast PL & Bornholm Basin	0.08	0.008	0.075	0.45
Coast RU & Baltic Proper	0.44	0.413	0.048	No estimate
Coast RU & Gulf of Finland	0.11	0.016	0.094	0.62
Coast SE & Arkona Basin	0.04	0.018	0.024	No estimate
Coast SE & Baltic Proper	0.23	0.156	0.087	0.36
Coast SE & Bornholm Basin	0.58	0.564	0.048	No estimate
Coast SE & Bothnian Bay	0.39	0.333	0.085	0.31
Coast SE & Bothnian Sea	0.37	0.313	0.089	0.40
Coast SE & Central Kattegat	0.06	0.029	0.028	0.06
Coast SE & Northern Kattegat	0.31	0.301	0.018	No estimate
Coast SE & Southern Kattegat	0.32	0.295	0.031	0.53
Coast SE & The Sound	0.09	0.063	0.033	0.40

10. Data validation and assessment methodologies for Maximum Allowable Inputs and the Nutrient Input Ceilings

10.1. Introduction

The aim of this chapter is to describe assessment methodologies including statistical methods when validating the PLC data and elaborating PLC assessments including evaluation of progress towards fulfilling MAI and NIC. Sub-chapters 10.2.–10.4. are expected to be carried out by the Contracting Parties whereas sub-chapters 10.5–10.8. will be carried out when assessing the results. This chapter includes one sub-chapter on accounting for extra reduction evaluating progress towards MAI and NIC.

The chapter includes equations for the required mathematical calculations applied in the statistical methods when elaborating pollution input (PLC) assessments, with focus on waterborne inputs. The described methods include flow normalization of nutrient loads, testing for trends and changes in inputs, filling in data gaps, estimation of the uncertainty of datasets, how to make assessment evaluating on progress towards fulfilment of MAI and NIC, and how to take into account extra reduction in one sub-basin in a neighboring basin.

Note that some of the methods are presented as guidance for elaboration of PLC assessments and that normalization, trends analysis and statistical tests on fulfilment of MAI and NIC will be performed in a uniform way within the HELCOM PLC data processing framework (Contracting Parties will not be required to make these calculations).

Some examples are included in sub-chapters 10.4. –10.8.

The chapter is based on the statistical methodology reports by Larsen & Svendsen (2013, 2019 and 2021) elaborated as products under former PLC projects and the current PLC-8 project. The report by Larsen & Svendsen (2021) includes examples of programming in software "R" and "SAS" to facilitate countries to make their own assessment with many of the methodology described in Chapter 10.

10.2. Data gaps

Before forwarding data to the HELCOM PLC Data Manager, Contracting Parties should check for data gaps and can make use of the proposed method in this sub-chapter. Further, the methods are used for PLC-assessments.

Several methods can be applied to fill in data gaps. Depending on the type of gap the following methods can be applied to fill in the gap:

- Mean value of a statistical distribution. The distribution is determined either by including all relevant data on the given catchment or from a shorter time series, for instance when estimating missing data from point sources in the beginning or end of a time series.
- Mean of adjacent values. Supposing that x_a and x_c are two time series values with the value x_b missing, then

$$x_b = \frac{x_a + x_c}{2} \tag{10.1}$$

- Linear interpolation. If x_a and x_b are perceived as two adjacent values to n missing values, then the k^{th} missing value (from x_a) can be estimated as

$$x_k = x_a + k \cdot \frac{x_b - x_a}{n+1} \tag{10.2}$$

- If runoff (q) is known and a good relationship can be established between the input by a certain variable and runoff, this relationship can be used to estimate missing values.

- A q-q relationship can be used to estimate missing runoff values; a good q-q relationship can often be established for a similar nearby river.
- A load-load relationship for another river for which high correlation can be verified.
- Model estimations of unmonitored catchment inputs, if possible – otherwise, inputs can be estimated from data from neighboring catchments with similar conditions.
- Assignment of a real value in the interval between zero and the LOQ (Limit of Quantification) to observations below a LOQ according to the description in Chapter 11.7 on how to handle concentrations under LOQ when calculating loads.

Most methods for trend analysis, like the non-parametric Mann-Kendall's trend method and linear regression, can handle missing values, preferably in the middle and not at the end of the time series (e.g. either the first 2 or the last 2 years). The trend test will only be negligibly affected with few missing values. The statistical power of the trend tests decrease if the time series includes gaps, as it is more difficult to prove a real significant trend at reduced statistical power. If many missing values have been estimated and the inserted values are identical for many years, a trend test should not be performed, as variation will be much smaller than when the data are based on real observations.

Above, several methods for filling in gaps are presented. The question is which method is the best to use. Usually, this will be decided by the given situation, but the following rank is suggested:

1. Model approach – i.e., a regression type model for estimating load or flow;
2. Linear interpolation including average of adjacent observations;
3. Values from a look-up table or values provided by experts;
4. No filling in of data gaps. Use the available time series as it is and assessments are made afterwards.

10.3. Outliers

Contracting Parties should check their data for outliers before it is submitted to the PLC Data Manager. Before HELCOM PLC assessments, reported data are checked for outliers.

Outliers are extreme data values compared to other reported values for the same locality (country, sub-catchment, sub-basin etc.), and can only be determined and flagged by conducting a formal outlier test using for instance:

- Dixon's 4 sigma (σ) test: Outliers are the values outside the interval consisting of the mean ±4 times the standard deviation;
- A box and whisker diagram (as Figure 10.1);
- Experience-based definition of maximum and minimum values that is not likely to be exceeded or fallen below;
- Water quality standards (interval values or limits), if available.

It is important to note that outliers are not necessarily faulty data. They could be extreme observations requiring an extra careful evaluation prior to use in statistical analyses and other assessments.

Suspect or dubious values are values that do not fulfil the requirement of being determined as a formal outlier by the outlier tests. They differ significantly from the remaining values in the time series or are unreliable values as for instance, a load value for the reported runoff or data from a neighboring catchment. Suspect or dubious values may occur if measurements in a sub-catchment have been made for only a limited period, if changes in laboratory or laboratory standards have occurred, or if changes have been made in other measurement methods, resulting in an abrupt change in data values. Another example is if the same value occurs for a number of successive years. In addition, calculation mistakes may occur due to use of wrong units, faulty water samples, laboratory mistakes, etc. Suspect or dubious values should be corrected and treated as a formal outlier unless they can be proven correct.

If a dubious value is determined, deemed to be wrong and omitted from assessments, and if it is not possible for the Contracting Party to correct the value, it should be removed from the PLC database by the Contracting Party. If a reported data value is determined to be an outlier and deemed to be omitted from assessments, the outlier can be replaced in the assessment using a method from the list on data gaps. Usually, filling in data gaps or replacing suspect data cannot substitute measured data; thus, if possible, preferably measured or consistent model data should be found and used. It should be stressed that filled-in data gaps must be clearly marked in the PLC database.

An example of the Dixon outlier test: consider the TP loads from the Pregolya River (Russia). Figure 10.1 shows a box and whisker plot of the TP loads during the period 1995-2018. The figure shows one outlier at a value of 880 for TP. The Dixon test using the software “R” shows that the value in 2017 (880 tons TP) is determined as an outlier in the series of yearly TP load values (with a significance value of P=0.007). The series of TN loads during the same period in the Pregolya River has no outliers.

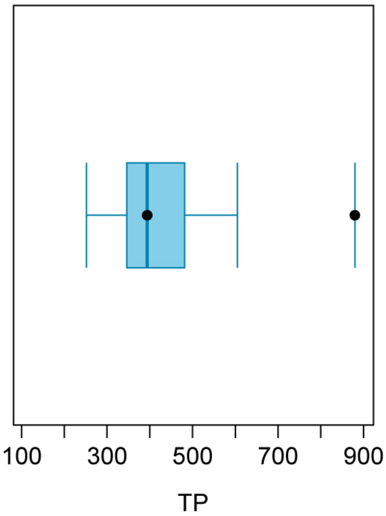


Figure 10.1 Box and whisker plot of the series of annual TP riverine loads (tons) in the Pregolya River during 1995-2018, where Dixon outlier test identify one with one significant outlier (value 880 tons P).

10.4. Uncertainty of inputs (yearly input from a specific country or area)

The uncertainty of annual input data is very important information when assessing data. Contracting Parties are expected to report as a minimum the total uncertainty on their total inputs by sub-catchment level for annual data (Chapter 12.6) and periodical data (Chapter 13.3). Further the total uncertainty will be estimated when assessing progress towards fulfilment of MAI and NIC (the nutrient reduction scheme in the 2021 BSAP).

Total uncertainty (bias plus variation) is an extremely complex sum (based on certain assumptions) of several different uncertainty components:

- Uncertainty due to field sampling (uncertainty from field sampling/measurements of concentrations of nutrients, metals and other substances, uncertainty from measurements of water velocity and stage, etc.);
- Laboratory uncertainty (from the applied analysis method in the laboratory or from changing laboratories over time);

- Uncertainty deriving from the sampling set-up (how often, where, when, sampling location, time) and the methods for calculating runoff (either stage-discharge relationship or other methods) and load (based on combined concentrations and runoff);
- Variation introduced by year-to-year differences in climate (amount, type, and distribution of rainfall and changes in accumulated pools (snow/ice, soil and groundwater));
- Uncertainty from estimation of unmeasured inputs (bias from omitting unmeasured inputs and uncertainty of the methods applied for estimating unmonitored inputs);
- Uncertainty of inputs from direct point sources, including sampling, analytical errors, etc.;
- And probably, several other components contributing to uncertainty.

This requires a standardized methodology for estimating the uncertainties in the national datasets from measured areas as described below. The calculation of the total uncertainty is done using the statistical principle “Propagation of errors”. This principle can be explained as:

Let *X* be the sum of *n* stochastically independent measured inputs X_i

$$X = \sum_{i=1}^{n} X_i. \qquad (10.3)$$

The variance of *X* can be calculated as:

$$\sigma_X^2 = Var(X) = \sum_{i=1}^{n} \sigma_{X_i}^2. \qquad (10.4)$$

The standard deviation is then calculated as:

$$\sigma_X = \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \qquad (10.5)$$

And the relative standard deviation (denoted as the *precision*) is calculated as

$$100 \cdot \frac{\sigma_X}{X} = \frac{100}{\sum_{i=1}^{n} X_i} \sqrt{\sum_{i=1}^{n} \sigma_{X_i}^2}. \qquad (10.6)$$

The calculation of the total inputs from the monitored areas constitutes of measurements from *n* stations in streams, as defined in (10.3). The relative bias and relative precision of the sum of X_i can then be calculated as

$$bias\ (\%) = \frac{100}{\sum_{i=1}^{n} X_i} \sum_{i=1}^{n} bias_i \cdot X_i, \qquad (10.7)$$

$$precision\ (\%) = \frac{100}{\sum_{i=1}^{n} X_i} \sqrt{\sum_{i=1}^{n} (precision_i \cdot X_i)^2}. \qquad (10.8)$$

Here $bias_i$ and $precision_i$ are the individual biases and precisions (given in decimal notation) for each river indexed by *i*. Bias is the consistent under- or overestimation of the true value of the mean. Precision is a measure of the size of the closeness of the individual measurement values. The total uncertainty can then be calculated as:

$$uncertainty\ (\%) = \frac{100}{\sum_{i=1}^{n} X_i} \sqrt{\sum_{i=1}^{n} (bias_i \cdot X_i)^2 + (precision_i \cdot X_i)^2}. \qquad (10.9)$$

The total uncertainty is the measure of the closeness of the measurements to the true value (bias plus precision). Theoretically, the total uncertainty is the Root Mean Squared Error (*RMSE*) as defined by the equation:

$$RMSE(\hat{L}) = (\sigma^2 + \beta^2)^2, \qquad (10.10)$$

where

$$\sigma^2 = E_X\left(\hat{X} - E_X(\hat{X})\right)^2 \text{ = the variance (precision)}$$

and

$$\beta = E_X(\hat{X}) - L \text{ = the bias.}$$

The symbol E_X means the theoretical mean value with respect to the stochastic variable *X*, and $\hat{X}$ is the estimate of *X*. This implies that the uncertainty (%) in (10.9) is the RMSE (%).

Below an example using formulas (10.7, bias), (10.8, precision) and (10.9, uncertainty) for calculating the bias, precision and uncertainty of the sum of X_1, X_2 and X_3:

	Load	Bias	Precision
X_1	10	-5%	5%
X_2	15	-5%	8%
X_3	20	-5%	10%

Bias (%) = $100/45 \cdot \sqrt{(-0.05 \cdot 10 - 0.05 \cdot 15 - 0.05 \cdot 20)} = -5\%$

Precision (%) = $100/45 \cdot \sqrt{((0.05 \cdot 10)^2 + (0.08 \cdot 15)^2 + (0.1 \cdot 20)^2))} = 100/45 \cdot \sqrt{(0.25 + 1.44 + 4)} = 5.3\%$

Uncertainty (%) = $100/45 \cdot \sqrt{(0.25 + 0.5625 + 1 + 0.25 + 1.44 + 4)} = 6.1\%$

One standardized methodology for estimating uncertainty of data from monitored rivers is DUET-H/WQ that was developed for monitored rivers and is described in a paper by Harmel et al. (2009). The method is based on RMSE (root mean square error) propagation method explained above and gives a fair approximation of the true value, which often is very complicated to derive.

In DUET-H/WQ the uncertainty of individual measurements is estimated by the equation:

$$EP = \sqrt{E_Q^2 + E_C^2 + E_{PS}^2 + E_A^2 + E_{DPM}^2}, \qquad (10.11)$$

where according to Harmel et al. (2009):

E_Q = Uncertainty of the discharge measurement (%);

E_C = Uncertainty of sample collection (%);

E_{PS} = Uncertainty of sample preservation/storage (%);

E_A = Uncertainty arising from laboratory analysis (%);

E_{DPM} = Uncertainty arising from data processing and data management (%), i.e. input calculation or model uncertainty (see Silgram and Schoumans (ed., 2004)).

Then, the total uncertainty of the aggregated data can be estimated by:

$$EP_{total} = \frac{100}{\sum_{i=1}^{n} x_i} \sqrt{\sum_{i=1}^{n} \left(x_i \cdot \frac{EP_i}{100} \right)^2} \quad (10.12)$$

where:

EP_{total} is given as %;

EP_{total} is the uncertainty of the sum $x = \sum_{i=1}^{n} x_i$;

x_i is the monthly load from a catchment or country.

The Contracting Parties will need to gather information on the different uncertainties, either from empirical data or from national or international papers and reports based on the same kind of data, i.e. riverine measurements based on more or less similar methods.

Furthermore, uncertainties regarding input estimates from unmonitored areas need to be described to estimate the total uncertainty for the whole catchment area. Uncertainty on direct inputs can be estimated using the same formula as above.

The uncertainties for many of the components listed above are not quantified or estimated, but the uncertainty on individual water flow quantifications is well known and should in most cases be lower than ± 5% (Herschy 2009 and WMO 2008). The precision on daily water flow depends on the number of discharge observations, and is estimated for open gauging stations in streams channels in Denmark to be from 8% (given as standard deviation) with 10 annual discharge observations (measurements of discharge), about 6% with 12 measurements to less than 1% with more than 40 annual measurements (Kronvang et al. 2014). For modelled water flow, the uncertainty might be higher. For chemical analysis the requirement in Denmark is that the total (expanded) uncertainty for total nitrogen and total phosphorus is less than 15% (or 0.1 mg N l^{-1} and 0.01 mg P l^{-1} at low concentration values in freshwater, respectively 5 mg N l^{-1} and 1 mg P l^{-1} at low concentration values in wastewater.

The method by Harmel et al. (2009) is illustrated by two examples: 1) total uncertainty for a river with high measurement precision and 2) total uncertainty for a river with low measurement precision – see table 3.1. High measurement precision stands for a low value of formula (3.6) and vice versa.

Table 10.1. Illustration of the method by Harmel et al. (2009) with 2 examples of variance components in formula (10.11). Example 1 with low total uncertainty (river with high measurement precision) and example 2 with high uncertainty (river with low measurement precision).

Variance components	Example 1	Example 2
E_Q	5%	50%
E_C	5%	100%
E_{PS}	5%	30%
E_A	5%	25%
E_{DPM}	5%	50%

In Example 1 (table 10.1) *EP* is 11% and in Example 2 *EP* is 129% when using formula 10.11. Total uncertainty of assuming a constant monthly input of 2500 tons (x_i) is 3% for Example 1 and 36% for Example 2. Total uncertainties were calculated using formula 10.12.

Another method of calculating the total uncertainty is illustrated using Danish data for total nitrogen (TN) and total phosphorus (TP) inputs to the marine areas around Denmark. The total input to the Danish marine environment is a sum of two components. One component is from the monitored catchment area and the other is from the unmonitored area. The inputs from the unmeasured area are estimated by using a model.

A Monte Carlo study (Kronvang & Bruhn, 1996) based on daily samples has shown that for Danish streams categorized by their catchment area, the following values for bias and precision are valid for TN load calculated using the linear interpolation method:

0-50 km^2:	Bias: -1% to -3%;	Precision: 1-3%
50-200 km^2:	Bias: -0.7% to -3%;	Precision: 1-3%
>200 km^2:	Bias: -1% to -4%;	Precision: 2-5%

These numbers are valid for the yearly load from one stream station and include the uncertainty of laboratory analysis, yearly variation of concentrations and stream discharge and uncertainty from the method for calculating yearly load (by linear interpolation). The uncertainty from the measurement of the concentration in the stream (placement of bottle horizontal and vertical in the stream) is not included and therefore 2% is added to the precision in the 3 categories.

Using the formulae (10.7-10.9), it can be calculated that, for the monitored area (210 stations) the total bias is -1% to -3%, the total precision is 0.7% to 1.2% and the total uncertainty is 0.7% to 1.3%. For an average stream monitoring station, the bias is -1% to -3%, the precision is 3% to 5% and the uncertainty is 3.2% to 5.8%.

Unmonitored areas

The TN input from the unmonitored area is based on model estimates for 1286 very small catchments covering the rest of the Danish area (approx. 39%). The annual load from each small catchment is calculated using the formula:

$$L = Ndiffuse_{model} + R_{lake} + R_{stream} + N_{waste} - R_{total}, \qquad (10.13)$$

where

$Ndiffuse_{model}$ = Estimated nitrogen inputs from the model;

R_{lake} = Estimated nitrogen retention in lakes;

R_{stream} = Estimated nitrogen retention in streams;

N_{waste} = Nitrogen load from wastewater;

R_{total} = Total nitrogen retention.

Table 10.2. Bias and precision for the components in formula 10.13. Based on both numerical calculations, the study by Kronvang & Bruhn (1996) and estimates.

Components	Bias (%)	Precision (%)
Model	-15 to 20	12 to 15
Retention lake	-5 to 5	40
Retention stream	-5 to 10	40
Retention total	-5	40
Point source: industry	-1 to -3	1to 10
Point source: wastewater	-1 to -3	1 to 10
Point source: fish farms	-1 to -3	1 to 20
Point source: rain water	-5	40

Using the formulae (10.7) to (10.9) and the bias and precision indicated in Table 10.2 the total bias for the unmonitored area is calculated to be 20% to 28%, the total precision is 0.8% to 2.0% and the total uncertainty is 1.2% to 2.2%. For an average small unmonitored catchment, the bias is 27%, precision 15% to 20% and the uncertainty 31% to 34%.

For the total Danish catchment area, combining the calculated bias, precision and uncertainty for both the monitored and unmonitored areas and using special versions of formulae (10.9) to (10.11), result in a total bias of 7.4% to 12.8%, a total precision of 0.5% to 1.1% and a total uncertainty of 7.4% to 12.8% on total nitrogen inputs.

With respect to total phosphorus (TP), calculations show that for the measured area the bias is -6 to -3%, the precision is 1 – 2% and the uncertainty is then 1 – 2.5%. For the unmeasured area the bias is between -5 and 30%, the precision is 1 – 3% and the uncertainty is 1 – 4%. These calculations are based on the following values of bias and precision from Kronvang and Bruhn (1996) for TP load (using linear interpolation method):

0-50 km2:	Bias: -16% to -27%;	Precision: 18-37%
50-200 km2:	Bias: -2% to -5%;	Precision: 9-13%
>200 km2:	Bias: -2% to -4%;	Precision: 3-8%

The Danish methodology is one recommended method for estimating uncertainty.

If the Contracting Parties don't have the information as used in the Danish methodology some standard values are elaborated in Tables 10.3 to 10.6. They are compiled for the two different methods calculating annual riverine load used by HELCOM countries:

- Linear interpolation (formula 4.1)
- Monthly mean method (formula 4.2)

In the Tables 10.3–10.6 below, values for bias and precision are given for the two load calculation methods for different catchment sizes, number of yearly samples, and catchment dominated by bedrock or dominated by soils for annual load of TN and TP, respectively.

Table 10.3. Bias and precision for yearly load based on the linear interpolation calculation method. TN (black) – TP (red). Catchment dominated by soils.

Catchment size (km^2)	Number of samples	Bias (%)	Precision (%)
0 – 50	<18	-1 → -3	2 → 5
		-17 → -25	25 → 45
0 – 50	>18	0 → -2	1 → 3
		-15 → -20	20 → 40
50 – 200	<18	-1 → -3	2 → 5
		-4 → -8	15 → 20
50 – 200	>18	0 → -2	1 → 3
		-2 → -5	10 → 15
200 – 1 000	<18	-1 → -3	4 → 7
		-3 → -7	8 → 14
200 – 1 000	>18	0 → -2	2 → 5
		-1 → -3	5 → 10
>1 000	<18	-1 → -3	4 → 7
		-3 → -7	8 → 14
>1 000	>18	0 → -2	2 → 5
		-1 → -3	5 → 10

Table 10.4. Bias and precision for yearly load based on the monthly mean calculation method. TN (black) – TP (red). Catchment dominated by soils.

Catchment size (km^2)	Number of samples	Bias (%)	Precision (%)
0 – 50	<18	-2 → -4	2 → 5
		-20 → -30	22 → 40
0 – 50	>18	-1 → -3	1 → 3
		-16 → -27	18 → 37
50 – 200	<18	-2 → -4	2 → 5
		-4 → -10	12 → 18
50 – 200	>18	-1 → -3	1 → 3
		-2 → -5	9 → 13
200 – 1 000	<18	-2 → -4	4 → 7
		-4 → -8	6 → 12
200 – 1 000	>18	-1 → -3	2 → 5
		-2 → -4	3 → 8
>1 000	<18	-2 → -4	4 → 7
		-4 → -8	6 → 12
>1 000	>18	-1 → -3	2 → 5
		-2 → -4	3 → 8

Table 10.5. Bias and precision for yearly load based on the linear interpolation calculation method. TN (black) – TP (red). Catchment dominated by bedrock.

Catchment size (km^2)	Number of samples	Bias (%)	Precision (%)
0 – 50	<18	-2 → -4	3 → 6
		-20 → -30	30 → 50
0 – 50	>18	-1 → -3	2 → 4
		-17 → -24	23 → 45
50 – 200	<18	-2 → -4	3 → 6
		-5 → -10	18 → 23
50 – 200	>18	-1 → -3	2 → 4
		-3 → -6	12 → 18
200 – 1 000	<18	-2 → -4	6 → 9
		-4 → -9	10 → 16
200 – 1 000	>18	-1 → -3	3 → 6
		-2 → -4	7 → 12
>1 000	<18	-2 → -4	6 → 9
		-4 → -9	10 → 16
>1 000	>18	-1 → -3	3 → 6
		-2 → -4	7→ 12

Table 10.6. Bias and precision for yearly load calculation based on the monthly mean calculation method. TN (black) – TP (red). Catchment dominated by bedrock.

Catchment size (km^2)	Number of samples	Bias (%)	Precision (%)
0 – 50	<18	-3 → -5	3 → 6
		-23 → -35	25 → 45
0 – 50	>18	-2 → -4	2 → 4
		-18 → -30	18 → 37
50 – 200	<18	-3 → -5	3 → 6
		-5 → -12	14 → 20
50 – 200	>18	-2 → -4	2 → 4
		-3 → -6	10 → 15
200 – 1 000	<18	-3 → -5	6 → 9
		-6 → -10	8 → 14
200 – 1 000	>18	-2 → -4	3 → 6
		-3 → -5	4 → 10
>1 000	<18	-3 → -5	6 → 9
		-6 → -10	8 → 14
>1 000	>18	-2 → -4	3 → 6
		-3 → -5	4 → 10

10.5. Hydrological normalization of riverine inputs

Input data are normalized to better be able to detect possible trends in inputs over time by smoothing out the effects of weather and hydrological factors such as precipitation, including accumulation and melting of snow/ice, and evapotranspiration, but also by temperature etc. The methods presented below are to serve as guidance for elaboration of the PLC assessments and will be performed in a uniform way within the HELCOM PLC data processing framework, and the Contracting Parties will not be required to make these calculations.

Normalization of riverine loads is a statistical method whose result is a new time series of nutrient inputs where major part of the hydrology-introduced variation has been removed. The normalized time series has a reduced interannual variation and the trend analysis is thus much more precise. Significant trends in the normalized series can probably mainly be attributed to an effect of human activities.

The hydrological normalization should be regarded as a prerequisite for analyzing trends. The trend analysis is a two-step process including: 1) the normalization and 2) the actual trend analysis.

Different methods for normalizing inputs are described in Silgram & Schoumans (ed., 2004), Chapter 4. The guidelines focus on methods based on empirical data. The empirical hydrological normalization method is based on the regression of annual loads and annual runoff; thus, the method normalizes the loads to an average runoff (averaged over the whole time series period). In this way, the variation attributable to the annual amount of runoff is removed, whereas the effect of differences in the distribution of runoff over the year is not removed. Based on experience with flow and load data, the regression explains slightly more of the variation if both annual input and annual runoff values are transformed by the natural logarithmic function before normalizing.

According to Silgram and Schoumans (ed., 2004), the empirical hydrological normalization method should be based on the linear relationship between annual runoff (Q) and the annual load (L) in year i of a nutrient:

$$L_i = \alpha + \beta \cdot Q_i + \varepsilon_i, \tag{10.14}$$

α and β = Parameters associated with linear regression that are estimated using least squares;

εi = Residual error in the linear regression.

Then, the normalized load L_N is calculated as:

$$L_{iN} = L_i - (Q_i - \bar{Q}) \cdot \hat{\beta}, \tag{10.15}$$

$\bar{Q}$ = Average runoff for the whole time series period;

Qi = Runoff in year I;

^ = Indicates that it is a parameter estimated using least squares on the linear regression.

Normally, the relationship is modelled after log-log transformation, reducing the influence of large loads and runoff values giving, as mentioned, a slightly more precise fit with residuals that are more likely to be Gaussian distributed, which is a statistical prerequisite for the regression method. Thus, normalization should be based on a log-log regression between load and runoff:

$$\log L_i = \alpha + \beta \cdot \log Q_i + \varepsilon_i, \tag{10.16}$$

where:

α and β = Parameters associated with linear regression obtained using least square method;

ε_i = Residual error in the linear regression;

Q_i = Annual runoff year I;

log = natural logarithm.

To avoid large negative values when log transforming very small loads or runoff values, it is suggested to multiply load and runoff with 1000 before log transforming.

Formula 10.16 gives the following equation for normalized loads:

$$L_{Ni} = \exp\left(\log L_i - (\log Q_i - \overline{\log Q}) \cdot \hat{\beta}\right)^{9} \cdot \Delta, \quad (10.17)$$

where

Log = Natural logarithmic function;

Exp = Exponential function;

$\bar{Q}$ = Average runoff for the whole time series period;

$\hat{\beta}$ = Estimated (^) inclination of regression line derived by least square method;

$\Delta = \frac{\sum_i L_i}{\sum_i L_{Ni}}$ = Log-transformation causes the average of the normalized time-series to differ from the original load time-series[9]. The factor Δ (that is computed posteriori although included in 10.17) ensures that the average of the normalized loads is the same as of the original loads.

The main reason for using the natural logarithmic function for transformation is stabilization of the variance among residuals. Without the transformation, residuals are often distributed with a heavy tail to the right.

In the footnote 9 and for later use Mean Square Error (MSE) is introduced. It is normally calculated in standard statistical software and is in general defined as:

$$\text{MSE} = \frac{1}{n-p} \sum_{i=1}^{n} (x_i - \hat{x_i})^2, \quad (10.18)$$

where

n = Number of observations in the time series;

x_i = Observed value; and

$\hat{x_i}$ = Modelled value from linear regression.

P = Number of parameters in the model, in standard regression p = 2.

In this chapter x_i would be log L_i and $\hat{x_i}$ would be $\widehat{\log L_i}$, and log the natural logarithm function.

Formula (10.17) has been used with minor modification for PLC-5.5 assessment and onwards.

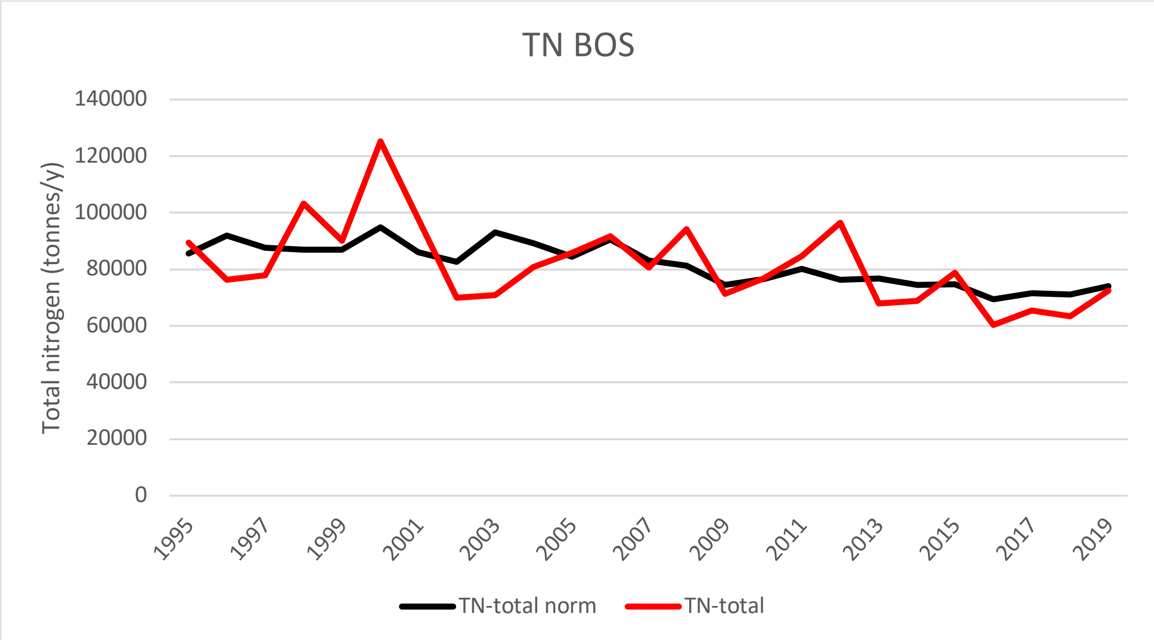
Note! Caution should be taken when handling loads/inputs with significant upstream point sources, as these sources affect the relationship between the substance and the discharge, which may result in different relationship during high and low flow situations. In addition, large changes in the load from the upstream point sources may have an impact on the normalization.

---

9 In Larsen and Svendsen (2021) formula 10.17 is multiplied by the factor "exp(0.5·MSE)". It is a bias correction factor derived as described by Ferguson (1986). The factor is needed to back-transform to a mean value and not to a geometric mean, whose calculation does not require this factor. If $\exp(0.5 \cdot \text{MSE}) > 1.25$, this indicates that the fit in formula (10.14) is not very good and it is probably better not to log transform and use formula (10.16) and (10.17) below.

Note: Hydrological normalization should be carried out river/catchment-wise, i.e. nutrient loads should be normalized for each river/catchment separately. If the normalization is performed country-wise or sub-basin-wise, the result will not be exactly the same as the catchment-wise normalized nutrient loads summed to country or sub-basin level. There will be a minor difference in the results.

Figure 10.2 shows the normalized inputs of total nitrogen and total phosphorus summed up for all rivers discharging to Bothnian Bay 1995-2016 including direct point sources (not normalized) and climate normalized airborne inputs (normalized according to Annex 6). As can be seen, the variation between years is reduced significantly. These normalized inputs summed for all the rivers together with inputs from direct point sources and from atmospheric deposition are used for trend analysis and target testing.



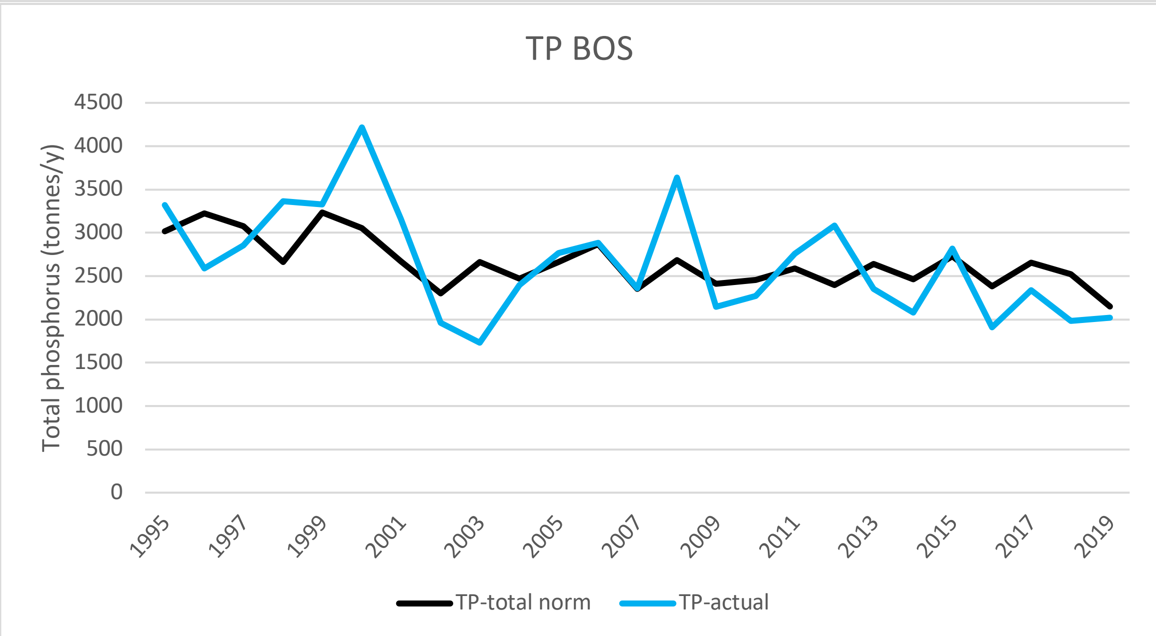


Figure 10.2 Time series of actual total nitrogen (red line upper figure) and actual total phosphorus (blue line lower figure) inputs (sum of water- and airborne inputs) in 1995-2019 for Bothnian Sea and the corresponding flow normalized total nitrogen and total phosphorus (black in both figures) in tons.

The models presented in (10.14) and (10.16) will result in a pattern in the model residuals if the time series is non-stationary (with a trend). In time series with trends, the relationship between *L* and *Q* changes over time. Furthermore, the residuals will also be serial correlated to a strong degree. This can be seen in the following example (Figure 10.3) showing the estimated linear relationship between diffuse TN load and discharge for the sum of all monitored Danish rivers in the period 1990-2018. It can be seen from the figure that the relationship changes from the beginning of the period to the end. In this case, the model residuals resulting in applying the model in (10.14), will start with large positive residuals decreasing linearly to large negative residuals as time elapses. This indicates a poor fit of the model to the time series data.

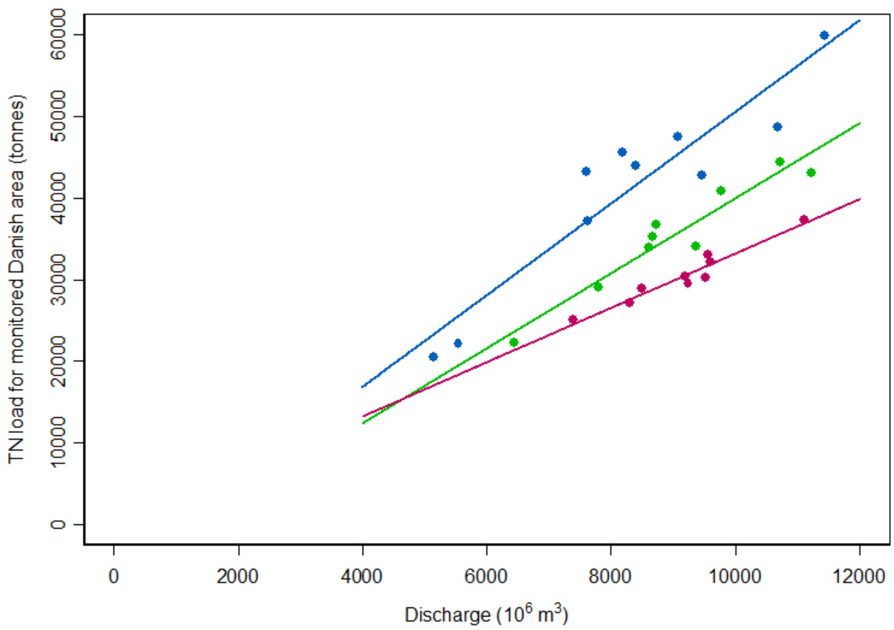


Figure 10.3 Estimated linear relationship between diffuse TN load and discharge for the sum of all monitored Danish rivers. Data is from the period 1990-2018. The total period is divided into 3 sub-periods: 1990-1999 (blue), 2000-2008 (green) and 2009-2018 (red).

Proposal of a revised normalization method

The normalization method described above has been used for some years in PLC assessment. However, in Larsen and Svendsen (2021) a revised normalization method is proposed, because the models presented in (10.14) and (10.16) will result in a pattern in the models' residuals if the time series is non-stationary (with a trend). In time series with trends, the relationship between load (L) and discharge (Q) changes over time. Furthermore, the residuals will also be serial correlated to a strong degree.

In order to manage with these model problems, models and methods from the statistical analysis of serial correlated time series are introduced (Box *et al.*, 2015). Applying the method of differencing the time series, which is a transformation of the time series used to stabilize the mean of the time series. For all years ($i, i = 2, \cdots, n$) then calculate $L_i - L_{i-1}$ and $Q_i - Q_{i-1}$ and fit the model

$$L_i - L_{i-1} = \alpha + \beta \cdot (Q_i - Q_{i-1}) + \varepsilon_i. \quad (10.19)$$

This model, generally, results in a much more appropriate distribution of model residuals over time. The model in (10.19) can be written as $(i, i = 2, \cdots, n)$

$$L_i = \alpha + \beta \cdot (Q_i - Q_{i-1}) + L_{i-1} + \varepsilon_i \quad (10.20)$$

$$\Updownarrow$$

$$L_i = \beta \cdot Q_i + \alpha \cdot i + \frac{1}{(1-B)} \varepsilon_i \quad (10.21)$$

where

$$\frac{1}{(1-B)} \varepsilon_i = \varepsilon_i + \varepsilon_{i-1} + \cdots + \varepsilon_1.$$

The *B* is the so-called back-shift operator used in time series mathematics (Box *et al.*, 2015) and it is defined as

$$(1 - B)L_i = L_i - L_{i-1}$$

Differencing the data results in what is called a random walk, which in the simplest form is $x_i = x_{i-1} + \varepsilon_i$ with ε_i as a white noise, i.e. independent identical distributed as $N(0,\sigma^2)$. The simplest random walk is a stochastic process depending on the value just before plus a random shock, a Gaussian distributed value with zero mean (=0) and a given variance (σ^2). A random walk can also be viewed as a simple autoregressive process of order 1. Differencing is equivalent to a stochastic differential equation in continuous time.

The model in (10.19-10.21) can also be used with logarithmic transformed loads (natural logarithm) and flow. Whether transforming can be determined by looking at the residuals of the model with untransformed data.

The normalized loads, using the model in (4.6–4.8) are calculated for untransformed data as $(i, i = 1, \cdots, n)$

$$L_{Ni} = \hat{\beta} \cdot \bar{Q} + \hat{\alpha} \cdot i + r_i = L_i - (Q_i - \bar{Q}) \cdot \hat{\beta} \quad (10.22)$$

where the r_i $(i, i = 1, \cdots, n)$ is defined as

$$r_i = L_i - \left(\hat{\alpha} \cdot i + \hat{\beta} \cdot Q_i\right). \quad (10.23)$$

It turns out that

$$r_1 = L_1 - \left(\hat{\alpha} + \hat{\beta} \cdot Q_1\right)$$

and for $(i, i = 2, \cdots, n)$

$$r_i = r_1 + \sum_{j=2}^{i} \left(L_j - \left(\hat{\alpha} + \hat{\beta} \cdot \left(Q_j - Q_{j-1}\right) + L_{j-1}\right)\right).$$

The right side in (10.22) is equal to (10.15) but it should be noted that $\hat{\beta}$ is from another model.

For transformed data

$$L_{Ni} = \exp\left(\hat{\beta} \cdot \log\bar{Q} + \hat{\alpha} \cdot i + r_i\right) \cdot \exp(0.5 \cdot MSE) \quad (10.24)$$

where r_i is defined as in (10.23) but now with logarithmic transformed data.

The parameter α can almost always be tested equal to zero and is in fact associated with a trend in the size of point source inputs, so in time series without point sources this parameter can be disregarded in the model (10.19).

In the case of using the transformed data for normalization, and in the case of a non-linear normalization model, the normalized values will not in average be equal to the un-normalized values, i.e.

$\frac{1}{n}\sum_{i=1}^{n} L_i \neq \frac{1}{n}\sum_{i=1}^{n} L_{Ni}$.

Therefore, the normalized values must be corrected for bias. This can be done in two different ways:

$$L_{NBi} = L_{Ni} + (\bar{L} - \overline{L_N}) \qquad (10.25)$$

or

$$L_{NBi} = L_{Ni}\frac{\bar{L}}{\overline{L_N}} \qquad (10.26)$$

The first way (formula 10.25) is recommended.

The revised normalization method will be tested and the results compared with the corresponding assessment using the models presented in (10.14) and (10.16) to evaluate if the revised method should be recommended for use in the future PLC assessments.

To illustrate the method defined in (10.19-10.24), total nitrogen load data from the River Aalbek (Germany) and total phosphorus load data from the River Vistula (Poland) are used. Figure 10.4 shows scatter plots and the linear relation between differenced loads and differenced flows. For the River Aalbek the relation is quite good, and for River Vistula, there is also a clear relationship but the scatter around the fitted line is larger. Figure 10.5 shows the normalized time series together with the unnormalized loads. Note the large reduction in interannual variation in the normalized time series. As can be seen in figure 10.5(a) the difference between the new method described above (10.19-10.24) and the method used until now (Gustafson, 2019) is very small. This is due to a constant relationship between TN load and runoff over time. There is a larger difference between the two methods in figure 10.5(b). In some periods, the new normalizing method introduced gives larger values, in other periods the opposite can be noticed. This is due to changes in the relationship between runoff and TP load.

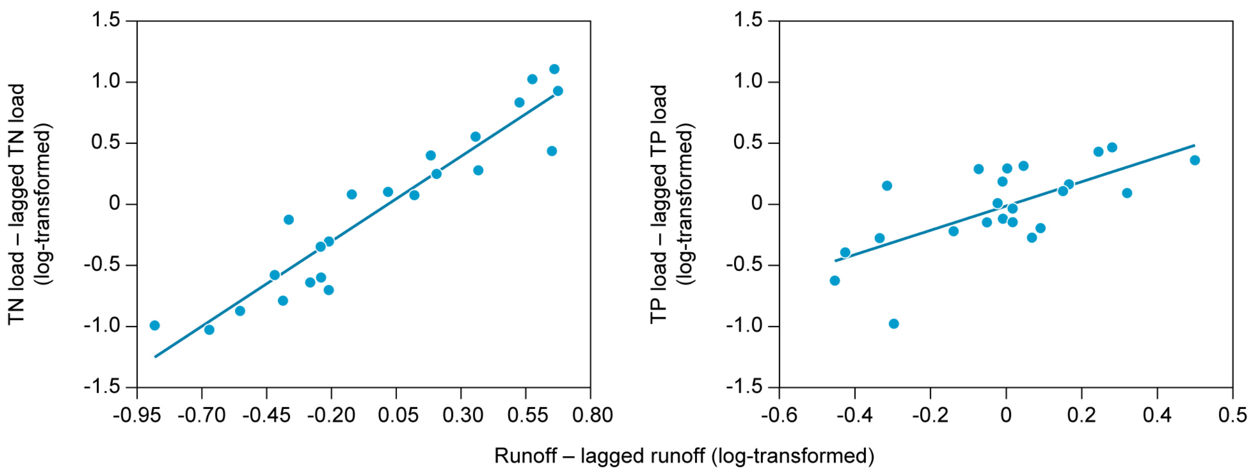


Figure 10.4 Scatter plots of annual loads of TN (a – plot to the left) in the Aalbek river and TP (b – plot to the right) in the Vistula river against runoff and the linear regressions (transformation based on natural logarithmic function). Plotted values are differences between the annual values and the annual values one year before as modeled in formula 10.19. Data represent the riverine loads of TN and TP in the two rivers during 1995-2018.

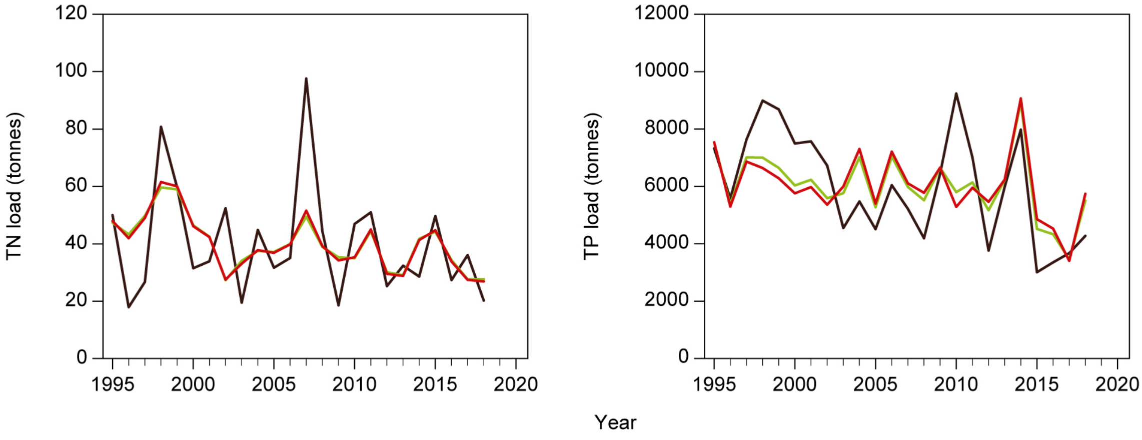


Figure 10.5 Time series plot of annual actual (not normalized) time series (black), the method used until now (red) and of normalized time series (green) with the difference method in formula 4.6 of annual TN (a, Aalbek, left figure) and TP (b, Vistula, right figure) in tons 1995-2018.

Figure 10.6 illustrates the improvement in the distribution of the model residuals over time when applying the introduced new normalizing method on TN loads measured in the Danish river Langvad. The plot in figure 10.6a shows the distribution of the model residuals over time applying the model in (10.16). The residuals show an almost linearly trend over time from large positive values to large negative values. This pattern in the residuals illustrate a poor model fit to the data. In Figure 10.6b the residuals, from applying the model in (10.20), look to be randomly distributed over time, both according to sign and size and therefore this model is a much-improved model for the data.

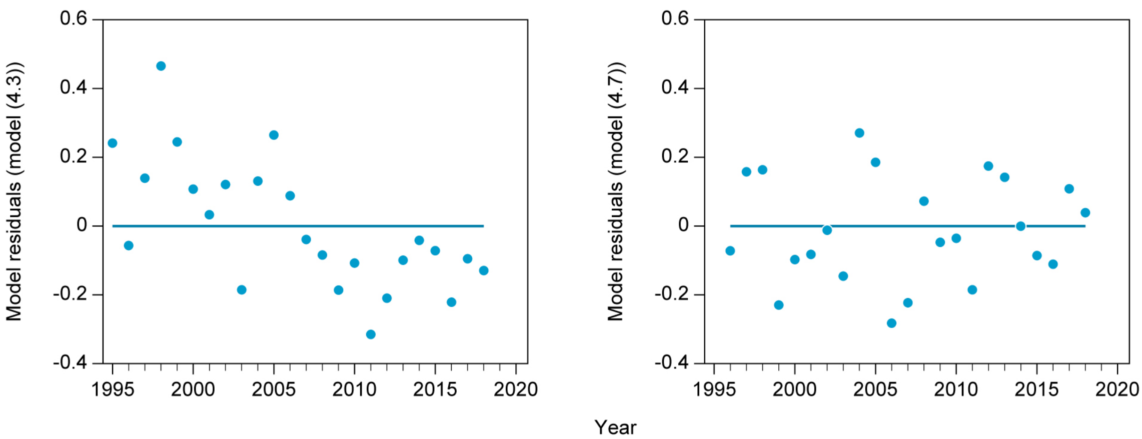


Figure 10.6 Model residual plots using TN loads measured in River Langvad (Denmark). a (left figure): residuals applying the model in (10.16). b (right figure): residuals applying the model in (10.20). Notice that there is no model residual for the first year in the time series when applying the model in (10.20).

10.6. Trend analysis, change points and the estimation of change

Trend analysis on normalized nutrient input series to different parts of the Baltic Sea, including trend analysis of the flow, is an important tool in the PLC assessments, when evaluating if nutrient inputs are reduced and evaluating the progress towards fulfilling the HELCOM 2021 BSAP nutrient reduction targets (MAI and NIC). Further, it supports evaluation of the effects of implemented measures.

As with e.g. hydrological normalization in Chapter 10.5, the trend analyses are performed in a uniform way within the HELCOM PLC data processing and assessment framework, and the Contracting Parties are not required to make these calculations. The procedure in Chapter 10.6 is called the trend-based methodology to estimate latest year value in a normalized time series and to evaluate the estimated value including an uncertainty with MAI or NIC in the Baltic Sea Action Plan.

Trend analysis can be performed using a range of different both parametric and non-parametric methods. Parametric methods comprise ordinary regression with year as the independent variable and linear and non-linear regression methods, such as polynomial, exponential, or more complex regression methods. The most well-known non-parametric method is the Mann-Kendall trend test and the Theil-Sen estimator for the yearly change in nutrient input.

The Mann-Kendall method (Hirsch et al. 1982) is a well-established procedure to test for a monotonic trend in a time series and is a non-parametric method based on Kendall's tau, which is a measure of the correlation between two different variables. The method is robust towards outliers and a few missing data. If the trend is linear, Mann-Kendall's method has slightly less power than ordinary regression analysis. A detailed mathematical description of the method can be found in sub-chapter 10.9 , and the R packages "trend", "rkt" and "Kendall" includes the Mann-Kendall trend test.

In the PLC assessments, the Mann-Kendall trend method is used for a preliminary analysis of possible trends in the total nitrogen and total phosphorus input time series. Furthermore, the Mann-Kendall method is used for analyzing possible trends in runoff time series. The remaining trend analysis, as estimating trend line (slope, intersect), estimating latest year input and changes in inputs is based on linear regression and parametric testing. In the first MAI and CART assessment more focus was placed on using the Mann-Kendall method.

Ordinary regression analysis is also a well-known statistical method (Figure 10.7), but demands a linear relationship with Gaussian distributed residuals, which are stochastic independent as well (Snedecor and Cochran, 1989). If the time series is serially correlated, both the Mann-Kendall test and ordinary regression must be modified, since the tests will be impacted by this, and the probabilities of statistical test values can therefore not be trusted. Serial correlation in a time series can be tested by the Durbin Watson test statistic (Durbin & Watson, 1971). On the other hand, it appears that the autocorrelation for annual time series of either loads or runoff is small and can be ignored; thus, the methods can be used without modifications as a good approximation. *The minimum time series length for application of the Mann-Kendall test is 8 years, and this rule should also be a guidance applying ordinary linear regression*.

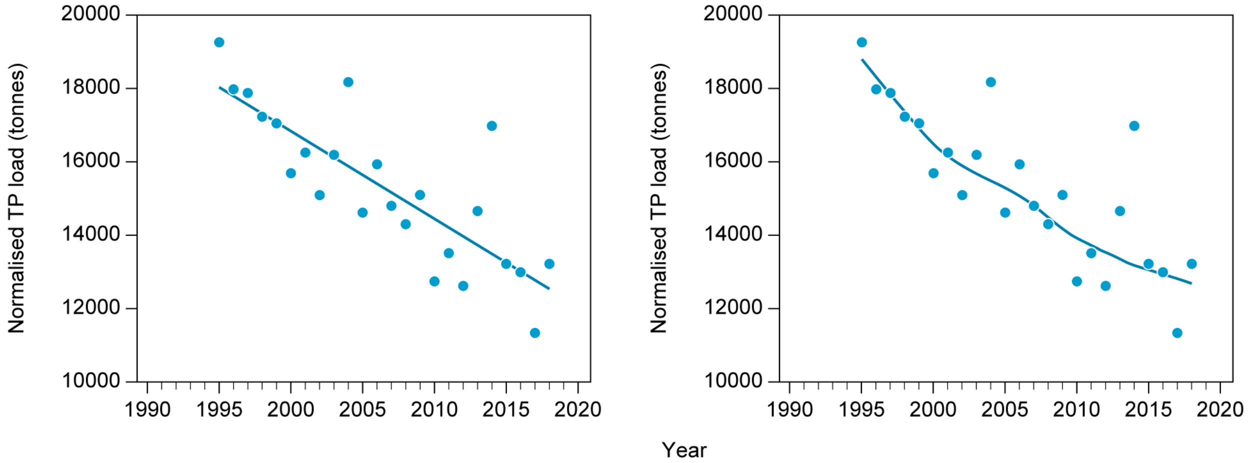


Figure 10.7 A. Left figure: Annual normalized TP waterborne inputs (tons) to the Baltic Sea. Trend line estimated with linear regression model. B. Right figure: As figure A, but the trend line is estimated with LOESS (locally weighted scatterplot smoothing) regression method.

Both Mann-Kendall's trend analysis and ordinary linear regression allow performance of a one-sided trend test if focus is on testing for a downward or increasing development in a time series. This is of relevance in the PLC assessments and when evaluating progress towards HELCOM BSAP MAI and NIC.

If a time series plot shows one or two clear trend reversals (also called change points in time), e.g., when the first part of the time series shows a linear increase and the second part shows a linear decrease in nutrient inputs. The trend analysis can be carried out by using a model with two or three linear curves (by linear regression) or by applying two or three Mann-Kendall trend tests if time series sections include enough number of years (example in Figure 10.8).

Year of trend reversal (the change point) can either be determined by inspecting the time series plot or by applying a statistical method (Carstensen and Larsen, 2006). If an exact year of change in the inputs is known (e.g. as changes due to implementation of a new wastewater treatment plant or new treatment methods), this year should be applied as change point, and the time series should be divided accordingly. Statistical estimation of the time when a change occurs in a time series is complex and involves a calculation procedure with iterative estimations. The LOESS (locally weighted scatterplot smoothing, Cleveland, 1979) regression method can be used as a supplement for detecting non-linear trends and for helping detecting change points/step trends. See the plots in Figure 10.7b and Figure 10.8b for examples of using LOESS.

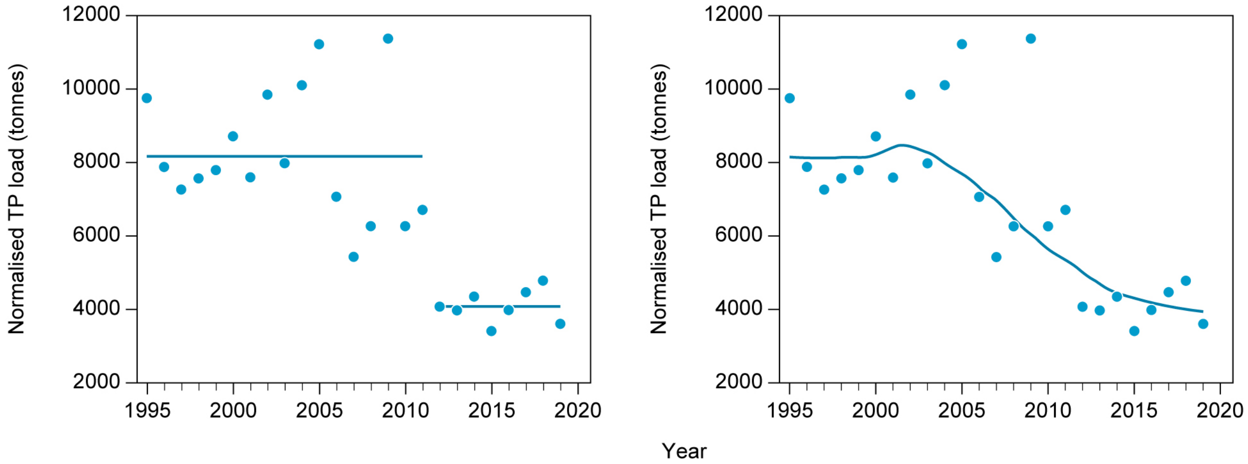


Figure 10.8 A (left figure)**:** Annual normalized TP inputs (tons) 1995-2018 to the Gulf of Finland. One change point in the time series is detected, and the trend lines are based on linear regression. B (right figure): As figure A, but the trend line is estimated with LOESS regression method.

It is suggested to use models with 1, 2 or 3 linear parts for different sections of the time series (it is still possible that no part of the time series includes significant linear trends). Determination of breakpoints will be statistically analyzed by using an iterative statistical process, which will determine the most significant breakpoint (the significance of the breakpoint is evaluated by the change in -2logQ) – or automatically where -2logQ is the result from testing a statistical hypothesis with likelihood-ratio test (Carstensen and Larsen, 2006). *Each part of the time series before and after a breakpoint should be at least 5 years or more*.

In the PLC assessments two different breakpoint models are tested, described with two linear parts:

Model 1:
$$L_{Ni} = \begin{cases} \alpha + \beta \cdot i, & for\ i < Y \\ \alpha + \beta \cdot i + d \cdot (i - Y), & for\ i \geq Y \end{cases} \quad (10.27)$$

Model 2:
$$L_{Ni} = \begin{cases} \alpha_1 + \beta_1 \cdot i, & for\ i < Y \\ \alpha_2 + \beta_2 \cdot i, & for\ i \geq Y \end{cases} \quad (10.28)$$

where

L_N = Normalized input;

α = Intercept;

β and d = Slopes;

Y = A given year;

i = Different years in the time series.

Model 1 is continuous at the breakpoint (the two lines are connected) while model 2 has disconnected lines at the breakpoint (a step).

After the first breakpoint is determined, another iterative process looking for a second breakpoint is performed. Change-points models are an aid for estimating the last year value, and to get an idea of the overall trend during the full time series period.

Finally, in the former PLC assessments of HELCOM MAI and NIC, significance of the slope in the last segment was tested, and if not significant different from zero the following model was used:

$$L_{Ni} = \begin{cases} \alpha + \beta \cdot i, & for\ i < Y \\ c, & for\ i \geq Y \end{cases} \quad (10.29)$$

c = Estimated input (a constant).

For the PLC assessments performed since 2021 the significance of slopes is tested in all identified parts of different segments of a time series, and e.g. a model is fitted with constant values in the segments where the slope can be accepted to be zero. For instance, it could end up with a model like:

$$L_{Ni} = \begin{cases} c_1, & for\ i < Y \\ c_2, & for\ i \geq Y \end{cases}.$$

Table 10.7 summarizes the iterative modelling process that is used in the PLC assessment modelling process that is suggested for fitting linear models with breakpoints to the time series.

Table 10.7 The iterative modelling process for identifying breakpoints, testing for significant slopes and fitting constants (no significant slopes) and regression parameters (significant slopes) in a time series.

1. step	2. step	3. step	4. step
A significant breakpoint	Test for additional breakpoints in each segment	Test for significant slopes in the segments	Fit a constant in segments with a non-significant slope. Fit regression parameters in the rest of the segments.
No breakpoint	Fit a constant for the whole time series		

The second part of the trend analysis concerns estimating the size of the trend or the change per year. Several different methods exist and which one to use depends on the shape of the trend. The Theil-Sen slope estimator (Hirsch et al. 1982) is a non-parametric estimator that is resistant towards outlier (suspicious) values. The method assumes a linear trend and estimates the change per year. However, the estimator fails if a trend is non-linear, and if the time series contain one or several change-points the time series must be split into two or more parts.

The size of a linear trend can also be estimated by regression. This is the classical approach, but it is not flexible regarding all shapes of trends. The simplest method is using the start and end values in the time series of flow-normalized inputs. However, if the start and/or end values are too distant from the general trend, this method is not reliable.

To identify the total change in nutrient inputs over the whole time series, expressed as a percentage, apply the following method. By using the fitted trend model, estimate the normalized values at the first year and the last year in the time series and then simply calculate the change as:

$$100 \cdot \frac{(\widehat{L_{Nn}} - \widehat{L_{N1}})}{\widehat{L_{N1}}}, \quad (10.30)$$

1 = First year in the series;

n = Length (number of years) in the series (last year);

$\widehat{L_{N1}}$= Estimated normalized input in year 1, the first year in the time series;

$\widehat{L_{Nn}}$ = Estimated normalized input in year n, the last year in the time series.

The same method as given in (10.30) can be used for segments of the time series, i.e. parts before, between and after breakpoints and add up the percentages. Remember to add the step trend if such one is detected at the change point. If the slope is not significant in one or more of the segments use a slope estimate equal to zero in the formula. For the evaluation of BSAP reduction targets and the PLC assessments formula 10.30 is based on linear regression estimates.

For some times series the start value, the end value or both can differ too much from the general trend – in such cases an approach using the average value of, for instance, the first three years and the last three years would reduce the influence of single years.

The trend analysis methods are illustrated in Figure 10.9 based on the time series of normalized TN inputs to the Kattegat. The normalized time series are shown together with a model fit of the trends. The model fit consists of one change point (a step change in the level) in year 2011 and the linear fit before the change point is significant, the linear fit after is not significant, so a constant value is fitted (as the average of the normalized TN inputs in the segment after the break point). A trend analysis should always be initiated with a time series plot of the data series.

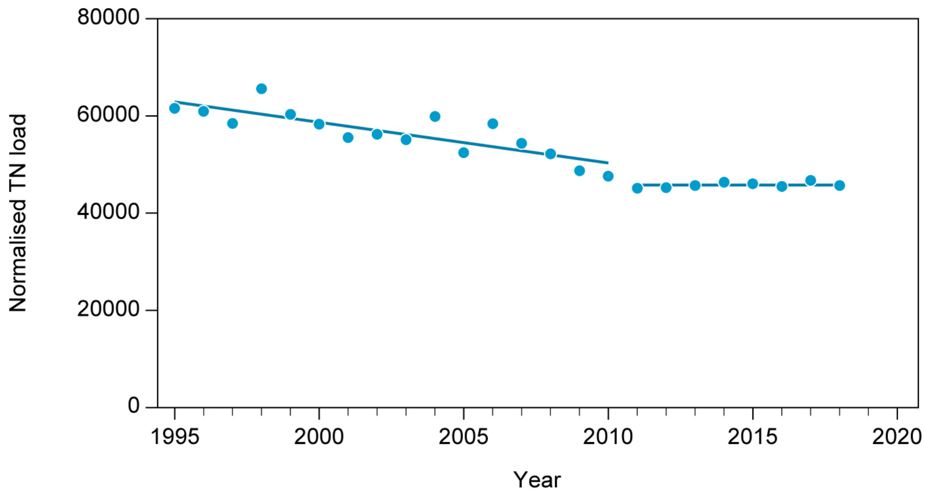


Figure 10.9 The fitting of a model with one change point (breakpoint) on the normalized waterborne total nitrogen (TN) inputs (tons) to the Kattegat.

The estimated change over the whole period for the normalized total nitrogen inputs in figure 10.9 is -27.2% according to formula 10.30.

Figure 10.10 shows another example of the trend analysis method for waterborne total nitrogen inputs to the Baltic Proper. Two change points are identified, the first in 2002, and the second in 2009. The middle part of the time series (2002-2008) is fitted with a constant value; the other two lines have significant slopes. The total estimated change is -17.7%.

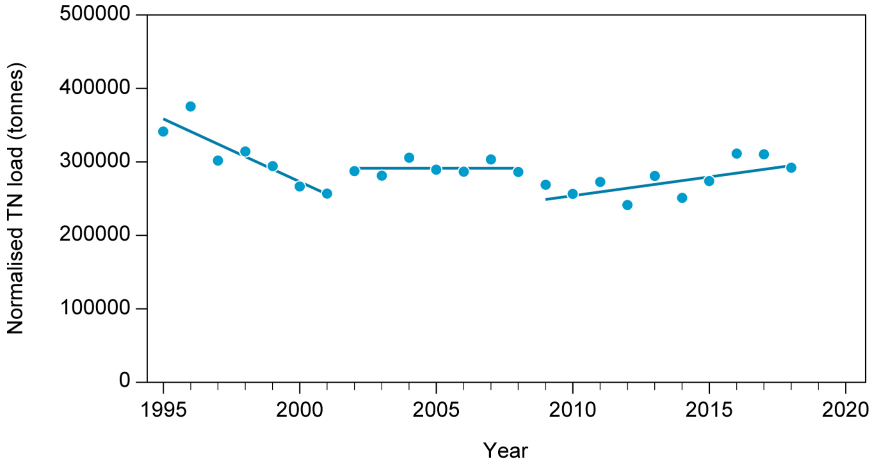


Figure 10.10 The fitting of a model with two change points(breakpoints) to the normalized waterborne total nitrogen (TN) inputs (tons) to the Baltic Proper.

10.7. Testing fulfilment of BSAP reduction targets

The methodology for testing fulfilment of BSAP reduction targets are applied in a uniform way by the HELCOM PLC project, when evaluating progress towards MAI and NIC in HELCOM 2021 BSAP nutrient reduction scheme. The Contracting Parties are not supposed to make these test.

10.7.1. Testing without significant trends

To test if a nutrient reduction target has been fulfilled the assumption is that we have a time series of normalized inputs. The time series is initially presumed to be without a statistically significant trend and without a significantly large serial correlation, and assume that the reduction target *T* (or any kind of target such as a maximum allowable inputs MAI for a Baltic Sea sub-basin or a nutrient input ceiling NIC from a country to a sub-basin) is defined without error, i.e. is a fixed value (an amount of nitrogen/phosphorus without uncertainty). Finally, it is assumed that the data are sampled from a Gaussian distribution with mean value μ and variance σ^2.

As a null hypothesis for the statistical test, assume that the target has not been fulfilled, i.e.

$$H_0 : \mu \geq T$$

where:

H = Hypothesis;

T = Target.

The alternative hypothesis

$$H_A : \mu < T$$

follows from this, i.e. the target has been fulfilled.

Then assume that the test significance level α is defined to be 5% (0.05), and then calculate the statistic:

$$\bar{x}_{AD} = \bar{x} + t_{n-1,0.05} \cdot SE_{\bar{x}}, \tag{10.31}$$

$\bar{x}_{AD}$ = Adjusted mean;

$\bar{x}$ = Mean of all values in the time series;

$SE_{\bar{x}}$ = Standard error (*SE* = standard deviation divided by square root of *n*), standard error of $\bar{x}$;

n = number of observations in the time series;

$t_{n-1,0.05}$ = 95% percentile in a *t*-distribution with *n*-1 degrees of freedom.

A test probability of 5% means there is a 5% probability of incorrectly rejecting the null hypothesis. For hypothesis testing and estimation of confidence intervals we use the t-distribution table since the true population standard deviation (σ) is not known and since the number of years (the sample size) is still small (less than 30 years).

This statistic is called the adjusted mean and if the statistic is less than the target *T*, then the reduction target is met.

10.7.2. Testing with significant trends

In the case of a time series of nutrient inputs with a significant trend, another statistical method is needed for testing if a HELCOM BSAP target is met. Assuming that the trend is linear, that a linear regression model with year as the independent variable can be fitted to the time series, and that estimates for α and β can be calculated – then the linear model can be used to predict a normalized nutrient input for the last year ($year_n$) in the time series. This estimate is calculated as:

$$\widehat{L_{Nn}} = \hat{\alpha} + \hat{\beta} \cdot year_n. \tag{10.32}$$

$\widehat{L_{Nn}}$ = Estimated normalized input in year n, the last year in the time series

$\hat{\alpha}$ = Estimated intercept

$\hat{\beta}$ = Estimated slope

Next, it is necessary to calculate the standard error of the prediction (predicted input) defined as:

$$SE_{\widehat{L_{Nn}}} = \sqrt{MSE} \cdot \sqrt{1/n + (year_n - \overline{year})^2 / \sum_{i=1}^{n} (year_i - \overline{year})^2} \tag{10.33}$$

where

MSE = Mean Squared Error as defined in formula 10.18;

n = Number of years in the time series;

$year_n$ = Last year in the time series (i.e. 2019); and

$year_i$ = A given year in the time series (i.e. 1997).

$$\overline{year} = \sum_{i=1}^{n} year_i \Big/ n$$

Then the statistic is calculated as:

$$\bar{x}_{AD} = \widehat{L_{Nn}} + t_{n-2,0.05} \cdot SE_{\widehat{L_{Nn}}}, \tag{10.34}$$

where

$t_{n-2,0.05}$ = the 95% percentile in a *t*-distribution with *n*-2 degrees of freedom.

A list with the 95% percentiles for different values of *n*-2 is given in the Annex 2 in Larsen & Svendsen (2021).

The mathematical definition of the standard error of the prediction *SE* given in (10.33) is from ordinary linear regression (Snedecor and Cochran, 1989). If the trend is not linear, other models must be used for the time series, and the formula for the standard error needs to be revised. The form of the trend in the data will dictate the methods to be applied. These methods are based on the assumption of the existence of one or two change points in the time series (see Chapter 10.6).

"Trend method"

A few examples are included based on models with one change-point *Y*, and assuming that the last year in the time series is denoted by $year_n$. In general, we denote the method the *"trend method".* The first example is a model with one change point and a linear model before and a linear model after the change point, and no change in level before and after the change point. The second example is equal to the first example but with a change in level at the change point. The last example (example 3) is with a constant level after the change point.

<u>Example 1</u>:

$$L_{Ni} = \begin{cases} \alpha + \beta \cdot i, & for\ i < Y \\ \alpha + \beta \cdot i + d \cdot (i - Y), & for\ i \geq Y \end{cases}$$

$$\widehat{L_{Nn}} = \hat{\alpha} + \hat{\beta} \cdot year_n + \hat{d} \cdot (year_n - Y)$$

<u>Example 2</u>:

$$L_{Ni} = \begin{cases} \alpha_1 + \beta_1 \cdot i, & for\ i < Y \\ \alpha_2 + \beta_2 \cdot i, & for\ i \geq Y \end{cases}$$

$$\widehat{L_{Nn}} = \widehat{\alpha_2} + \widehat{\beta_2} \cdot year_n.$$

<u>Example 3</u>:

$$L_{Ni} = \begin{cases} \alpha + \beta \cdot i, for\ i < Y \\ c, \qquad for\ i \geq Y \end{cases}$$

$$\widehat{L_{nN}} = \hat{k}$$

The *SE* (standard error) for the estimated input for the last year ($year_n$) has the general form of

$$SE_{\widehat{L_{Nn}}} = \sqrt{MSE} \cdot \sqrt{1/m + (year_n - \overline{year})^2 \Big/ \sum_{i=Y}^{year_n} (i - \overline{year})^2} \tag{10.35}$$

where

m = Number of years after *Y* (≥*Y*).

$$\overline{year} = \sum_{i=Y}^{year_n} i \Big/ m$$

MSE is calculated for the full model i.e. including all years in the time series.

If the model includes a constant level after the last change point the $SE_{\widehat{L_{Nn}}}$ for the estimated input for the last year ($year_n$) has the form

$$SE_{\widehat{L_{Nn}}} = \sqrt{MSE} \cdot \sqrt{1/m}.$$

Correction for calculating control value for $year_n$

$$\bar{x}_{AD} = \widehat{L_{Nn}} + k \cdot SE_{\widehat{L_{Nn}}}. \tag{10.36}$$

where

k factor = 95% percentile in a t-distribution with *n-p* degrees of freedom;

p = number of parameters in the final model.

Traffic light system

Finally, the following "traffic light" system is used for evaluating whether a country or a sub-basin has met the BSAP target (NIC and MAI, respectively), is close to meeting the target (not possible to judge fulfilment due to the uncertainty on the estimated inputs) or has not met the target.

Statistically, the system is defined as:

Red:

If $\bar{x}$ or $\widehat{L_{Nn}} > T$ i.e. estimated normalized input for the last year or the average normalized nutrient input over the considered period (when there is no trend) is above target value T.

Yellow:

If $\bar{x}$ or $\widehat{L_{Nn}} < T$, and if $\bar{x}_{AD} > T$, i.e. the null hypothesis of the target test is accepted, but the estimated normalized input for the last year or the average normalized input over the considered period (when there is no trend) is lower than the target.

Green:

If $\bar{x}_{AD} < T$, i.e. the null hypothesis of the target test is rejected, i.e. the alternative hypothesis is accepted meaning the target has been fulfilled, and the estimated normalized input for the last year or the average normalized input over the considered period (when there is no trend) is lower than the target value.

Testing whether estimated last year input is lower than input in the reference period

For testing whether the estimated last year value $\widehat{L_{Nn}}$ is significantly different from the mean value in the reference period apply the following procedure.

The reference period in BSAP nutrient reduction scheme is defined to be the years 1997-2003. First calculate the mean value in the reference period

$$\overline{L_{N\,(ref)}} = \frac{1}{7}\sum_{i=1997}^{2003} L_{Ni} \qquad (10.37)$$

and calculate the 95% confidence interval for $\overline{L_{N\,(ref)}}$ by

$$\overline{L_{N\,(ref)}} \pm k \cdot \mathrm{SE}_{\overline{L_{N\,(ref)}}}. \qquad (10.38)$$

The *k* factor is the 97.5% percentile in a t-distribution with 6 degrees of freedom (*k*=2.447) (7 years in the reference period minus 1). The $\mathrm{SE}_{\overline{L_{N\,(ref)}}}$ is the standard error of the mean value.

For the estimate of the last year $\widehat{L_{Nn}}$ we can calculate the 95% confidence interval as well by calculating

$$\widehat{L_{Nn}} \pm k \cdot SE_{\widehat{L_{Nn}}} \qquad (10.39)$$

where the *k* factor is the 97.5% percentile in a t-distribution with *n-p* degrees of freedom. The number *p* is the number of parameters in the final model. *SE* is the standard error for the specified model, used for the time series. How to calculate the $SE_{\widehat{L_{Nn}}}$ is given above in this sub-chapter.

Testing the hypothesis of no difference between the reference period and the last year value can simply be done by determining if

$$\left|\overline{L_{N\,(ref)}} - \widehat{L_{Nn}}\right| - k \cdot \sqrt{\mathrm{SE}_{\overline{L_{N\,(ref)}}}^{\,2} + SE_{\widehat{L_{Nn}}}^{\,2}} > 0 \qquad (10.40)$$

where *k* is the 97.5% percentile in a t-distribution with *n-p+6* degrees of freedom. $\left|\overline{L_{N\,(ref)}} - \widehat{L_{Nn}}\right|$ must be the absolute value.

To illustrate the principles, we tested if the normalized total nitrogen inputs to the Danish Straits met the provisional MAI input ceiling of 65,998 tons TN per year in 2018. Using the model with one change point in 2003 (see figure 10.9) the estimating input in year 2018 is 56,719 tons with a $SE_{\widehat{L_{Nn}}}$ of 1,082 tons. According to formula (10.36) the control value becomes 58,683 tons, which is less than 65,998 tons, so in the example the traffic light evaluation results in a green light. This example is illustrated in figure 10.11.

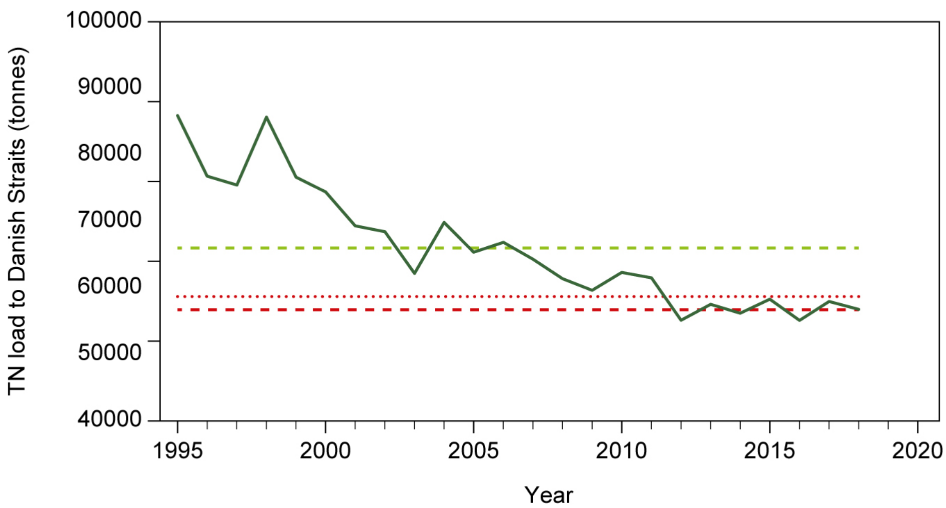


Figure 10.11 Principles on time series with trend created annual total nitrogen (TN in tons) input to the Danish Straits. Dashed green line is the target (MAI), "-----" red line is the estimated value (estimated TN input) in 2018, and "…." red line is the test value (TN input taking into account uncertainty) according to formula 10.36.

The average total nitrogen inputs in the reference period to Danish Straits were 73,167 tons and the confidence interval according to formula (10.37) is [66,280; 80,054] tons. The confidence interval for the 2018 estimated inputs is [54,343; 59,094] tons according to formula (10.38). Using formula (10.39 and 10.40) we calculate that the left side of the inequality sign is 11,280 tons, which is larger than zero, so we conclude that total nitrogen input in 2018 to Danish Straits is statistical significantly reduced (with 22%) since the reference period 1997-2003.

Table 10.8 includes another example of applying of the statistical analysis described to evaluate fulfilment of Finnish phosphorus input ceilings based on data from 1995-2017. Total phosphorus inputs to Gulf of Finland (647 tons P) are higher than the inputs ceiling to GUF (322 tons P), and the traffic light is then red and taking into account uncertainty the remaining reduction to fulfill reductions targets was 351 tons. The traffic light for Bothnian Sea is yellow, because the estimated total phosphorus inputs in 2017 when including uncertainty on the input estimate are higher than the input ceilings to BOS. Bothnian Bay meets the input ceiling (green) with 137 tons P (extra reduction, see Chapter 10.8) taking into account uncertainty.

Table 10.8. Illustration of the traffic light system. Evaluation of progress towards reductions targets (nutrient inputs ceiling) of total phosphorus (TP) for Finland to Bothnian Bay (BOB), Bothnian Sea (BOS) and Gulf of Finland (GUF) based on normalized annual total phosphorus inputs from Finland during 1995-2017. Green: input ceiling is meet. Red: input ceilings are not fulfilled. Yellow: It can not be judge if Input ceilings are fulfilled taking into account uncertainty. Values are in tons.

Finland TP	**BOB**	**BOS**	**GUF**
A : Input ceiling	1 668	1 255	322
B: Estimated input 2017	1 545	1 292	634
C: Inputs in 2017 including uncertainty (test value)	1 608	1 357	668
Extra reduction (A-C)	60		
Remaining reduction to fulfill MAI		103	346

Note: In Larsen & Svendsen (2021) is a step-by-step example using the described assessment procedures on HELCOM data, and an annex with many of the procedures given as programs for SAS and R allowing countries to make assessment on their own data.

10.8 Accounting for extra reductions in the evaluation of fulfilment of MAI and NIC

This sub-chapter shows how we take into account for extra reduction in the evaluation of fulfilment of MAI and NIC including the principles to follow to take into account extra reductions in one Baltic Sea sub-basin in a neighboring sub-basin with remaining reduction for fulfilling MAI and /or NIC.

This sub-chapter is slightly modified extracted from the report “Background document on the methodology for calculation accounting for extra reductions” by Bo Gustafsson, BNI Stockholm University and Lars M. Svendsen, DCE Aarhus University (2020). More information on the rationale and understanding the effects of extra and remaining reduction can be found in that report.

10.8.1 Introduction

As a part of the nutrient reduction scheme in the 2013 HELCOM Ministerial Declaration, the following principle was approved:

RECOGNIZING that reductions in nutrient inputs in sub-basins may have wide-spread effects, WE AGREE that extra reductions can be accounted for, in proportion to the effect on a neighboring basin with reduction targets, by the countries in reaching their Country Allocated Reduction Targets.

In Chapter 10.7 as a result of evaluating progress towards MAI and NIC taking into statistical uncertainty on nutrient input extra or remaining reduction were calculated. They are defined as:

- ***Extra reduction*** *is the margin to NIC (nutrient input ceiling) including the statistical uncertainty for a given country and basin combination.*
- ***Missing reduction*** *is defined additional input reduction needed to reach NIC including the statistical uncertainty for a given country and basin combination.*

Following the principles below allows for taking into account extra reduction in one Baltic Sea sub-basin a neighboring sub-basin with remaining reduction for fulfilling MAI and /or NIC.

10.8.2 Principles for accounting extra reductions

HELCOM HOD 56-2019 agreed (Outcome of the meeting, para. 3.26) on eight principles to be used for the reallocation of extra reduction to basins with missing reductions (HOD 56-2019 document 3-4).

The eight principles are:

1. Accounting should be based on countries individually

This implies that countries can plan and implement measures across basins at their own discretion as long as it results in conforming to nutrient input ceilings (NIC after accounting of extra reduction is performed.

2. Countries could claim accounting for missing reductions even if MAI is exceeded due to inputs from other countries

No country should need to wait for any other country before claiming themselves fulfilment of NIC.

3. Any relocation of measures should lead to at least the same environmental improvement as if national nutrient ceilings were reached

This is imperative for the good environmental status (GES) to be achieved eventually. Inevitably, using extra reductions will lead to less inputs than MAI as seen as a total for the Baltic Sea, but its distribution needs to be such that GES will be achieved everywhere.

4. The effect of extra reductions on neighboring basins with missing reductions should be estimated given that these are minor deviations from MAI

The Baltic Sea is a strongly perturbed system and hence, functioning quite different today compared to how it will function when measures been implemented and status approach GES. The whole calculation of MAI is taking this into account and when deviations to MAI are to be analysed, it should be done assuming that we are close to GES.

5. Accounting for extra reductions in connection with HELCOM nutrient reduction scheme follow-up assessments are to be performed in a uniform way supervised by RedCore DG

Accounting for extra reductions should be included in the regular NIC assessment using a common and harmonized methodology. RedCore DG is the forum that supervises development of methodology and, after appropriate approval, implementation of this in the assessment.

6. The Archipelago Sea phosphorus input reductions should be accounted in the Finnish NIC for Gulf of Finland

Already in BSAP 2007, Finland pointed out that models failed to separate the Archipelago Sea from Bothnian Sea and that this should be taken into account at a later stage. Also, in the 2013 revision of the nutrient reduction scheme, model limitations failed to address separate MAI calculations for the Archipelago Sea. However, in the context of accounting for extra reduction the nutrient inputs to Archipelago Sea can be taken into account separately from the remaining Bothnian Sea inputs.

7. In the context of extra reduction accounting reductions of phosphorus to Baltic Proper could be accounted as input reduction in Gulf of Finland

In the calculations of MAI, the most limiting targets affecting the distribution of MAI for phosphorus were the winter nutrient concentrations in the Baltic Proper. Strictly following the principle of "maximum" inputs, led to a situation where this gave an optimal solution resulting in removal of virtually all phosphorus inputs to the Baltic Proper and barely any reductions to Gulf of Finland. This solution clearly violated the principle of cost-efficiency so additional calculations based on cost functions for phosphorus input reductions were performed to distribute reductions between Baltic Proper and Gulf of Finland in a cost-efficient way. The obtained MAI results in conforming to phosphorus target in Baltic Proper, but in Gulf of Finland the resulting phosphorus concentrations will be significantly less than target. In line with this, it could be argued for states having phosphorus inputs both to Baltic Proper and Gulf of Finland, that *extra reductions* to Baltic Proper could be deducted from missing reductions in Gulf of Finland with 100% efficiency. However, one should keep in mind that the MAI for nitrogen to Gulf of Finland was determined from applying the HEAT approach, balancing nitrogen and phosphorus concentrations, so if MAI for phosphorus to Gulf of Finland is not achieved fully additional reductions on nitrogen inputs might be necessary.

8. Following the precautionary principle, re-allocation of extra reductions cannot be used to purposely increase inputs to a neighboring basin

Following the precautionary principle, extra reductions achieved in a specific basin cannot be used to purposely increase inputs to a neighboring basin beyond the national input ceilings for basins with reduction targets and beyond the inputs in the reference period 1997-2003 for basins without reduction targets, taking statistical uncertainties into account.

Possible use of extra reductions to increase inputs up to the national input ceilings within a basin are not within the scope of the re-allocation principles. This issue is to be further discussed.

Although the re-allocation methodology is based on current scientific knowledge and modelling, it comes with significant uncertainty and will sooner or later be subject of improvement. Therefore, it would be a risk for the environment to increase inputs to neighbouring basins based on this methodology. In addition, a prerequisite for the calculations here is an environment close to GES.

10.8.3 A method to match missing reductions with extra reductions

The BALTSEM model was used to find the combination of maximum allowable inputs (MAI) that would eventually lead to the good environmental status as quantified by the eutrophication status targets, taking into account the circulation and biogeochemical cycles of the Baltic Sea. The same model can be used as a basis for a method to match missing reductions with extra reductions.

The methodology takes the starting point from the state obtained when MAI is achieved and GES is reached, i.e., the model is run with inputs as given by MAI for a very long time. From this state, a series of model experiments are performed for which N and P inputs are systematically perturbed from MAI, that is different N and P input combinations for one basin at a time. In total about 160 simulations were performed providing a large data set on how the state change in the Baltic Sea basins depending on a nutrient input change to one basin.

To simplify the further analysis, a few assumptions were made:

1. assume that deviation from MAI is relatively small so that linear response can be expected
2. assume the analysis can be done separately for each single nutrient and basin combination

It would be straightforward to evaluate single cases that violate the two assumptions but presenting the results in an easily understandable way would be difficult.

We have to define terms dealing with the use of extra reduction:

- **Equivalent reduction** is input reduction to basin A that leads to the equivalent environmental benefit in basin B as 1 ton reduction to basin B. **NB!** It is a prerequisite that all other basins fulfil MAI.
- **Effective reduction** is the apparent input reduction in a basin resulting from extra reductions in another basin, in practice: the **extra reduction** divided by **equivalent reduction. NB!** Missing reductions will lead to "negative" effective reductions because lateral nutrient transports were taken into account when MAI-CART was calculated.

The equivalent reductions for phosphorus and nitrogen obtained from BALTSEM simulations are shown in Tables 10.9 and 10.10. Since nitrogen retention in the Baltic Sea sub-basins are generally higher than phosphorus retention, the equivalent reductions are in most cases higher for nitrogen than phosphorus. The uncertainty increases for distant basins when the effective reduction becomes really small and equivalent reduction high. It is chosen not to show values higher than 10 in the tables.

Table 10.9: Equivalent reductions on phosphorus. The table should be read as each row provides the necessary input reduction to the basins to the left to provide the equivalent environmental effect in the basins in the top row, e.g. 1.5 ton reduction to BOS gives the same effect in the BAP as 1 ton reduction directly to BAP. Note that the factors are valid on single basin pairs under condition that all other basins fulfill MAI.

	KAT	DS	BAP	BOS	BOB	GUR	GUF
KAT	1	4.0	–	–	–	–	–
DS	0.8	1	3.2	–	–	–	–
BAP	2.4	2.8	1	3.3	7.7	–	3.8
BOS	3.8	4.6	1.5	1	2.6	–	5.8
BOB	–	–	9.0	8.3	1	–	–
GUR	3.6	4.3	1.6	4.8	–	1	6.5
GUF	3.6	4.2	1.3	4.1	–	–	1

Table 10.10: Equivalent reductions on nitrogen. The table should be read as each row provides the necessary input reduction to the basins to the left to provide the equivalent environmental effect in the basins in the top row, e.g. 1.3 t reduction to GUR gives the same effect in the BAP as 1 t reduction directly to BAP. Note that the factors are valid on single basin pairs under condition that all other basins fulfill MAI.

	KAT	DS	BAP	BOS	BOB	GUR	GUF
KAT	1	7.3	–	–	–	–	–
DS	1.7	1	4.6	–	–	–	–
BAP	–	–	1	–	–	–	–
BOS	–	–	–	1	7.8	–	–
BOB	–	–	–	1.1	1	–	–
GUR	–	–	1.3	–	–	1	–
GUF	–	–	4.0	–	–	–	1

10.8.4 How to use the equivalent reductions tables

In Tables 10.11 there are examples on how the Tables 10.9 and 10.10 can be used to calculate the achieved effective reductions from extra reductions published in the NIC-2017 follow-up[10]. Exactly the same calculation should be used when relocating measures in developments of programmes of measures, but it may be on future expected extra reductions rather than achieved reduction.

It should be noted that not fulfilling NIC in one basin leads to that other basins may not reach GES as defined by the environmental targets because of the same reasons behind the equivalent reduction calculation. This implies that one cannot necessarily use the extra reduction to one basin to compensate for missing reduction in several basins. Thus, calculation is quite straightforward when analyzing single pairs of basins, one with extra reduction and one taking benefit of the effective reduction. In more general terms, it quickly becomes more complicated.

Table 10.11: Examples on accounting for extra reduction in the evaluation of NIC based on the NIC assessment on 1995-2017 data published in 2020 (see the link in footnote 10). Example: Germany total nitrogen (TN). Germany has reduced total nitrogen inputs with 2.539 tons TN below NIC to Danish Straits (taking into account uncertainty). The extra reduction is used to compensate for the remaining reduction requirement of 874 tons TN in Kattegat. According to the Table 10.10 the equivalent reduction between Danish Straits and the Kattegat is 1.7 – so 2,539 tons TN extra reduction in Danish Straits is equivalent to 1,495 tons TN (2,539/1.7) reduction in the Kattegat, or more than enough to compensate for the missing reduction to fulfil NIC. The remaining part of the extra reduction in Danish Straits together with extra reduction in Gulf of Riga is then used to compensate for missing reduction in Baltic Proper with 644 tons TN (2,539/4.6+120/1.3 tons TN).

10 https://helcom.fi/baltic-sea-action-plan/nutrient-reduction-scheme/national-nutrient-input-ceilings/

Germany Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction	62	142			120	2539	
Missing reduction to fulfill NIC			10 731	242			874
Used extra reduction			644				1 495
Missing reduction after used extra reduction	0	0	10 087	242	0	0	0

Extra reduction in DS is used to compensate for the remaining reduction requirement of 874 tons TN in KAT.

Extra reduction in DS and GUR is used to reduce the remaining reduction requirements in BAP with 644 tons.

Denmark Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction	74	272		52	128	7 566	4 613
Missing reduction to fulfill NIC			209				
Used extra reduction			1 755				
Missing reduction after used extra reduction	0	0	0	0	0	0	0

Extra reduction in DS (and GUR and GUF) is used to compensate for the remaining reduction requirement of 209 tons TN in BAP.

Denmark Total Phosphorus	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction						222	103
Missing reduction to fulfill NIC			23				
Used extra reduction			70				
Missing reduction after used extra reduction			0				

Extra reduction in DS is used to compensate for the remaining reduction requirement of 23 tons TP in BAP.

Finland Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction		3 135	127		70	19	20
Missing reduction to fulfill NIC	419			1 544			
Used extra reduction	403						
Missing reduction after used extra reduction	16	0	0	1 544	0	0	0

Extra reduction in BOS is used to reduce the remaining reduction requirements in BOB with 403 tons TN.

Finland Total Phosphorus	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction	60						
Missing reduction to fulfill NIC		103		346			
Used extra reduction		7					
Missing reduction after used extra reduction	0	96		346			

Extra reduction in BOB is used to reduce the remaining reduction requirements in BOS with 7 tons TP.

Lithuania Total Phosphorus	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction					69		
Missing reduction to fulfill NIC			271				
Used extra reduction			45				
Missing reduction after used extra reduction			226		0		

Extra reduction in GUR is used to reduce the remaining reduction requirements in BAP with 45 tons TP.

Latvia Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction					7 511		
Missing reduction to fulfill NIC	12	60	5 540	121		5.9	11
Used extra reduction			5 837				
Missing reduction after used extra reduction	12	60	0	121	0	5.9	11

Extra reduction in GUR is used to compensate for the remaining reduction requirement of 5,540 tons TN in BAP.

Poland Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT
Extra reduction	20						
Missing reduction to fulfill NIC		30	34 314	388	56	195	286
Used extra reduction		19					
Missing reduction after used extra reduction	0	11	34 314	388	56	1950	286

Extra reduction in BOB is used to reduce the remaining reduction requirements in BOS with 19 tons TN.

Sweden Total Nitrogen	BOB	BOS	BAP	GUF	GUR	DS	KAT

Extra reduction	1652	6 745			91	750	4 886
Missing reduction to fulfill NIC			7 571	11			
Used extra reduction			234				
Missing reduction after used extra reduction	0	0	7 337	11	0	0	0

Extra reduction in DS and GUR is used to reduce the remaining reduction requirements in BAP with 234 tons TN.

Sweden Total Phosphorus	**BOB**	**BOS**	**BAP**	**GUF**	**GUR**	**DS**	**KAT**
Extra reduction		303				20	
Missing reduction to fulfill NIC	44		407				32
Used extra reduction	94		208				23.9
Missing reduction after used extra reduction	0		199				8.1

A proportion of extra reduction in BOS is used to compensate for the remaining reduction requirement of 44 tons TP in BOB.

Extra reduction in BOB and DS is used to reduce the remaining reduction requirements in BAP with 208 tons TP.

Extra reduction in DS is used to reduce the remaining reduction requirements in KAT with 24 tons TP.

10.9. Mathematical description of the Mann-Kendall trend test

Trend analysis of a time series of length *T* consisting of yearly inputs of nutrients can be done by applying Mann-Kendall's trend test (Hirsch et al. 1982). This test method is also known as Kendall's τ (Kendall 1975). The aim of this test is to show if a downward or an upward trend over the period of *T* years is statistically significant or if the time series merely consists of a set of random observations of a certain size. The Mann-Kendall's trend test has become a very effective and popular method for trend analysis of water quality data.

The Mann-Kendall's trend test is a non-parametric statistical method, which means that the method has fewer assumptions than a formal parametric test method. The data do not need to follow a Gaussian distribution like in ordinary linear regression but should be without serial correlation. Furthermore, the method tests for monotonic trends and not necessarily linear trends, and it thus tests for a wider range of possible trend shapes. Monotonic trends are an either downward or upward tendency without any specific form. If the time series data are Gaussian distributed and the trend is actually linear, the power of the Mann-Kendall trend method is slightly lower than that of ordinary linear regression due to the accommodation of the slightly less restrictive assumptions.

Let $x_1, x_2, \ldots, x_n$ be yearly inputs of total nitrogen or total phosphorus for the years $1, 2, \ldots, n$. The null hypothesis of the trend analysis is that the *n* yearly data values are randomly ordered. The null hypothesis is tested against the alternative hypothesis that the time series has a monotonic trend. The Kendall statistic is calculated as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i), \qquad (10.41)$$

where

$$.\,\mathrm{sgn}(x)=\begin{cases}1 & x>0\\ 0 & x=0\\ -1 & x<0\end{cases}.$$

If either x_j or x_i is missing, then $\mathrm{sgn}(x_j - x_i) = 0$ per definition.

The trend is tested by calculating the test statistic

$$.\,Z=\begin{cases}\dfrac{S-1}{(\mathrm{var}(S))^{\frac{1}{2}}} & S>0\\ 0 & S=0\\ \dfrac{S+1}{(\mathrm{var}(S))^{\frac{1}{2}}} & S<0\end{cases}.$$

The variance of *S* under the hypothesis of no trend is calculated as

$$\mathrm{var}(S)=\frac{n(n-1)(2n+5)}{18}, \qquad (10.42)$$

where n is the number of loads in the time series.

A positive *S*-value indicates an upward trend and a negative value a downward trend. When both a downward and an upward trend are of interest (a two-sided test), the null hypothesis of randomly ordered data is rejected when the numerical value of *Z* is less than the $(\alpha/2)$-percentile or greater than the $(1-\alpha/2)$-percentile (two-sided test) in the Gaussian distribution with mean value 0 and variance 1. A one-sided test can be carried out as well. The significance level α is typically 5%. The reason for evaluating *Z* in the standard Gaussian distribution is the fact that *S* under the null hypothesis is Gaussian distributed with mean value 0 and variance $\mathrm{var}(S)$ for $n \to \infty$. The Gaussian approximation is very good if $n \geq 10$ and fair for $5 \leq n \leq 10$.

An estimate of the trend β (a slope estimate) can be calculated by assuming a constant (linear) trend during the period and presenting the estimate as change per year. Hirsch et al. (1982) introduced Theil-Sen's slope estimator: for all pairs of observations (x_i, x_j) with $1 \leq j < i \leq n$ $1 \leq j < i \leq n$ $1 \leq j < i \leq n$ calculate

$$d_{ij}=\frac{x_i - x_j}{i-j}. \qquad (10.43)$$

Then the slope estimator is the median value of all the d_{ij}-values and is a robust non-parametric estimator and will generally work for time series with serial correlation and non-Gaussian distributed data. A $100(1-\alpha)$% confidence interval for the slope can be obtained as follows (Gilbert 1987):

Choose the desired confidence level α α α (1, 5 or 10%) and apply

$$,\,Z_{1-\alpha/2}=\begin{cases}2{,}576 & \alpha=0.01\\ 1{,}960 & \alpha=0.05\\ 1{,}645 & \alpha=0.10\end{cases},$$

in the following calculations. A confidence level of 5% is standard.

Calculate

$$C_\alpha = Z_{1-\alpha/2} \cdot (\mathrm{var}(S))^{\frac{1}{2}}. \quad (10.44)$$

Calculate

$$M_1 = \frac{N - C_\alpha}{2}, \quad (10.45)$$

and

$$M_2 = \frac{N + C_\alpha}{2}, \quad (10.46)$$

where

$$N = \frac{1}{2} n(n-1).$$

Lower and upper confidence limits are the M_1th largest and the $(M_2 + 1)$th largest value of the *N* ranked slope estimates d_{ij}.

A non-parametric estimate for the intercept α can be calculated according to Conover (1980). The estimator is calculated as

$$\hat{\alpha} = M_x - \hat{\beta} \cdot M_i, \quad (10.47)$$

where M_x is the median value of all the data in the time series and M_i is the median value of $1,2,\ldots,n$ $1,2,\ldots,n$ $1,2,\ldots,n$.

If the time series consists of data from different seasons (i.e. monthly loads), Mann-Kendall's seasonal trend test may be applied (Hirsch and Slack 1984). This is done by calculating the test statistic *S* for every season separately. Then the test statistic for the whole time series is equal to the sum of each of the seasonal test statistics. We refer to Carstensen and Larsen (2006) for a detailed mathematical description of the seasonal trend test.

11. Quality assurance of water chemical analysis

11.1. Specific aspects of quality assurance

The Article 3, paragraph 5, of Helsinki Convention states that the Contracting Parties shall ensure that measurements and calculations of emissions from point sources to water and air, and of inputs from diffuse sources to water and air, are carried out in a scientifically appropriate manner in order to assess the state of the marine environment of the Baltic Sea Area and ascertain the implementation of the Convention. Additionally, HELCOM 16 has adopted a quality assurance policy, according to which:

1. Contracting Parties acknowledge that only reliable information can provide the basis for effective and economic environmental policy and management regarding the Convention area;
2. Contracting Parties acknowledge that environmental information is the product of a chain of activities, constituting programme design, execution, evaluation and reporting, and that each activity has to meet certain quality requirements;
3. Contracting Parties agree to quality assurance requirements be set for each of these activities;
4. Contracting Parties agree to make sure that suitable resources are available nationally (e.g. ships, laboratories) in order to achieve this goal;
5. Contracting Parties fully commit themselves to follow the guidelines, protocols etc. adopted by the Commission and its Committees in accordance with this procedure of quality assurance.

Basic principles of quality assurance are also referred to in the HELCOM Monitoring and Assessment Strategy adopted by the 2013 HELCOM Copenhagen Ministerial Meeting.

Detailed description of general aspects of quality control and assurance (QA/QC) is described in the HELCOM COMBINE Manual, Part B. General Guidelines on Quality Assurance for Monitoring in the Baltic Sea, available on the HELCOM website. Technical specifications for chemical analysis and monitoring of water status in relation to the water framework directive can be found in the QA/QC directive (Commission Directive 2009/90/EC) as well.

The Contracting Parties are responsible for the quality assurance of the data submitted to the HELCOM PLC-Water database.

The laboratories providing data to PLC process should have a quality assurance system that follows the requirements of ISO/IEC 17025 (EN/ISOIEC 2005). Participating laboratories are encouraged to endeavour the obtainment of official accreditation for variables on which they report data in accordance with PLC.

All institutes/laboratories should participate in regular (annual) inter-laboratory comparison tests at relevant levels of nutrients and metals. Also, the laboratories should use appropriate reference materials for internal quality control and assurance. The use of certified reference material is encouraged.

All institutes/laboratories performing the collection of samples to PLC have to be careful in order to get representative and uncontaminated samples. Guidance on sampling can be found in WMO Guidance 168 chapter 7.3 and ISO 5667 standards on Water Quality – Sampling. Different aspects of sampling are covered in different parts of the ISO standard.

All Contracting Parties have to nominate a national QA contact person responsible for PLC quality assurance.

The national QA contact person will help in ensuring comparability and reliability of analytical data provided by the laboratories in their country. The national QA contact person should:

- provide information about the PLC-Water at the national level and guarantee that information on the PLC Guidelines and the QA section of the COMBINE Manual reach the laboratories submitting PLC data;
- co-operate nationally with the laboratories participating in the PLC-Water data collection and

- collect the mandatory information (see end of Chapter 11.4) from laboratories and report them to PLC-8 Project by the end of March 2022.

11.2. Minimum quality assurance by the Contracting Parties

The COMBINE Manual for marine monitoring in HELCOM describes quality assurance as covering all aspects of analytical investigation, and includes the following principal elements (last updated 16 November 2017):

- Knowledge of the purpose of the investigation is essential to establish the required data quality;
- Provision and optimization of appropriate laboratory facilities and analytical equipment;
- Selection and training of staff for the analytical task in question;
- Establishment of definitive directions for appropriate collection, preservation, storage and transport procedures to maintain the integrity of samples prior to analysis;
- Use of suitable pre-treatment procedures prior to analysis of samples, to prevent uncontrolled contamination or loss of the determinant in the samples;
- Validation of appropriate analytical methods to ensure that measurements are of the required quality to meet the needs of the investigations;
- Conduct of regular intra-laboratory checks on the accuracy of routine measurements, by the analysis of appropriate reference materials, to assess whether the analytical methods are remaining under control, and the documentation and interpretation of the results on control charts;
- Participation in inter-laboratory quality assessments (proficiency testing schemes, ring-tests, training courses) to provide an independent assessment of the laboratory's capability of producing reliable measurements and
- The preparation and use of written instructions, laboratory protocols, laboratory journals, etc., so that specific analytical data can be traced to the relevant samples and vice versa.

As minimum quality assurance in PLC, the Contracting Parties have to consider:

- Monitoring water level and discharge, and establish water level–discharge relationships;
- Guidance on water sampling;
- Demands on sample storage and preservation;
- Demands on laboratory performance and
- Guidance on compiling and assessing data, and reporting data including data on quality assurance.

11.3. Inter-laboratory comparison tests on chemical analyses

All institutes/laboratories should participate in regular (annual) inter-laboratory comparison tests. It is recommended to perform the inter-laboratory comparison tests according to the ISO/IEC Guide 17043. Participation in inter-laboratory comparison tests is obligatory for accredited laboratories as well as for laboratories that have a quality assurance system that follows the requirements of ISO /IEC 17025.

For the inter-laboratory comparison tests that the laboratories participate in, it is essential that:

- The test material is as similar as possible to the matrices (e.g. riverine water and/or wastewater) to be analysed within PLC-Water;
- Different concentration levels of each substance in each matrix are included in the test and they are adequate to the concentrations of the samples collected in the PLC-Water and
- The participating laboratories use the analytical methods, which are intended to apply for the PLC-Water.

Inter-laboratory comparison tests can be found on the Internet. Here are some examples:

- QUASIMEME: http://www.quasimeme.org
- Eurofins (for wastewater): http://www.eurofins.dk/dk/milj0/vores-ydelser/praestationspr0vning-milj0/proficiency-testing-environment.aspx

- EPTIS: http://www.eptis.bam.de
- Department of Applied Environmental Science. Stockholm University: http://enviropro.itm.su.se
- Proftest SYKE. Finnish Environment Institute: http://www.syke.fi/proftest/en

11.4. The PLC-8 inter-laboratory comparison test on chemical analyses

An inter-laboratory comparison test was conducted in 2020-2021 within the PLC-8 project in order to have laboratories from each of the Contracting Parties participating in the same test study. The aim was to get an overall picture of the quality of the data from chemical analyses and of the comparability of data in PLC.

The interlaboratory comparison study was performed with statistical analysis with outlier test according to ISO 5725-2 and Youden plots. The study included nutrients and metals in riverine water and wastewater. In total 22 laboratories representing all Contracting Parties participated with either analyses of nutrients or metals or both in either riverine water and/or wastewater.

In the report on the inter-laboratory comparison test (Lassen & Larsen 2022) it is concluded that:

- Generally the analytical quality is good and comparable between the laboratories with a few exceptions;
- Generally the analytical quality for most parameters appear to be quite stable over the years. Higher relative values of the total variation can be explained by lower concentrations;
- Deviation on metals was higher than deviation on nutrients especially for freshwater;
- NO_2-N showed good recovery in freshwater which is an improvement compared to the former inter-laboratory testing. However, the recovery in wastewater was below the expected value due to instability of the samples;
- According to the recommendation from the former inter-laboratory testing samples for both nutrients and metals have been spiked. The outcome was that none of the laboratories have reported data below detection limits. Further, the concentration levels have been reduced for some metals and a concentration range have been introduced as a guideline for the laboratories.

11.5. Validation of PLC-Water chemical data

The national QA contact persons are responsible for validation of the chemical data to be submitted to the HELCOM PLC-Water Database. The validation by the Contracting Parties of the laboratory analysis results should be carried out at the national level based on information on:

- Accreditation status (strongly advised for laboratories);
- Use of quality assurance system that follows the requirements of EN ISO/IEC 17025 (strongly advised for laboratories);
- Measurement uncertainty, estimated as expanded uncertainty, see Lassen & Larsen (2021) (mandatory for laboratories);
- Limit of quantification (mandatory for laboratories);
- Use of reference material (recommended for laboratories);
- Use of control charts (mandatory for laboratories) and
- Participation in laboratory inter-comparison tests (strongly advised for laboratories).

The measurement uncertainty has to be estimated as combined standard uncertainty, which means that reproducibility within a laboratory and repeatability between laboratories are included in the calculation of the uncertainty and the further calculation of expanded uncertainty. Further explanation can be found in Magnusson et al. (2004).

Measurement uncertainty can be calculated with a new software tool – Mukit (measurement uncertainty kit) which is based on the Nordtest method (Näykki et al. 2012). This free software is available in the website of the SYKE calibration laboratory (ENVICAL): http://www.syke.fi/envical/en.

Missing mandatory information will be flagged in the PLC-Water database.

11.6. Recommended limits of quantification (LOQ)

The levels of quantifications should in principle be lower than the expected concentrations in order to have as few observations as possible below LOQ (to avoid inclusion of concentrations estimated on basis of LOQ in the load calculation). As a guidance, in Table 12.1 the levels of quantification not to be exceeded are suggested.

Table 11.1 Recommended LOQ (should be seen as a guidance level Suggested limit of quantification (LOQ)).

Parameter	River water	Wastewater
BOD	0.5 mg l^{-1}	
TOC	0.5 mg l^{-1}	
NH4-N	10 µg l^{-1}	20 µg l^{-1}
NO_{23}-N	20 µg l^{-1}	40 µg l^{-1}
N_{tot}	50 µg l^{-1}	200 µg l^{-1}
PO_4-P	5 µg l^{-1}	20 µg l^{-1}
P_{tot}	10 µg l^{-1}	50 µg l^{-1}
Cd	0.01 µg l^{-1}	0.5 µg l^{-1}
Cr	0.05 µg l^{-1}	1.0 µg l^{-1}
Cu	0.1 µg l^{-1}	10 µg l^{-1}
Ni	0.05 µg l^{-1}	1.0 µg l^{-1}
Pb	0.05 µg l^{-1}	1.0 µg l^{-1}
Zn	0.5 µg l^{-1}	5 µg l^{-1}
Hg	0.005 µg l^{-1}	0.5 µg l^{-1}

Comparing the recommended LOQ above with the corresponding LOQ requirements in the Water Framework Directive according to the QA/QC directive (with LOQ ≤ 0.33 • EQS[11]) the HELCOM LOQ recommendations are lower for those metals where it is possible to compare (cadmium, nickel and lead). It must be emphasized that the LOQs in WFD are set in order to determine if the water quality criteria are met, while in the PLC they are set in order to obtain as many observations > LOQ as possible in order to estimate the load as precisely as possible.

11.7. Values under the limit of quantification

It is important to distinguish between the limit of detection (LOD – the lowest detectable amount of a compound) and the limit of quantification (LOQ – the lowest quantifiable amount of a compound). LOD is the smallest amount or concentration of an analyte in the test sample that can be reliably distinguished from zero. LOQ is a performance characteristic that marks the ability of an analytical method to adequately "quantify" the analyte.

11 EQS = Environmental Quality Standard; EQS-Directive 2013/39/EU

LOQ is in the WFD QA/QC directive (Commission Directive 2009/90/EC) defined as a stated multiple of LOD. There has been much diversity in the way in which LOD of an analytical system is defined. Most approaches are based on multiplication of the within-batch standard deviation of results of blanks by a factor. Further information can be found in the ISO/TS 13530 or in the chapter B.4.2.3. of the HELCOM Combine Manual.

In the PLC-8 the LOQ is used to assign a numeric value when handling low-level data. The use of LOQ instead of LOD is in accordance with the directive on quality assurance of water chemical analyses (2009/90/EC).

If measured concentrations are below LOQ, the estimated concentration should be calculated using the equation:

$$\text{Estimation} = ((100\%-A) \bullet \text{LOQ})/100 \qquad (11.1)$$

Where

A = percentage of samples below LOQ[12].

If >50% of the observations are <LOQ then use LOQ/2 as the estimation to avoid zero inputs.

11.8. Technical notes on the determination of variables in rivers and wastewater

This chapter includes technical notes for determination of some variables. The well tested and documented European or international standard methods (ISO) or methods based on these standards are highly recommended to use.

Particles can give rise to light-scattering effects that result in interferences in all photometric nutrient analyses. This bias can be avoided by measuring the sample before addition of the color reagent, or by filtration or centrifugation where this does not cause contamination.

Particularly in the case of nutrients and metal analysis, a satisfactory blank control is necessary. Therefore, it is important to control the blank daily, for reproducibility and constancy over a longer time. The blank should include all analytical pre-treatment procedures, including the addition of the same quantities of chemical substances as for the samples.

In all analytical work, water of sufficiently high purity shall always be used when needed. High purity water can be distilled or deionized water, “MilliQ-water” or comparable. When very high purity is needed the water might need treatment in several steps, e.g. double or triple distilled water. More information on various degrees of water purity and testing of the purity may be found in ISO 3696:1987.

For calibration purpose in general, a working standard should be prepared from a stock standard solution for every batch of samples.

Apart from manual methods, various automated methods are in use. The analyst has to be aware of the effects of the different analytical conditions in automated analysis that might affect accuracy.

Biological Oxygen Demand (BOD)

[12] The QA/QC directive says that when the amount of a measure and is below LOQ the result shall be set to half the value of LOQ in the calculation of annual average values. In PLC it is not annual average values that are calculated but loads, which means that it is two different situations and therefore use of different methods makes sense.

For the determination of BOD in wastewater samples it is strongly recommended to follow the ISO 5815:2019 "Water quality - Determination of biochemical oxygen demand after n days (BODn) - Part 1: Dilution and seeding method with allylthiourea addition", and in surface water samples "- Part 2: Method for undiluted samples".

ISO 5815-1:2003 is applicable to all waters having biochemical oxygen demands greater than or equal to 3 mg/l of oxygen (the limit of quantification) and not exceeding 6,000 mg/l of oxygen.

ISO 5815-2:2003 specifies determination of the biochemical oxygen demand in undiluted samples of water. It is applicable to all waters having biochemical oxygen demands greater than or equal to 0.5 mg/l of oxygen (the limit of quantification) and not exceeding 6 mg/l of oxygen.

BOD should be reported as either BOD_5 or BOD_7. If BOD is reported as BOD_7 it will be stored in the HELCOM PLC-Water database, and for PLC assessments a conversion factor $BOD_5 = BOD_7 /1.15$ will be used for converting to BOD_5.

Nutrients

Sample bottles of plastic or glass can be used. It is recommended to use new clean plastic bottles. Every new batch of plastic bottles need to be verified that they are clean by filling them with water of high purity, and after several days analyse the water for potential nutrients. If plastic bottles are reused or if glass bottles are used, they need to be cleaned e.g. by rinsing them in hydrochloric acid (ca 2 mol l^{-1}) and thereafter rinsing them carefully with high purity water. The cleaning procedure has to be verified regularly. The samples should be stored in cold (4 °C) and dark from sampling until analysis.

Orthophosphate

The molybdenum blue method with reduction by ascorbic acid is recommended for determination of orthophosphate.

The analyses should be carried out as soon as possible. Samples that are not analysed within one day have to be preserved. The samples should be stored in cold (4 °C) and dark.

Total Phosphorus

Digestion with potassium peroxodisulfate (potassium persulfate) is recommended. For analyses of wastewater with a high content of organic matter a more powerful oxidation method (with nitric-sulfuric acid) may be necessary. A quality control sample can be prepared of e.g. Na-β-glycerophosphate or thiamine pyrophosphate chloride.

The samples should be stored in cold (4 °C) and dark and should be preserved as fast as possible (within one day).

Ammonium

Samples for determination of ammonia should <u>not</u> be preserved. The indophenol blue method is recommended. High concentrations of ammonium can be determined by sample dilution. The Nessler method is not recommended.

The analyses should be carried out as soon as possible and within one day on unpreserved samples. The samples should be stored in cold (4 °C) and dark.

Nitrate

The cadmium reduction method is recommended for the analyses of nitrate. It is necessary to check the capacity of the reductor (at least 90 % exchange) systematically. The salicylate method is not recommended because of many interfering effects.

The analyses should be carried out as soon as possible. Samples that are not analysed within one day have to be preserved. The samples should be stored in cold (4 °C) and dark.

Total Nitrogen

Total nitrogen in river water can be analysed by a method based on oxidation with potassium peroxodisulfate followed by reduction of nitrate with a cadmium reductor (cf. Nitrate above) (ISO 11905-1:997). Especially for analyses of industrial wastewater the modified Kjeldahl method with Dewarda´s alloy or the Kjeldahl method and the determination of nitrate separately is recommended.

The quality control sample can be prepared of e.g. EDTA, glycine or 4-nitroaniline.

Metals

The basis for reliable measurements at low metal concentrations in water is to avoid contamination when handling the samples in all the different stages from sampling to the analysis of the samples.

For sampling of riverine water for measurement of metals except mercury (for Hg see below) bottles of polypropylene, polyethene, polytetrafluoroethylene (PTFE) or resistant glass (e.g. Pyrex) are recommended. The bottle and the cap should be prepared from colourless material.

Bottles, glass and plastic ware and containers have to be cleaned by soaking them in nitric acid at least for one day and then be rinsed with water of high purity at least three times. For determination of ultra trace level it is necessary to follow more extensive cleaning procedures. If the laboratory collects both river and wastewater it is necessary to use separate samplers and bottles for sampling at low levels and high levels of metals. It is essential to maintain a clean environment during analyses. All chemicals should be of highest possible purity and high purity water shall be used for preparation of solutions. If low content of metals are to be determined, a field blank shall be analysed as well.

Samples that contain particulate material shall be digested with nitric acid in a closed vessel under pressure.

For measurement of metals, atomic absorption spectroscopy (AAS flame or flameless), inductive plasma-optical emission (ICP-OES) or inductive coupled plasma-mass spectroscopy (ICP-MS) can be used. For measurement of low contents of metals in rivers ICP/MS or anodic stripping voltammetry (ASV) are highly recommended.

Calibration is important to carry out correctly. Commercial stock solutions are available for preparation of calibration solutions. The calibration should be performed with a blank solution and 4-5 different calibration solutions for an appropriate concentration range. Need for recalibration has to be checked by measuring a quality control sample once per 20 determinations. In order to reduce potential effects of chemical and physical interferences (i.e. high contents of chlorides) the method of standard addition may be applied. Interference effects can also be reduced by gradual dilution or by addition of different chemical modifiers to the sample. If both high and low contents of metals are determined in the same batch, the high-level samples should preferably be analysed after low level samples. If this is not possible there should be a blank sample between the samples in order to prevent the memory effect.

Mercury

Good quality of plastic or resistant glass bottles should be used for collecting of samples for measurement of mercury.

The quality of the reagents used for the analyses of mercury should be controlled.

Mercury can be detected with cold vapour atomic absorption or fluorescence spectroscopy. For measurement of low contents of mercury (pg l^{-1}) it is recommended to enrich the mercury on a gold trap before analysis by fluorescence technique.

The control chart on blanks has to be used to enhance the detection of contamination during analyses.

Total Organic Carbon (TOC)

For the determination of TOC in surface and wastewater samples it is strongly recommended to follow the standard ISO 8245:1999 "Water quality -- Guidelines for the determination of total organic carbon (TOC) and dissolved organic carbon (DOC)", which is identical to EN 1484:1997

Further information on determination on chemical variables is described in Annex B-17 of the HELCOM COMBINE Manual.

12. Annual PLC reporting requirements

According to the **HELCOM Recommendation 37-38/1** "Waterborne pollution input assessment (PLC-WATER)" (HELCOM, 2016a), the total waterborne inputs to the Baltic Sea should be quantified annually. Hence, every year the Contracting Parties should quantify and report the total input to the Baltic Sea from:

- Monitored rivers (Chapter 4);
- Unmonitored areas (Chapter 7);
- Point sources (Chapter 5) which *discharge directly* into the Baltic Sea and
- Monitoring stations (chemical and hydrological).

Transboundary riverine nutrient inputs should also be reported annually to follow-up progress towards nutrient input ceilings set for each Contracting Party to the Helsinki Convention and for countries in the Baltic Sea catchment area which are non-Contracting Parties by the Baltic Sea Action Plan. Also, provisional input ceilings have been proposed for transboundary river basins (Gustafsson & Svendsen, 2021).

The inputs should be reported separately for each monitored river catchment, transboundary parts of monitored rives, unmonitored parts of river catchments and other unmonitored areas of each Baltic Sea sub-basin (Figure 2.5) (the sub-basin division is described in Chapter 2.6).

The reporting of data on monitored rivers and unmonitored areas is based on the parameters referenced to sub-catchments (Figures 2.6 and 2.7). Monitored sub-catchments are parts of river basins upstream from the monitoring stations within the national borders. All sub-catchments are to be coded.

Transboundary areas are upstream parts of the river basins located within the borders of countries without the river mouth. Transboundary inputs and their parameters are reported separately by the receiving country (Figure 2.8). It is important to emphasize that the parameters characterizing loads from the transboundary sub-catchments are to be reported as they are at the border. Despite that the loads from the transboundary sub-catchments are reported by receiving (downstream) country, the country responsible for the transboundary loads is obliged to verify the data in the PLC-water database and approve them.

The data on inputs from the whole transboundary river basin should also be reported by the country where the river mouth is located. This report has geographical reference to a point located in the river mouth and does not have polygonal geographical reference.

Unmonitored sub-catchments represent unmonitored rivers, unmonitored parts of monitored rivers and other areas where reported parameters are estimated by modelling approach.

Before and during reporting the Contracting Parties should perform quality assurance (Chapter 11) and data validation (Chapter 10). Selected quality parameters should be reported (Chapter 12.6).

All data have to be reported electronically to the PLC-water database PLUS according to the reporting format prepared by the Data Manager (see the Annex 2).

Annex 4 contains a user guide on reporting and quality assuring of the annual and periodic data.

12.1. Reporting of the inputs from monitored sub-catchments (monitored rivers)

Contracting Parties should annually report parameters of the monitored sub-catchments according to the Table 1.1 in Chapter 1. Contracting Parties should report the input calculation method(s) and equations applied for quantifying river flow and load. It is recommended to use one of the input calculation methods described in Chapters 4 and 5:

- Daily flow and daily concentration (interpolated);
- Annual input (in t a^{-1}) calculation based on daily flow and daily concentration regression;
- An alternative input calculation method (country specific).

If alternative input calculation methods have been used, they need to be described in detail.

All information and data that have to be reported electronically are summarized in the Annex 2.

Contracting Parties should use their own estimates of retention if specific data about the local conditions are available. Where Contracting Parties do not follow the methods in these guidelines the method should be described including the calculation methods used, and relevant data and information must be reported (see also Chapter 9).

12.2. Reporting of the input from unmonitored areas

The annual input from unmonitored areas should be reported every year as a total input from the Contracting Party to each Baltic Sea sub-basin. Alternatively, the unmonitored part of monitored rivers can be reported individually. Parameters which should be annually reported for the unmonitored sub-catchments are listed in the Table 1.1 in Chapter 1. Chapter 7 describes methods for estimating inputs from unmonitored areas on the basis of:

- Model results;
- Land use within these areas and
- Extrapolating the knowledge about neighboring rivers under similar conditions.

The method(s) used to estimate the input from unmonitored areas should be reported. If Contracting Parties use an alternative method, the country specific methods should be described in detail when reporting.

Diffuse sources discharging directly into the sea must be reported as part of the inputs from unmonitored areas.

All information and data that have to be reported electronically are summarized in the Annex 2.

12.3. Reporting of the inputs from direct point sources

Contracting Parties are to quantify and report annually the inputs from point sources discharging directly into the Baltic Sea. Point source categories are municipal wastewater treatment plants (MWWTP), industrial plants (INDUSTRY) and aquaculture plants (AQUACULTURE). A guidance to identify direct point sources is given in Chapter 2.5 and direct (point) sources are defined in the Annex 1. Reporting parameters are listed in Table 1.1 in Chapter 1 with the remark that flow parameter might not be applicable for marine based aquaculture. Point sources discharging directly to the sea should preferably be reported individually but can be reported as a sum for every Baltic Sea marine sub-basin for municipal effluents, industrial effluents and aquaculture plants, respectively.

Chapter 5 describes how the discharges from point sources are quantified, and these methods should be used when quantifying discharges from point sources entering directly to the Baltic Sea. The Contracting Parties are urged to report individually by plant, but it is possible to report aggregated by point source category by marine sub-basin. Quantification of discharges is described in Chapter 5.1 for MWWTP, Chapter 5.2 for INDUSTRY and Chapter 5.3 for AQUACULTURE.

In addition to reporting of inputs from direct point sources, also the methods used for estimating the discharges should also be reported. If the Contracting Parties apply any alternative (country specific) method, a detailed description of the calculation method should be reported.

All information and data that have to be reported electronically are summarized in the Annex 2.

12.4. Reporting of the monitoring stations

Information on monitoring stations is substantial for data quality verification, including their spatial parameters. Information on monitoring stations consists of background data characterizing the type of monitoring station (chemical, hydrological) as well as data used to compute the flow. The reported data also sets the link between monitoring stations and monitored sub-catchment.

Flow data should be carried out according to the recommendations given in Chapter 3. If the Contracting Parties use an alternative method, it should be described in detail when reporting. Countries should report information on monitoring stations as given in the Annex 2.

12.5. Retention of nutrients

Data on retention of nutrients is also a part of the annual reporting. The applied estimation method should be reported together with retention figures. Methods for calculating retention are described in Chapter 9. The parameters to be reported are given in the Table 1.2. The retention parameters should be reported individually for all sub-catchments to monitored rivers and for unmonitored areas by sub-catchment on the territory of the Contracting Party utilizing the sub-catchment's structure described in the Chapter 2 and used for both annual and periodic reporting.

All information and data which have to be reported electronically are summarized in the Annex 3. The methods used to identify retention should also be reported to assure data transparency and compatibility. Since the nutrient retention rate may vary considerably during a year, the retention should be reported as a yearly or longer than yearly average.

12.6. Reporting on quality assurance

When reporting annual PLC data the Contracting Parties should report their quality assurance criteria as:

- LOQ;
- Total uncertainty (in the field ”expanded uncertainty” of the reporting template);
- Number of samples below LOQ.

The Contracting Parties should estimate and report on the estimated total uncertainty on their reported annual load and flow data according to Chapter 10.4. The estimated total uncertainty on the total input per sub-catchment should be reported as a minimum.

12.7. Reporting spatial data

Most of spatial parameters of the PLC water data are part of annual reporting, except for coordinates of indirect point sources. Spatial parameters of the PLC water data consist of coordinates of the point features such as direct and indirect point sources, monitoring stations and transboundary river mouths and spatial borders of polygonal monitored and unmonitored sub-catchments, including transboundary and border rivers.

Spatial parameters of point features are reported in the format of coordinates as a part of background information. The coordinates should be reported in decimal degrees in the WGS-84 coordinate system.

Spatial parameters of polygonal features are to be reported in ArcGIS shape format contemporary with periodic reporting. Verification and reporting of spatial data on sub-catchments include the update of geometrical parameters of the polygons and update of their attributes. The list of mandatory attributes of the polygonal feature is given in the table 12.1.

Table 12.1. The list of attributes mandatory attributes reported for spatial data on sub-catchments.

	Attribute name	Description
1	SourceCode	The code of sub-catchment according to PLC-water database
2	NAME	Name of the river basin or coastal area
3	SubBasin	Sub-basin of the Baltic Sea (see Chapter 2.6)
4	COUNTR	Abbreviation of the country within the Baltic Sea catchment area
5	COMMENT	Free comment to set the link with national databases
6	MONITORING	M-monitored, U-unmonitored, N-not reported
7	TRANSBOUND	Abbreviation of receiving country for the load from transboundary sub-catchment
8	DATA_SOURCE	Reporting period (e.g. PLC-8)

To facilitate reporting of spatial data, the PLC data manager provides national data reporters with national datasets from the latest reporting period. The national data reporters are requested to verify and make corrections to the dataset or re-report the whole national dataset in case of substantial changes in the national monitoring programme. Please note that changes in the polygonal data are to be harmonized with related updates of coordinates in the background information for monitoring stations.

13. Periodic PLC reporting requirements

According to **HELCOM Recommendation 37-38/1** "Waterborne pollution input assessment (PLC-WATER)", in addition to annual quantification of the total waterborne inputs to the Baltic Sea as described in Chapter 12, an assessment of the inputs from different sources within the catchment area of the Baltic Sea, should be carried out periodically in accordance with the decision by the Contracting parties.

The following should be reported in order to quantify sources of inputs to inland surface waters (the so-called **source-oriented approach**):

1. Municipal wastewater treatment plants (Chapter 5.1);
2. Industrial plants (Chapter 5.2);
3. Aquaculture (Chapter 5.3);
4. Nutrient losses from diffuse sources (Chapter 6.2) and
5. Natural background nutrient losses (Chapter 6.1).

In order to quantify the importance of the different sources of waterborne input to the total input entering the Baltic Sea (the so-called **load-oriented approach**), annually reported parameters such as riverine load and retention (both in Chapter 9).

The inputs from different sources should be reported for catchment areas of each Baltic Sea sub-basin (Figure 2.5, the sub-basin division is described in Chapter 2.6).

Periodic reporting format contains sheets with background and factual data. Reporting of the data is based on the same structure of sub-catchments as annual reporting (Chapter 12) to assure consistency of the PLC-water data. Background information for monitored, unmonitored and transboundary sub-catchments is identical to one in annual reporting for the same year. Additional background information for inland point sources should be provided.

The load parameters to be reported are listed in Chapter 1 (Table 1.2).

Annual PLC reporting requirements are also valid in the year decided for periodic reporting. Contracting Parties report the annual data separately from periodic data in accordance with the procedure for annual reporting (Chapter 12 and Annex 2) and in respective the timeframe.

Before reporting the Contracting Parties should perform quality assurance (Chapter 11) and data validation (Chapter 10). Selected quality parameters should be reported (Chapter 13.3).

All data must be reported electronically according to the reporting format prepared by the Data Manager (see the Annex 3).

Where the Contracting Parties do not follow the methods in the guidelines the used method should be described, including the calculation methods used, and all relevant data and information must be reported.

Annex 4 contains a user guide on reporting and quality assuring of the annual and periodic data.

13.1. Source-orientated approach: Methodology for quantifying sources of waterborne inputs to inland waters

13.1.1. Data requirements

According to the source-oriented approach, the inputs from point sources, diffuse sources and natural background losses into inland surface waters should be quantified. Contracting Parties should supplement information on inputs from different sources with description of methods used to identify it.

13.1.2. Point source discharges into inland surface waters

13.1.2.1. MWWTP discharges into inland surface waters

Discharges from MWWTPs into inland surface waters within the Baltic Sea catchment area is a part of periodic reporting. Descriptions for measuring flow and calculating input are given in Chapters 3.1 and 5, respectively. Information on MWWTPs discharging directly into the Baltic Sea is to be reported annually as described in Chapter 12 and is not included as a part of the periodic reporting.

Discharges from MWWTPs into inland surface waters should be reported as follows: All MWWTPs > 10,000 PE should preferable be reported individually. MWWTPs < 10,000 PE can be reported aggregated by sub-catchment.

Flow data, flow measurement methods and estimates of their accuracy should be reported by each Contracting Party. The calculation methodology should be reported.

In addition to parameters mentioned in the Table 1.2, also the following information should be reported:

- The number of municipalities (if aggregated);
- number of connected PE and
- main and supplementary treatment methods.

All information and data that have to be reported are summarized in the Annex 3.

13.1.2.2. Industrial point source discharges into inland surface waters

The quantification of discharges from industrial plants into inland surface waters within the Baltic Sea catchment area should be carried out as a part of the PLC-water periodic reporting. Plants discharging directly into the Baltic Sea are reported annually and not a subject for periodic reporting (Chapter 12). The identification of sources as well as descriptions for measuring flow and calculating input are given in Chapters 3.1 and 5, respectively. EU member countries can submit data reported on industry linked to the E-PRTR, but for completeness of the dataset for the HELCOM PLC assessments, any other plants with industrial effluents entering surface waters in the Baltic Sea catchment areas should be reported. Description of reporting requirements is given in the Annex 3. The division of industry in E-PRTR sectors[13] to be reported is listed in the Annex 3, Table 12. Industrial plant areas should preferably be reported individually, but in some cases, they can be aggregated by sector within sub-catchment area as described in the Annex 3.

In addition to load data, the following information should be reported for indirect industrial point sources:

13 https://ec.europa.eu/environment/industry/stationary/e-prtr/legislation.htm

- Number of industrial plants (if aggregated);
- Indication of level of treatment and elimination of nitrogen and phosphorus[14] according to the classification in the Annex 3;
- Size of the industrial plant;
- Flow data, flow measurement methods and estimation of their accuracy and
- All calculation and/or estimation methods.

13.1.2.3. Discharges from aquaculture into inland surface waters

The quantification of discharges from aquaculture plants into inland surface waters within the Baltic Sea catchment area should be carried out as a part of the PLC-water periodic reporting. Descriptions for measuring flow and calculating input are given in Chapters 3 and 5.3, respectively.

For the HELCOM PLC assessments, the discharges from aquaculture plants should be reported separately for aquaculture plants with a production > 200 $t\ a^{-1}$; but can be reported in aggregated form for aquaculture plants with a production ≤ 200 $t\ a^{-1}$. Further aquaculture discharge could be reported aggregated for unmonitored areas.

The direct discharges from aquaculture plants into the Baltic Sea are to be reported annually and are not a subject for periodic reporting.

Flow data, flow measurement methods and estimates of their accuracy should be reported by each Contracting Party. The calculation methodology should be reported. All information and data that have to be reported are summarized in the Annex 3.

In addition to the information on nutrient loads to inland waters the following information on aquaculture plants should be reported:

- Number of plants (if aggregated);
- Production;
- Feed consumption;
- Type of treatment, e.g. no treatment, sediment traps, micro sieves, biofilter, plant lagoons and/or sludge storage (if any);
- Flow data, flow measurement methods and estimation of their accuracy and
- All calculation and/or estimation methods.

13.1.3. Diffuse losses to inland surface waters

The quantification of losses from diffuse sources of nutrients into inland surface waters within the Baltic Sea catchment area is a part of the PLC water periodic reporting. A description for quantifying losses from diffuse sources is given in Chapter 6.

According to the Chapter 6 the following categories of diffuse anthropogenic nitrogen and phosphorus losses should be considered in the reporting:

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[14] Russia is clarifying whether they can provide aggregated figures for Russian point sources

- Agricultural land;
- Managed forestry and other managed land;
- Atmospheric deposition directly on inland surface waters;
- Scattered dwellings and
- Rainwater constructions (e.g. paved surfaces without a distinct outlet).

In the absence of harmonized quantification procedures, the Contracting Parties should apply the most appropriate method/model to quantify losses from diffuse sources, taking into account the relevant geology, topography, soil type, climate, land use, and agricultural practices in their region. Applied models must be calibrated with monitoring data and afterwards validated on another set of monitoring data. The Contracting Parties should provide documentation on model validations and calibrations (see Chapter 6.2).

Whatever methodology is adopted by a Contracting Party, it is essential that certain minimum requirements are fulfilled as described in the Chapter 6. In particular, the methodology should be based on measurements or upon objectively determined loss coefficients that should be sensitive to variations in losses associated with different land use types (e.g. different agricultural crops, forestry practices and livestock densities).

Information on pathway type might also be provided on the voluntary basis in accordance with the following classification (Chapter 6):

- Surface run-off;
- Erosion;
- Groundwater ;
- Tile drainage;
- Interflow[15];
- Atmospheric deposition on inland surface waters;
- Scattered dwellings and
- Rainwater constructions.

The nutrient losses from diffuse sources to inland waters should be reported in accordance with the requirements of the source-oriented approach and:

- Monitored and transboundary rivers should be reported individually;
- Unmonitored areas should be reported aggregated for each catchment to Baltic Sea sub basin per country.

The applied method should be described in detail and reported. All information and data that have to be reported are summarized in the Annex 3.

13.1.4. Natural background losses into inland surface waters

The quantification of natural background nutrient losses to inland surface waters within the Baltic Sea catchment area is a part of the periodic reporting. The losses should be reported in accordance with the requirements for the source-orientated approach. Information on background losses should be provided for all catchment to monitored rivers within national borders of the Contracting Parties. A description of the quantification of inputs from natural background losses is given in Chapter 6.1. The parameters to be reported are given in the Table 1.2.

All information and data that have to be reported are summarized in the Annex 3.

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15 Substance transport within the vadose zone, i.e. unsaturated soils above the groundwater table.

13.1.5. Transboundary inputs

Point and diffuse sources of nutrient loads for transboundary parts of river catchments should be reported separately utilizing "transboundary inputs" spreadsheet. Countries receiving transboundary loads can consider it as a separate source for the apportionment of national sources of nutrient loads. The Contracting Party where transboundary input originates from should report sources of transboundary inputs according to classification given in Chapters 5 and 6 and applied for reporting point and diffuse sources.

13.2. Load-oriented approach - reporting riverine load apportionment

HELCOM PLC periodic assessments include evaluation of contribution of different sources (point, diffuse and natural background losses) on the riverine nutrient load taking into account retention in inland surface waters. This assessment requires the quantification of:

- Retention in inland surface waters and
- Riverine load apportionment.

The method for qualification of sources of riverine inputs by their loads at the river mouth is described in Chapter 9.2.

Riverine load apportionment should be made as a part of the HELCOM PLC-water periodic reporting. Categories used for the apportionment are natural background load, diffuse anthropogenic load, point source load, transboundary load and unknown load. These categories might be further specified as described in the Annex 3. The data should be reported for all sub-catchments on the territory of the Contracting Party utilizing the sub-catchment's structure described in Chapter 2 and used for both annual and periodic reporting.

Only two parameters – total nitrogen and total phosphorus – should be reported for all categories used for the load-oriented apportionment of nutrient sources. All values should be reported in tons per year except for the natural background where percentage of total load is to be also reported for both nitrogen and phosphorus.

Load oriented approach should be reported individually per monitored river and aggregated for unmonitored areas in the sub catchment to the Baltic Sea sub-basins per country.

The applied estimation methods should be reported together with riverine load apportionment data. All information and data that have to be reported are summarized in the Annex 3.

13.3. Reporting on uncertainty on national data sets

Contracting Parties should estimate and report on the estimated total uncertainty on their reported data according to Chapter 10.4. The estimated total uncertainty on the total input per sub-catchment on reported data according to Chapter 13 should be estimates and reported as a minimum.

14. References

Behrendt, H. and Opitz, D. 1999. Retention of nutrients in river systems: dependence on specific runoff and hydraulic load. Hydrobiologica Volume 410, pp 111-122.

Box, E.P., Jenkins, G. M., Reinsel, G. C. and Ljung, G. M. 2015. Time Series Analysis: Forecasting and Control. John Wiley and Sons, New York.

Carstensen, J. & Larsen, S. E. 2006. Statistisk bearbejdning af overvågningsdata – Trendanalyser. NOVANA. (Statistical assessment of monitoring data. Trend analysis. NOVANA). Danmarks Miljøundersøgelser. 38 s. – Teknisk anvisning fra DMU nr. 24. http://www.dmu.dk/Pub/TA24.pdf (in Danish).

Cleveland, W. S. 1979 Robust Locally Weighted Regression and Smoothing Scatterplots. Journal of the American Statistical Association, 74, p. 829-836.

Cho, C.Y., Hynes, J.D. Wood, K.R. & Yoshida H.K. 1991. Quantitation of fish culture wastes by biological (nutritional) and chemical (limnological) methods; the development of high nutrient dense (HND) diets. In: Cowey, C.B. & Cho, C.Y. (eds). Nutritional strategies and aquaculture waste. Proceedings of the First International Symposium on Nutritional Strategies in Management of Aquaculture Waste. University of Guelph, Ontario. pp 37–50.

Conover, W.J. 1980. Practical Nonparametric Statistics. Second Edition. John Wiley and Sons, New York.

Durbin, J. & Watson, G. S. 1971. Testing for serial correlation in least squares regression. III. Biometrika, 58 (1): 1–19.

Ekholm, P., Kronvang, B., Posch, M. & Rekolainen, S. 1995. Accuracy and precision of annual nutrient load estimates in Nordic rivers. National Board of Waters and the Environment. Vesi- ja ympäristöhallinnon julkaisuja - sarja A, no. 205.

EC 2000. Directive 2000/60/EC of the European Parliament and of the Council (QA/QC directive). Technical Specifications for chemical analysis and monitoring of water status. 21 July 2009.

EC 2009. Directive 2009/90/EC on the technical specifications for chemical analysis and monitoring of water status came into force on 20 August 2009. It is a 'daughter' Directive of the Water Framework Directive (2000/60/EC) (WFD) and is commonly known as the QAQC (Quality Assurance Quality Control) Directive.

EC 2010. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast).

EN ISO/IEC 2005. General requirements for the competence of testing and calibration laboratories. EN ISO/IEC 17025.

EN 1997. Water analysis - Guidelines for the determination of total organic carbon (TOC) and dissolved organic carbon (DOC). EN 1484.

EU 2013. Directive 2013/39/EU of the European Parliament and of the Council of 12 August 201 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy.

Ferguson, R. I., (1986) River loads underestimated by rating curves: Water Resources Research, 22, 1, p. 74-76.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. New York: Van Nostrand Reinhold.

Gustafsson, B. & Svendsen, L.M. in press. The revised Nutrient input ceilings (NIC) to the BSAP 2021 update. To be published on HELCOM web-site, approx..30 pp.

Gustafsson, B.G & Mörth, C.M. (in prep.). Revision of the Maximum Allowable Inputs and Country Allocation Scheme of the Baltic Sea Action Plan V. 3 with contributions from the BNI team: Müller-Karulis, B., Gustafsson, E., Hong, B., Humborg, C. Lyon, S. Nekoro, M., Rodriguez-Medina, M., Savchuk, O., Smedberg, E., Sokolov, A., Swaney, D. & Wulff, F. Baltic Nest Institute, Stockholm University, SE-106 91 Stockholm.

Harmel, R. D., Smith, D. R., King, K. W. & Slade, R. M. 2009. Estimating storm discharge and water quality data uncertainty: A software tool for monitoring and modeling application. Environmental Modelling & Software, 24, 832-842.

Hejzlar, J., Anthony, S., Arheimer, B., Behrendt, H., Bouraoui, F., Grizetti, F., Groenendijk, P., Jeuken, M.H.J.L., Johnsson, H., Lo Porto, A., Kronvang, B., Panagopoulos, Y., Siderius, C., Silgram, M., Venohr, M. & Zaloudík, J. 2009. Nitrogen and phosphorus retention in surface waters: an inter-comparison of predictions by catchment models of different complexity. J. Environ. Monit., 2009, 11, 584-593

HELCOM 1995. HELCOM Recommendation 16/9 "Nitrogen removal at municipal sewage water treatment plants", 3 pp.

HELCOM 2004. HELCOM Recommendation 25/4 "Measures aimed at the reduction of discharges from fresh water and marine fish farming". Adopted 2 March 2004. Supersedes HELCOM Recommendations 18/3 and 20/1.

HELCOM 2007. Baltic Sea Action Plan. Adopted 15 November 2007 in Krakow, Poland.

HELCOM 2011. The Fifth Baltic Sea Pollution Load Compilation (PLC-5). Helsinki Commission – Baltic Marine Environment Commission, Helsinki. Baltic Sea Environment Proceedings No. 128.

HELCOM 2013. HELCOM Copenhagen Declaration "Taking Further Action to Implement the Baltic Sea Action Plan - Reaching Good Environmental Status for a healthy Baltic Sea". Adopted 3 October 2013.

HELCOM 2016a. HELCOM Recommendation 37-38-1 "Waterborne pollution input assessment (PLC-Water)". Adopted 16 June 2016. Supersedes HELCOM Recommendations 26/2.

HELCOM 2016b. HELCOM Recommendation 37-38-2 "Monitoring of airborne pollution input". Adopted 16 June 2016. Supersedes HELCOM Recommendations 24/1.

HELCOM 2016c. HELCOM recommendation 37-3 "Sustainalbe aquaculture in the Baltic Sea region". Adopted 11 March 2016. Supersedes Recommendation 18/3, 20/1 and 25/4.

HELCOM 2021. HELCOM Recommendation 23/5rev1. "Reductions of discharges from urban areas by the proper management of storm water systems, 7 pp.

HELCOM Baltic Sea Action Plan – 2021 update. HELCOM 2021, 60 pp.

https://helcom.fi/media/publications/Baltic-Sea-Action-Plan-2021-update.pdf

HELCOM COMBINE Manual, Part B. General Guidelines on Quality Assurance for Monitoring in the Baltic Sea. http://helcom.fi/action-areas/monitoring-and-assessment/manuals-and-guidelines/combine-manual

HELCOM Monitoring and Assessment Strategy as part of 2013 HELCOM Ministerial Declaration with updates in 2017 and 2019, 37 pp. https://helcom.fi/wp-content/uploads/2020/02/Monitoring-and-assessment-strategy.pdf

Herschy, R.W. 2009. Streamflow measurements. Third edition, Routledge Taylor & Francis, 507 p.

Hirsch, R.M. & Slack, J.R. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research, 20, 727-732.

Hirsch, R.M., Slack, J.R. & Smith, R. A. 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research, 18, 107-121.

Hong, B., Swaney, D.P., Mörth, C.-M., Smedberg, E., Hägg, H.E., Humborg, C., Howarth, R.W., & Bouraoui, F. 2012. Evaluating regional variation of net anthropogenic nitrogen and phosphorus inputs (NANI/NAPI), major drivers, nutrient retention pattern and management implications in the multinational areas of Baltic Sea basin. Ecological Modelling 227, 117–135.

Integrated Pollution Prevention and Control (IPPC). Reference Document on the General Principles of Monitoring. November 2002

ISO 3696:1987 Water for analytical laboratory use. Specification and test methods

ISO 1999. Water quality - Guidelines for the determination of total organic carbon (TOC) and dissolved organic carbon (DOC). ISO 8245.

ISO 2004. Water quality - Determination of adsorbable organically bound halogens (AOX). ISO 9562.

ISO 2003. Water quality - Determination of biochemical oxygen demand after n days (BODn). ISO 5815.

ISO 17025 2005. General requirements.

ISO 1703:2010: Conformity assessment.

ISO 5667-6 Water quality – Sampling. Part 6: Guidance on sampling of rivers and streams.

ISO 5667-10 Water quality – Sampling. Part 10: Guidance on sampling of waste waters.

ISO 5725-2 2019. Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method.

ISO 5815-2:2003. Water quality — Determination of biochemical oxygen demand after n days (BODn) — Part 2: Method for undiluted samples.

ISO 5815-1:2019. Water quality — Determination of biochemical oxygen demand after n days (BODn) — Part 1: Dilution and seeding method with allylthiourea addition.

Kendall, M.G. 1975. Rank Correlation Methods. Charles Griffin, London.

Kronvang, B. & Bruhn, A. 1996. Choice of sampling strategy and estimation method for calculating nitrogen and phosphorus transport in small lowland streams. Hydrological Processes 10: 1483-1501.

Kronvang, B., Behrendt, H., Andersen, H.E., Arheimer, B., Barr, A., Borgvang, B., Bouraoui, F., Granlund, K., Grizetti, Groenendijk, P., Schwaiger, Hejzlar, J., E., F., Hoffmann, L., Johnsson, H., Panagopoulos, Y., Porto, A. Lo, Reisser, H., Schoumans, O.F., Anthony, S., Silgram, M., Venohr, M. & Larsen, S.E., 2009: Ensemble modelling of nutrient load in 17 European catchments. J. Environ. Monit., 2009, 11, 572-583.

Kronvang, B., Larsen, S.E., Windolf, J. & Søndergaard, M. 2014. Uncertainties in monitoring – how much do we tolerate. Presentation of NJF Workshop, 19-21 March 2014, Stavanger, Norway.

Larsen, S.E. & Svendsen, L.M. 2013. Statistical aspects in relation to Baltic Sea Pollution Load Compilation. Task 1 under HELCOM PLC-6. Aarhus University. DCE – Danish Centre for Environment and Energy. 34 pp. Technical Report from DCE – Danish Centre for Environment and Energy No. 33. http://dce2.au.dk/pub/TR33.pdf.

Larsen, S.E, & Svendsen, L.M. 2019. Statistical aspects in relation to Baltic Sea Pollution Load Compilation. Task under HELCOM PLC-7 project. Aarhus University, DCE Danish Centre for Environment and Energy, 42 pp. Technical Report No. 137. http://dce2.au.dk/pub/TR137.pdf

Larsen, S.E, & Svendsen, L.M. 2021. Statistical aspects in relation to Baltic Sea Pollution Load Compilation. Task under HELCOM PLC-8 project. Aarhus University, DCE Danish Centre for Environment and Energy, 60 pp. Technical Report No. 224. https://dce2.au.dk/pub/TR224.pdf

Lassen. P. & Larsen. M.M. 2021. Report on the HELCOM PLC-8 intercalibration. Aarhus University. DCE – Danish Centre for Environment and Energy. 128 pp. Technical Report No. 212. http://dce2.au.dk/pub/TR212.pdf

Magnusson, B., Näykki, T., Hovind, H., & Krysell, M. 2004. Handbook for calculation of measurement uncertainty in environmental laboratories, 2nd edition. NORDTEST Report TR 537. http://www.nordicinnovation.net/nordtestfiler/tec537.pdf

Michaelis, L. and Menten, M. L. 1913: Die Kinetik der Invertinwirkung. Biochemische Zeitschrift, Vol. 49, pp. 333-369.

Näykki. T. Virtanen. A. & Leito. I. 2012. Software support for the Nordtest method of measurement uncertainty evaluation. Accred. Qual. Assur. 17:603-612. http://www.springerlink.com/content/704121770l181786/

OSPAR 2007. OSPAR HARP NUT Guideline 6: Guideline for the Quantification and Reporting of Nitrogen and Phosphorus Losses from Diffuse Anthropogenic Sources, and natural Background Losses. Updated in 2010.

OSPAR 2015. OSPAR HARP NUT Guideline 2: Guidelines for the Quantification and Reporting of Nitrogen and Phosphorus Discharges/Losses from Aquaculture Plants. OSPAR Agreement 2004-26, revised in 2018, 10 pp.

Rekolainen S., Pitkänen H., Bleeker A. & Felix S. 1995. Nitrogen and phosphorus fluxes from Finnish agricultural areas to the Baltic Sea. Nord. Hydrol. 26: 55-72.

Rönnback, P., Sonesten L. & Wallin M. 2009. Transport of substances during spring flow in rivers Ume älv and Kalix älv (Ämnestransporter under vårflöden i Ume älv och Kalix älv). Swedish University of Agricultural Sciences, Department of Aquatic Sciences and Assessment, Report 2009:20 (In Swedish with an English summary).

Schoumans, O.F. & Silgram, M. 2003. Review and literature evaluation of nutrient quantification tools. EUROHARP report 1-2003, NIVA report SNO 4739-2003, Oslo, Norway 2003. Available from http://rapp.niva.no/symfoni/RappArkiv4.nsf/URL/C125730900460902C1256FB800545652/$FILE/4739-2003_72dpi.pdf.

Schoumans, O.F., Silgram, M., Groenendijk, P., Bouraoui, F., Andersen, H.E., Kronvang, B., Behrendt, H., Arheimer, B., Johnsson, H., Panagopoulos, Y., Mimikou, M., Reisser, H., LeGall, G., Barr, A. & Anthony, S.G. 2009a. Description of nine nutrient loss models: capabilities and suitability based on their characteristics. J. Environ. Monit., 2009, 11, 506-514.

Schoumans, O., Silgram, M., Walvoort, D.J.J., Groenendijk, P., Bouraoui, F., Andersen, H.E., Lo Porto, A., Reisser, H., LeGall, G., Anthony, S., Arheimer, B., Johnsson, H., Panagopoulos, Y., Mimikou, M., Zweybert, U., Behrendt, H. & Barr, A. 2009b. Evaluation of the difference of eight model applications to assess diffuse annual nutrient losses from agricultural land. J. Environ. Monit., 2009, 11, 540-533.

Silgram, M. and Schoumans, O. F. editors 2004. Modeling approaches: Model parameterization, calibration and performance assessment methods in the EUROHARP project. EUROHARP 8-2004.

Silgram, M. Schoumans, O.F., Walvoort, D.J., Anthony, S.G., Groenendijk, P., Stromqvist, J., Bouraoui, F., Arheimer, B., Kapetanaki, M., Lo Porto, A. & Mårtensson, K. 2009. Subannual models for catchment management: evaluation model performance on three European catchments. J. Environ. Monit., 2009, 11, 526-539.

Snedecor, G. W. and Cochran, G. W 1989. Statistical Methods. Iowa State University Press, Ames, Iowa.

Stålnacke, P., Grimvall, A., Libiseller, C., Laznik, A. & Kokorite, I. 2003. Trends in nutrient concentrations in Latvian rivers and the response to the dramatic change in agriculture. Journal of Hydrology 283: 184–205.

Stålnacke. P., Pengerud. A., Vassiljev. A., Smedberg. E., Morth. C-M., Hägg. A. E., Humborg. C. and Andersen. H.E. (2011): Nutrient surface water retention in the Baltic Sea drainage basin. RECOCA Report Deliverable 6.2. 27pp. Available upon request from Per Stålnacke (Per.Stalnacke@nibio.no) or Bo Gustafsson (bo.gustafsson@su.se)

Stålnacke. P., Pengerud. A., Vassiljev. A., Smedberg. E., Mörth. C.-M., Hägg. H. E.l. (2015). Nitrogen surface water retention in the Baltic Sea drainage basin. Hydrology and Earth System Sciences. 19(2). 981–996. https://doi.org/10.5194/hess-19-981-2015

Svendsen. L.M. (ed.) 2021. Applied methodology for the PLC 7 assessment. HELCOM background information report. HELCOM, 82 pp.

WMO 2008. Guidance to Hydrological Practices. Volume 1. Hydrology – From Measurement to Hydrological Information. World Meteorological Organization, WMO No. 168 Sixth ed. 2008. WNT, Warszawa, p. 296.

Annex 1. List of definitions and acronyms

Airborne	Substances carried or distributed by air
Anthropogenic	Caused by human activities
Aquaculture	The cultivation of aquatic animals and plants in natural or controlled marine or freshwater environments
ARC	Archipelago Sea
Atmospheric deposition	Airborne nutrients or other chemical substances originating from emissions to the air and deposited from the air on land and water surfaces
Border river	A river that has its outlet to the Baltic Sea at the border between two countries. For these rivers, the loads to the Baltic Sea are divided between the countries in relation to each country's share of total load.
BAP	Baltic Proper
BAS	The entire Baltic Sea (as a sum of the Baltic Sea sub-basins). See the definition of sub-basins.
BNI	Baltic Nest Institute, Stockholm University, Sweden
BOD_5 or BOD_7	Biological oxygen demand within 5 or 7 days as an estimate of easily available organic matter
BOB	Bothnian Bay
BOS	Bothnian Sea
BSAP	Baltic Sea Action Plan
BY	Belarus
Calculated value	A value determined by mathematical calculation as opposed to a value derived from monitoring
Catchment area	The area of land bounded by watersheds draining into a body of water (river, basin, reservoir, sea)
Contracting Parties (CP)	Signatories of the Helsinki Convention (Denmark, Estonia, European Commission, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden)
Country-Allocated Reduction Targets (CARTs)	Country-wise requirements to reduce waterborne and airborne nutrient inputs to reach the maximum allowable nutrient input levels (MAI) in accordance to the 2007 Baltic Sea Action Plan.
DCE	Danish Center for the Environment and Energy, Aarhus University, Denmark
DE	Germany
Diffuse sources	Sources without distinct points of emission e.g. agricultural and forest land, natural background sources, scattered dwellings, atmospheric deposition (mainly in rural areas)
Direct (point) sources	Point sources (municipal wastewater treatment plants (MWWTP), industrial plants and aquaculture plants) discharging (defined by location of the outlet) directly to the sea
DK	Denmark
DS	Danish Straits
EE	Estonia
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
Estimated value	A number that has been calculated approximately (the amount, extent, magnitude, position, or value of something). A tentative evaluation or rough calculation, which accepts that there is uncertainty in the values.

Eutrophication	Condition in an aquatic ecosystem where increased nutrient concentrations stimulate excessive primary production, which leads to an imbalanced function of the ecosystem
FCR	Feed conversion ratio
FI	Finland
Flow normalization	A statistical method that adjusts a data time series by removing the influence of variations imposed by river flow, e.g. to facilitate assessment of development in e.g. nitrogen or phosphorus inputs without being obstructed by variations in water flow
GIS	Geographic Information System
GUF	Gulf of Finland
GUR	Gulf of Riga
HOD	Head of Delegation of HELCOM
ISO	International organization for Standardization
KAT	Kattegat
HELCOM PRESSURE	HELCOM Working Group on Reduction of Pressures from the Baltic Sea Catchment Area
LOD	Limit of detection
LOD	Limit of quantification
LT	Lithuania
LV	Latvia
Maximum Allowable Input (MAI)	The maximum annual amount of a substance that a Baltic Sea sub-basin may receive and still fulfil HELCOM's ecological objectives for a Baltic Sea unaffected by eutrophication
Measured value	An amount determined by measurement
Monitored areas	The catchment area upstream of the river monitoring station. The chemical monitoring decides the monitored area in cases where the locations of chemical and hydrological monitoring stations do not coincide.
Monitoring stations	Stations where hydrographic and/or chemical parameters are monitored
MWWTP	Municipal wastewater treatment plant
NO	Norway
Non-contracting parties	Countries that are not partners to the Helsinki Convention 1992, but that have an indirect effect on the Baltic Sea by contributing with inputs of nutrients or other substances via water and/or air
Nutrient Input Ceilings (NIC)	The allowable amount of nitrogen and phosphorus input per country and sub-basin according to the nutrient reduction scheme of the Baltic Sea Action Plan
PE	Person Equivalent
PL	Poland
PLC	Pollution Load Compilation
Point sources	Municipal wastewater treatment plants (MWWTP), industrial plants and aquaculture plants that discharge (defined by location of the outlet) into monitored areas, unmonitored areas or directly to the sea (coastal or transitional waters) through one or several outlets
QA	Quality assurance
Reference period	The BSAP reference period is 1997-2003

Reference input	The average normalized water + airborne input of nitrogen and phosphorus during the reference period 1997-2003 used to calculate nutrient input ceilings
Retention (R)	The amount of a substance lost/retained during transport in soil and/or water including groundwater from the source to a recipient water body. Generally, retention is only related to inland surface waters in these guidelines.
Riverine inputs	The amount of a substance carried to the maritime area by a watercourse (natural or man-made) per unit of time
RU	Russia
SE	Sweden
SK	Slovakia
SOU	The Sound
Statistically significant	In statistics, a result is called "statistically significant" if it is unlikely to have occurred by chance. The degree of significance is expressed by the probability, P. $P< 0.05$ means that the probability for a result to occur by chance is less than 5%.
Sub-basins	Sub-division units of the Baltic Sea: the Kattegat (KAT), The Sound (SOU), Western Baltic (WEB), Baltic Proper (BAP), Gulf of Riga (GUR), Gulf of Finland (GUF), Archipelago Sea (ARC) Bothnian Sea (BOS) and Bothnian Bay (BOB). The whole Baltic Sea is abbreviated BAS (Figure 2.5)
Sub-catchment	A portion of a catchment as e.g. the corresponding catchment to each monitoring station or the unmonitored area of a river catchment
TOC	Total organic carbon
Transboundary input	Transport of an amount of a substance (via air or water) across a country border
TN and TP	Total nitrogen and total phosphorus, which includes all fractions of nitrogen and phosphorus
UA	Ukraine
Unmonitored area	Any sub-catchment(s) located downstream of the (riverine) chemical monitoring point within the catchment and further all unmonitored catchments, e.g. unmonitored part of monitored
UWWTD	Urban Waste Water Treatment Directive
Waterborne	Substances carried or distributed by water
WEB	Western Baltic Sea
WFD	EU Water Framework Directive
WMO	World Meteorological Organization

Annex 2. Annual reporting formats

The annual data are to be reported electronically utilizing a WEB reporting application of the PLC-WATER database. Annual reporting template in MS Excel format is to be used for the reporting. The annual prefilled reporting template can be downloaded from the Application and the background information on the reported data is to be verified. Once verified and updated the template should be uploaded to the Application and the data manager is to make related updates in the database prior the actual data reporting.

Reporting and quality assurance procedures using PLC WEB-application are described in the Annex 4.

Reporting in general

Actual data reporting is to be done utilizing the verified templates. No additional columns should be inserted or any prefilled rows, columns shouldn't be deleted in the prefilled spreadsheets

Decimal separator to be used '.' (dot) not a ',' (comma)

If the type of an attribute is **'NOT NULL'**, data must be reported.

Each reported attribute heading has a comment box (Table 1), which consists of a format of the data and a list of options and/or instructions for data entry. Any of the boxes can be made visible by moving the mouse to the heading.

Many of the cells also include an instruction box or a drop-down menu for entering the data, but they also may include constraints and may even show an error message, when trying to enter data in an incorrect format. Instructions will be displayed as drop-down menu (Table 2) and the constraints will block false data entry and error messages will give a further advice.

The aim is to improve the quality of the entered data and to ease the final QA process. The constraints work only for the punched data. 'Copy – Paste' commands in the templates will remove the defined constraints.

When entering any data the length and the type of format must be respected, e.g., (CHAR (9)) = 9 characters SCDK00001, (CHAR (7)) = 7 characters MDE0005, Date (10)) dd.mm.yyyy as should be 01.01.2014. Period name format is (STRING 4-10) like ,2014 (year) or PLC-8.

Fixed length of characters has been noted as e.g., 'CHAR (9)', a variable length of characters as 'STRING (1-255)', and integer numbers as '(INTERGER)'. In case of real number with decimal the length and the number of decimals have been noted as (DECIMAL (8.2)) (=nnnnn.nn).

Reporting obligations will be indicated in each of the spreadsheet of the template as follows:

= 'Prefilled data' i.e. tentative definitions of existing in the database once established will be indicated in gray color in the template.

= Mandatory information - data will be indicated in pink in the template, e.g. sub-catchment and point source codes in load flow tables, parameters, parameter types, values, value units, etc.

= Voluntarily reported information - data will be indicated in white in the template, e.g. national codes, links, sector codes, etc.

Table 1 An example of comment box.

1	STATION_CODE	SUBCATCHMENT_CODE	SUBCATCHMENT_NAME	PARAMETER_ID	PARAMETER_TYPE	PERIOD_NAME	PERIOD_TYPE	VALUE
2	HDK0129	SCDK00210	HERREDS Å	9	AVE	2013	A	
3	HDK0128	SCDK00209	HVIDBJERG Å	9	AVE	2013	A	
4	HDK0130	SCDK00211	TREND Å	9	AVE	2013	A	
5	HDK0115	SCDK00059	LINDENBORG Å	9	AVE	2013	A	
6	HDK0112	SCDK00047	KASTBJERG Å	9	AVE	2013	A	
7	HDK0024	SCDK00031	HASLEVGÅRDS Å	9	AVE	2013	A	
8	HDK0097	SCDK00114	VILLESTRUP Å	9	AVE	2013	A	
9	HDK0004	SCDK00006	BREDKÆR BÆK	9	AVE	2013	A	
10	HDK0106	SCDK00014	FALD Å	9	AVE	2013	A	
11	HDK0131	SCDK00212	LYBY-GRØNNING GRØFT	9	AVE	2013	A	
12	HDK0071	SCDK00085	SIMESTED Å	9	AVE	2013	A	
13	HDK0073	SCDK00087	SKALS Å	9	AVE	2013	A	
14	HDK0035	SCDK00043	JORDBRO Å	9	AVE	2013	A	
15	HDK0036	SCDK00046	KARUP Å	9	AVE	2013	A	
16	HDK0008	SCDK00010	ELLING Å	9	AVE	2013	A	
17	HDK0104	SCDK00001	ALLING Å	9	AVE	2013	A	
18	HDK0021	SCDK00026	GUDEN Å	9	AVE	2013	A	
19	HDK0127	SCDK00208	FELDBÆK	9	AVE	2013	A	
20	HDK0101	SCDK00118	ÅRHUS Å	9	AVE	2013	A	
21	HDK0023	SCDK00030	HANSTED Å	9	AVE	2013	A	
22	HDK0006	SCDK00008	BYGHOLM Å	9	AVE	2013	A	
23	HDK0093	SCDK00110	VEJLE Å	9	AVE	2013	A	
24	HDK0018	SCDK00024	GREJS Å	9	AVE	2013	A	
25	HDK0033	SCDK00041	HØJEN Å	9	AVE	2013	A	
26	HDK0076	SCDK00090	SPANG Å	9	AVE	2013	A	
27	HDK0039	SCDK00050	KOLDING Å	9	AVE	2013	A	
28	HDK0075	SCDK00089	SOLKÆR Å	9	AVE	2013	A	
29	HDK0022	SCDK00027	HADERSLEV MØLLESTRØM	9	AVE	2013	A	
30	HDK0041	SCDK00044	KÆR MØLLE Å	9	AVE	2013	A	
31	HDK0085	SCDK00099	TAPS Å	9	AVE	2013	A	
32	HDK0009	SCDK00011	ELSTED BÆK	9	AVE	2013	A	
33	HDK0012	SCDK00015	FISKBÆK	9	AVE	2013	A	
34	HDK0062	SCDK00076	PULVERBÆK	9	AVE	2013	A	
35	HDK0080	SCDK00094	STORÅ	9	AVE	2013	A	
36	HDK0098	SCDK00115	VINDINGE Å	9	AVE	2013	A	
37	HDK0060	SCDK00074	ODENSE Å	9	AVE	2013	A	
38	HDK0078	SCDK00092	STAVIS Å	9	AVE	2013	A	
39	HDK0049	SCDK00061	LINDVED Å	9	AVE	2013	A	
40	HDK0108	SCDK00020	GEELS Å	9	AVE	2013	A	

FORMAT: (SMALLINT): NOT NULL!
Code for measured/estimated flow

parameter; loads or flow of parameters which are indicated in red should be collected annually
2 = BOD5
3 = BOD7
4 = Cd
7 = Cr
8 = Cu
9 = FLOW
10 = Hg
11 = Ni
12 = NH4
13 = NO2
14 = NO23
15 = NO3
16 = Ntot
18 = Pb
19 = PPO4
20 = Ptot
23 = Zn

MON_RIVER_LOAD / UNMON_SUBCATCHMENT_FLOW_LOAD / TRANSBOUNDARY_FLOW_LOAD / STATION_FLOW_CONCENTRATION

Table 2 An example of a drop-down menu.

	A	B	C	D	E	F
1	SUBCATCHMENT_C	CATCHMENT	PARAMETER_ID	PARAMETER_TYPE	PERIOD_NAME	PERIOD_TYPE
2	SCDK00259	BAPDKLAND	12	TOT	13	A
3	SCDK00259	BAPDKLAND	14	TOT		A
4	SCDK00259	BAPDKLAND	16	TOT		A
5	SCDK00259	BAPDKLAND	19	TOT		A
6	SCDK00259	BAPDKLAND	20	TOT		A
7	SCDK00260	KATDKLAND	12	TOT	2013	A
8	SCDK00260	KATDKLAND	14	TOT	2013	A
9	SCDK00260	KATDKLAND	16	TOT	2013	A
10	SCDK00260	KATDKLAND	19	TOT	2013	A
11	SCDK00260	KATDKLAND	20	TOT	2013	A
12	SCDK00261	SOUDKLAND	12	TOT	2013	A
13	SCDK00261	SOUDKLAND	14	TOT	2013	A
14	SCDK00261	SOUDKLAND	16	TOT	2013	A
15	SCDK00261	SOUDKLAND	19	TOT	2013	A
16	SCDK00261	SOUDKLAND	20	TOT	2013	A
17	SCDK00262	WEBDKLAND	12	TOT	2013	A
18	SCDK00262	WEBDKLAND	14	TOT	2013	A
19	SCDK00262	WEBDKLAND	16	TOT	2013	A
20	SCDK00262	WEBDKLAND	19	TOT	2013	A
21	SCDK00262	WEBDKLAND	20	TOT	2013	A

TOT = TOTAL LOAD
AVE = AVERAGE FLOW

As it is described in Chapter 12, the annual reporting template consists of background information and actual data on monitored and unmonitored sub-catchments, including transboundary; point sources and monitoring stations. Further related tables of the annual reporting template will be described.

Background information

The annual data reporting includes collection of background information on different sources, i.e. areal definitions, stations and point sources.

The sources are: Monitored sub-catchments, river catchments, unmonitored areas (by parameter), transboundary sub-catchments (country wise), hydrological and chemical stations and individual point sources in three different categories (MWWTP, Industry and Aquaculture).

In the MON_RIVER_BACKGROUND sheet will be listed

- monitored sub-catchments within one country (code example SCccnnnnn);
- monitored transboundary rivers (code example RCccnnnnn) and
- monitored border rivers (code example RCccnnnnn).

In the code examples cc is a two-letter country code and nnnnn is a number with leading zeroes, e.g. RCLV00055.

Transboundary and border rivers will be listed in the template of the Contracting Party who has the reporting responsibility of the river, i.e., The CP which has the lowest monitoring station of the river has the reporting responsibility if not agreed differently. Both the transboundary and border rivers have a slightly different catchment code compared with the sub-catchments (RCccnnnnn instead of SCccnnnnn). Figure 1 at the end of the annex clarifies the difference between a sub-catchment and a river catchment and the background information to be reported.

For example, for the entire river (RCLV00055) DAUGAVA the following sub-catchments should be listed:

SCLV00055 (only the Latvian part), SCBY00001, SCRU00049, SCLT00009 and SCEE00035, as listed in table 3. In the sheet the attribute 'IS_PRIMARY_STATION' indicates the catchment, which includes the lowest monitoring station.

Additional information to be collected from rivers and separate sub-catchments are: river mouth coordinates, as latitude and longitude (in WGS-84), national sub-catchment and river code, monitoring status (IS_MONITORED), and surface and lake areas (in km^2).

Transboundary catchments will be divided to sub-catchments by country (TRANS_SUBCATCHMENT _BACKGROUND).

Table 3. An example for transboundary sub-catchments.

SUBCATCH	SUBCATCHMENT_NAME	RIVER_CATCHMENT_CODE	RIVER_TYPE	NATION	NATIONAL_RI	NR_CAT	IS_MONITORED	PERIOD_NAME	IS_PRIMARY_S	CREATION_	END_DATE	TOTAL_DRA	COUNTRY_DR
SCLV00001	BARTA	BAP07001	T				1	2013	1	01.01.1994		1968.00	1227.
SCLV00005	GAUJA	GUR07002	T				1	2013	1	01.01.1994		8890.00	7790.
SCLV00009	LIELUPE	GUR07004	T				1	2013	1	01.01.1994		17600.00	8730.
SCLV00013	SALACA	GUR07005	T				1	2013	1	01.01.1994		3471.00	3190.
SCLV00015	VENTA	BAP07003	T				1	2013	0	01.01.1994		11795.00	6649.
SCLV00055	DAUGAVA	GUR07001	T				1	2013	1	01.01.1994		87900.00	23735.
SCLT00010	BARTA	BAP07001	T				0	2013	0	01.01.1994		1968.00	741.
SCEE00033	GAUJA	GUR07002	T				0	2013	0	01.01.1994		8890.00	1100.
SCLT00003	LIELUPE	GUR07004	T				0	2013	0	01.01.1994		17600.00	9390.
SCEE00034	SALACA	GUR07005	T				0	2013	0	01.01.1994		3471.00	281.
SCLT00008	VENTA	BAP07003	T				0	2013	0	01.01.1994		11795.00	5169.
SCBY00001	DAUGAVA	GUR07001	T				0	2013	0	01.01.1994		87900.00	33100.
SCEE00035	DAUGAVA	GUR07001	T				0	2013	0	01.01.1994		87900.00	1335.
SCLT00009	DAUGAVA	GUR07001	T				0	2013	0	01.01.1994		87900.00	1875.
SCRU00049	DAUGAVA	GUR07001	T				0	2013	0	01.01.1994		87900.00	27000.
SCLV00018	NEMUNAS	BAP06002	T				0	2013	0	01.01.1994		98179.00	88.
SCLV00017	NARVA	GUF04005	T				0	2013	0	01.01.1994		56225.00	3570.
SCLV00020	SVENTOJI	BAP06003	T				0	2013	0	01.01.1994		472.00	82.
SCLV00019	PĀRNU	GUR04002	T				0	2013	0	01.01.1994		6920.00	2.

All unmonitored sub-catchment information of a country will be listed in the UNMON_SUBCATCHMENT_BACKGROUND sheet. In case an unmonitored area varies by parameter, each unmonitored area (in km^2) and parameter should be listed individually as in table 4.

Table 4. An example of unmonitored sub-catchments.

SUBCATCHMENT_CODE	SUBCATCHMENT_NAME	SUBCATCHMENT_TYPE	PARAMETER_ID	PERIOD_NAME	UNMONITORED_AREA	LAKE_AREA	REMARKS
SCSE00309	BAPSELAND	L	0	2013	24559.00		
SCSE00310	BOBSELAND	L	0	2013	17644.00		
SCSE00311	BOSSELAND	L	0	2013	19765.00		
SCSE00312	KATSELAND	L	0	2013	4536.00		
SCSE00313	SKASELAND	L	0	2013	2942.00		
SCSE00314	SOUSELAND	L	0	2013	2389.00		

The ‘station’ and ‘point source’ information in STATION_BACKGROUND and in POINT_SOURCE_BACKGROUND sheets to be collected are:

- code of a station or a point source and their activity status (‘IS_ACTIVE’ and ‘REPORTING_END_DATE’);
- location, i.e., coordinates of each monitoring station or an outlet of an individual point source (in decimal degrees, (WGS-84) latitude and longitude).
- related sub-catchment (of each station)
- recipient sea area (for a discharging point source) and
- size (in km^2) of the monitored area of each station

In addition, information on national station code, EU national point source code and E-PRTR sector type can be reported.

Reference sheet of the MS Excel reporting template for each set of background information is indicated in table 5 and the type and the format of all the reported background information are listed by attribute and by spreadsheet in table 6 and 7.

The prefilled information of areal definitions, stations or point sources to be reported will be updated before the actual reporting. Once the prefilled information has been provided, <u>none of the data sets</u>, i.e. monitored rivers or sub-catchments, unmonitored areas, transboundary catchments or point sources <u>should be deleted</u>. For rivers and sub-catchments, the attribute ‘IS_MONITORED’ indicates whether the catchment has been reported or not in that year, and similarly for stations ‘IS_ACTIVE’ attribute indicates if the station has been reported or not.

Table 5. Background information to be reported.

GENERAL VIEW OF THE ANNUAL BACKGROUND INFORMATION TO BE PROVIDED							
BACKGROUND DEFINITIONS	**REPORTING**	**REFERENCE TABLE**	**SURFACE AREAS**				**ADDITIONAL INFORMATION**
			TOTAL_ DRAINAGE (in km²)	**COUNTRY_ DRAINAGE (in km²)**	**CONTROL AREA by STATION (in km²)**	**TRANSBOUNDARY DRAINAGE (in km²)**	
RIVER/MONITORED SUB-CATCHMENT	INDIVIDUAL	MON_RIVER_BACKGROUND	X	X		X	River mouth coordinates; IS_MONITORED /IS_ UNMONITORED during the period; end date of the catchment validity: lake area of the catchment
UNMONITORED SUBCATCHMENT	BY SUBBASIN and PARAMETER	UNMON_SUBCATCHMENT_BACKGROUND	X				Lake area of the catchment
TRANSBOUNDARY SUBCATCHMENT	INDIVIDUAL	TRANSB_SUBCATCHMENT_BACKGROUND	X	X		X	Lake area of the catchment
MONITORING STATION	INDIVIDUAL	STATION_BACKGROUND			X		activity/station coordinates
POINT SOURCES of 3 CATEGORIES	INDIVIDUAL	POINT_SOURCE_BACKGROUND					outlet coordinates; PRTR_sector code; end date of a PS (date of closing)

Table 6. Data type and format of catchment background information.

ATTRIBUTE/SHEET	MON_RIVER_BACKGROUND	UNMON_SUBCATCHMENT_BACKGROUND_	TRANS_SUBCATCHMENT_BACKGROUND
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)
SUBCATCHMENT_TYPE	CHAR(1)	CHAR(1)	
RIVER_CATCHMENT_CODE	CHAR(8)	-	CHAR(8)
PARAMETER_ID	-	INTEGER	-
RIVER_MOUTH_LATITUDE	DECIMAL (dd.dddd)	-	-
RIVER_MOUTH_LONGITUDE	DECIMAL (dd.dddd)	-	-
RIVER_TYPE	CHAR(1)	-	CHAR(1)
NATIONAL_SUBCATCHMENT_CODE	STRING (1-255)	-	STRING(1-255)
NATIONAL_RIVER_CODE	STRING (1-255)	-	STRING(1-255)
NR_CATCHMENTS	INTEGER	INTEGER	INTEGER
IS_MONITORED	INTEGER	-	INTEGER
PERIOD_NAME	STRING (4-10)	STRING (4-10)	STRING (4-10)
IS_PRIMARY_STATION	-	-	BIT 0/1
CREATION_DATE	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy
END_DATE	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy
TOTAL_DRAINAGE_AREA	DECIMAL (8.2)		DECIMAL (8.2)
UNMONITORED_AREA	-	DECIMAL (8.2)	-
COUNTRY_DRAINAGE_AREA	DECIMAL (8.2)	-	DECIMAL (8.2)
TRANSBOUNDARY_AREA	-	-	DECIMAL (8.2)
LAKE_AREA	DECIMAL (8.2)	DECIMAL (8.2)	DECIMAL (8.2)
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)

Table 7. Data type and format of station and point source background information.

ATTRIBUTE/SHEET	STATION_BACKGROUND	POINT_SOURCE_BACKGROUND
STATION_CODE	CHAR (7)	-
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)
STATION_NAME	STRING (1-25)	-
PLANT_CODE	-	STRING (7)
PLANT_NAME	-	STRING (1-255)
PERIOD_NAME	STRING (4-10)	STRING (4-10)
IS_ACTIVE	BIT 0/1	-
RIVER_CATCHMENT_CODE	CHAR(8)	-
NATIONAL_STATION_CODE	STRING (1-25)	-
EU/NATIONAL_CODE	-	CHAR(255)
PRTR_SECTOR_CODE *)	-	CHAR(1)
STATION/PLANT_CODE_LAT	DECIMAL (dd.dddd)	DECIMAL (dd.dddd)
STATION/PLANT_CODE_LON	DECIMAL (dd.dddd)	DECIMAL (dd.dddd)
WFD_CODE	STRING (1-50)	-
REPORTING_START_DATE	-	DATE(10)
REPORTING_END_DATE	-	DATE(10)
TOTAL_NR_OF_PLANTS	-	INTEGER
TOTAL_NR_OF_TREATED_PLANTS	-	INTEGER
MONITORED_AREA	DECIMAL (8.2)	-
REMARKS	STRING(1-255)	STRING(1-255)

*) The document listing new E-PRTR_SECTOR_CODEs can be downloaded:
https://ec.europa.eu/environment/industry/stationary/e-prtr/legislation.htm

Actual Data

Actual data on loads from monitored sub-catchments and transboundary rivers should be reported individually and for unmonitored areas as aggregated by basin. Though, unmonitored parts of monitored rivers can be reported as individual sub-catchments.

MONITORED SUB-CATCHMENTS AND RIVER

The loads of monitored rivers should be reported in the MON_RIVER_LOAD sheet. The following loads should be reported:

- loads of monitored rivers within one country
- loads of transboundary rivers
- loads of border rivers

The collected mandatory and voluntary parameters have been listed in the PLC Guidelines (Table 1.1)

In some cases the conducted measurements are below the LOQ / LOD (Limit of quantification / detection). LOQ/LOD information (LIMIT_VALUE, LIMIT_UNIT and NUMBER_BELOW_LIMIT) should be reported in the MON_RIVER_LOAD sheet. Related to LOQ/LOD information, also the number of measurements and total uncertainty for the obtained load should be reported.

Total flow of a monitored river should be reported in the STATION_FLOW_CONCENTRATION sheet by monitoring station. All records of the monitoring stations in the spreadsheet should also contain code of the sub-catchment where the monitoring station is located.

Flow will be reported as $m^3 s^{-1}$ and the other parameters as $t a^{-1}$ or $kg a^{-1}$ (heavy metals).

As for the background information, the reporting responsibility of a transboundary/border river is for the country which has the lowest monitoring station of the catchment

- to report the total inputs
- to report transboundary input at the border

Reporting of loads will be agreed between the countries sharing a transboundary river. Figure 1 at the end of the document clarifies the reporting of sub-catchment and transboundary loads.

The loads and flows of separate catchments (by country, i.e. country allocations) of transboundary and border rivers should be reported in the TRANSBOUNDARY_FLOW_LOAD sheet. Related to the transboundary loads their retention can be reported on a voluntary basis in the TRANB_SUBCATCHMENT_RETENTION

Reported parameters are: average flow, N_{tot} and P_{tot} and they will be reported in $m^3 s^{-1}$ and in $t a^{-1}$.

Additional information on total uncertainty and basic calculation information should be reported. Reporting of LOQ/LOD information should be reported for monitored transboundary loads, as well.

UNMONITORED SUB-CATCHMENTS

The data for unmonitored area should be reported by country and by basin. Each unmonitored area consists of the areas between the monitored catchments, unmonitored parts of the monitored rivers, coastal areas and islands. Both the loads and flow of unmonitored areas should be reported in the UNMON_SUBCATCHMENT_ FLOW_LOAD sheet.

The loads and flow of each unmonitored area should also include all loads and flow for the point sources in the area.

The reported parameters for unmonitored areas have been listed in table 1.1. Flow will be reported as $m^3 s^{-1}$ and the other parameters as $t a^{-1}$. Total uncertainty of obtained loads should be reported. Calculation methodology can also be reported.

An overview of the reported data has been presented in table 8 and type and format of loads, flow and metadata by attribute and for each spreadsheet have been compiled in table 9.

Table 8. An overview of the data for the annual reporting

GENERAL VIEW OF THE ANNUAL DATA REPORTING ON SUBCATCHMENTS AND STATIONS						
SOURCE	**REPORTING**	**REFERENCE TABLE**	**FLOW**	**LOAD**	**ADDITIONAL INFORMATION**	**CALC. ESTIMATION METHODS**
MONITORED SUB-CATCHMENTS/RIVERs	INDIVIDUALLY	MON_RIVER_LOAD		as listed in Table 1.1	LOQ/LOD information, total uncertainty	X
UNMONITORED SUBCATCHMENT (*	BY COUNTRY AND BASIN. (OPTIONALLY BY PARAMETER)	UNMON_SUBCATCHMENT_FLOW_LOAD	average flow (in $m^3 s^{-1}$)	as listed in Table 1.1	Total uncertainty	X
TRANSBOUNDARY SUBCATCHMENT (**	INDIVIDUALLY for each SUBCATCHMENT	TRANSBOUNDARY_FLOW_LOAD	average flow (in $m^3 s^{-1}$)	as listed in Table 1.1		X
TRANSBOUNDARY SUBCATCHMENT (***	INDIVIDUALLY for each TRANSBOUNDARY SUBCATCHMENT	TRANSBOUNDARY_:RETENTION		as listed in Table 1.1		
MONITORED STATION	INDIVIDUALLY	STATION_FLOW_ CONCENTRATION	average flow (in $m^3 s^{-1}$) (****		Annual min. max and long-term flows (1981-2010) and concentrations voluntarily (m^3/s. mg/l)	X

(* Unmonitored parts of monitored rivers should be reported together with unmonitored areas
(** Transboundary loads/flow of monitored rivers only Flow, Ntot and Ptot should be reported on a mandatory basis
(*** Retention of the nutrient load of transboundary sub-catchments can be reported on a voluntary basis
(**** Voluntarily minimum. maximum and long-term flows can be reported

Table 9. Type and format of sub-catchment (load and flow) and station (flow and concentration) data

ATTRIBUTE/SHEET	MON_RIVER_LOAD	UNMON_SUBCATCHMENT_FLOW_LOAD	TRANSBOUNDARY_FLOW_LOAD	TRANSBOUNDARY_RETENTION	STATION_FLOW_CONCENTRATION
STATION_CODE	-	-	-		CHAR (7)
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)	CHAR (9)	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)	STRING (1-255)	STRING (1-255)
PARAMETER_ID	INTEGER	INTEGER	INTEGER	INTEGER	INTEGER
PARAMETER_TYPE	CHAR (3)	CHAR (3)	CHAR (3)	CHAR (3)	CHAR (3)
PERIOD_NAME	STRING(4-10)	STRING(4-10)	STRING(4-10)	STRING(4-10)	STRING(4-10)
PERIOD_TYPE	CHAR (1)	CHAR (1)	-		CHAR (1)
IS_LOQ/LOD	BIT (0/1)	-	BIT (0/1)		-
LIMIT_VALUE	DECIMAL (8(.6))	-	DECIMAL (8(.6))		-
LIMIT_UNIT	CHAR(4)	-	CHAR(4)		-
NUMBER_BELOW_LIMIT	INTEGER	-	INTEGER		-
NR_MEASUREMENTS	INTEGER	-	INTEGER		INTEGER
VALUE	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))
VALUE_UNIT	STRING(3-6)	STRING(3-6)	STRING(3-6)	STRING(3-6)	STRING(3-6)
TOT_UNCERTAINTY	INTEGER	INTEGER	INTEGER	INTEGER	INTEGER
DATA_SOURCE_FLAG	CHAR(2)	CHAR(2)	CHAR(2)	CHAR(2)	CHAR(2)
METHOD_ID	INTEGER	INTEGER	INTEGER	INTEGER	INTEGER
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)	STRING(1-255)	STRING(1-255)

Actual data on DIRECT POINT SOURCEs

Annual loads and flows of direct point sources will be reported individually and for three different categories, municipal wastewater treatment plants (MWWTP), industries and aquaculture. Direct point source has been defined in Chapter 2.5 and in Annex 1 as: “Direct point sources: Point sources discharging (defined by location of the outlet) directly to the sea”. Further, this implies, that the loads and flow data of point sources, which are located downstream the monitoring station, but not discharging directly to the sea, should be included in the loads of unmonitored areas.

The data to be reported by different category have been listed below (table 10).

MWWTPs

The data to be collected on municipal wastewater treatment plants have been listed in the table 1.1.

Flow will be reported as total flow in m^3 a^{-1} and the other parameters as t a^{-1}.

Information on LOQ or LOD (IS_LOQ/LOD) and related data. number of measurements (NR_MEASUREMENTS) and total uncertainty (TOT_UNCERTAINTY) are mandatory to report. Information on sampling methodology. and used methods can be reported voluntarily.

INDUSTRIES

The data to be collected on industrial plants have been listed in the table 1.1

Flow will be reported as total in m^3 a^{-1} and the other parameters as t a^{-1}. Information on LOQ or LOD (IS_LOQ/LOD) and related data, number of measurements (NR_MEASUREMENTS) and total uncertainty (TOT_UNCERTAINTY) are mandatory to report. Information on sampling methodology. and used methods can be reported voluntarily.

AQUACULTURAL PLANTS

The parameters to be collected on aquacultural plants have been listed in the table 1.1

Flow will be reported as total in m^3 a^{-1} and N_{tot}, P_{tot} or $BOD_{5/7}$ as t a^{-1}. Total uncertainty of the obtained loads should be reported and used methods on a voluntary basis. respectively.

Apart from the load reporting. amount of feed, feed type and fish production can be reported on a voluntary basis in the AQUACULTURE_PRODUCTION sheet.

The type and format of point source load flow and metadata as well as the information on aquaculture production is given in Table 11.

Table 10. An overview of the point source data for annual reporting.

GENERAL VIEW OF THE ANNUAL DATA REPORTING ON POINT SOURCES						
SOURCE	**REPORTING**	**REFERENCE TABLE**	**FLOW**	**LOAD**	**ADDITIONAL INFORMATION**	**CALC. ESTIMATION METHODS OF INPUTS**
MWWTP	MWWTPs INDIVIDUALLY (*	MUNICIPAL_LOAD_FLOW	$m^3\ a^{-1}$	as listed in Table 1.1	LOQ/LOD and related information, total uncertainty	X
INDUSTRY	INDUSTRIES INDIVIDUALLY (*	INDUSTRIAL_LOAD_FLOW	$m^3\ a^{-1}$	as listed in Table 1.1	LOQ/LOD and related information, total uncertainty PRTR sector/ individual reporting	X
AQUACULTURE	AQUACULTURE INDIVIDUALLY (*	AQUACULTURE_LOAD	$m^3\ a^{-1}$ (**	as listed in Table 1.1	Total uncertainty	X
AQUACULTURE PRODUCTION	AQUACULTURE INDIVIDUALLY (*	AQUACULTURE_PRODUCTION			Voluntarily feed type, amount of feed used and total production	

(* Point sources might be reported as aggregated by sub-basin

(** Flow of an individual aquaculture can be reported on a voluntary basis when it is relevant, i.e. outlet of discharges exists.

Table 11. Type and format by attribute and spreadsheet of the point source data

ATTRIBUTE/SHEET	MUNICIPAL_LOAD_FLOW	INDUSTRIAL_LOAD_FLOW	AQUACULTURE_LOAD	AQUACULTURE_PRODUCTION
PLANT_CODE	CHAR (7)	CHAR (7)	CHAR (7)	CHAR (7)
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)	-
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)	-
PARAMETER_ID	INTEGER	INTEGER	INTEGER	
PARAMETER_TYPE	CHAR (3)	CHAR (3)	CHAR (3)	
PERIOD_NAME	STRING (4-10)	STRING (4-10)	STRING (4-10)	STRING (4-10)
PERIOD_TYPE	CHAR (1)	CHAR (1)	CHAR (1)	-
IS_LOQ/LOD	BIT 1/0	BIT 1/0	-	-
LIMIT_VALUE	DECIMAL (8(.6))	DECIMAL (8(.6))	-	-
LIMIT_UNIT	CHAR(4)	CHAR(4)	-	-
NUMBER_BELOW_LIMIT	INTEGER	INTEGER	-	-
NR_MEASUREMENTS	INTEGER	INTEGER	-	-
VALUE	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))	-
VALUE_UNIT	STRING(3-6)	STRING(3-6)	STRING(3-6)	-
TOT_UNCERTAINTY	INTEGER	INTEGER	INTEGER	-
SAMPLING_METHODOLOGY	CHAR(1)	CHAR(1)	-	-
DATA_SOURCE_FLAG	CHAR(2)	CHAR(2)	CHAR(2)	-
METHOD_ID	INTEGER	INTEGER	INTEGER	-
FEED_TYPE	-	-	-	CHAR(1)
AMOUNT_OF_FEED	-	-	-	DECIMAL (10(.3))
AQUACULTURE_PRODUCTION	-	-	-	DECIMAL (10(.3))
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)	-

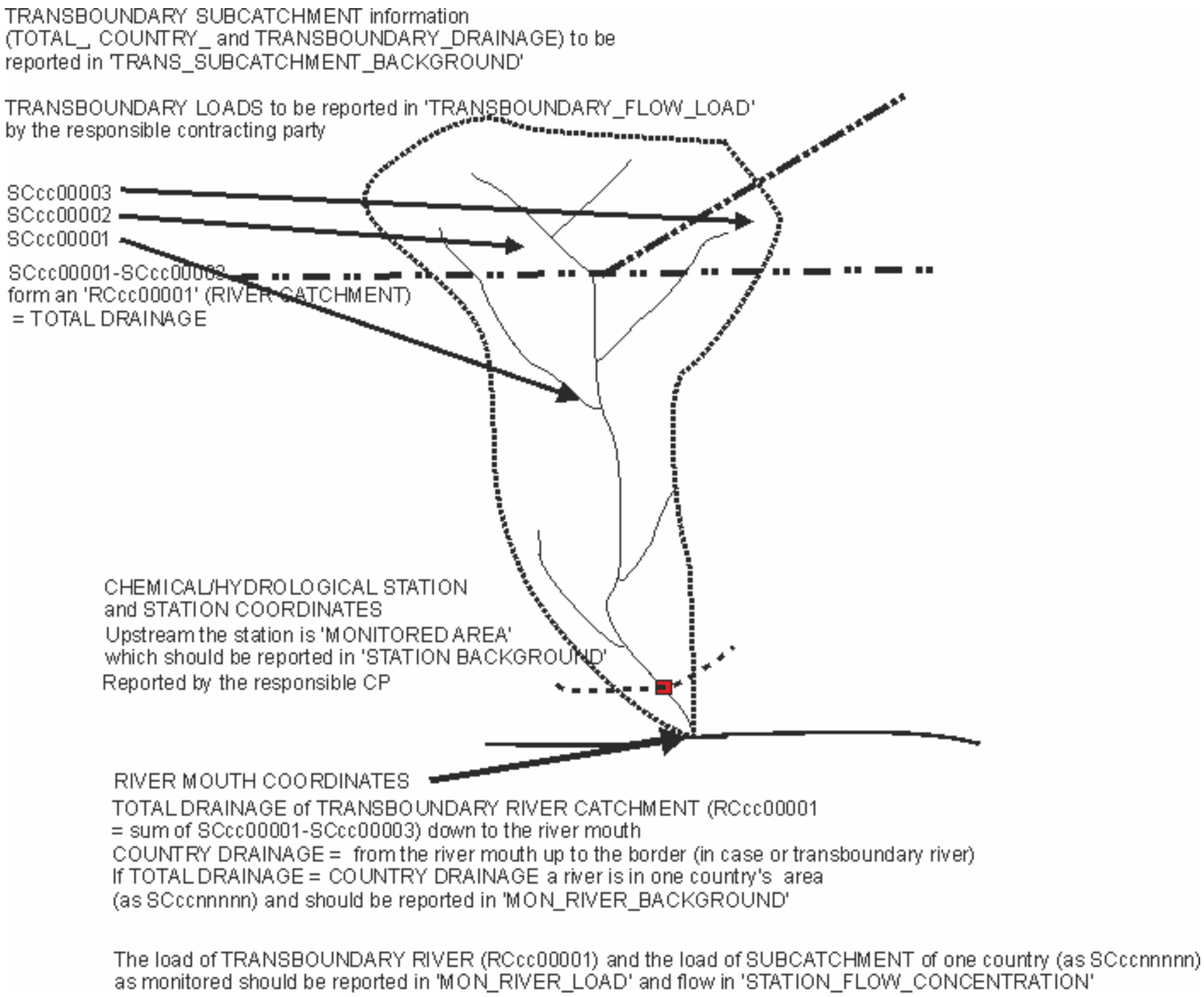


Figure 1. Reporting river catchment and monitored sub-catchment background information and flow and loads.

Annex 3. Periodic reporting formats

Periodic PLC-water reporting is arranged on decision of the Contracting Parties with the main aim to identify sources of the Baltic Sea pollution and evaluate effectiveness of measures to reduce nutrient loads undertaken in various sectors. The data on retention of nutrients in the different sub-catchments of the Baltic Sea region are also updated based on the results of periodic data reporting.

Reporting instructions also include data reporting sheets. They have been established separately for each Contracting Party as CC_PERIODIC REPORTING_YYYY.xlsx (CC = COUNTRY CODE: DK = DENMARK, EE = ESTONIA, FI = FINLAND, DE = GERMANY, LV = LATVIA, LT = LITHUANIA, PL = POLAND and SE = SWEDEN; YYYY - year of reporting data). For example. for Estonia the file is: **EE_PERIODIC_REPORTING_ 2021.xlsx.** This data entry file of Estonia works as an example. Similar files with the same structure will be provided to each contracting party. including prefilled data by country.

REPORTING IN GENERAL

When entering the data general settings should be used:

- No additional columns should be added, or any columns deleted in the prefilled spreadsheets.
- Decimal separator to be used '.' (dot) not a ',' (comma)
- If the type of an attribute is **'NOT NULL',** data should be reported.

Each reported attribute has a comment box (Table 1), which consists of a format of the data and a list of options and/or instructions for data entry. Any of the boxes can be made visible by moving the mouse to the attribute.

Many of the cells also include an instruction box or a drop-down menu for entering the data, but they also may include constraints and may even show an error message, when trying to enter data in an incorrect format. Instructions will be displayed as drop-down menu (Table 2) and the constraints will block false data entry and error messages will give further advice.

The aim is to improve the quality of the entered data and to ease the final QA process. The constraints work only for the punched data. 'Copy – Paste' -commands in the templates will remove the defined constraints.

When entering any data the length and the type of format must be respected, e.g., (CHAR (9)) = 9 characters SCDK00001, (CHAR (7)) = 7 characters MDE0005, Date (10) dd.mm.yyyy or dd-mm-yyyy e.g., 01.01.2014 and 01-07-2014

Fixed length of characters has been noted as e.g., 'CHAR (9)', a variable length of characters either as 'STRING (1-255)', 'CHAR (4)' and small numbers as '(INTERGER)'. In case of number with decimal the length and the number of decimals have been noted as (DECIMAL (8.2)) (=nnnnn.nn).

Reporting obligations will be indicated in each of the spreadsheet of the template as follows:

= 'Prefilled data' i.e. tentative definitions of existing in the database once established will be indicated in gray color in the template

= Mandatory information - data will be indicated in pink in the template, e.g. sub-catchment and point source codes in load flow tables, parameters, parameter types, values, value units, etc.

= Voluntarily reported information - data will be indicated in white in the template, e.g. national codes, links, sector codes, etc.

Table 1. An example of a comment box.

	A	B	C	D	E	F	G	H	I	J	K
1	STATION_CODE	STATION_NAME	SUBCATCHMEN	BCATCHMENT_NA	RIVER_CATCHMENT_CODE	PERIOD_N	NATIONAL_STATION_CODE	IS_ACTIVE	ST_LAT	ST_LON	MONITORED_AREA
2	CEE0001	LINNAMAE	SCEE00001	JÄGALA	GUF04001	PLC-6	SJA2203000	1	59.4717	25.1523	1570.00
3	CEE0002	KASAR ISILD	SCEE00003	KASARI	GUR04001	PLC-6	SJA4483000	1	58.7336	23.9895	2640.00
4	CEE0003	SUUE	SCEE00005	KEILA	GUF04002	PLC-6	SJA5960000	1	59.3953	24.2964	682.00
5	CEE0004	SUUE	SCEE00007	KUNDA	GUF04003	PLC-6	SJA8841000	1	59.5098	26.5383	528.00
6	CEE0005	VIHASOO	SCEE00009	LOOBU	GUF04004	PLC-6	SJA5258000	1	59.5517	25.785	308.00
7	CEE0006	SUUE (NARVAST ALLAVOOLU)	SCRU00025	NARVA	GUF04005	PLC-6	SJA9741000		…4204	28.1354	56000.00
8	CEE0007	PUDISOO	SCEE00015	PUDISOO	GUF04007	PLC-6	SJA9316000		…5175	25.5556	123.00
9	CEE0008	SUUE (TALLINN-NARVA MNT)	SCEE00017	PURTSE	GUF04008	PLC-6	SJA3032000		…4117	27.0068	810.00
10	CEE0009	OORE	SCEE00021	PÄRNU	GUR04002	PLC-6	SJA8483000		…4553	24.7635	5154.00
11	CEE0010	SUUE	SCEE00019	PÜHAJÕGI	GUF04009	PLC-6	SJA3956000		…4199	27.5279	196.00
12	CEE0012	LOKSA JALAKÄIJATE SILD	SCEE00025	VALGEJÕGI	GUF04011	PLC-6	SJA6880000		…5831	25.7114	453.00
13	CEE0013	VASALEMMA JÕGI	SCEE00027	VASALEMMA	GUF04012	PLC-6					403.00
14	CEE0014	VIHTERPALU	SCEE00029	VIHTERPALU	GUF04013	PLC-6	SJA2051000		…2595	23.8734	474.00
15	CEE0015	SUUE	SCEE00031	VÄÄNA	GUF04014	PLC-6	SJA7837000		…4314	24.3642	316.00
16	CEE0016	LUKATI	SCEE00013	PIRITA	GUF04006	PLC-6	SJA5140000		…6065	24.85526	794.00
17	CEE0017		SCEE00109	SELJAJÕGI	GUF04010	PLC-6					380.00
18	HEE0001	KEHRA	SCEE00001	JÄGALA	GUF04001	PLC-6	SJA3814000		…3333	25.3333	903.00
19	HEE0002	KASARI	SCEE00003	KASARI	GUR04001	PLC-6	SJA9179000	1	…7336	23.9895	2640.00
20	HEE0003	KEILA	SCEE00005	KEILA	GUF04002	PLC-6	SJA6896000	1	59.3102	24.4344	635.00
21	HEE0004	SÄMI	SCEE00007	KUNDA	GUF04003	PLC-6	SJA1417000	1	59.3667	26.6	406.00
22	HEE0005	ARBAVERE	SCEE00009	LOOBU	GUF04004	PLC-6	SJA7798000	1	59.44242	25.96859	205.00
23	HEE0006	NARVA	SCEE00011	NARVA	GUF04005	PLC-6	SJA4515000	1	59.35	28.2	56000.00
24	HEE0007	PUDISOO	SCEE00015	PUDISOO	GUF04007	PLC-6	SJA4401000	1	59.5175	25.5556	123.00
25	HEE0008	LÜGANUSE	SCEE00017	PURTSE	GUF04008	PLC-6	SJA5163000	1	59.3833	27.5	784.00
26	HEE0009	OREKÜLA	SCEE00021	PÄRNU	GUR04002	PLC-6	SJA2731000	1	58.4553	24.7635	5154.00
27	HEE0010	TOILA-ORU	SCEE00019	PÜHAJÕGI	GUF04009	PLC-6	SJA5604000	1	59.42305	27.53	196.00
28	HEE0012	VANAKÜLA	SCEE00025	VALGEJÕGI	GUF04011	PLC-6	SJA8764000	1	59.4667	25.7833	404.00
29	HEE0013	URBA	SCEE00027	VASALEMMA	GUF04012	PLC-6		1	59.3013	24.1954	
30	HEE0014	VIHTERPALU	SCEE00029	VIHTERPALU	GUF04013	PLC-6	SJA3959000	1	59.2595	23.8734	474.00
31	HEE0015	HÜÜRU	SCEE00031	VÄÄNA	GUF04014	PLC-6	SJA2072000	1	59.3833	24.5333	209.00
32	HEE0016	KLOOSTRIMETSA	SCEE00013	PIRITA	GUF04006	PLC-6	SJA6279000	1	59.46598	24.87791	794.00

FORMAT (BIT):
when any
Measurements
have carried out
at the station
then
1 = MONITORED
otherwise
0 = UNMONITORED
(DEFAULT)

Table 2. An example of a drop-down menu.

	A	B	C	D	E	F	G	H
1	STATION_CODE	SUBCATCHMENT_CODE	SUBCATCHMENT_NAME	PARAMETER_ID	PARAMETER_TYPE	PERIOD_NAME	PERIOD_TYPE	LTA_S
2						…C-6		
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								
26								
27								

AVE
MIN
MAX
LTA

As it was described in Chapter 13, the periodic reporting template consist of background information and actual data on contribution of various sources into total nutrient loads from monitored, unmonitored and transboundary sub-catchments as well as on inland point sources. Further the tables of the periodic reporting format will be described.

BACKGROUND INFORMATION

The collection of periodic background information is very similar to annual background information (i.e. areal definitions. stations and point sources) collection. The main difference is that for periodic reporting the name of PLC assessment (e.g., PLC-8) is to be used as PERIOD_NAME, but for annual reporting the reporting year, (e.g. 2013), is used as PERIOD_NAME.

The background information should be reported for the monitored, unmonitored and transboundary sub-catchments as well as for individual point sources discharging into the freshwater either individually or as aggregated by sub-catchment.

Background information for the monitored. unmonitored and transboundary sub-catchments in the periodic reporting should be identical to the annual reporting in the same year (see Chapter 12 and Annex 2). The only difference is that the name of the PLC assessment (e.g. PLC-8) is to be used as the period name in the periodic reporting. Examples of background data for transboundary and unmonitored sub-catchments are given in the tables 3 and 4.

Table 3. An example of background information for transboundary sub-catchments.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	SUBCATCH	TCHMENT	RIVER_CAT	RIVER_TYPE	NATION	NATIONAL_RI	NR_CAT	IS_MONITORED	PERIOD_NAME	IS_PRIMARY_STATION	CREATION_	END_DATE	TOTAL_DRA	COUNTRY_DRAIN	TRANSBOUNDARY_AREA
2	SCEE00033	GAUJA	GUR07002	T			1	0	PLC-6	0	01.01.1995		8890.00	7790.00	1100.00
3	SCEE00034	SALACA	GUR07005	T			1	0	PLC-6	0	01.01.1995		3471.00	3190.00	281.00
4	SCEE00035	DAUGAVA	GUR07001	T			1	0	PLC-6	0	01.01.1994		87045.00	1335.00	85710.00
5	SCEE00021	PÄRNU	GUR04002	T			1	1	PLC-6	1	01.01.1994		6920.00	6918.00	2.00
6	SCEE00011	NARVA	GUF04005	B			1	1	PLC-6	1	01.01.1994		56225.00	17215.80	39009.20
7	SCLV00017	NARVA	GUF04005	B			1	0	PLC-6	0	01.01.1994		56225.00	3570.00	52655.00
8	SCRU00025	NARVA	GUF04005	B		104100001	1	0	PLC-6	0	01.01.1995		56255.00	39000.00	17255.00
9	SCLV00019	PÄRNU	GUR04002	T			1	0	PLC-6	0	01.01.1994		6920.00	2.00	6918.00

Table 4. An example of background information for unmonitored sub-catchments.

	A	B	C	D	E	F	(
1	SUBCATCHMENT_CODE	SUBCATCHMENT_NAME	SUBCATCHMENT_TYPE	PARAMETER_ID	PERIOD_NAME	UNMONITORED_AREA	LAKE_
2	SCDK00259	BAPDKLAND	L	4	PLC-6	1043.00	
3	SCDK00259	BAPDKLAND	L	12	PLC-6	200.00	
4	SCDK00259	BAPDKLAND	L	16	PLC-6	200.00	
5	SCDK00259	BAPDKLAND	L	20	PLC-6	200.00	
6	SCDK00260	KATDKLAND	L	0	PLC-6	7687.00	
7	SCDK00261	SOUDKLAND	L	0	PLC-6	886.00	
8	SCDK00262	WEBDKLAND	L	0	.C-6	7719.00	
9				NOT NULL!			
10							
11							

The following background information for indirect point sources should be reported:

- Code of a point source and the change of activity status (REPORTING_END_DATE. in case the point source has been closed);
- Location. i.e. coordinates of each outlet of an individual point source (latitude and longitude in decimal degrees. (WGS-84)),
- Recipient area of a discharging point source (a defined monitored, unmonitored or a sea area for a discharging point source) is a must, otherwise the location of the point source cannot be defined.
- EU national point source code and E-PRTR sector type. E-PRTR sector codes and their descriptions can be found in table 12 or to be downloaded in https://ec.europa.eu/environment/industry/stationary/e-prtr/legislation.htm.

Reference sheets for each background information in the periodic reporting template are listed in table 5 and the types and the formats of attributes are given in table 6 and 7.

Once the definitions and background information for individual indirect point sources have been updated in the database, a prefilled periodic reporting templates can be downloaded.

In case the prefilled information doesn't contain all point sources to be reported, data manager should be contacted. Aggregated point sources cannot be prefilled and thus data manager should be contacted if point sources will be reported as aggregated.

Table 5. Background information to be reported.

GENERAL VIEW OF THE PERIODIC BACKGROUND INFORMATION TO BE PROVIDED							
BACKGROUND DEFINITIONS	REPORTING	REFERENCE SHEET	SURFACE AREAS				ADDITIONAL INFORMATION
			TOTAL_ DRAINAGE (in km²)	COUNTRY_ DRAINAGE (in km²)	CONTROL AREA by STATION (in km²)	TRANSBOUNDARY DRAINAGE (in km²)	
RIVER/MONITORED SUB-CATCHMENT	INDIVIDUAL	MON_RIVER_BACKGROUND	X	X		X	River mouth coordinates; IS_MONITORED /IS_ UNMONITORED during the period; end date of the catchment validity: lake area of the catchment
UNMONITORED SUB-CATCHMENT	BY SUBBASIN and PARAMETER	UNMON_SUBCATCHMENT_BACKGROUND	X				Lake area of the catchment
TRANSBOUNDARY SUB-SUBCATCHMENT	INDIVIDUAL	TRANS_SUBCATCHMENT_BACKGROUND	X	X		X	Lake area of the catchment
INDIRECT POINT SOURCES	INDIVIDUALLY or AGGREGATED	INDIR_POINT_SOURCE_BACKGROUND					outlet coordinates; PRTR_sector code; end date of a PS (date of closing)

Table 6. Data type and format of catchment background information for periodic reporting.

ATTRIBUTE/SHEET	MON_RIVER_BACKGROUND	UNMON_SUBCATCHMENT_BACKGROUND_	TRANS_SUBCATCHMENT_BACKGROUND
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)
SUBCATCHMENT_TYPE	CHAR(1)	CHAR(1)	
RIVER_CATCHMENT_CODE	CHAR(8)	-	CHAR(8)
PARAMETER_ID	-	INTEGER	-
RIVER_MOUTH_LATITUDE	DECIMAL (dd.dddd)	-	-
RIVER_MOUTH_LONGITUDE	DECIMAL (dd.dddd)	-	-
RIVER_TYPE	CHAR(1)	-	CHAR(1)
NATIONAL_SUBCATCHMENT_CODE	STRING (1-255)	-	STRING(1-255)
NATIONAL_RIVER_CODE	STRING (1-255)	-	STRING(1-255)
NR_CATCHMENTS	INTEGER	INTEGER	INTEGER
MONITORING_TYPE	INTEGER	-	INTEGER
PERIOD_NAME	STRING (4-10)	STRING (4-10)	STRING (4-10)
IS_PRIMARY	-	-	BIT 0/1
CREATION_DATE	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy
END_DATE	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy	DATE(10) dd.mm.yyyy
TOTAL_DRAINAGE_AREA	DECIMAL (8.2)		DECIMAL (8.2)
UNMONITORED_AREA	-	DECIMAL (8.2)	-
COUNTRY_DRAINAGE_AREA	DECIMAL (8.2)	-	DECIMAL (8.2)
TRANSBOUNDARY_AREA	-	-	DECIMAL (8.2)
LAKE_AREA	DECIMAL (8.2)	DECIMAL (8.2)	DECIMAL (8.2)
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)

Table 7. Data type and format of background information for indirect point sources in the periodic reporting template.

ATTRIBUTE/SHEET	INDIR_POINT_SOURCE_BACKGROUND
STATION_CODE	-
SUBCATCHMENT_CODE	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)
STATION_NAME	-
PLANT_CODE	STRING (7)
PLANT_NAME	STRING (1-255)
PERIOD_NAME	STRING (4-10)
IS_ACTIVE	-
RIVER_CATCHMENT_CODE	-
NATIONAL_STATION_CODE	-
EU/ NATIONAL_CODE	CHAR(255)
PRTR_SECTOR_CODE *)	CHAR(1)
STATION/PLANT_CODE_LAT	DECIMAL (dd.dddd)
STATION/PLANT_CODE_LON	DECIMAL (dd.dddd)
WFD_CODE	-
REPORTING_START_DATE	DATE(10)
REPORTING_END_DATE	DATE(10)
TOTAL_NR_OF_PLANTS	INTEGER
TOTAL_NR_OF_TREATED_PLAN	INTEGER
MONITORED_AREA	-
REMARKS	STRING(1-255)

*) PRTR_SECTOR_CODEs are listed below in table 12.

ACTUAL PERIODIC DATA REPORTING

Since the data on loads and flows from monitored. unmonitored and transboundary sub-catchments as well as direct point sources is the subject for annual reporting this data are not included into periodic reporting templates.

INDIRECT POINT SOURCEs (point sources discharging into the freshwater)

Point source discharges into the freshwater is a part of periodic reporting. The indirect point source data should preferably be reported individually, but unlike the direct point source data, periodic loads could also be reported as aggregated, if individual reporting wouldn't be possible.

If the loads will be reported as aggregated, the level of aggregation should correspond to sub-catchment and point source category (MWWTP, INDUSTRY and AQUACULTURE). This means that the load of aggregated MWWTPs could be reported as totals by each monitored sub-catchment and unmonitored sub-catchment. The point source data in the transboundary sub-catchments could also be reported either individually or as aggregated. Unlike the annual reporting, the reported parameters of indirect point sources discharges are: Flow, Ntot, Ptot, and voluntarily Cd, Hg and Pb. The collected parameters on indirect point sources (MWWTP, INDUSTRY and AQUACULTURE) have been listed in the table 1.2. Flow will be reported as total flow in m^3/a and the other parameters as t/a. Heavy metals will be reported only for MWWTPs and INDUSTRIES on a voluntary basis. Reporting of indirect discharges should be carried out in INDIR_MUNICIPAL_FLOW_LOAD. INDIR_INDUSTRIAL_FLOW_LOAD and INDIR_AQUACULTURE_LOAD worksheets.

The data to be reported have been listed below in table 8 and the type and format of each attribute in table 9.

Table 8. An overview of the point source data for periodic reporting.

GENERAL VIEW OF THE PERIODIC DATA REPORTING ON POINT SOURCES						
SOURCE	**REPORTING**	**REFERENCE TABLE**	**FLOW**	**LOAD**	**ADDITIONAL INFORMATION (*****	**CALC. ESTIMATION METHODS OF INPUTS**
MWWTP DISCHARGES INTO FRESHWATER	INDIVIDUALLY/AGGREGATED (*	INDIR_MUNICIPAL_FLOW_LOAD	m^3/a	as listed in Table 1.2	Treatment method and PE (individual reporting)	X
INDUSTRIAL DISCHARGES INTO FRESHWATER	INDIVIDUALLY/AGGREGATED (*	INDIR_INDUSTRIAL_FLOW_LOAD	m^3/a	as listed in Table 1.2	(PRTR sector/ individual reporting)	X
AQUACULTURAL DISCHARGES INTO FRESHWATER	INDIVIDUALLY/AGGREGATED (*	INDIR_AQUACULTURE_LOAD	m^3/a (**	as listed in Table 1.2	Voluntarily feed type, amount of feed used and total production	X

(* Preferably to be reported individually. but can be reported as aggregated by sub-catchment (monitored. unmonitored or transboundary sub-catchment)

(**Flow of an individual aquaculture can be reported on a voluntary basis when it is relevant. i.e. outlet of discharge exists.

(*** Only for individually reported point sources

ADDITIONAL INFORMATION ON POINT SOURCES

In addition to the discharges of MWWTPs, information on LOQ or LOD, number of measurements (NR_MEASUREMENTS), treatment method (TREATMENT_METHOD), number of population equivalent (NR_PE) should be reported for each individual MWWTP, as well as the information on sampling methodology (e.g., non-systematic, systematic, etc.), uncertainty (in %) and used methods of calculation and/or estimation (METHOD_ID) of loads.

Additional data on individually reported industrial plants include information on Limit of quantification or detection (LOQ or LOD), number of measurements (NR_MEASUREMENTS), treatment methods, (TREATMENT_METHOD), E-PRTR sectors, sampling methodology, total uncertainty (in %) and used methods of calculation and estimation of loads (METHOD_ID).

Wastewater treatment methods are listed in tables 10a and 10b and calculation and estimation methods in table 11 for individual MWWTPs and INDUSTRIAL PLANTs. PRTR sectors for industrial plants have been listed in table 12.

Apart from reporting the loads of aquacultural plants, amount of feed (as t/a), feed type (moist, semi-moist and dry) and production (in t/a) can be reported on a voluntary basis in the AQUACULTURE_PRODUCTION sheet. Total uncertainty (TOT_UNCERTAINTY, in %) of the obtained loads and used methods (METHOD_ID) can also be reported. The methods are listed in table 13.

Table 9. Type and format of attributs of the point source data.

ATTRIBUTE/SHEET	DIR/INDIR_MUNICIPAL_LOAD_FLOW	DIR/INDIR_INDUSTRIAL_LOAD_FLOW	DIR/INDIR_AQUACULTURE_LOAD	AQUACULTURE_PRODUCTION
PLANT_CODE	CHAR (7)	CHAR (7)	CHAR (7)	CHAR (7)
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)	-
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)	-
PARAMETER_ID	INTEGER	INTEGER	INTEGER	
PARAMETER_TYPE	CHAR (3)	CHAR (3)	CHAR (3)	
PERIOD_NAME	STRING (4-10)	STRING (4-10)	STRING (4-10)	STRING (4-10)
PERIOD_TYPE	CHAR (1)	CHAR (1)	CHAR (1)	-
IS_LOQ/LOD	BIT 1/0	BIT 1/0	-	-
LIMIT_VALUE	DECIMAL (8(.6))	DECIMAL (8(.6))	-	-
LIMIT_UNIT	CHAR(4)	CHAR(4)	-	-
NUMBER_BELOW_LIMIT	INTEGER	INTEGER	-	-
NR_MEASUREMENTS	INTEGER	INTEGER	-	-
VALUE	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))	-
VALUE_UNIT	STRING(3-6)	STRING(3-6)	STRING(3-6)	-
TOT_UNCERTAINTY	INTEGER	INTEGER	INTEGER	-
NR_PE	INTEGER	-	-	-
TREATMENT_METHOD	INTEGER	INTEGER	-	-
SAMPLING_METHODOLOGY	CHAR(1)	CHAR(1)	-	-
DATA_SOURCE_FLAG	CHAR(2)	CHAR(2)	CHAR(2)	-
METHOD_ID	INTEGER	INTEGER	INTEGER	-
FEED_TYPE	-	-	-	CHAR(1)
AMOUNT_OF_FEED	-	-	-	DECIMAL (10(.3))
AQUACULTURE_PRODUCTION	-	-	-	DECIMAL (10(.3))
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)	-

Table 10a and b. Wastewater treatment methods (a) and supplementary methods (b) of individually reported MWWTPs and industrial plants.

TREATMENT	METHOD DESCRIPTION
N	UNKNOWN
U	UNTREATED
P	PRIMARY
S	SECONDARY
T	TERTIARY

SUPPLEMENTARY	METHOD DESCRIPTION
0	NO SUPPLEMENTARY METHOD
1	ADDITIONAL N REMOVAL
2	ADDITIONAL P REMOVAL
3	UV DISINFECTION
4	CHLORINATION
5	SAND FILTRATION
6	MICRO - / ULTRA FILTRATION
7	OTHER METHOD (TO BE SPECIFIED)

Table 11. List of calculation / estimation methods of individually reported MWWTPs and industrial plant discharges.

METHOD_ID	METHOD DESCRIPTION
0	UNKNOWN
11	CONTINUOUS FLOW AND CONCENTRATION MEASUREMENTS
12	CONTINUOUS FLOW AND NON-CONTINUOUS CONCENTRATION
13	NON-CONTINUOUS FLOW AND CONCENTRATION SAMPLING
14	ESTIMATION OF LOAD BASED ON NUMBER OF POPULATION CONNECTED BOD_7 = 70g O_2/PERSON/DAY, N_{tot} = 12g N/PERSON/DAY, PTOTAL = 2.7g P_{tot}/PERSON/DAY
15	A COUNTRY SPECIFIC METHOD (SHOULD BE DESCRIBED IN DETAIL)

Table 12. List of E-PRTR sectors of industrial plants. Sector 6,7 and 8 make up category 6 in the IE Directive[16]. See also footnote 14.

PRTR	CODE DESCRIPTION
1	ENERGY SECTOR
2	PRODUCTION AND PROCESSING OF METALS
3	MINERAL INDUSTRY
4	CHEMICAL INDUSTRY
5	WASTE AND WASTEWATER MANAGEMENT
6	PAPER AND WOOD PRODUCTION AND PROCESSING
7	INTENSIVE LIVE STOCK PRODUCTION AND AQUACULTURE
8	ANIMAL AND VEGETABLE PRODUCTS FROM THE FOOD AND BEVERAGE SECTOR
9	OTHER ACTIVITIES

Table 13. List of estimation / calculation method of aquaculture discharge.

METHOD_ID	METHOD DESCRIPTION
0	UNKNOWN
36	MONITORING AT THE OUTLETS FROM THESE PLANTS
37	BASED ON PRODUCTION AND FEED CONSUMPTION OF A PLANT
38	BASED ON PRODUCTION OR FEED CONSUMPTION OF A PLANT

[16] EC 2010: Industrial Emissions Directive: https://ec.europa.eu/environment/industry/stationary/ied/legislation.htm

DIFFUSE SOURCES INTO THE INLAND SURFACE WATER (Source orientated approach)

Diffuse sources to be reported include natural background and anthropogenic gross loads (losses) of nutrients into the freshwater. Data on diffuse sources should be reported by sub-catchment as defined in '**BACKGROUND INFORMATION'** above**.** The sub-catchments are:

- Monitored sub-catchments;
- Monitored transboundary rivers;
- Monitored border rivers and
- Unmonitored sub-catchments.

Transboundary and border rivers will be listed in the template of the Contracting Party who has the reporting responsibility of the river.

Diffuse sources of the monitored sub-catchments and monitored rivers should be reported in MON_DIFF_SOURCE sheet, diffuse sources of unmonitored sub-catchments in UNMON_DIFF_SOURCE sheet and the transboundary diffuse sources in the TRANS_DIFF_SOURCE sheet, respectively (Table 14).

Diffuse loads into the freshwater to be reported include the following source categories:

- Natural background source (NBS);
- Agricultural source (AGS);
- Source of managed forestry (MFS);
- Source of atmospheric deposition into the inland surface waters (ATS);
- Source of scattered dwellings (SCS);
- Source of storm water overflow and by-passes (SWS);
- Transboundary sources measured at border (TRS);
- Unknown sources (UKS) – the category is used to equalize the sum of loads to the total load from sub-catchment when all other sources are reported;
- Sum of diffuse sources (DIS) – the category is used to report aggregated load for several diffuse sources and require specification of aggregated sources.

In case transboundary losses cannot be divided into above categories then a common category for transboundary sources (TRS) can be used.

Unknown sources (UKS) should be used if none of the above categories can be defined.

Agricultural and managed forestry sources can be divided further into pathways, which are:

- Soil erosion (ER);
- Surface run-off (SR);
- Natural interflow (NI);
- Tile drainage (TD);
- Ground water (BF, formerly = base flow);
- Sum of pathways (SP).

If 'pathways' cannot be defined then 'sum of pathways '(as 'SP'), should be used instead. Diffuse sources into the inland surface waters should be calculated or estimated to each defined sub-catchment. Applied calculation/estimation methods of sources should be reported, as well. Types and formats of attribute in spreadsheet for diffuse losses reporting are listed in table 17.

Table 14. Overview of reporting obligations related to diffuse sources.

GENERAL VIEW OF THE PERIODIC DATA REPORTING ON DIFFUSE SOURCES				
AREA	REPORTING	DIFFUSE SOURCES INTO THE INLAND SURFACE WATER		
		REFERENCE TABLE	ANTHROPOGENIC AND NATURAL SOURCES	
			DIFFUSE SOURCES	DIFFUSE SOURCE PATHWAY
MONITORED SUBCATCHMENT	INDIVIDUALLY	MON_DIFFUSE_SOURCE	Total N and total P t/a by diffuse source category (*	Total N and total P t/a by pathway (**
TRANDBOUNDARY/ BORDER RIVERs	INDIVIDUALLY	TRANS_DIFFUSE_SOURCE	Total N and total P t/a by diffuse source category (*	Total N and total P t/a by pathway (**
UNMONITORED AREAS	AGGREGATED by country and subbasin	UNMON_DIFFUSE_SOURCE	Total N and total P t/a by diffuse source category (*	Total N and total P t/a by pathway (**

(* Diffuse source categories are: natural background. agriculture. managed forestry. atmospheric deposition into the inland surface water. scattered dwellings. storm water overflow and by-passes and if the listed sources aren't available. then transboundary sources and unknown sources to be used.

(** Agricultural and manage forestry pathways are: Soil erosion (ER). surface run-off (SR). natural interflow (NI). tile drainage (TD). ground water (formerly base flow. BF). If all pathways cannot be reported separately then for the 'sum of pathways' (SP) should be used.

RETENTION (retained nutrients in the inland surface waters)

Retention, total amount of retained nutrients in inland surface water, should be reported by sub-catchment as defined in '**BACKGROUND INFORMATION'** above**.** The sub-catchments are:

- Monitored sub-catchments;
- Monitored transboundary rivers,
- Monitored border rivers;
- Unmonitored sub-catchments

Sources, reporting reference tables and reported parameters are given in table 15 and the type and the format of the reported attributes in table 17.

Table 15. Overview of reporting obligations related to retention.

GENERAL VIEW OF THE PERIODIC DATA REPORTING ON RETENTION			
SOURCE	**REPORTING**	**RETENTION IN THE INLAND SURFACE WATER**	
		REFERENCE TABLE	**RETENTION**
MONITORED SUBCATCHMENT	INDIVIDUALLY	MON_RETENTION	Retention of N and P t/a
TRANDBOUNDARY/BORDER RIVERs	INDIVIDUALLY	TRANS_RETENTION	Retention of N and P t/a
UNMONITORED AREAS	AGGREGATED by country and sub-basin	UNMON_RETENTION	Retention of N and P t/a

Retention of nutrients should be reported for the same sub-catchments as the total loads. Also negative or 'zero' retention values should be reported. The losses of upper parts of the transboundary rivers (at border) should be taken into account and the Contracting Parties sharing the river should agree on retention values between the countries.

In addition, methods estimating retention should be reported. It has been agreed on that the Contracting parties can use their own specific methods, but they should be described in detail.

LOAD ORIENTATED APPROACH (loads by source to the Baltic Sea)

Loads by source to the Baltic Sea should be reported by sub-catchment as specified in '**BACKROUND INFORMATION'.**

The sub-catchments are:

Monitored sub-catchments;

Monitored transboundary rivers;

Unmonitored sub-catchments

Transboundary and border rivers will be listed in the template of the Contracting Party who has the reporting responsibility of the river.

The load by source should be reported to the same defined sub-catchments as the loads of monitored, transboundary and border rivers and sub-catchments as well as the loads of unmonitored sub-catchments. If the loads by source cannot be reported for the same sub-catchments as the annual total loads, periodic data verification and comparison of total annual loads and periodic loads will not be possible, i.e., total annual discharges by sub-catchment = sum of loads by source by sub-catchment.

Source categories to be reported are:

DL = Diffuse load (including natural background load) **(A reference below)**

PL= Point source load **(B reference below)**

TL = Transboundary load **(C reference below)**

UL = Unknown load **(D reference below)**

If discharges cannot be divided into origins of loads (as below in A: Diffuse loads and B: Point source loads), then a sum of all sources should be reported (Diffuse loads, DIL and Point source loads, PIL). If none of the three sources cannot be defined, then only unknown load (UL) should be used.

A: DIFFUSE LOADS

AGL = Load of agriculture

ATL = Atmospheric deposition

DIL = Diffuse load can be used as a sum of the sources. if aggregated sources can be specified

DUL = Unknown diffuse load can be used for loads from unspecified sources (total river load to the sea if sources are not reported)

MFL = Load of managed forestry and other managed land load

NBL = Natural background load

SCL = Load of scattered dwellings

SWL = storm water and overflows

B: POINT SOURCE LOADS

MWL = Municipal

INL = Industry

AQL = Aquaculture

OTL = Other point source load (none of the three categories)

PIL = Point source loads from more than one category (require specification of aggregated sources)

PUL = Point source unknown load

C: TRANSBOUNDARY LOAD

-to be left empty

D: UNKNOWN LOAD

-to be left empty

Table 16. Overview of reporting obligations related to load orientated approach.

AREA	REPORTING	LOAD ORIENTATED APPROACH		
		DIFFUSE LOAD	**POINT SOURCE LOAD**)**	**TRANSBOUNDARY LOAD***)**
RIVER/MONITORED CATCHMENT	INDIVIDUALLY	Ntot and Ptot in t/a by source*)	Total N and total P t/a by point source load category **)	Total N and total P t/a by source
TRANDBOUNDARY/BORDER RIVERs	INDIVIDUALLY	Ntot and Ptot in t/a by source*)	Total N and total P t/a by point source load category **)	Total N and total P t/a by source
UNMONITORED AREAS	BY SUBBASIN and COUNTRY	Ntot and Ptot in t/a by source*)	Total N and total P t/a by point source load category **)	

*) Diffuse loads to be reported separately for agriculture. managed forestry. atmospheric deposition into the freshwater. scattered dwellings, storm water overflows and by-passes and transboundary load

**) Point source load categories are: MWWTP, industry, fish farms

***) For transboundary loads both DIFFUSE LOAD and POINT SOURCE LOAD sources should be used, but if not possible then total estimate of transboundary load should be used reported for transboundary/ border river loads

In order to ensure a complete coverage of the data collection same areas should be used in reporting the point source loads in the catchments, diffuse losses by source into the freshwater, retention and loads by source finally entering to the Baltic Sea.

Table 17. Type and format by attribute and spreadsheet of diffuse losses. retention and loads by source.

ATTRIBUTE/SHEET	MON/UNMON/TRANS_DIFFUSE_SOURCE	MON/UNMON/TRANS_RETENTION	MON/UNMON/TRANS_LOAD ORIENTATED
SUBCATCHMENT_CODE	CHAR (9)	CHAR (9)	CHAR (9)
SUBCATCHMENT_NAME	STRING (1-255)	STRING (1-255)	STRING (1-255)
PARAMETER_ID	INTEGER	INTEGER	INTEGER
PARAMETER_TYPE	CHAR (3)	CHAR (3)	CHAR (3)
PERIOD_NAME	STRING (4-10)	STRING(4-10)	STRING (4-10)
PERIOD_TYPE	CHAR (1)	-	CHAR (1)
START_TIME	-	DATE(10)	-
END_TIME	-	DATE(10)	-
DIFFUSE_TYPE	CHAR (3)	-	-
PATHWAY_TYPE	CHAR (2)	-	-
SOURCE_CATEGORY	-	-	CHAR (2)
SOURCE_NAME	-	-	CHAR (3)
VALUE	DECIMAL (10(.3))	DECIMAL (10(.3))	DECIMAL (10(.3))
VALUE_UNIT	STRING(3-6)	STRING(3-6)	STRING(3-6)
TOT_UNCERTAINTY	INTEGER	INTEGER	INTEGER
DATA_SOURCE_FLAG	CHAR(2)	CHAR(2)	CHAR(2)
METHOD_ID	INTEGER	INTEGER	INTEGER
REMARKS	STRING(1-255)	STRING(1-255)	STRING(1-255)

Annex 4. Reporting and quality assurance using PLC WEB-application

Annual and periodic data should be reported using the PLUS web application which can be found at http://nest.su.se/helcom_plus. The application provides set of tools to report and manage the data in the HELCOM PLC-Water database. Generally, reporting of the data consists of four steps:

1. Fill in data into a template. obtained from the PLUS system;
2. Upload the template with the data to the PLUS archive in Excel format;
3. Run Quality assurance checks and then insert the data into the database;
4. Check and approve the data in the database.

Annual and periodic templates with prefilled background information are prepared by the HELCOM secre**tariat (data manager) for each country and they can be downloaded from the system (**Figure 1 and Figure 2). Contracting Parties are invited to verify prefilled background information and update it if necessary. In the latter case the modified template should be uploaded to the system in order to make related updates of the database.

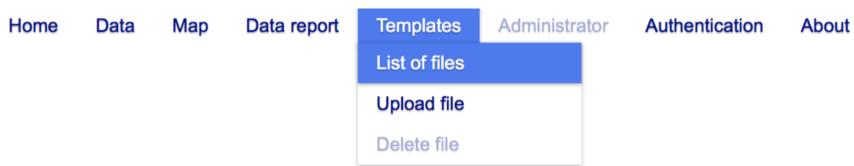


Figure 1. Show list of templates and documents.

Document id	Notes	File name	Date of upload	First name	Surname
48		FI_ANNUAL_REPORTING_2016_04122017.xlsx	2017-12-04 15:42:32.997	Antti	Raike
47		RU_ANNUAL_REPORTING_2016_updated.xlsx	2017-11-10 07:55:14.987	Natalia	Ivaskova
46		DK_ANNUAL_REPORTING_2016_updated.xlsx	2017-11-08 06:53:41.95	Henrik	Tornbjerg
45		LT_ANNUAL_REPORTING_2016_updated.xlsx	2017-10-20 11:54:17.1	Svajunas	Plunge
44		SE_ANNUAL_REPORTING_2016.xlsx	2017-10-11 06:16:56.437	Dmitry	Frank-Kamenetsky
43		RU_ANNUAL_REPORTING_2016.xlsx	2017-10-11 06:16:50.337	Dmitry	Frank-Kamenetsky

Figure 2. List of prepared and updated templates.

Templates (MS Excel files in .xlsx format) filled with the actual data should be uploaded to the database (Figure 3).

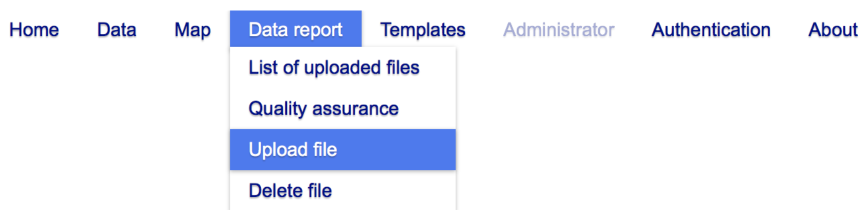


Figure 3. Dialog menu for uploading data.

Uploaded data reports are stored in the database in original form as archived copy and to make data available in the database additional steps have to be made. Firstly, one need to check that uploaded file is in the database archive (Figure 4).

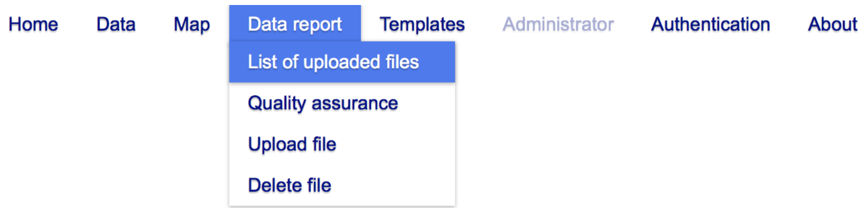


Figure 4. Show list of uploaded files (data in Excel format).

In the example presented in Figure 5, the file with ID=1866 has been uploaded to the system. Note, empty cells **Date of QA** and **QA log** indicate that this report has not been processed and the data are not available from the database.

ID	Name	Surname	e-mail	Date of report	File name	Date of QA	QA log	Notes
1866	Lars	Sonesten	[redacted]	2017-10-18 08:27	SE_ANNUAL_REPORTING_2016_REV2			
1865	Lars	Sonesten	[redacted]	2017-10-16 15:17	SE_ANNUAL_REPORTING_2016v2.xlsx	2017-10-16 15:17	Show log	
1864	Lars	Sonesten	[redacted]	2017-10-16 15:07	SE_ANNUAL_REPORTING_2016.xlsx	2017-10-16 15:08	Show log	

Figure 5. Example of list of uploaded data.

To check the data a quality an assurance procedure should be performed. To do so the corresponding line should be selected in the table (Figure 6) to indicate the report to be processed.

ID	Name	Surname	e-mail	Date of report	File name	Date of QA	QA log	Notes
1866	Lars	Sonesten	[redacted]	2017-10-18 08:27	SE_ANNUAL_REPORTING_2016_REV2			
1865	Lars	Sonesten	[redacted]	2017-10-16 15:17	SE_ANNUAL_REPORTING_2016v2.xlsx	2017-10-16 15:17	Show log	
1864	Lars	Sonesten	[redacted]	2017-10-16 15:07	SE_ANNUAL_REPORTING_2016.xlsx	2017-10-16 15:08	Show log	

Figure 6. Select uploaded data before run quality assurance procedures.

Quality assurance menu (Figure 7) provides several tools to work with the selected data report. Here we are interested in the first one - **Check data.** It performs QA level 1 and QA level 2 checks and writes diagnostics to the log file. Nothing is inserted into the database by this procedure. This is a first step just to check quality of the data.

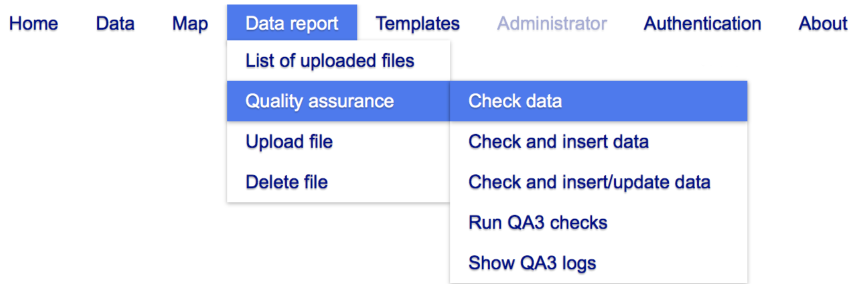


Figure 7. Check the data by running quality assurance procedure.

After performing the **Check data** procedure one can click the link **Show log** (**Figure 8**).

ID	Name	Surname	e-mail	Date of report	File name	Date of QA	QA log	Notes
1866	Lars	Sonesten		2017-10-18 08:27	SE_ANNUAL_REPORTING_2016_REV2	2017-10-26 10:14	Show log	
1865	Lars	Sonesten		2017-10-16 15:17	SE_ANNUAL_REPORTING_2016v2.xlsx	2017-10-16 15:17	Show log	
1864	Lars	Sonesten		2017-10-16 15:07	SE_ANNUAL_REPORTING_2016.xlsx	2017-10-16 15:08	Show log	

Figure 8. Date of QA and link to the log is added to the checked reported data and analyse the results of QA Check data procedure (Figure 9).

QA level 1: verification of the format and conformity of the data with the database structure

Number of errors: 9

ERROR - 'AQUACULTURE_PRODUCTION'!A2 Cell PLANT_CODE cannot be null or blank
ERROR - 'TRANSBOUNDARY_FLOW_LOAD'!A2 Cell SUBCATCHMENT_CODE cannot be null or blank
ERROR - 'TRANSBOUNDARY_FLOW_LOAD'!C2 Cell PARAMETER_ID cannot be null or blank
ERROR - 'TRANSBOUNDARY_FLOW_LOAD'!D2 Cell PARAMETER_TYPE cannot be null or blank
ERROR - 'TRANSBOUNDARY_FLOW_LOAD'!L2 Cell VALUE_UNIT cannot be null or blank
ERROR - 'TRANSB_SUBCATCHMENT_RETENTION'!A2 Cell SUBCATCHMENT_CODE cannot be null or blank
ERROR - 'TRANSB_SUBCATCHMENT_RETENTION'!C2 Cell PARAMETER_ID cannot be null or blank
ERROR - 'TRANSB_SUBCATCHMENT_RETENTION'!D2 Cell PARAMETER_TYPE cannot be null or blank
ERROR - 'TRANSB_SUBCATCHMENT_RETENTION'!G2 Cell VALUE_UNIT cannot be null or blank

Number of warnings: 0

Number of notifications: 0

Number of missing required values: 7730

Total number of processed rows : 2164

Number of rows passed QA level 1 : 2161

Commented Excel file SE_ANNUAL_REPORTING_2016v2_20171016151759.xlsx is available.

QA level 2: verification of the content for questionable data values

Number of distrust values: 8

Number of suspicious values: 59

Number of unchecked values: 606

Figure 9. Log of the Quality assurance - Check data task.

There are nine errors in this example. which should be corrected in the original data report, then corrected report should be reuploaded to the system and checked again. When all errors and warnings are corrected the data can be inserted into the PLC-Water database. It can be done by selecting **Quality assurance > Check and insert data** (Figure 10).

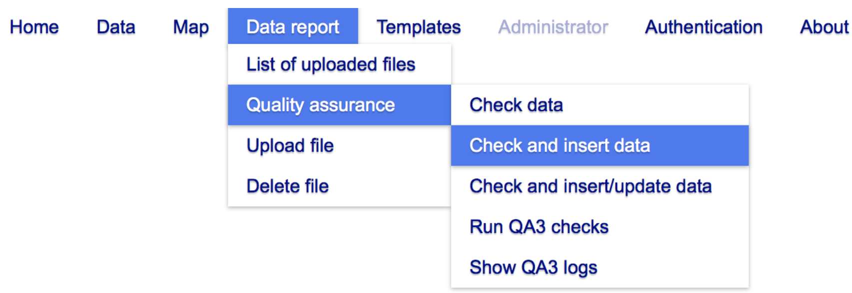


Figure 10. Command to insert data into the database.

In this step the data will be checked in the same way as it was done before and data from the rows without errors are inserted into the database. Example of the log file is presented in Figure 11. One should pay attention on the line "Number of rejected rows". It should be equal to zero. Otherwise, the errors should be located and whole procedure (correct data in the template, upload it, check data, check and insert data) should be repeated.

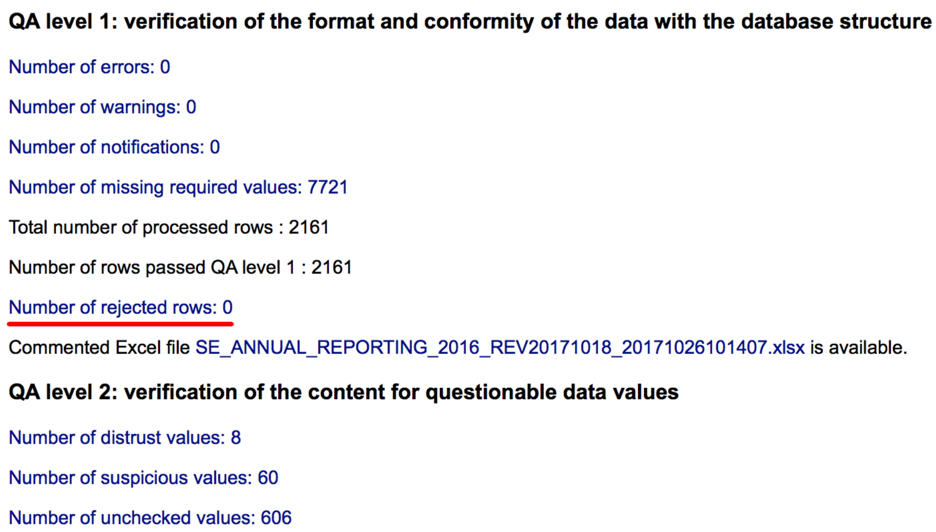
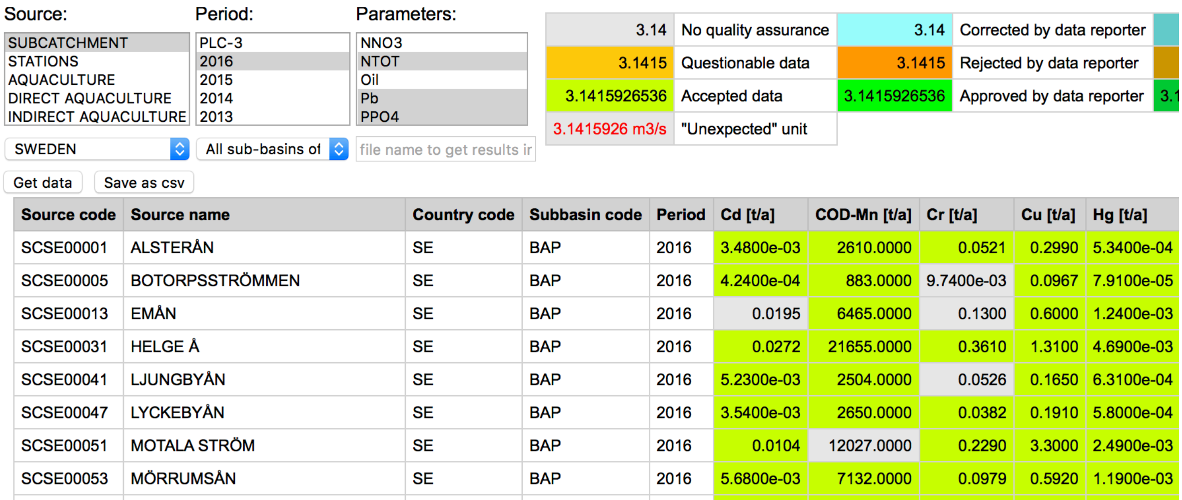


Figure 11. Log after insertion of the data into the database.

Now the data are in the database and they can be checked using "**Data > Request data for year**" (Figure 12)

Figure 12. Command to request data from the database.

Here one can select appropriate set of parameters and click **Get data** button (Figure 13).



Source code	Source name	Country code	Subbasin code	Period	Cd [t/a]	COD-Mn [t/a]	Cr [t/a]	Cu [t/a]	Hg [t/a]
SCSE00001	ALSTERÅN	SE	BAP	2016	3.4800e-03	2610.0000	0.0521	0.2990	5.3400e-04
SCSE00005	BOTORPSSTRÖMMEN	SE	BAP	2016	4.2400e-04	883.0000	9.7400e-03	0.0967	7.9100e-05
SCSE00013	EMÅN	SE	BAP	2016	0.0195	6465.0000	0.1300	0.6000	1.2400e-03
SCSE00031	HELGE Å	SE	BAP	2016	0.0272	21655.0000	0.3610	1.3100	4.6900e-03
SCSE00041	LJUNGBYÅN	SE	BAP	2016	5.2300e-03	2504.0000	0.0526	0.1650	6.3100e-04
SCSE00047	LYCKEBYÅN	SE	BAP	2016	3.5400e-03	2650.0000	0.0382	0.1910	5.8000e-04
SCSE00051	MOTALA STRÖM	SE	BAP	2016	0.0104	12027.0000	0.2290	3.3000	2.4900e-03
SCSE00053	MÖRRUMSÅN	SE	BAP	2016	5.6800e-03	7132.0000	0.0979	0.5920	1.1900e-03

Figure 13. Example of the data. Background colour of the cells represents a quality flag.

Background colour represents data quality flags which were assigned to the data during quality check (QA level 2: statistical testing of the data with the existing data) of the data. The QA level 2 procedure can assign following flags to the data:

- No quality assurance – there are not enough data for statistical tests;
- Questionable data – data lie outside of a 95% confidence interval;
- Accepted data – data lie inside the confidence interval;
- "Unexpected" unit – data are reported in a unit which is not the same as a majority of the data.

The contracting parties should manually approve the data without quality assurance (grey colored cells) and the questionable data (light brown colored cells). It can be done by selecting the cell and right mouse click will show pop-up dialog to manage the data **(**Figure 14).

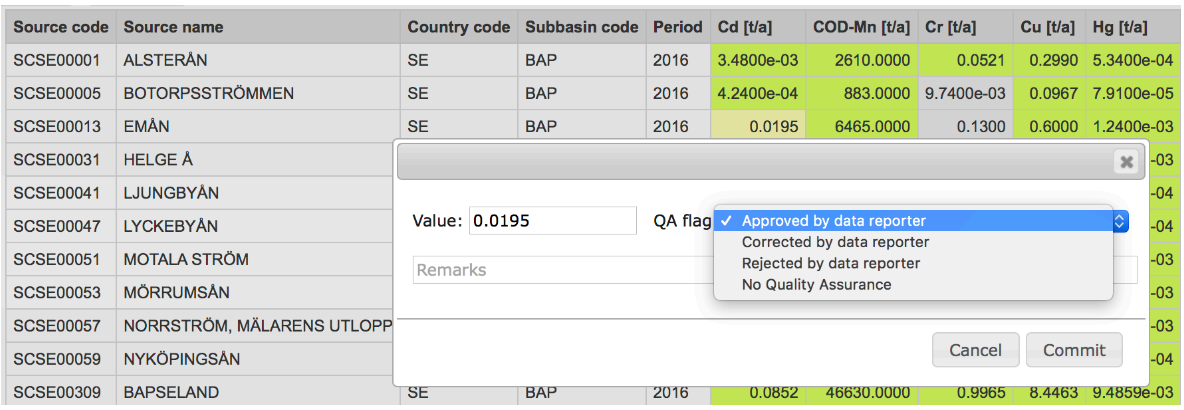


Figure 14. Quality assurance level 3: manual approval of the data.

Data, passed the statistical tests and automatically accepted (light green colored cells) considered to be of a good quality and shouldn't be manually approved. As a result of the approval procedure (see for example Figure 15), the data should be marked as:

- Accepted; Approved by data reporter; Approved by quality assurer/data manager
- Corrected by data reporter; Corrected by quality assurer/data manager
- Rejected by data reporter; Rejected by quality assurer/data manager

Source code	Source name	Country code	Subbasin code	Period	Cd [t/a]	COD-Mn [t/a]	Cr [t/a]	Cu [t/a]	Hg [t/a]
SCSE00001	ALSTERÅN	SE	BAP	2016	3.4800e-03	2610.0000	0.0521	0.2990	5.3400e-04
SCSE00005	BOTORPSSTRÖMMEN	SE	BAP	2016	4.2400e-04	883.0000	9.7400e-03	0.0967	7.9100e-05
SCSE00013	EMÅN	SE	BAP	2016	0.0195	6465.0000	0.1300	0.6000	1.2400e-03
SCSE00031	HELGE Å	SE	BAP	2016	0.0272	21655.0000	0.3610	1.3100	4.6900e-03
SCSE00041	LJUNGBYÅN	SE	BAP	2016	5.2300e-03	2504.0000	0.0526	0.1650	6.3100e-04
SCSE00047	LYCKEBYÅN	SE	BAP	2016	3.5400e-03	2650.0000	0.0382	0.1910	5.8000e-04
SCSE00051	MOTALA STRÖM	SE	BAP	2016	0.0104	12027.0000	0.2290	3.3000	2.4900e-03

Figure 15. Example of quality assured data.

Annex 5. Example of instructions to personnel carrying out the sampling

Note: Collection of water samples in rivers can potentially be dangerous and the Contracting Parties should therefore ensure that safety instructions are given. Some countries have legislative requirements for the safety of personnel.

Suggested instructions to personnel carrying out the sampling:

a. Make sure that you collect the sample from a location where the water is well mixed (e.g. downstream a weir, waterfall, or in turbulent rapids). Avoid locations just downstream of a road, drainage pipe, tributary or other potential pollutant sources. Also ensure that the location is upstream of saltwater intrusion.
b. Make sure that all bottles are properly labelled with the required information (e.g., sample number, date, time, and site).
c. Bottles should preferably be filled directly from the river water. If this is not possible, and a sampling container must be used, make sure to avoid cross-contamination between sites. In some cases, one set of sampling equipment per site should be used to avoid contamination. In some cases, bottles may already be filled with solutions (e.g., for preservation), and it is necessary to use a sampling vessel.
d. If a sampling container is used, ensure that at no time any metal containing objects are stored in the container. Also, if a metal "messenger weight" is used to close the sampler, ensure that the weight is completely encapsulated with plastics or other inert material to avoid contamination (often the weight contains metals like Pb and/or Cu and Zn).
e. Wade into the river if possible, but make sure the sample will not be contaminated by disturbed (resuspended) bank or bed material.
f. If the sample is collected from the bank side, an extension pole or a rope can be useful. Again, it is best if the bottle is filled directly from the river water, if this is not possible, see point c) above.
g. If sampling is done from a boat, a bridge or similar constructions, care should be taken to avoid contamination of the sample from the boat or the construction, or with disturbed river sediments.
h. If samples need to be taken under ice, the sampling point may have to be moved (this should be mentioned in the sampling report). Clear loose ice and snow from around the sampling point, and drill through the ice. Ensure that the area around the hole remains clean and free of potential contamination. Remove ice and slush from the hole and wait to let the water run freely before taking the sample. Take the sample from well below the lower layer of ice. Be cautious if there is water on the ice that will flow into the hole, as this might contaminate the sample.
i. When taking the sample, face upstream towards the flow of the water and take the sample upstream from yourself. Remove the cap and plunge the neck of the open bottle under the surface of the water, about 25 cm deep, with the bottle neck facing upstream. Ensure that the bottle does not touch the bottom in shallow streams.
j. All bottles should be filled to the top, except glass bottles (since, at temperatures below zero, the glass may break if the water freezes).
k. If there is reason to believe that the concentration of sampled substances can change markedly within a short time period, pooled sampling strategy is recommended. This involves that several sub-samples are taken and combined into one sample. Otherwise,

discrete grab samples can be collected. Ensure that a clean vessel is used for the pooling of the sample.

l. Do not smoke while sampling, as this can contaminate the water samples. If the sampling personnel are smokers or using chewing tobacco, plastic gloves should be used.
m. Do not touch the neck of the bottle or inside of the stopper/cork, as this may contaminate the sample.
n. Transfer the bottles to a dark, cool place (e.g., use a cooler) as soon as possible before transport to the laboratory.
o. Samples should be sent to the laboratory as soon as possible and preferably be received at the laboratory no later than 24 hours after sampling.
p. Keep a sampling record where dates and time of each sample is recorded, as well as any additional information (weather conditions, sampling under ice, any anomalies, etc.).

Annex 6. EMEP assessment of atmospheric nitrogen and heavy metal deposition on the Baltic Sea

Written by EMEP MSC-W and EMEP MSC-E

The EMEP centers MSC-W and MSC-E prepare annual assessments for HELCOM of emissions and depositions of nitrogen, heavy metals and PCDD/Fs to the Baltic Sea. These are based on modelling and monitoring data, which are annually presented to the Steering Body of EMEP.

NB: References mentioned in this annex are in the end of the annex.

Assessing atmospheric nitrogen deposition to the Baltic Sea

The atmospheric depositions of oxidized and reduced nitrogen are calculated annually with the latest version of the EMEP MSC-W model (Simpson et al., 2012). The latest available official emission data for the HELCOM countries are used in the model computations. In 2021, emissions of nitrogen species for each year of the period 2000-2019 have been officially reported to the UN ECE Secretariat by several HELCOM Contracting Parties and further processed (gap-filled and spatially gridded) for modelling by the EMEP Centre on Emission Inventories and Projections (CEIP). Both official data and expert estimates are used for modelling atmospheric transport and deposition of nitrogen compounds to the Baltic Sea. The emission data used for modelling are reported by EMEP MSC-W to HELCOM but can also be downloaded directly from the website of CEIP (https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models).

Atmospheric depositions of oxidized and reduced nitrogen are computed for the entire EMEP domain, which includes the Baltic Sea basin and its catchment. Time series of annual atmospheric depositions are available for the period 1990 – 2019.

The EMEP MSC-W model is a multipollutant, three-dimensional Eulerian model, which takes into account processes of emission, advection, turbulent diffusion, chemical transformations, wet and dry depositions, and inflow of pollutants into the model domain. A complete description of the model can be found in Simpson et al. (2012), while documentation of later updates can be found in the EMEP status reports of EMEP MSC-W (Simpson et al., 2019; 2020 and references therein). The model is also available as *Open Source* code at https://github.com/metno/emep-ctm. The results of the EMEP MSC-W model are routinely evaluated against available measurements at EMEP and HELCOM stations (see, e.g. Gauss et al., 2020a).

Assessing atmospheric heavy metal depositions to the Baltic Sea

Atmospheric deposition and long-term trends of heavy metals (cadmium, lead, mercury, and copper) are regularly assessed for HELCOM by the EMEP Centre MSC-E, using the latest version of the GLEMOS model over the EMEP domain (https://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/). GLEMOS is a multi-scale multi-pollutant simulation platform developed for operational and research applications within the EMEP programme (Tarrason and Gusev, 2008; Travnikov et al., 2009; Jonson and Travnikov, 2010, Travnikov and Jonson, 2011). The framework allows simulations of dispersion and cycling of different classes of pollutants (e.g. heavy metals and persistent organic pollutants) in the environment with a flexible choice of the simulation domain (from global to local scales) and spatial resolution. In the vertical, the model domain covers heights up to 10 hPa (about 30 km). The global-scale configuration of the GLEMOS model is used to simulate boundary concentrations of heavy metals for the EMEP domain.

Pollution levels and source-receptor relationships for lead are simulated using the latest version of the MSCE-HM model (Travnikov and Ilyin, 2005; Gusev et al., 2005), a three-dimensional Eulerian model operating within the geographical scope of the EMEP region with spatial resolution 50 km at 60° latitude. The hemispheric-scale version of MSCE-HM is used for simulation of boundary concentrations at the borders of the old EMEP domain.

It is assumed that lead and cadmium and their compounds are transported in the atmosphere in composition of aerosol particles. It is believed that possible chemical transformations of lead and cadmium do not change properties of carrying particles with regard to removal processes. For mercury the model considers transformations in the atmosphere including transition between the gaseous, aqueous and solid phases, and chemical reactions in air and in water of cloud droplets. The model description of removal processes includes dry deposition and wet scavenging. The dry deposition scheme is based on the resistance analogy and takes into account deposition to different land cover types. The model distinguishes in-cloud and sub-cloud wet scavenging of particulate species and highly soluble reactive gaseous mercury. The model includes parameterization of heavy metal re-suspension with dust aerosol particles from soil and generation of sea-salt aerosol and wind suspension of heavy metals from sea surface.

The formulation of the MSCE-HM model and its performance has been thoroughly evaluated within the framework of activity of EMEP/TFMM on the EMEP Models Review (ECE/EB.AIR/GE.1/2006/4). One of the main conclusions of the TFMM Workshop held in Moscow in 2005 was that the MSCE-HM model represents the state of the science and is fit for the purpose of evaluating the contribution of long-range transport to the environmental impacts caused by HMs. The GLEMOS model results are regularly evaluated against measurements of the EMEP network under the LRTAP Convention (e.g. Travnikov et al., 2020).

Normalizing atmospheric deposition

In order to reduce the influence of meteorology on computed annual deposition an thus allow for better evaluation of the effectiveness of measures taken to reduce pollution loads, EMEP has developed a simple procedure for normalizing atmospheric deposition values. The following is a description of how EMEP have used the source-receptor matrices and depositions for calculating "normalized" depositions to the Baltic Sea for oxidized, reduced and total nitrogen and for each year of the period 1995-2019. The equations below were used for each of 25-year period 1995-2019 with available EMEP model runs.

The total nitrogen deposition to the Baltic Sea basin in the year ***iy*** can be calculated as:

$$D^{tot}(iy) = D^{ox}(iy) + D^{rd}(iy) = \sum_{i=1}^{ns1} A_i^{ox}(iy) \times E_i^{ox}(iy) + \sum_{i=1}^{ns2} A_i^{rd}(iy) \times E_i^{rd}(iy) \qquad \text{(A6.1)}$$

Where $D^{ox}(iy)$ and $D^{rd}(iy)$ are the annual total depositions of oxidized and reduced nitrogen, respectively, to the Baltic Sea in the year iy. The numbers of emission sources contributing to oxidized nitrogen deposition (*ns1*) and reduced nitrogen (*ns2*) are different in general, because some sources (e.g. ship traffic on the Baltic Sea) emit only oxidized nitrogen.

The annual depositions are calculated for each combination of meteorological and emission years:

$$D^{ox}(ie,im) = \sum_{i=1}^{ns1} A^{ox}(im) \times E^{ox}(ie) + R^{ox}(ie,im)$$
$$D^{rd}(ie,im) = \sum_{i=1}^{ns2} A^{rd}(im) \times E^{rd}(ie) + R^{rd}(ie,im) \qquad \text{(A6.2)}$$

Terms $R^{ox}(ie,im)$ and R^{rd} (ie,im) are introduced mainly because of the contribution of BIC (Initial and Boundary Conditions) in the model calculations, an additional source for which emissions cannot be specified. For the

Baltic Sea basin this additional source is contributing in non-negligible amounts only to oxidized nitrogen deposition, i.e. $R^{rd}(ie,im)=0$. The normalized deposition of total nitrogen for the emission year, i.e. DN(ie) is defined as:

$$DN(ie) = MED\left\{D^{ox}(ie,1) + D^{rd}(ie,1),\ldots,D^{ox}(ie,im) + D^{rd}(ie,im),\ldots,D^{ox}(ie,16) + D^{rd}(ie,16)\right\} \quad \text{(A6.3)}$$

Where *MED* is the median taken, in this example, over 16 values corresponding to the 16 meteorological years chosen for the normalization. In addition, the maximum and minimum values are calculated for each emission year.

For more information, see the latest annual report prepared by EMEP (Gauss et al., 2020b) as well as the latest Baltic Sea Environment Fact Sheets on emissions and depositions of nitrogen, heavy metals and PCDDF/s, which can be accessed via the HELCOM website.

References

Gauss, M. S. Tsyro, H. Fagerli, A.-G. Hjellbrekke, and W. Aas, 2020a: Acidifying and eutrophying components. Supplementary material to EMEP Status Report 1/2020, The Norwegian Meteorological Institute, Oslo, Norway, 2020. Available online at https://emep.int/publ/reports/2020/sup_Status_Report_1_2020.pdf

Gauss, M., Gusev, A. and Aas, W., 2020b: Atmospheric Supply of Nitrogen, Cadmium, Lead, Mercury, PCDD/Fs, PCB-153, and B(a)P to the Baltic Sea, final project report to HELCOM, available online at https://emep.int/publ/helcom/2020/

Gusev A., E. Mantseva, V. Shatalov, and B. Strukov (2005) Regional Multicompartment Model MSCE-POP. EMEP/MSC-E Technical Report 5/2005. (http://www.msceast.org/reports/5_2005.pdf)

Jonson J. E. and Travnikov O. (Eds.). [2010] Development of the EMEP global modeling framework: Progress report. Joint MSC-W/MSC-E Report. EMEP/MSC-E Technical Report 1/2010. (http://en.msceast.org/reports/1_2010.pdf)

Simpson, D., et al., The EMEP MSC-W chemical transport model – technical description, Atmos. Chem. Phys., 12, 7825–7865, 2012.

Simpson, D., R. Bergström, S. Tsyro, and P. Wind. 2019. Updates to the EMEP MSC-W model, 2018-2019. In Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status report 1/2019. The Norwegian Meteorological Institute, Oslo, Norway. URL: https://emep.int/publ/reports/2019/EMEP_Status_Report_1_2019.pdf

Simpson, D., R. Bergström, S. Tsyro, and P. Wind. 2020. Updates to the EMEP MSC-W model, 2019-2020. In Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status report 1/2020. The Norwegian Meteorological Institute, Oslo, Norway. URL: https://emep.int/publ/reports/2020/EMEP_Status_Report_1_2020.pdf

Tarrasón L. and Gusev A. [2008] Towards the development of a common EMEP global modeling framework. MSC-W Technical Report 1/2008. (https://emep.int/publ/reports/2008/emep_technical_1_2008.pdf)

Travnikov O., J.E. Jonson, A.S Andersen, M. Gauss, A. Gusev, O. Rozovskaya, D. Simpson, V. Sokovykh, S. Valiyaveetil and P. Wind [2009] Development of the EMEP global modelling framework: Progress report. Joint MSC-E/MSC-W Report.EMEP/MSC-E Technical Report 7/2009. (http://en.msceast.org/reports/7_2009.pdf)

Travnikov O. & Ilyin I. 2005. Regional Model MSCE-HM of Heavy Metal Transboundary Air Pollution in Europe. EMEP/MSC-E Technical Report 6/2005.

Travnikov, O. and J. E. Jonson (Eds.): Global scale modelling within EMEP: Progress report, EMEP/MSC-E Technical report 1/2011. (http://en.msceast.org/reports/1_2011.pdf)

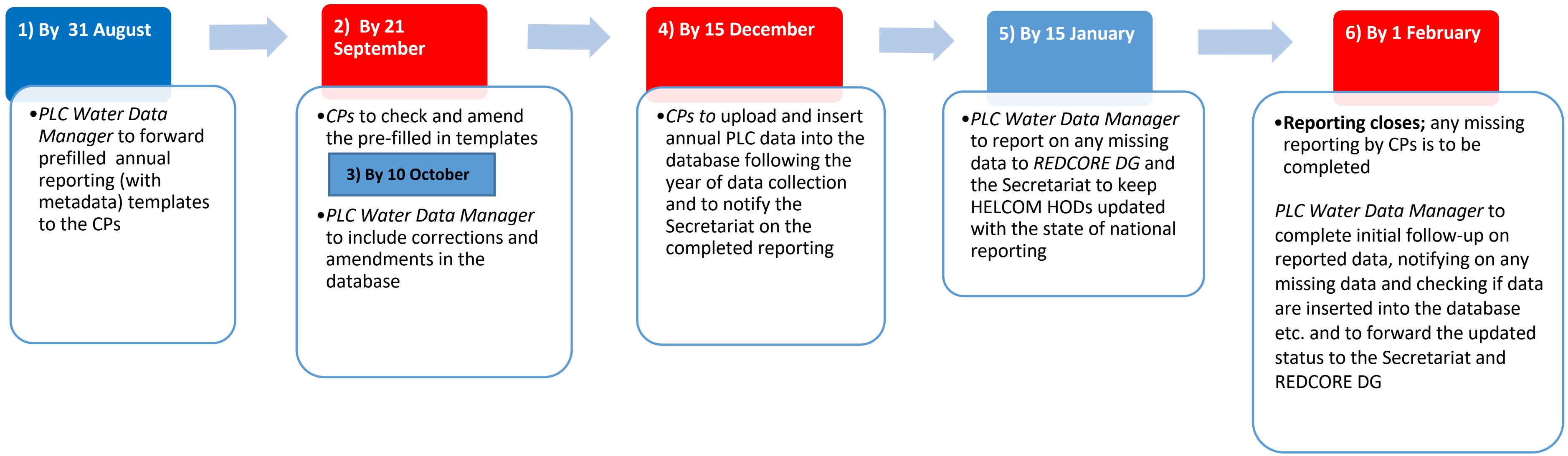
Travnikov, O., N. Batrakova, A. Gusev, I. Ilyin, M. Kleimenov, O. Rozovskaya, V. Shatalov, I. Strijkina, W. Aas, K. Breivik, P.B. Nizzetto, K.Pfaffhuber,K. Mareckova, S. Poupa, R. Wankmueller, K. Seussall EMEP Status Report 2/2020, Assessment of transboundary pollution by toxic substances: Heavy metals and POPs. (http://en.msceast.org/reports/2_2020.pdf)

Annex 7. Procedures for the reporting of data for HELCOM pollution load compilation (PLC) and releasing of PLC products based on reported data

Annual PLC data reporting and releasing of related PLC products

Color categories:

- Red color indicates CPs to report;
- Blue color indicates data processing;
- Green color indicates data/product approval by CPs;
- Yellow color indicates procedure for assessment based on reported data.



7) By 1 March

- *PLC Water Data Manager* to conduct follow up clarification with the CPs and to finalize quality assurance and inform REDCORE DG accordingly. The data which are not rejected are considered as quality assured and become publicaly available.

8) PRESSURE WG

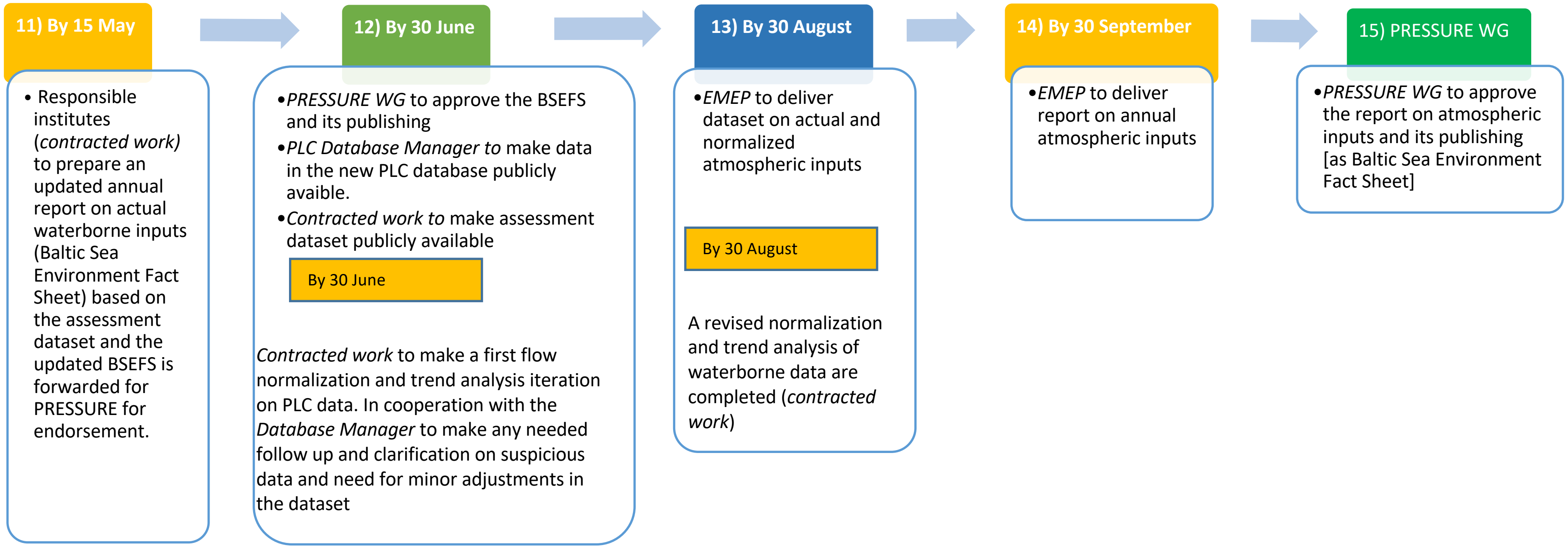
- *REDCORE DG* to report on status of data reporting and quality assurance

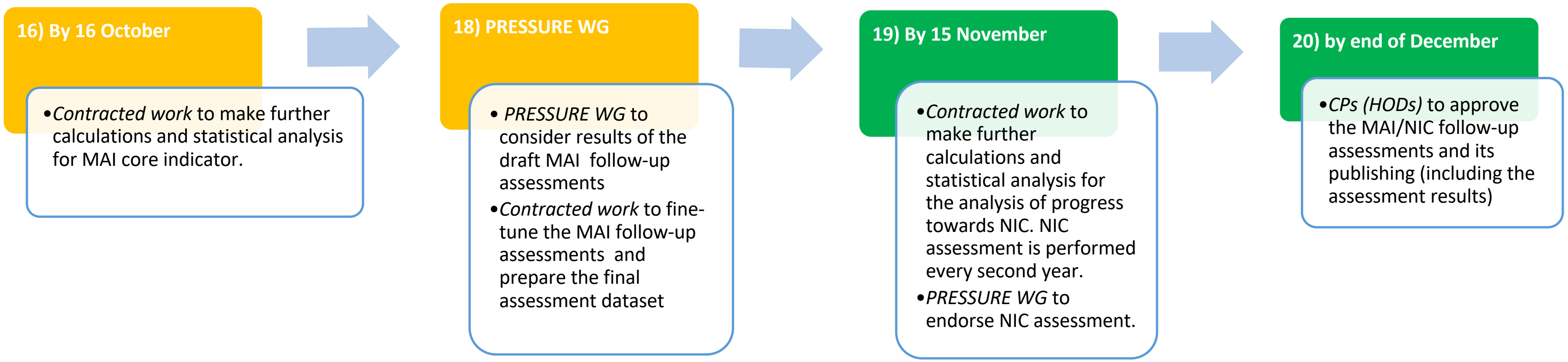
9) By 31 March

- *REDCORE DG* to assess data, fill in data gaps, follow-up on suspicious data, and make a report based on a common protocol on how missing data has been filled in and suspicious data has been corrected/ replaced
- The dataset for BSEFS on warterborne input of nutrients is made available for CPs to approve

10) by 20 of April

- National approvals of the dataset for BSEFS on warterborne input of nutrients
- by *CPs* (national PRESSURE contacts are kept informed)

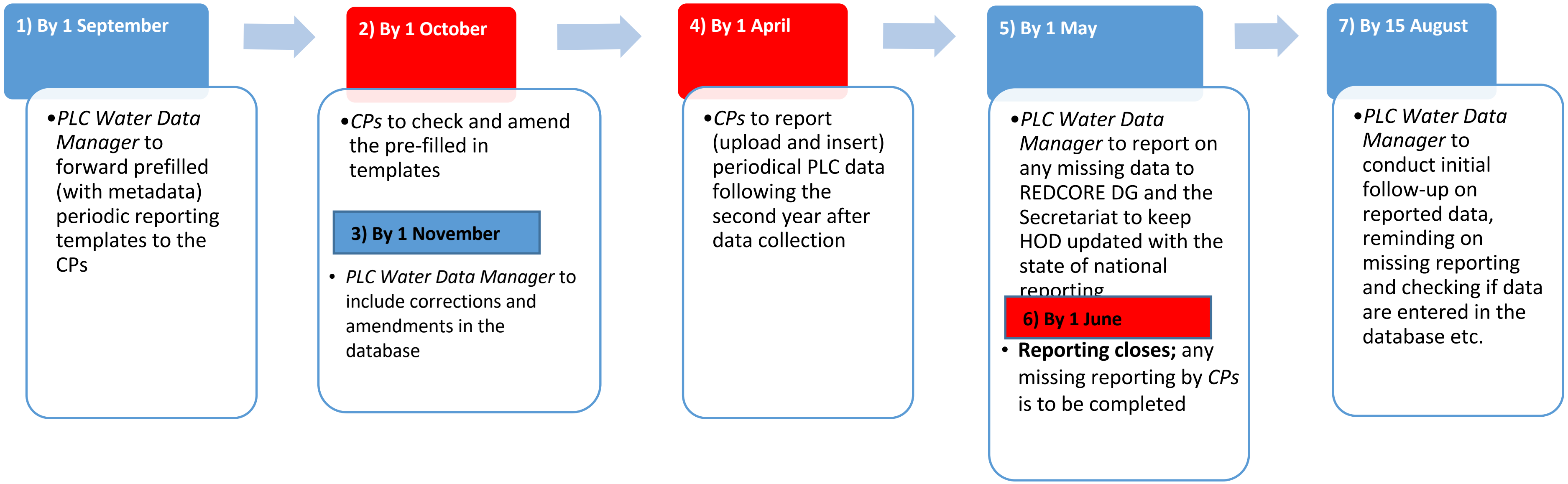

11) By 15 May
• Responsible institutes (*contracted work)* to prepare an updated annual report on actual waterborne inputs (Baltic Sea Environment Fact Sheet) based on the assessment dataset and the updated BSEFS is forwarded for PRESSURE for endorsement.
12) By 30 June
• *PRESSURE WG* to approve the BSEFS and its publishing
• *PLC Database Manager to* make data in the new PLC database publicly avaible.
• *Contracted work to* make assessment dataset publicly available
By 30 June
Contracted work to make a first flow normalization and trend analysis iteration on PLC data. In cooperation with the *Database Manager* to make any needed follow up and clarification on suspicious data and need for minor adjustments in the dataset
13) By 30 August
• *EMEP* to deliver dataset on actual and normalized atmospheric inputs
By 30 August
A revised normalization and trend analysis of waterborne data are completed (*contracted work*)
14) By 30 September
• *EMEP* to deliver report on annual atmospheric inputs
15) PRESSURE WG
• *PRESSURE WG* to approve the report on atmospheric inputs and its publishing [as Baltic Sea Environment Fact Sheet]


16) By 16 October
•Contracted work to make further calculations and statistical analysis for MAI core indicator.
18) PRESSURE WG
• PRESSURE WG to consider results of the draft MAI follow-up assessments
•Contracted work to fine-tune the MAI follow-up assessments and prepare the final assessment dataset
19) By 15 November
•Contracted work to make further calculations and statistical analysis for the analysis of progress towards NIC. NIC assessment is performed every second year.
•PRESSURE WG to endorse NIC assessment.
20) by end of December
•CPs (HODs) to approve the MAI/NIC follow-up assessments and its publishing (including the assessment results)

Periodic PLC data reporting and releasing of related PLC products

Color categories:

- Red color indicates CPs to report;
- Blue color indicates data processing;
- Green color indicates data/product approval by CPs;
- Yellow color indicates procedure for assessment based on reported data.



8) PRESSURE WG

- *REDCORE DG to* report on status for reporting

9) By 10 September

- *PLC Water Data Manager* to conduct quality assurance and follow up clarifications with CPs and follow up on missing data/metada

10) By the end of October

- *PLC Water Data Manager* to compile data set with some basic figures to the PLC project for evaluating data

11) By 10 December

- *PLC Project/REDCORE DG* to assess data, fill in data gaps, follow-up on suspicious data, get missing data from CP's/other sources and make a report pr. CP based on a common protocol on how missing data have been filled in and suspicious data been corrected/replaced

By 11 December

- *PLC Project* to send dataset with periodical data to CPs together with a short report