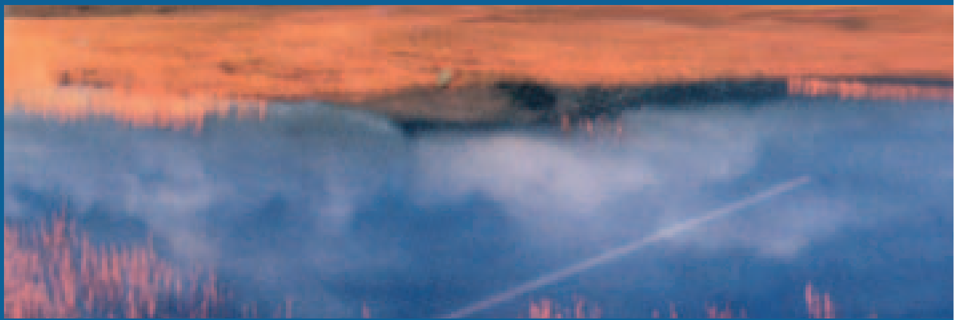
SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

SPSD II

TYPOLOGY, REFERENCE CONDITION AND CLASSIFICATION OF THE BELGIAN COASTAL WATERS (REFCOAST)

P. MEIRE, M. VINCX, E. VAN CLEEMPUT



PART 2

GLOBAL CHANGE, ECOSYSTEMS AND BIODIVERSITY

ATMOSPHERE AND CLIMATE

MARINE ECOSYSTEMS AND BIODIVERSITY

TERRESTRIAL ECOSYSTEMS AND BIODIVERSITY

NORTH SEA

ANTARCTICA

BIODIVERSITY

SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY
(SPSD II)

Part 2:

Global change, Ecosystems and Biodiversity

FINAL REPORT

REFCOAST
Typology, Reference condition and Classification of the Belgian coastal waters

EV/40

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1. INTRODUCTION

1.1 Context and objectives

In 2000 a framework for Community action within the field of water policy was established trough the Water Framework Directive (2000/60/EC) (WFD). The Directive requires surface waters to be split in River Basin Districts and in their turn divided into one of the six surface water categories (cfr. rivers, lakes, transitional and coastal waters, artificial and heavily modified waters). After categorisation, the different surface waters need to be differentiated in different types. The purpose of this typing is to ensure that a valid comparison of its ecological status can be made. For each type, reference conditions must be described as, these form the 'anchor' for classification of the water bodies 'ecological' status or quality.

The REFCOAST project has been initiated to fulfil the requirements of the WFD for the Belgian coastal waters. The methodology followed to make the typology and to describe the reference condition and make up the classification has been given in the Directive itself as well as in a guidance document, developed under the Common Implementation Strategy (CIS).

Objectives of the REFCOAST projects were:

- To make up the typology for the Belgian Coastal Waters and to evaluate the methodologies (A and B) proposed in the WFD;
- To describe the reference condition of the different types of coastal waters in Belgium and to indicate the bottlenecks to do so; and
- To assess the ecological status of the coastal water bodies in Belgian (classification).

1.2 Definition of coastal waters

Coastal waters are defined in the WFD as follows:

> *" 'Coastal water' means surface water on the landward side of a line, every point of which is at a distance of one nautical mile on the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters."*

The baseline is measured as the low-water line except along the mouths of estuaries and heads of bays where it cuts across open water.

The directive gives no indication of the landward extent of either transitional or coastal waters. The guidance on typology, reference conditions and classification systems for transitional and coastal waters stipulates that is recommended that transitional and coastal water bodies include the intertidal area from the highest to the lowest astronomical tide.

The structure of the intertidal zone is one of the important hydromorphological quality elements for both transitional and coastal waters.

In the frame of current study the coastal waters are defined as the zone between the following boundaries:

- Seaward boundary: the line formed by the points at a distance of ***three*** nautical miles on the seaward side from the nearest point of the baseline.

  The extension from one to three nautical miles has been made because only few data for the zone within the one mile zone are available and because the 3 miles zone is more policy-related then the 1 mile line.

- Landward boundary: the physical boundary where the influence of the coastal water ends, i.e. the highest high water boundary.
- Lateral boundary: the boundary of the Belgian Continental Shelf.

This definition implies that the entire intertidal zone is included in the coastal waters.

The entire coastal zone in Belgium lies within the Scheldt river basin district (see Figure 1).

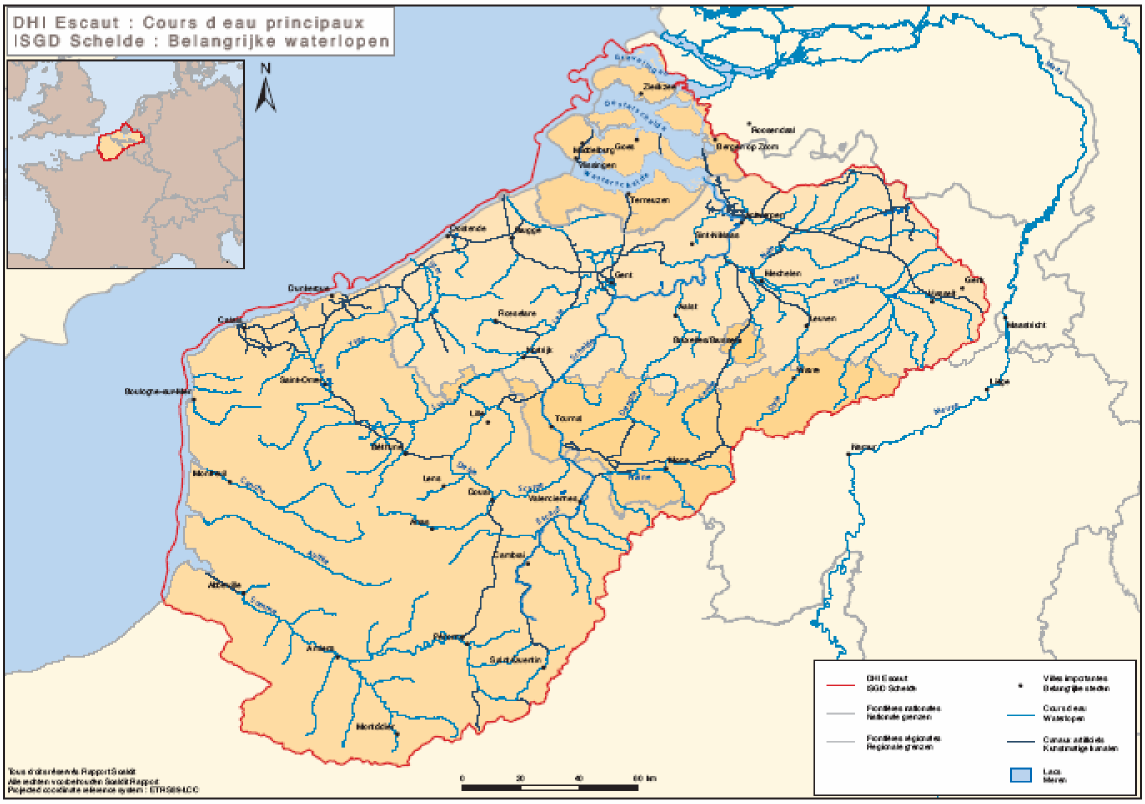

Figure 1: Scheldt river basin district

Source: Scaldit, 2005. Rapport Scaldit Ruimtelijke Ordening. Overstromingsrisico en ruimtelijke ordening in het internationale stroomdistrict van de Schelde

1.3 Bookmarker

An introduction with respect to the research subject is given in Chapter 2. On the one hand, some explications are given with respect to the Belgian jurisdiction with respect to the marine environment, on the other hand the state of the art of the implementation of the Water Framework Directive in Belgium has been discussed.

Chapter 3 handles the make up of the typology of coastal waters in Belgium, both following the system A and system B as described in the WFD. Besides, the typology criteria have been detailed to better fit the differences in macrobenthos in the coastal waters.

In Chapter 4, a classification has been made for the types of coastal waters in Belgium and the reference condition has been described.

The conclusions of the research have been summarized in Chapter 5 and recommendations and future research have been given in Chapter 6.

2. THE WATER FRAMEWORK DIRECTIVE AND ITS IMPLEMENTATION IN BELGIUM

This chapter clarifies on the one hand briefly the Belgian jurisdiction with respect to the marine environment and on the other hand describes the implementation of the WFD in Belgium.

2.1 Belgian jurisdiction with respect to the marine environment

2.1.1 The Belgian part of the North Sea

The Belgian coast is 66 km long. The Belgian part of the North Sea has a surface of about 36.000 km². This part represents less than 0.5 % of the total surface of the North Sea (Source: MUMM).

The geographical location of the Belgian part of the North Sea is given in Figure 2.

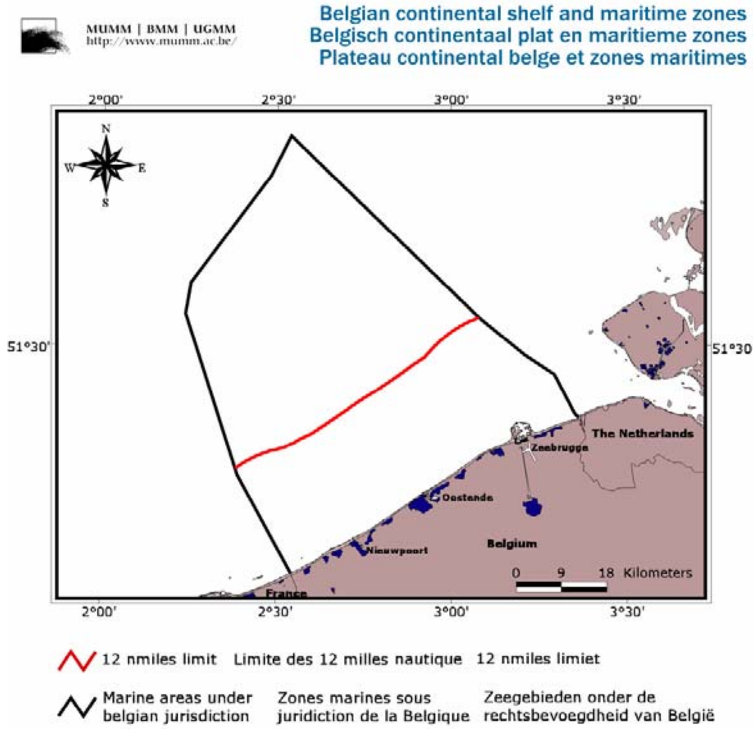

Figure 2: Location of the Belgian part of the North Sea (Source: BMM)

2.1.2 Competences of the federal and regional authorities with respect to the coastal zone

The coastal zone integrates a marine part and a land-based part. The marine part includes all zones of which Belgium has competence, such as the Territorial sea, Fishery zone, Continental Shelf and the Exclusive Economical zone. The land-based part includes dunes, coastal polders and beaches.

Belgium is a federal state. This implies that the competences are divided between the federal and the regional authorities.

The territory for which the Flemish authorities are competent is limited to the baseline country-inward, i.e. the baseline is characterized by the average low water spring-tide. The Flemish authorities can carry out activities in the Belgian continental shelf if these activities are necessary for the execution of the regional competences with respect to waterways, port activities, etc.

Beyond this baseline, the federal authorities are competent.

In accordance with the special law of July 13th 2001 (Law Lambermont), sea fishery also belongs to the regional competences.

The competent federal and regional authorities are summarized in Table 1. The different competent ministries of the federal and the regional authorities and the legal matters in the coastal zone are given in Annex A.

Table 1: Distribution of responsibilities between federal and regional authorities

	Sea		Land	
	Legal description	**Ecological description**	**Legal description**	**Ecological description**
Competent authority	Territorial sea EEZ Continental shelf	Seawater Seabed and underground	Internal waters Territory of coast municipalities	Intertidal zone Mudflats and saltmarsches Beach Dunes Coastal polders
Federal authority	Navigation Military activities Exploitation of the seabed Energy (off-shore wind energy) Cables and pipelines Protection of the marine environment Control (police) Calamity suppression Science policy		Navigation Military activities Energy Control (police) Calamity suppression	
Flemish authority	To dredge To pilot Rescue on sea Shipping accompaniment To clear wrecks Sea fisheries		Environment and nature conservation Spatial planning Groundwaterextraction Tourism Ports Coastal defense Management public zones Science policy	
Provincie West-Vlaanderen	Aid at calamity suppression		Implementation of higher right	
Coast municipalities			Implementation of higher right Police Maintenance of the beach (concession)	

*Source: Cliquet and Maes (2001) Beleidsondersteunend onderzoek voor een geïntegreerd kustzonebeleid in België: welk ge*integreerd kustzonebeleid? In: Vlaams instituut voor de zee. VLIZ Special Publication 4 (2001) Beheer van kust en zee: beleidsondersteunend onderzoek in Vlaanderen. Studiedag 9 november 2001.*

2.2 Implementation of the WFD in Belgium

In this paragraph the status of implementation of the WFD is discussed. In a first paragraph the status of make up of the river basin management plans is discussed, in a second paragraph the status of the identification of the typology of the water bodies.

2.2.1 River basin management plans

According to the WFD, river basin management plans have to be produced for each river basin district. In case of an international river basin district, Member States have to ensure coordination with the aim of producing a single international river basin management plan. In Flanders, two river basin districts can be distinguished: the Scheldt and the Maas river basin district. For each of them an international commission has been set up.

River basin management plan for the Scheldt river (www.scaldit.org)

The project Scaldit is meant to lay the basis for the development of integrated water management in the Scheldt River basin District. They are investigating the feasibility of the guidance documents that the European Union has provided in connection with the Common Implementation Strategy. Most of the project's actions are of importance for the implementation of the Water Framework Directive in the entire river basin district. The experience accumulated will later on benefit all international river basin districts in the European Union and the Candidate Member States.

The action programme for the Scaldit project is constructed around five themes:

1. Characterizations of the river basin district;
2. Data and information management;
3. Water management and spatial planning;
4. Communication and public participation;
5. Up to the international river basin management plan.

The project group P10 of Scaldit (transitional and coastal waters) has made the typology of the transitional and coastal waters in the international Scheldt River basin District. For the Belgian part of their study territory, one type has been identified: meso tidal, euhaline, not sheltered water with a sandy substratum. The Zwin Nature Reserve is distinguished from this type by the degree of salinity (polyhaline instead of euhaline) and by the degree of wave exposure (very sheltered instead of not sheltered).

River basins in Flanders

In Flanders, 11 river basins (sub river basins) can be distinguished (Figure 3).

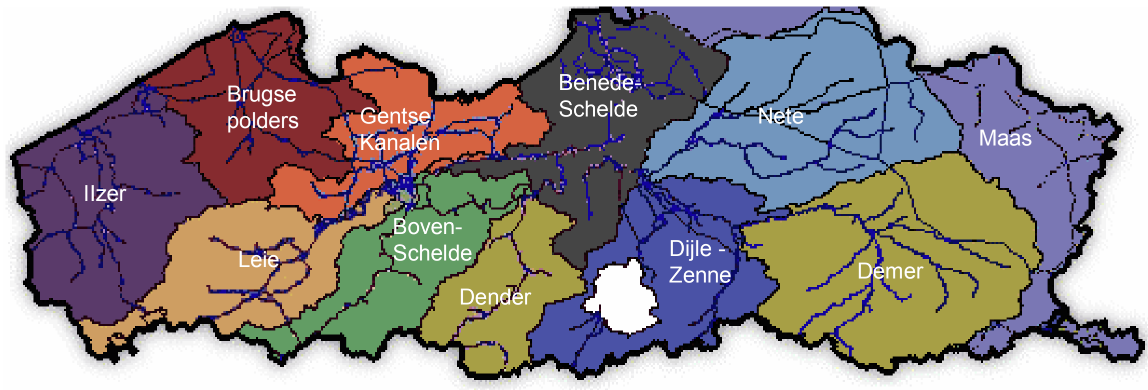

Figure 3: River basins in Flanders

For each of these River basins, a river basin management plan is being made. The Nete basin, the Demer basin and the IJzer basin had been designated as pilot basins to make up the management plan. The information about the status of the plan can be found on de website of the Flemish environmental authorities (http://www.mina.vlaanderen.be/wiedoetwat/aminal/taken/water/water/content/index.htm).

The interpretation of the objectives of the basin management plan is systematically developed in a sustainable local water plan.

River basins in Walloon

In Walloon, 14 river basins can be distinguished (Figure 4). River basin management plans are called "Contrat de rivière". For each of the river basins the analysis phase has been finished. Following data have been gathered:

- The characteristics of the water bodies;
- The pressures of human activities on the water bodies; and
- The economic aspects of the water use.

More information per river basin can be found on the website of the Walloon authorities (http://environnement.wallonie.be/directive_eau/sousbassin.asp?Menu=2).

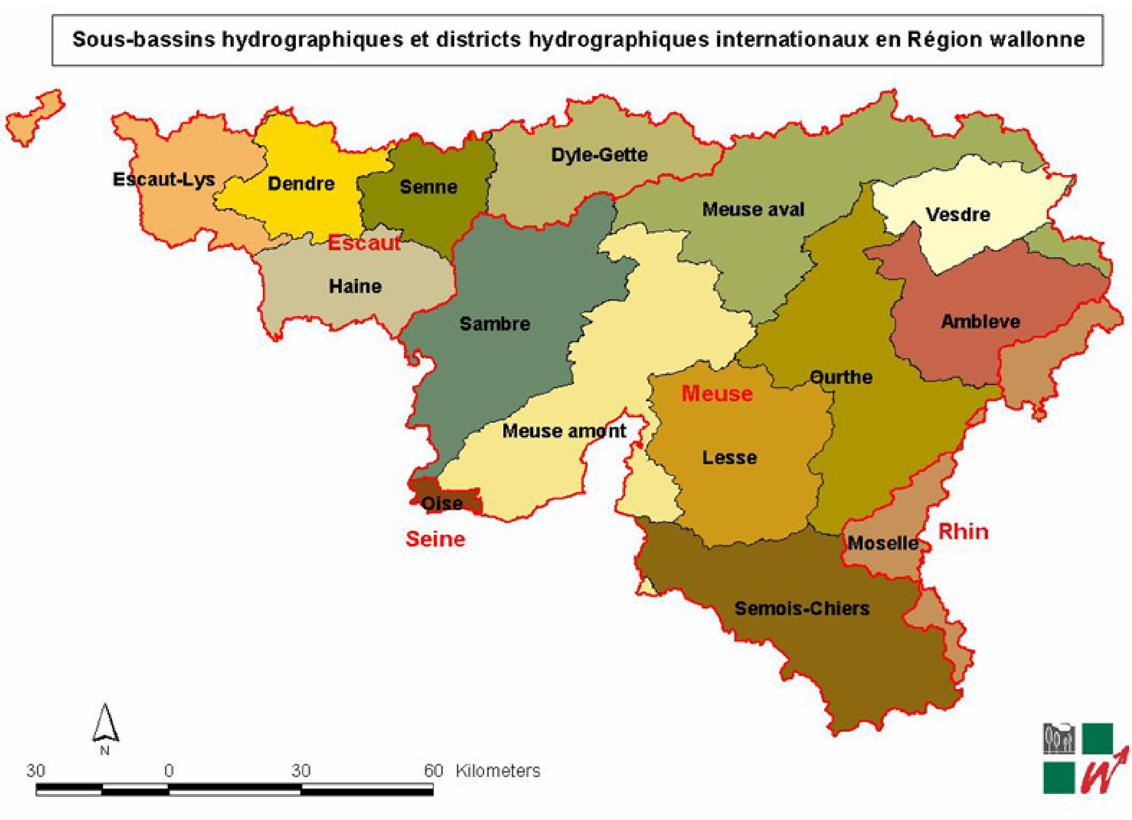

Figure 4: River basins in Walloon

Source: http://environnement.wallonie.be/directive_eau/

2.2.2 Typology, reference condition and classification for water bodies

Following the WFD, a typology has to be made for all the types of waters, i.e. rivers, lakes, groundwater, transitional zones and coastal waters.

In Belgium, the typology is being made by different instances (in different communities).

Flemish community

The Institute of Nature Conservation (a Flemish research institute) has made a proposal for the typology of Flemish surface waters: lakes, rivers, transitional and coastal waters (Jochems *et al*., 2002) for the VMM (Flemish Environmental Agency).

Eight river types have been distinguished in Flanders based on the differences in hydro-ecoregions, in size of the river basis and in the ratio breadth-depth.

For lakes, the ecoregion in combination with water quality variables (acidity, concentration of ions) and morphological parameters as depth and size were important to distinguish 10 base types.

The transitional waters are divided in macro-tidal estuary (Scheldt River) and meso-tidal estuary (IJzer estuary).

For Coastal waters, the Institute of Nature Conservation limited the typology on the Flemish coastal waters, i.e. the water bodies landward of the baseline (average low water line). Only one type was found, the Nature Reserve "Zwin" – a sea arm.

Different studies now have to define the reference situation for each of the types.

Walloon community

The environmental administration of the Walloon community makes up the typology for the rivers and lakes in Walloon. The state of the art in the Walloon community is unsure. The information could not be found on the website http://environnement.wallonie.be/directive_eau.

3. TYPOLOGY OF COASTAL WATERS IN BELGIUM

The typology of the coastal waters in Belgium has to be made by the federal authorities. In this chapter firstly the methodology will be discussed to make a typology (paragraph 3.1), then typology has been given according to system A and system B (paragraph 3.2 and 3.3). Based on the insight of the diversity in macrobenthos in the Belgian coastal zone waters, a proposition to refine the system B for making a typology is made in Paragraph 3.4. Finally, the typology has been adapted for practical considerations (Paragraph 3.5).

3.1 Methodology to produce a typology for coastal waters.

A common understanding and approach is crucial to the successful and effective implementation of the WFD. Therefore, the member states and the Commission agreed on a Common Implementation Strategy (CIS) for the WFD.

The CIS working group 2.4 (COAST) produced a "Guidance on typology, reference conditions and classification system for transitional and coastal waters". The guidelines for typology and reference conditions are summarized hereafter.

The aim of typology is to produce as simple a physical typology as possible that is both ecologically relevant and practical to implement.

In general two systems are proposed in the WFD to produce a typology for surface waters: system A or system B.

If system A is used, differentiation is made by the relevant ecoregions in accordance with geographical areas. Within each ecoregion the surface water bodies are further to be differentiated according to specific descriptors.

If system B is used, the surface water bodies shall be differentiated into types using the values for the obligatory descriptors and such optional descriptors, or combinations of descriptors, as are required to ensure that type specific biological reference conditions can be reliably derived.

For coastal water bodies the descriptors for system A are given in Table 2; for system B in Table 3.

Table 2: Descriptors for coastal water bodies (system A)

Fixed typology	**Descriptors**
Ecoregion	The following as identified on map B in Annex XI (WFD): Baltic Sea Barents Sea Norwegian Sea North Sea North Atlantic Ocean Mediterranean Sea
Type	Based on mean annual salinity < 0,5 pro mille: freshwater 0,5 to < 5 pro mille: oligohaline 5 to < 18 pro mille: mesohaline 18 to < 30 pro mille: polyhaline 30 to < 40 pro mille: euhaline Based on mean depth Shallow waters: < 30 m Intermediate: 30 to 200 m Deep: > 200 m

Source: WFD

Table 3: Descriptors for coastal water bodies (system B)

Alternative characterization	**Physical and chemical factors that determine the characteristics of the coastal water and hence the biological community structure and composition**
Obligatory factors	Latitude
	Longitude
	Tidal range
	< 1 m
	1 m to 5 m
	> 5 m
	Salinity
	< 0,5 pro mille: freshwater
	0,5 to < 5 - 6 pro mille: oligohaline
	5 - 6 to 18 - 20 pro mille: mesohaline
	18 - 20 to 30 pro mille: polyhaline
	> 30 pro mille: euhaline
Optional factors	Wave exposure
	Extremely exposed
	Very exposed
	Exposed
	Moderately exposed
	Sheltered
	Very sheltered
	Depth†
	Shallow waters: < 30 m
	Intermediate: 30 to 200 m
	Deep: > 200 m
	Current velocity
	Weak (< 1 knot) or subdivision: 0 – 0.5 knot and 0.5 – 1 knot
	Moderate (1 to 3 knots)
	Strong (> 3 knots)
	Mean water temperature
	Mixing characteristics
	Permanently fully mixed
	Partially stratified
	Permanently stratified
	Turbidity
	Retention time (of enclosed bays)
	Short (days)
	Moderate (weeks)
	Long (months to years)
	Mean substratum composition
	Hard (rock, boulders, cobble)
	Sand-gravel

	Mud
	Mixed sediments
	Water temperature range
	Duration of ice coverage
	Irregular
	Short (< 90 days)
	Medium (90 to 150 days)
	Long (> 150 days)

† *The optional factor Depth is nog mentioned in the Annex II list of the WFD, but is proposed by the CIS working group 2.4 (COAST).*

Source: WFD + Guidance

For system B, the CIS working group 2.4 (COAST) suggests that a hierarchical approach is used for the use of the optional factors. If ecological separation to define the type specific reference conditions can be achieved by using only the obligatory factors, the use of optional factors is unnecessary, otherwise the optional factors should also be used.

The optional factors may be used in the following order if possible:

1. Wave exposure;
2. Depth;
3. Other factors to include until an ecologically relevant water body type is achieved.

However, the CIS working group 2.4 (COAST) also suggests describing all factors in order to be able to compare the results with the results of other countries.

3.2 Typology system A

The system A for making up the typology is based on 3 descriptors:

- The ecoregion;
- The salinity of the water; and
- The mean depth.

The data for average salinity concentration and the mean depth are obtained from the Belgian Marine Datacentre or BMDC (http://www.mumm.ac.be/EN/Monitoring/DataCenter/index.php).

For salinity, the average concentration has been calculated over all sample events between January 2000 and December 2003. In total 14 sample events have taken place in this period (Table 4).

Table 4: Sample events during the years 2000 to 2003

Year	Sample events
2000	7 February 2000
	17 – 18 April 2000
	9 – 11 May 2000
	13 – 14 September 2000
	5 – 6 December 2000
2001	29 – 31 January 2001
	17 – 18 April 2001
	19 – 22 November 2001
2002	4 – 5 February 2002
	25 – 27 March 2002
	2 – 3 December 2002
2003	10 – 11 February 2003
	10 – 13 March 2003
	18 – 20 November 203

Figure 5 gives the location of the sample points of BMDC. Only few of them are located in the 3 miles zone from the coast. Moreover, not for all the sample points, salinity concentration had been measured. The relevant sample points for the study are given in Map 1 (Annex A).

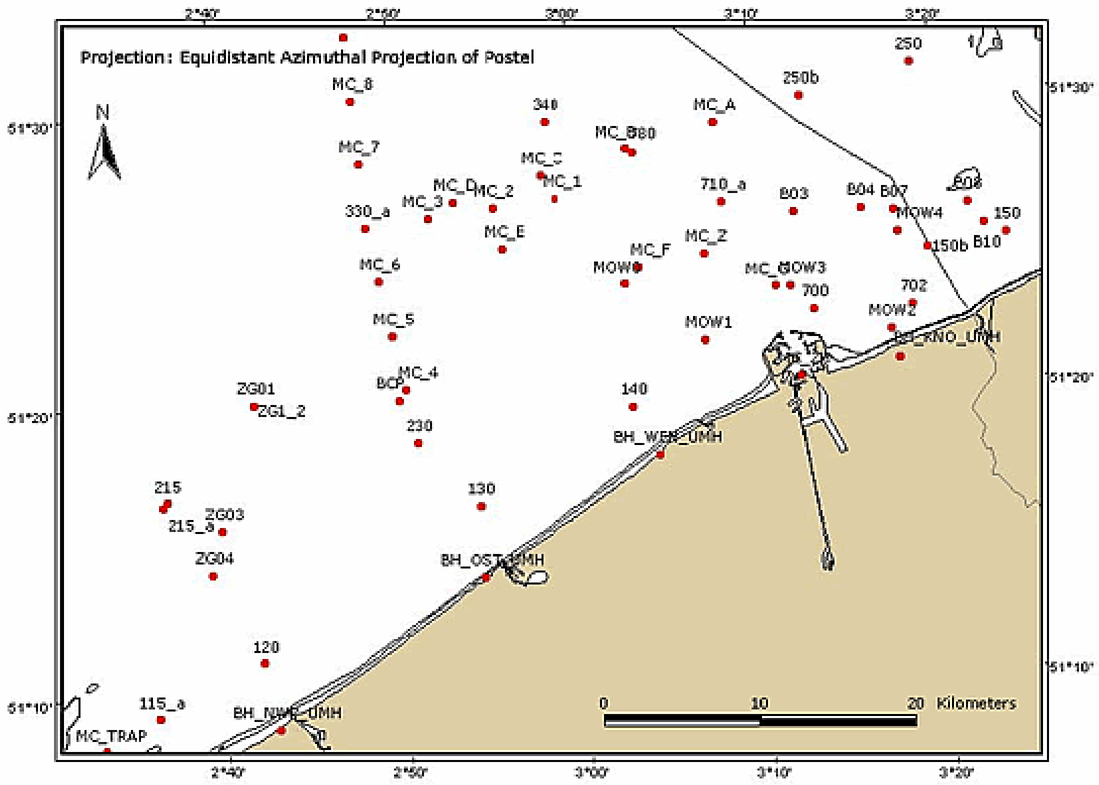

Figure 5: Sample points of BMDC – for points 115, 120, 130, 230, 700 data of temperature, turbidity and salinity are available

The values for the descriptors for the Belgian North Sea are given in Table 5. The source for the data is given for each of the values of the descriptors. If different sources are available, the values of all sources are given and compared to each other.

Table 5: Values for the descriptors for the typology making use of System A

Descriptor	Source of data	Value	Class
Ecoregion		North Sea	North Sea
Mean depth	(1)	Zones with a depth of: 2 m 5 m; and 10 m are distinguished in the coastal zone of the Belgian Marine Waters.	Shallow waters (< 30 m depth)
Mean annual salinity	(2)	Sample points 115b, 120, 130, 230: > 30 pro mille	Euhaline for most of Belgian coast
		Sample point 700: < 30 pro mille ‡	Polyhaline for eastern part of the Belgian coast
	(3)	Three zones can be distinguished (from east to west)†: 31 – 32 pro mille 32 – 33 pro mille 33 – 34 pro mille	Euhaline (30 – 40 pro mille) for the entire Belgian coast
	(4)	Beween 18 and 30 pro mille for the Zwin Nature Reserve.	Polyhaline (between 18 and 30 pro mille)

(1) Source: http://www.mumm.ac.be/datacentre/Catalogues/datathemelayers.php

(2) Source: Average data of samplings of the sampling points 115b,120, 130, 230, 700 (http://www.mumm.ac.be/Datacentre) - year 2000 until year 2003 (See also Map 3, Annex B).

(3) Source: http://www.mumm.ac.be/Assets/Pages/sal0228a.jpg. Sampling event 02/28 in December 2002 (Map 4 Annex B).

(4) Jochems, H.; Schneiders, A.; Denys, L; and Van den Bergh, E. 2002. Typologie van de oppervlaktewateren in Vlaanderen. Eindverslag van hetproject VMM. KRLW-typologie. 2001 (met CD-ROM).
No detailed data are available for the Zwin. VMM does not have sampling points in the nature reserve the Zwin.

Mean depth

The mean depth is given in Map 2 (Annex A).

Salinity

The average salinity concentration of the seawater during sampling is given in Map 3 (Annex B). Only the sample points within or near by the zone of 3 nautical mile of the coast are given. Comparing the results of the sample points 115b, 120, 130 and 230 with the results of sample points 700, 150b and 150 indicates a significant difference between the two groups of sample points ($p < 0{,}001$).

For every sampling campaign, an interpolation of the results for the sample points is being made by the BMDC. An example is given in Map 4 (Annex B), based on the results of the sampling campaign in December 2002. For this interpolation, the results of more sample points have been used compared with the sample points in Map 3.

Map 5 (Annex B) shows more interpolation figures of the salinity concentration in the Belgian coastal waters. It is clear from these figures that the salinity concentration does not remain constant during the year. The salinity concentration in the eastern part of the coastal zone always is somewhat lower than the salinity concentration in the western part of the coastal zone. In some sample events, the salinity concentration in the eastern part of the coastal zone drops below the limit of euhaline waters (30 pro mille).

Typology

Based on the data in Table 5, following types of coastal waters can be distinguished for the Belgian coast:

- Type 1: shallow waters, euhaline (most part of Belgian coast);
- Type 2: shallow waters, polyhaline (the Zwin nature reserve).

Dependent of the moment of the sampling, the most eastern part of the Belgian coast also is polyhaline and is similar to the type of the Zwin Nature Rerserve. The class of < 30 pro mille salinity is not always present in the salinity maps made by the BMDC (Map 4) and the mean salinity of sample point 700 (most eastern sample point) does not differ significantly of 30 (29,72 pro mille ± 1,57). No maps have been made by the BMDC with annual average salinity (average of

14 sampling events between February 2000 and November 2003). The sampling points on the Dutch Continental Shelf near the border of the Belgian Continental Shelf (points nr 150 and 150b) also show values under (but near to) 30 pro mille.

3.3 Typology system B

For system B, a distinction is made between the obligatory descriptors and the optional descriptors. A description of the obligatory descriptors is given in paragraph 3.3.1, the optional descriptors have been discussed in paragraph 3.3.2.

3.3.1 Obligatory descriptors in system B

The obligatory descriptors are latitude, longitude, tidal range and mean annual salinity. Longitude and latitude do not form a parameter to distinguish different types of coastal waters for Belgium given the short coastal line. The values for the obligatory descriptors are given and discussed in Table 6.

Table 6: Values for the obligatory descriptors for the typology making use of System B

Descriptor	Source of data	Value	Class
Latitude		From about 2°30' to 3°20'	
Longitude		From about 51°5' to 51°25'	
Tidal range	(1)	Predictions for years 2004 and 2005 Ostend: tidal range < 5 m Zeebrugge: tidal range:< 5	Mesotidal range (1 – 5 m)
	(2)	Ostend (period 01 01 2000 until 31 12 2003): Minimal tidal range: 2,1 m Maximal tidal range: 5,5 m Average tidal range: 3,9	Mesotidal range (1 – 5 m). Only 4 % of the predictions exceeded a tidal range of 5 m.
	(3)	Predictions of tidal range for 5 days (5 12 2004 until 10 12 2004) (average tidal range and stdev for the 5 days) De Panne: 3,6 m ± 0,6 m Koksijde: 3,6 m ± 0,6 m Nieuwpoort: 3,5 m ± 0,6 m Middelkerke: 3,4 m ± 0,6 m Oostende: 3,3m ± 0,5 m Bredene: 3,3 m ± 0,5 m Blankenberge: 3,1 m ± 0,5 m Zeebrugge: 3,0 m ± 0,5 m Knokke: 3,0 m ± 0,5 m	Mesotidal range (1 – 5 m) for all the stations.
	(4)	The Zwin nature reserve: between 1 and 5 m	Mesotidal range (1 – 5 m)
Mean annual salinity	(5)	Sample points 115b, 120, 130, 230: > 30 pro mille Sample point 700: < 30 pro mille [‡]	Euhaline for most of Belgian coast Polyhaline for eastern part of the Belgian coast
	(6)	Three zones can be distinguished (from east to west)[†]: 31 – 32 pro mille 32 – 33 pro mille 33 – 34 pro mille	Euhaline (30 – 40 pro mille) for the entire Belgian coast
	(7)	Between 18 and 30 pro mille for the Zwin Nature Reserve.	Polyhaline (between 18 and 30 pro mille) for the Zwin Nature Reserve.

(1) http://www.lin.vlaanderen.be/awz/html/tijvoor.htm. Prediction of astronomical tides in Oostend and Zeebrugge for 2004 (prediction made in 2003) and 2005 (prediction made in 2004).

(2) http://www.mumm.ac.be/NL/Models/Operational/Tides/predictor.php. The data are predictions and concern only the astronomical tides. This is the indicator proposed by the CIS Workiung Groep 2.4 (COAST) in the report Guidance on typology, reference conditions and classification systems for transitional and coastal waters.

(3) Source: Operational predictions of the tidal range (dated on 6 December 2004): http://www.mumm.ac.be/NL/Models/Operational/Tides/index.php

(4) Jochems, H.; Schneiders, A.; Denys, L; and Van den Bergh, E. 2002. Typologie van de oppervlaktewateren in Vlaanderen. Eindverslag van hetproject VMM. KRLW-typologie. 2001 (met CD-ROM). No detailed data are available for the Zwin. VMM does not have sampling points in the nature reserve the Zwin.

(5) Source: Average data of samplings of the sampling points 115b,120, 130, 230, 700 (http://www.mumm.ac.be/Datacentre) - year 2000 until year 2003 (Map 3 in Annex A).

(6) Source: http://www.mumm.ac.be/Assets/Pages/sal0228a.jpg. Sampling event 02/28 in December 2002 (Map 4 in Annex A).

(7) Jochems, H.; Schneiders, A.; Denys, L; and Van den Bergh, E. 2002. Typologie van de oppervlaktewateren in Vlaanderen. Eindverslag van hetproject VMM. KRLW-typologie. 2001 (met CD-ROM). No detailed data are available for the Zwin. VMM does not have sampling points in the nature reserve the Zwin.

Tidal range

The predictions of the tidal range in Ostend by the MUMM for the month November 2004 is given in Figure 6.

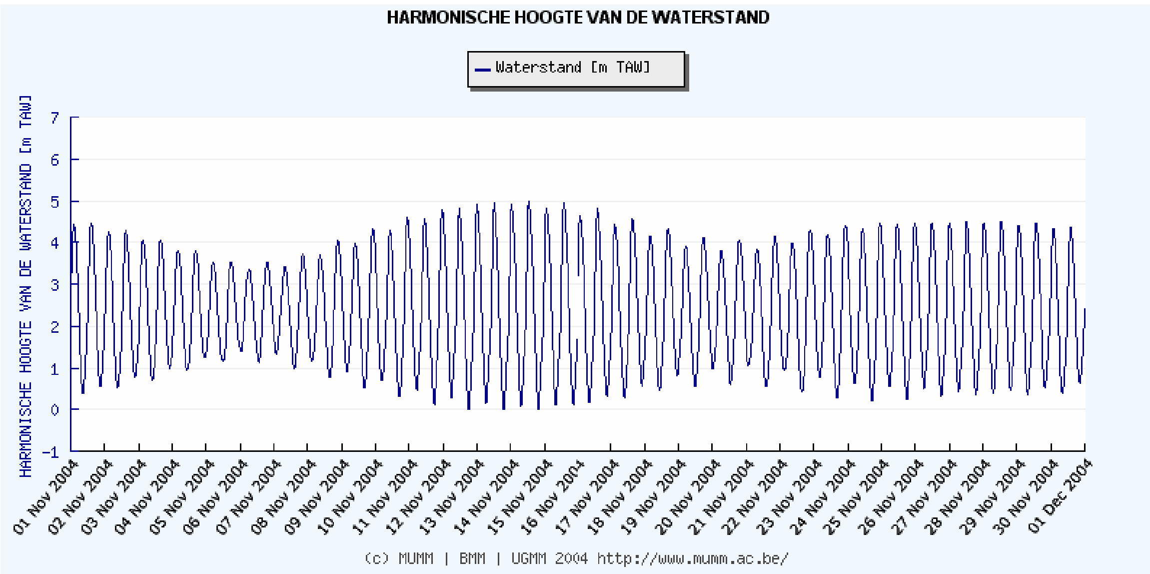

Figure 6: Predications of astronomic tides in Ostend for the month November 2004

In Ostend the real tidal ranges in the period 07 11 2004 until 06 12 2004 is given in Figure 7. These real tidal ranges are, as was expected, somewhat larger than the predictions of the astronomic tides because also wind direction and wind speed are of influence for the real tidal ranges, but rarely exceed 5 m for the month of November 2004.

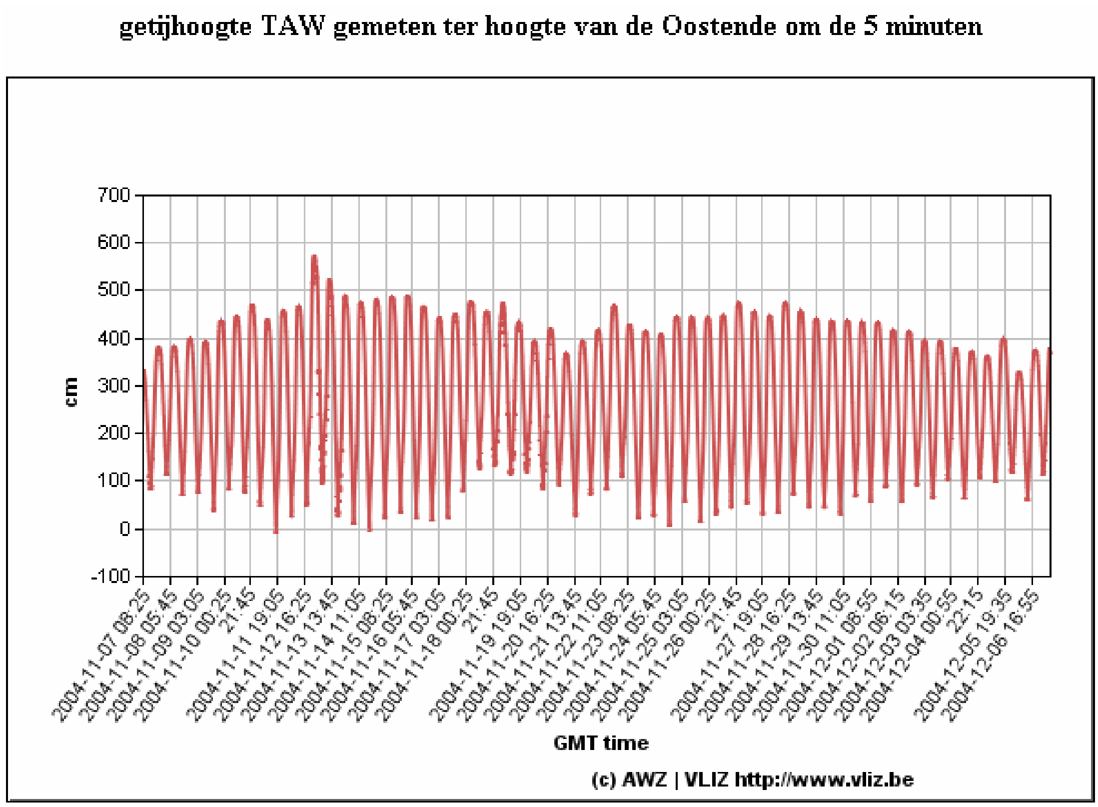

Figure 7: Measured tidal ranges in Ostend in the month 07 11 2004 until 06 12 2004

Source: Meetnet Vlaamse banken (http://www.vliz.be/vmdcdata/midas/mvb.php?listpar)

The measurement points for the tidal range are shown in Figure 8. The tidal range for a period of 5 days (5 December 2004 until 10 December 2004) is varying from 3,0 m at the most eastern measurement point (Knokke) to 3,6 m at the most western measurement point (De Panne) (Table 7).

The tidal range for all the measurement points for this specific period remains under the limit for classification as macro-tidal (i.e. 5 m).

Table 7: Predictions of Tidal ranges for 9 measurement points at the Belgian coast (period 05 12 2004 until 10 12 2004)

	De Panne (m)	Koksijde (m)	Nieuwpoort (m)	Middelkerke (m)	Oostende (m)	Bredene (m)	Blankenberge (m)	Zeebrugge (m)	Knokke (m)
06 12 2004	2,64	2,59	2,53	2,46	2,36	2,35	2,21	2,14	2,16
06 12 2004	3,58,	3,54	3,50	3,45	3,38	3,37	3,27	3,24	3,27
07 12 2004	3,04	2,97	2,90	2,82	2,72	2,70	2,55	2,48	3,50
07 12 2004	3,79	3,74	3,68	3,61	3,51	3,50	3,36	3,31	3,33
08 12 2004	3,21	3,13	3,04	2,95	2,81	2,79	2,60	2,50	2,52
08 12 2004	4,08	4,01	3,93	3,85	3,74	3,73	3,55	3,47	3,50
09 12 2004	3,82	3,72	3,63	3,53	3,38	3,36	3,14	3,03	3,05
09 12 2004	4,39	4,29	4,19	4,10	3,96	3,93	3,73	3,62	3,65
10 12 2004	4,24	4,14	4,03	3,92	3,76	3,73	3,50	3,38	3,40
Mean tidal range	3,64 ± 0,58	3,57 ± 0,57	3,49 ± 0,56	3,41 ± 0,55	3,29 ± 0,54	3,27 ± 0,54	3,10 ± 0,52	3,01 ± 0,52	3,04 ± 0,52

Source: Operational predictions of the tidal range (dated on 6 December 2004): *http://www.mumm.ac.be/NL/Models/Operational/Tides/index.php*

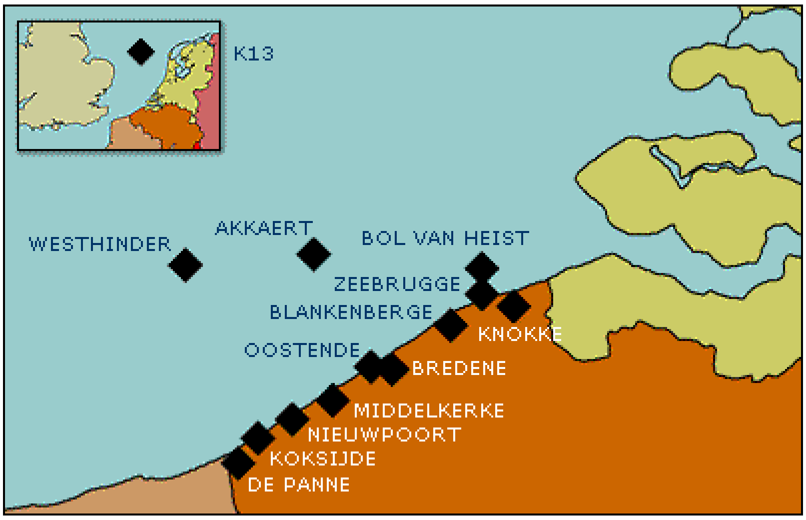

Figure 8: Measurement points of tidal ranges for the Belgian Coast

Typology

Based on the data in Table 6 two types can be distinguished for the Belgian Coastal Waters:

- Type 1: Mesotidal, euhaline waters;
- Type 2: Mesotidal, polyhaline waters (the Zwin nature reserve).

The same remark about the salinity of the coastal waters can be made as in paragraph 3.2.

3.3.2 Optional descriptors in system B

The CIS working group 2.4 (COAST) proposes in the Guidance on typology, reference conditions and classification systems for transitional and coastal waters following importance for the optional descriptors:

1. Wave exposure;
2. Depth; and
3. Other descriptors.

Even if not all the optional descriptors are necessary for the typology, values for all descriptors are given in Table 8 so that a comparison with the typology of other European countries can be made.

Table 8: Values for the optional descriptors for the typology making use of System B

Descriptor	Source of data	Value	Class
Current velocity	(1a)	Average year velocity: < 0,5 knots.	
	(1b)	Temporarily the velocity can be up to < 1 knot in the central part and between 1 – 3 knots in the most eastern and most western part.	Weak to moderate
Wave exposure	(2)	Belgian Coast: exposed The Zwin nature reserve: very sheltered	Belgian Coast: exposed The Zwin nature reserve: very sheltered
	(3)	The Zwin reserve: Sheltered	Sheltered
Mean Water temperature	(4)	Average values at measurement points vary from 8,65 °C ± 3,62 °C (most eastern measurement point) to 9,85 °C ± 3,35 °C at the most western measurement point.	
Mixing characteristics	(5)	Permanently fully mixed	
Turbidity	(4)	Average values for turbidity at measurement points vary from 8,92 FTU ± 6,15 and 56,49 FTU ± 49,34. Very high variations are found between the different sample periods for all the sample points.	
Retention time of enclosed bays	(6)	Not relevant for Belgian Coast ± 4.5 hours retention time in the Zwin Nature Reserve	Not Relevant for Belgian Coast Short (up to several days)
Mean substratum composition	(7)	Sand – difference between fine sand and thick sand Average median grain size between 125-250 µm (= fine sand)	Sandy-gravel substratum
Water temperature range	(4)	Temperature ranges from 4 °C to 18 °C for all the sampling points for the years 2000 until 2003. No significant differences between different locations.	
Mean depth	(4)	Zones with a depth of: 2 m 5 m; and 10 m are distinguished in the coastal zone of the Belgian Marine Waters.	Shallow waters (< 30 m depth)
Proportion of Intertidal-zone	(8)	6 % of surface Coastal Zone (from 3 miles line up to high water line) = intertidal zone	Small proportion of intertidal area
Duration of ice coverage		Not relevant for Belgian Coast	

*(1a) Modelling velocity for the year 2004 by mumm with a resolution of 1 hour and 750 * 750 m. The average value for the year 2004 has been calculated.*

(1b) Predictions of current direction and current velocity for the period 02 12 2004 until 10 12 2004. (http://www.mumm.ac.be/NL/Models/Operational/Currents/)

(2) Scaldit project. Report on the result of project Coastal and transitional waters. Water bodies. 2004.

(3) Jochems, H.; Schneiders, A.; Denys, L; and Van den Bergh, E. 2002. Typologie van de oppervlaktewateren in Vlaanderen. Eindverslag van hetproject VMM. KRLW-typologie. 2001 (met CD-ROM). No detailed data are available for the Zwin. VMM does not have sampling points in the nature reserve the Zwin.

(4) htttp://www.mumm.ac.be/datacentre

(5) Expert judgement

(6) Van Colen C. (2004). De afdamming van het Zwin als gevolg van de Tricolor olieverontreiniging: effecten op en herstel van het macrobenthos. MSc Thesis Ghent University 2003-2004.

(7) LANCKNEUS, J., VAN LANCKER, V., MOERKERKE, G., VAN DEN EYNDE, D., FETTWEIS, M., DE BATIST, M. & JACOBS, P. (2001). Investigation of natural sand transport on the Belgian continental shelf BUDGET (Beneficial usage of data and geo-environmental techniques). Final report. Federal Office for Scientific, Technical and Cultural Affairs (OSTC).

(8) Own calculations

Mean current velocity

Map 6 in Annex B shows the mean current velocity (prediction) for 8 December 2004 at 05:00 h in meter per second (1 knot = 0,5144 m/s). The velocity prediction for 5 days never exceeded 1 knot for the central part of the Belgian Coastal Waters, but did so for the most eastern and most western part of the coast (i.e. near France and near the Scheldt river).

Map 7 (Annex B) gives the mean current velocity of the entire year 2004, modeled by the MUMM for the current study. On average the current velocity does not exceed 0,5 knots in the entire Belgian Shelf.

Mean temperature

The values of the mean temperature of the coastal waters at a depth of about 3 m at the sampling events of the MUMM during the years 2000 to 2003 are given in Map 8 (Annex B). No significant differences have been found between the sampling points. The variation during the year is large (higher temperatures in summer and lower temperatures in winter).

Average turbidity

Map 9 (Annex B) shows the average turbidity of the coastal waters.

Median grain size

Map 10 (Annex B) shows the median grain size of the sand fraction of the surficial sediment in the Belgian Coastal Waters. The substratum is sandy, but a distinction can be made between very fine (median grain size of 63-125 µm) fine (125-250 µm) and medium to coarse (>250 µm) sand. The dominating sediment fraction is fine sand. Very fine sand patches also occur, mainly between Zeebrugge and the Dutch border and off the coast of De Haan. Medium sand occurs only infrequently (for instance off the coast of Ostend).

Proportion of intertidal area

The proportion of intertidal area has been calculated as the surface of the intertidal area (from the low low water line up to the high water line[1]) divided by the surface of the coastal zone as defined in paragraph 1.2). The surface of the intertidal zone equals about 2.450 ha. The total surface of the coastal zone equals about 40.600 ha. The boundary for distinguishing a small and a large proportion of intertidal area, as proposed by the CIS working group 2.4 (COAST), equals 50 %. The proportion of intertidal area for the Belgian coast equals 6 % (up to the 3 miles line) and 16 % (up to the 1 miles line).

Typology

The following descriptors are distinguishing different zones in the Belgian Coastal Waters:

- Mean annual salinity (obligatory descriptor) – if also the Zwin Nature Reserve is included in typology;
- Wave exposure – if Zwin in included in typology (optional descriptor).

The types are:

- Type 1: Euhaline, shallow, mesotidal, not sheltered, sandy (Belgian coast);
- Type 2: Polyhaline, shallow, mesotidal, sheltered, sandy (Zwin Nature reserve).

[1] The low low water line has been obtained of the Flemish administration responsible for the coast management. A official high high waterline does not exist. Therefore, the isoline of 4,5 mTAW has been taken for the high water line

For the classification and the reference condition, only the Belgian coast will be considered, namely the euhaline, shallow, mesotidal and not sheltered waters. The Zwin Nature reserve has been considered within the Scaldit project.

3.4 Ideal typology from the macrobenthic point of view

The (guidance) documents of the Water Framework Directive state that two systems for typology (A and B) can be used (see above).

A typology based on system A or on system B (only obligate factors) seemed not be able to discern the actual types, existing in the Belgian coastal waters. This will be illustrated by means of the diversity and geographical distribution of the macrobenthic communities in this area.

Van Hoey et al. (2004) analyzed 728 macrobenthos samples (443 sampling sites) from the whole BCP to determine which macrobenthic communities occurred on the BCP. By means of multivariate analyses these samples were assigned to 10 sample groups. 4 of these groups were identified as separate communities (*Abra alba – Mysella bidentata* community, *Nephtys cirrosa* community, *Ophelia limacina – Glycera lapidum* community and *Eurydice pulchra-Scolelepis squamata* community), while the other groups constituted transitional species associations between the other communities. Only three communities (*A. alba – M. bidentata, N. cirrosa and O. limacine – G. lapidum* communities) and 3 transitional species associations (species associations 3, 5 and 7) occur in the Belgian coastal zone. These communities (and to a lesser extent the species associations) are characterized by their own specific species composition, habitat preferences and community parameter values (Table 9).

Table 9: Habitat preferences and community parameter values of the 3 macrobenthic communities and 3 transitional species association occurring in the Belgian coastal waters.

	Habitat preferences	Community parameter values
A. alba – M. bidentata community	Fine sandy sediments High mud content More shallow waters	Species richness very high Density very high
N. cirrosa community	Medium sandy sediments Low mud content More shallow waters	Species richness medium high Density medium high
O. limacina – G. lapidum community	Coarse sediments Relatively low mud content Deep waters	Species richness very low Density very low
Species association 3	Medium sandy sediments Relatively low mud content Deep waters	Species richness high Density high
Species association 5	Medium sandy sediments Low mud content Deep waters	Species richness medium high Density low
Species association 7	Fine sandy sediments Almost no mud present Very shallow waters	Species richness very low Density very low

When the geographical distribution of these communities is analyzed (Figure 9), it can be seen that the community diversity decreases towards the east coast (although it should also be mentioned that there are relatively less samples taken at the east coast than at the west coast). This could be explained by the estuarine effect of the mouth of the Westerschelde, with a high input of fine particles. At the west coast also different patterns can be seen in community diversity, with specific communities having their largest relative occurrences in certain zones (related to the habitat characteristics in these zones). This is due to high habitat diversity at the west coast (sandbank-gully variation with different sediment composition). The *Abra alba-Mysella bidentata* is mostly restricted to the most western part of the Belgian coast, as is species association 5. The middle coast shows a more mosaic pattern of communities and this could reflect the transition of the low community diversity at the east coast to the high community diversity at the west coast. Species association 7 seems to occur more at the middle part of the coast.

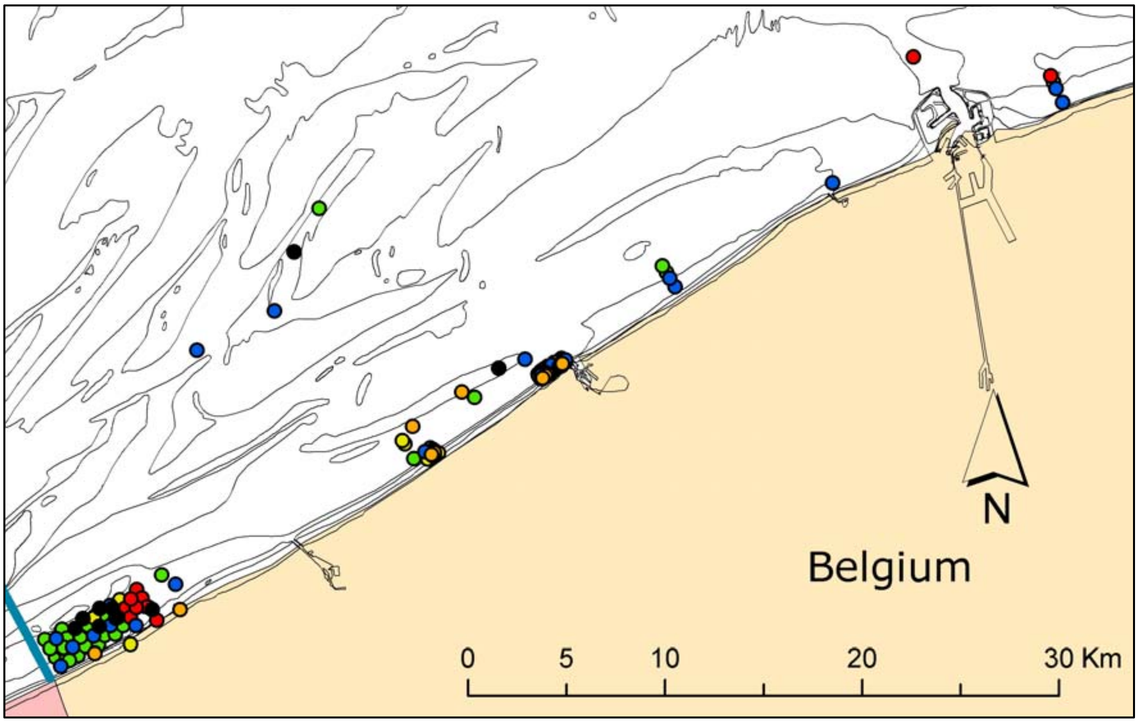

Figure 9: Overview of the distribution of the macrobenthic communities and transitional species associations along the Belgian coast. Green dots: Abra alba-Mysella bidentata community; yellow dots: Nephtys cirrosa community; red dots: Ophelia limacina-Glycera lapidum community; blue dots: species association 3; black dots: species association 5; orange dots: species association 7.

To account for this geographical distribution of macrobenthic communities additional factors should be included in the system B typology (Table 10). Because the defined water types will be used for the determination of the reference conditions and classification, they should be able to distinguish between the different zones of the macrobenthic distribution. Human activities like fisheries and organic pollution will have different impacts on the different communities, because some species are more sensitive to physical disturbance than others. Since the main factors influencing the occurrence of macrobenthic communities are depth and sediment characteristics, these should be implemented in the typology.

Table 10: Factors that influence the occurrence of macrobenthic communities.

Influencing factors	Detailed	Proposed in WFD documents ?
Depth		Additional factor (suggested by guidance documents)
Sediment characteristics	Median grain size	~ Facultative factor ('average composition of substrate')
	Mud content	Specification of 'average composition of substrate'

The WFD document discerns different classes for the application of the facultative factor '**Average composition of substrate'**, namely hard substrates, sand-gravel sediments, muddy sediments and mixed sediments. These rough classes are not sufficiently detailed to lead to a type-distinction that is needed to address the geographical distribution of the macrobenthic communities. But the WFD allows suggestions on new factors to be included or existing factors to be detailed. Here the suggestion is made to make a specification of the factor '**Average composition of substrate'** into '**Median grain size**' and '**Relative mud content'.**

The additional factor 'Depth' considers three classes (< 30 m: shallow, 30-50 m: medium depth, > 50 m deep). Since the Belgian coastal area within the 3 nautical miles zone is a very shallow environment, the 'shallow' class needs probably to be further divided into subclasses to account for the distribution of macrobenthic communities.

3.5 Typology adapted for practical considerations

At the first end-user meeting of the REFCOAST project it was mentioned by the end-users that it was already decided on European level that only one type would be discerned for the whole Belgian coast. This type can be classified according to the guidance documents as 'mesotidal, euhaline waters', using the system A typology, or as 'euhaline, shallow, mesotidal, not sheltered, sandy waters', using the system B typology (paragraphs 3.2 en 3.3).

This "rough" typology can be considered in more detail for classification purposes. It will be ecologically more relevant to consider different habitat types or water bodies within this one type. Next to the six habitats (related to each of the 6 macrobenthic communities) described above, a seventh habitat should be considered for the Belgian coast. As described in 3.2 and 3.3 the Zwin area should also be considered. It is proposed to treat the Zwin area as a different habitat within the Belgian coastal type, instead of treating it as a different type. Next to these habitats it is also possible to distinguish the beach habitat(s) occurring along the Belgian coast. All of these habitats could be designated by using other additional factors, described in the guidance documents on typology (e.g. sediment size parameters). The distribution of macrobenthic communities along the Belgian coast is clearly linked to the distribution of the sediment classes and large ecological differences can be seen between the east, middle and west coast. So, considering this variety of communities as a whole in the classification exercise would blur out the real differences between them and hence be ecologically irrelevant.

The distinct type of the Zwin Nature Reserve (paragraph 3.3) will thus not be considered in the rest of this report.

4. REFERENCE CONDITION AND CLASSIFICATION OF THE BELGIAN COASTAL WATERS

In this chapter, a system scale reconstruction of different scenarios is worked out, allowing to derive a reference condition for system averaged production. The different scenarios also give opportunities to derive classification limits. Next to this classification on the system scale, classifications for the macrobenthos on a more detailed scale are given for each habitat occurring in the Belgian coastal zone. Such in-depth classification was not possible for the phytoplankton (which is only classified at the system scale).

4.1 Methodology to make classification and reference condition

The method to derive a system averaged reference condition is based on top down trophic relations from the level of benthic macro-invertebrates to the primary production. Primary production is then linked to the water quality of the receiving watershed by coupling two models, a model of the non tidal watershed, and a model of the tidal river stretch.

The reference condition used for the within-habitat classification of the macrobenthos is based on available historical data.

4.2 Development of a macrobenthic classification method for the Belgian coastal waters

According to the Water Framework Directive a classification method for coastal waters should define the status of different biological quality elements: phytoplankton, macroalgae and angiosperms and benthic invertebrate fauna. In the following classification method both phytoplankton and benthos are included. Macroalgae and angiosperms are not included in the analysis due to the fact that they are not occurring along the Belgian coast. The only macroalgae occurring along the Belgian coast grow on man-made hard constructions like dikes and groins. Because they need a hard substrate (e.g. rocky shores) to attach themselves they were not likely to occur along the sandy beaches of Belgium before these anthropogenic alterations of the beach area took place (Engledow et al., 2001). The sandy intertidal Belgian strip also couldn't be colonized by macroalgae due to the strong current effects and wave action upon the coastline.

UA has developed a classification system for the Belgian coastal waters, based on their experience in transitional waters and based on the study of Ysebaert &

Herman (2004) for the Western Scheldt (transitional water). The classification tool proposed by the latter authors is based on a hierarchical approach with three hierarchical levels/scales. On the first level of the whole ecosystem one can evaluate if the benthic macrofauna fulfils the functional role one might expect given the current ecological circumstances. At this level also integration with other quality measures (i.e. for phytoplankton, see below) is most appropriate, and information on the ecosystem can be summarized. On the subsequent level the distribution of sub-areas (e.g. ecotopes/habitats) can be evaluated. The size, shape and spatial relationships of these ecotopes influence the dynamics of populations, communities and ecosystems. The third within-ecotope (or within-habitat) level evaluated the quality of each distinguished ecotope/habitat (based on the diversity, abundance or biomass of the associated benthic macrofauna), with indicators that are sensitive to different types of stress and that can explain possible deviations. The three levels in the hierarchy all produce an indicator for the ecological status and these indicators can then be combined to one overall indicator of the status of the system: $ECO^3_{BEN} = [(1*IND_{Ecosystem}) + (2*IND_{Ecotope}) + (2*IND_{Within\text{-}Ecotope})]/5$ (Escaravage et al., 2004). In the following sections this classification tool was applied to the Belgian coastal waters.

4.2.1 Macrobenthic classification on the ecosystem level - Reconstructing the link between the coastal zone and the river catchment

4.2.1.1 Relation between benthos and primary production

In ecology there is always a relation between a trophic level and its food source. Such a relation has been found for well documented saline and brackish transitional waters between macrozoobenthos biomass and its food source, primary production (Figure 10). The relation is only apparent on system scale. If this link is extendable for the coastal zone, then a tool is available to classify benthos on system scale, based on primary production, which mainly consists of phytoplankton. This approach would have a major advantage, namely because the link between primary production and the nutrient status is more direct than the relation between benthos and human waste discharge. The benthos-primary production relation implies that the nutrient status can be linked with benthos biomass, allowing a classification of benthos biomass based on the trophic status of the surrounding water body. This study has followed this track as it opens further possibilities. With the current knowledge it is possible to model water quality scenarios even beyond the range of available data. Ecological conditions of which no data are available can be reconstructed, leading through the relation with plankton to new insights in the status of benthos.

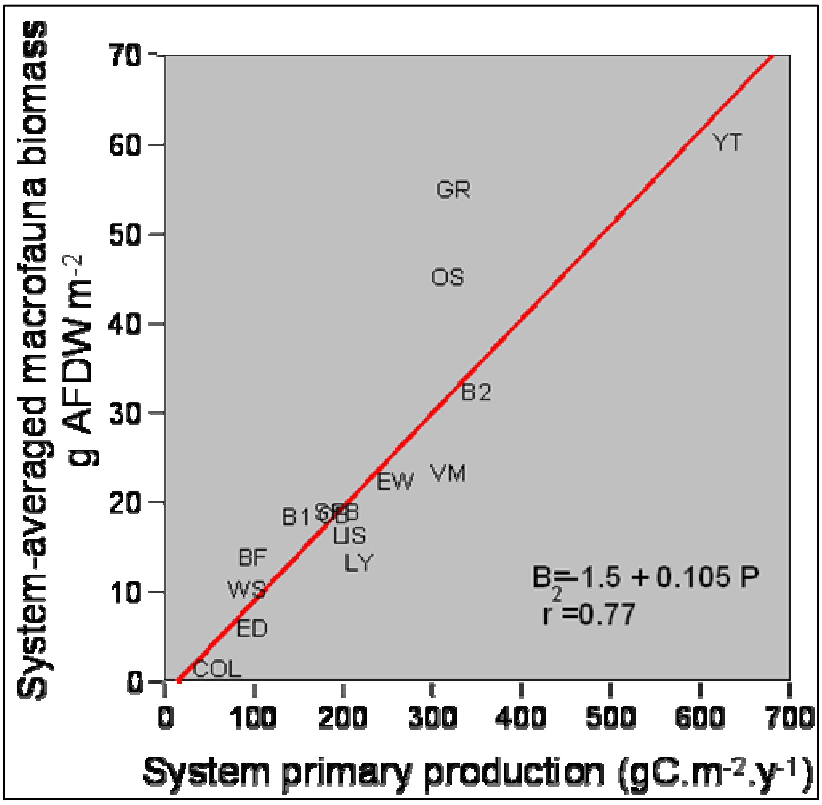

Figure 10: Relation between system averaged benthos biomass and system averaged primary production. Each symbol represents an estuary (Escaravage et al., 2004)

First, it has been investigated whether the relation benthos – primary production can be applied for the coastal zone. The conclusion that it can be extrapolated is argued in the following sections.

Then the link between primary production and human impact is studied. Primary production is related with the nutrient status of the surrounding water. The nutrient concentration of the coastal zone is affected by the emission from the rivers. A source to mouth approach has been followed in the reconstruction of the water quality status. Coupling the reconstruction of the emission from the watershed with ecological modelling of transitional waters allows linking the quality of the coastal zone with the human impact resulting from the watershed, thus providing a sound basis to ecological classification of the coastal zone.

4.2.1.2 Applicability of the relation benthos-primary production on the coastal zone

The used relation between benthos and primary production was constructed for saline transitional waters. An obvious question then is if the relation can be applied on coastal waters (Figure 10). It is accepted that a link exists between any trophic level and its food source. The relation expresses a yield of 10%, which is not uncommon between trophic levels of many kinds.

Stressors can change the relation. A stressor, for instance oxygen deficiency, toxic substances or physical disturbance, can affect the upper trophic level (benthos) more than the lower level. If stressors affect the primary production more than the benthos (e.g. through human induced light limitation), then the benthic biomass will eventually follow according to the change in carrying capacity provided by primary production.

The first question concerns the relation itself. Is primary production really the food source of benthos? Then the possible interference of zooplankton will be evaluated. Depth is also a factor that can cause failing applicability.

Detritus

A lot of species are detrivores. The relation implies that the detritus originates from primary production that died off. It could be that not only primary production is a food source for macrozoobenthos. Anthropogenic detritus, could play a role, as it is discharged from rivers and estuaries.

Quantification of the human contribution in the detritus load is to our knowledge not available for the coastal zone. Knowledge of the Scheldt estuary however provides some information. In the freshwater part of the Scheldt estuary the anthropogenic fraction of the particulate organic carbon (POC) has been estimated at around 45% during summer and 80% during winter (Hellings et al., 1999; Van Damme et al., 2005). The POC fraction of suspended matter gradually dwindles towards the river mouth, as only the most refractory phase of detritus reaches the sea. The rest is transformed into CO_2 by internal estuarine bacterial consumption (Frankignoulle et al., 1998; Goossen et al., 1995).

A number of arguments suggest that primary production is highly preferred as food source. First, the relation between macrozoobenthos and primary production itself is already evidence that anthropogenic detritus is not important. So far, neither detritus nor bacteria were proven to constitute an important nutrient source for higher trophic levels, considering such facts as the importance of phytoplankton for macrobenthic suspension feeders and of microphytobenthos for deposit feeders (Herman et al., 2000), the feeding selectivity of zooplankton (Tackx et al., 2003), or the lesser importance of grazing on bactivorous ciliates than on herbivorous ciliates (Hamels et al., 1998).

Even in the heavily burdened freshwater zone of the Scheldt estuary no evidence has been found that anthropogenic detritus would be consumed. One study focussed specifically on the source of POC as food, however not for Oligochaetes or other benthos, but for zooplankton (De Brabandere, 2005). This study confirms that in the brackish zone detritus is ignored as food source. In the freshwater part detritus is consumed by zooplankton. The source of this detritus was found to be mainly riverine phytoplankton. Antropogenic detritus was not important. Expert judgement estimates that macrozoobenthos will only consume anthropogenic detritus if no other food source is available.

Zooplankton

It could be that zooplankton interferes in the relation benthos – primary production by scavenging a considerable percentage of the phytoplankton population. Again estuarine research gives an indication that this is not the case in coastal waters, as the predation pressure of zooplankton on phytoplankton showed to be much lower in the mouth region than in the brackish zone (Desmit, 2004). Even in the brackish zone of estuaries, where benthos biomass is not larger than in the saline part, the zooplankton impact cannot disturb the relation benthos – primary production.

Depth

Vertical profiles of the oxygen utilisation rate show that benthic respiration in deep water (i.e. deeper than 200m) is fundamentally different than in shallow zones, which was attributed to a difference in net settling velocity of organic matter and degradation constants (Andersson et al., 2004). Organic matter that has a long way to sink before it settles is more degraded when it finally reaches the bottom. In this study, however, only the shallow coastal zone is considered, which is less deep than 200m. Depth is therefore not a factor that is likely to interfere the scoped trophic relation.

Conclusion

It is likely that antropogenic detritus constitutes a negligible part in the coastal food chain. Primary production (as living or dead material) is the dominant food source for coastal macrobenthos. In the coastal zone zooplankton has probably much less impact on phytoplankton than macrozoobenthos. In deeper water this might not be the case, but in this study only the shallow coastal zone is considered.

No indications have been found that the relation benthos – primary production would not be applicable to the Belgian coastal zone.

4.2.1.3 Reconstruction of watershed emissions in the Scheldt estuary

In the scope of this study – aiming at defining the measures to be taken to restore the ecological functioning of the coastal zone in the Belgian territory – it has been found necessary to gain the knowledge of the fluxes of biogenic elements (algal biomass, detritus and nutrients: nitrogen, phosphorus and silica) brought to the estuarine system by the rivers draining the upstream watershed. These fluxes represent indeed, beside of the internal processes, a major control on the ecological functioning of this estuarine system.

The fluxes of material carried by the rivers at their outlet reflect in a complex way the agricultural, domestic and industrial activities in the basin. The RIVERSTRAHLER model is a simplified model of the biogeochemical functioning of river systems at the basin scale allowing to relate water quality and nutrient fluxes to anthropogenic activity in the watershed (Billen et al., 1994, 1997, 1999; Garnier et al. 1995, 1999, 2002a). Recently, Billen, Rousseau et al. (2005) have applied the RIVERSTRAHLER model to the Scheldt river system, and have reconstructed the respective role of hydrology and human activity in the watershed during the last 50 years. They were able to explain the observed long-term trends in water quality changes as the combined effects of climate variations on the one hand, and urban, industrial and agricultural development on the other hand.

Here we make use of the same model to provide an estimate of the nutrient fluxes from the upper Scheldt and Rupel basins to the tidal estuarine Scheldt system, for different past, present and future conditions of land use, and under 3 types of hydrological conditions. If these results are then used as input in an ecological model of the Scheldt estuary, then the output of this estuarine model will allow linking the ecological quality in the coastal zone with anthropogenic activity in the watershed.

The Riverstrahler model

Geographical representation

The RIVERSTRAHLER model will be applied in its 'idealized basin' version to the upper Scheldt watershed (including the Dender river) on the one hand, to the Rupel watershed on the other hand (Figure 11). The fluxes values provided thus represent integrated values of the fluxes discharged at Temse and Boom respectively. Because of the hydraulic regulation of the Leie river in the region of Ghent, which nowadays has entirely discarded its flow from the lower Scheldt course, the Leie basin is not included in the analysis.

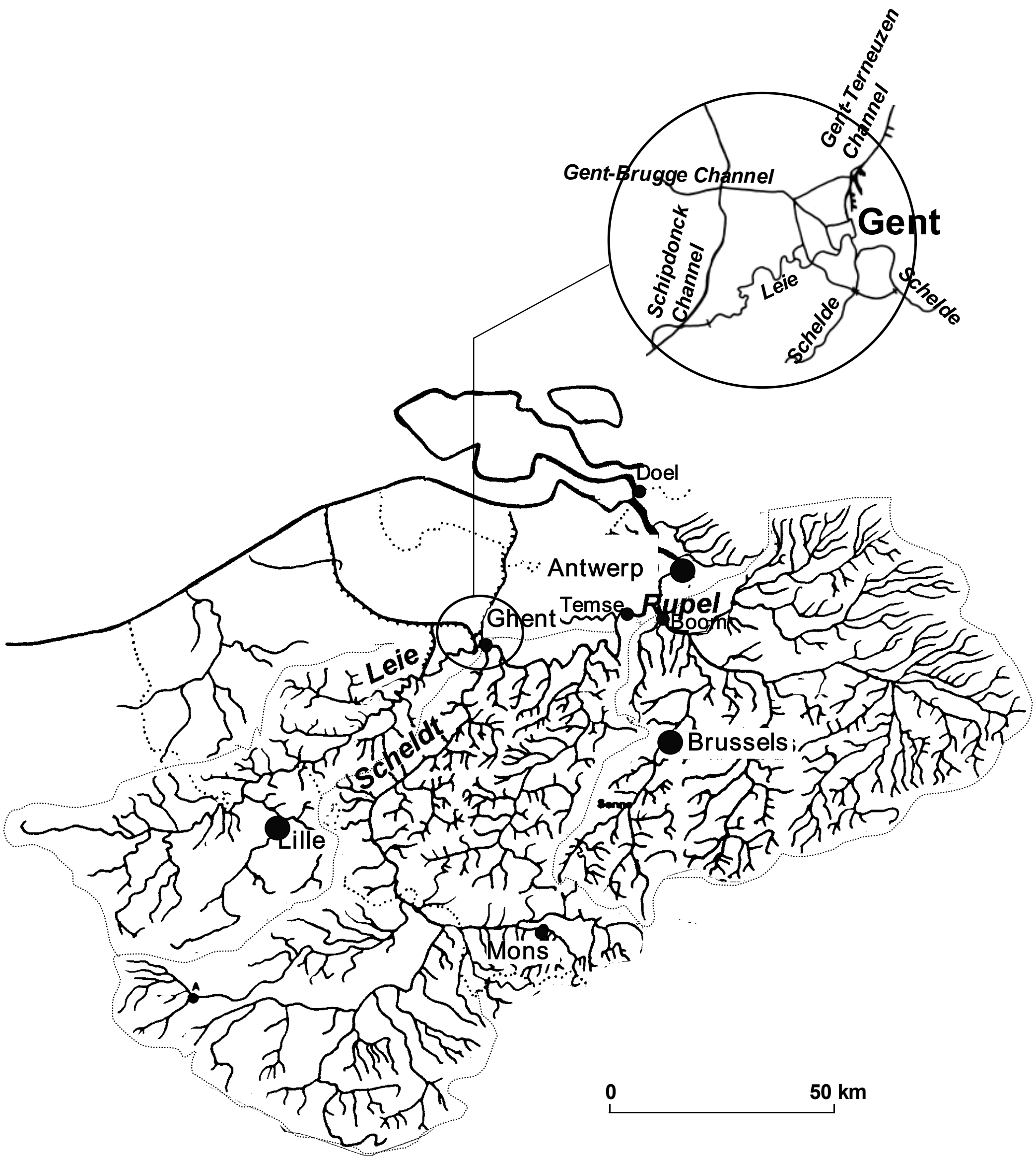

Figure 11: Upper Scheldt estuary

Hydrology

The fluxes of organic matter and nutrients delivered by a river at its outlet depends strongly on the hydrologic conditions, both because the diffuse sources of nutrient are directly related to the discharge, and because the effect of on-stream retention processes are an inverse function of the residence time of the water-masses within the drainage network (see eg. Behrendt et al., 1989). Year to year variability of the hydrology thus can obscure the long-term trends of nutrient delivery resulting from changes in land use and human activity in the watershed.

For this reason, we here decided to calculate theoretical organic matter and nutrient delivery at constant hydrological conditions. We used 3 typical rainfall and evapotranspiration conditions representative respectively of "mean", "wet" and "dry" climate over the 2 sub-basins.

Based on the analysis of the long-term rainfall data for the Scheldt watershed over the last 50 years (Figure 12), we chose the following conditions as representative of our 3 classes of hydraulicity:

- 1995 (804 mm/year) for the 'mean' conditions, i.e. a mean discharge of 185 m^3/s at Schelle
- 1984 (1275 mm/yr) for the 'wet' conditions, i.e. a mean discharge of 250 m^3/s at Schelle
- 1976 (541 mm/yr) for the 'dry' conditions, i.e. a mean discharge of 65 m^3/s at Schelle

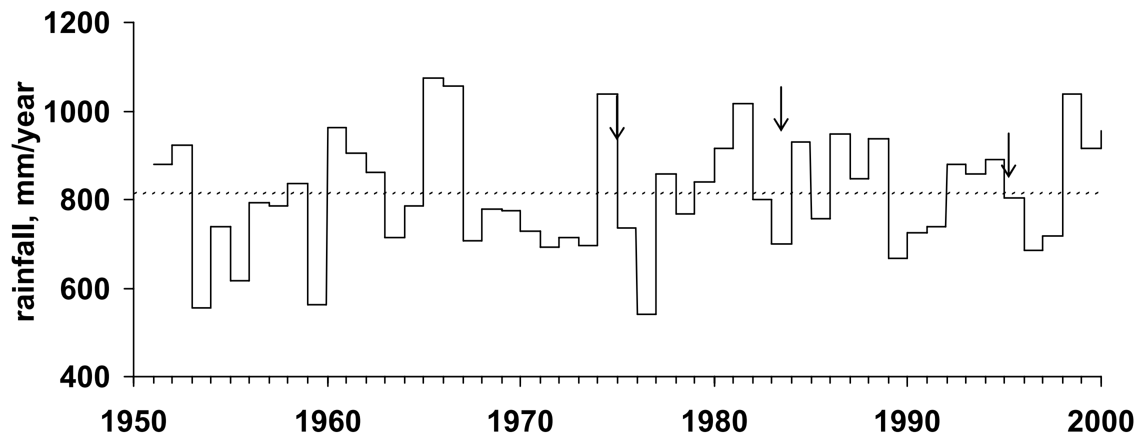

Figure 12: Long term variations of annual rainfall over the Scheldt basin. The dotted line represents the mean over the period 1950-2000.

Point and non point sources of nutrients

The scenarios for which the RIVERSTRAHLER model has been run represent the combination of the 3 above defined hydrological conditions, with a given set of files representing point and non point sources of nutrients from the watershed, characterising a certain 'historical' state of land use and human activity.

The scenarios '1950' to '2000' consist of a reconstruction of the evolution of agriculture, industrial and urban wastewater management policies over the last 50 years, as explained in details by Billen, Rousseau et al. (2005).

The '2015' scenario is a prospective scenario assuming that the requirements of all European directives on wastewater treatment and water management are met everywhere in the basin. In particular, this scenario takes into account a 90% abatement of the organic load of urban wastewater by secondary treatment, and an abatement of 90% of the phosphorus load and 70% of the nitrogen load by tertiary treatment. This scenario represents, admittedly, a quite optimistic view of the future situation of the Scheldt hydrographic district.

The 'pristine' scenario represents a hypothetical state of the Scheldt basin before any human disturbance. It corresponds to a watershed entirely covered by forest. Low soil leaching and erosion as well as direct litter fall in the tributaries are the only external inputs of nutrient considered.

Other retrospective scenarios, including 'traditional' cottage economy, are under consideration for the Scheldt river system, but are not available at the present stage of this study.

Results

The tables in Annex C and the figures below summarize the results in terms of total annual fluxes of nutrient and organic particulate carbon to the tidal estuarine zone, as well as in terms of summer level of oxygenation.

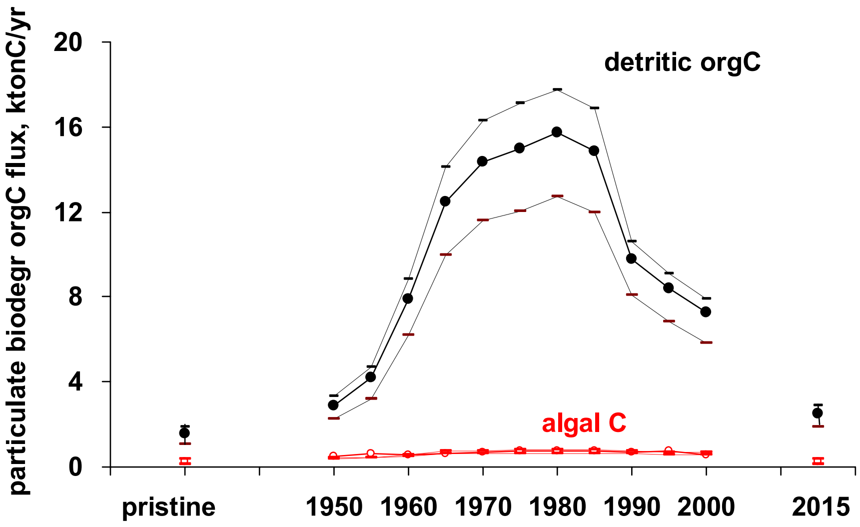

Figure 13: Total fluxes of detritic biodegradable particulate organic carbon and algal biomass from the upstream Scheldt and Rupel river basin, by mean (dots), wet or dry hydrological conditions (bars) (in ktonC/yr)

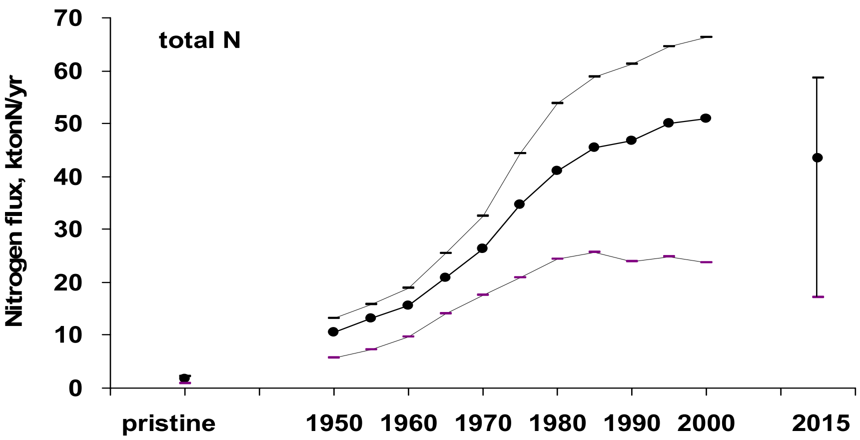

Figure 14: Total fluxes of total nitrogen from the upstream Scheldt and Rupel river basin by mean (dots), wet or dry hydrological conditions (bars). (in ktonN/yr)

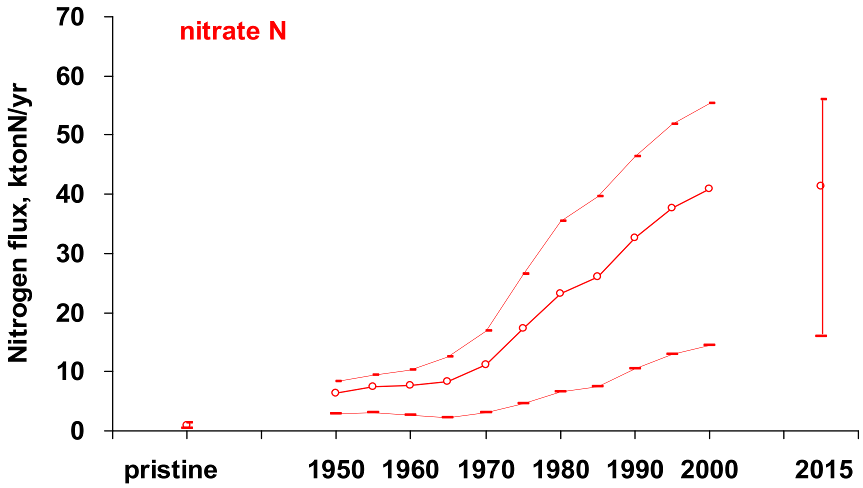

Figure 15: Total fluxes of nitrate-N from the upstream Scheldt and Rupel river basin by mean (dots), wet or dry hydrological conditions (bars). (in ktonN/yr)

The results of the nitrogen fluxes show no reduction of nitrogen load from 1985 to 2000, in contrast to the reported Belgian situation to Ospar, stating that a reduction of 19% between 1985 and 2000 took place (OSPAR, 2003). Of course the Scheldt river is not fully covering the Belgian emission, but similarity between the Scheldt watershed and the Belgian territory can be expected.

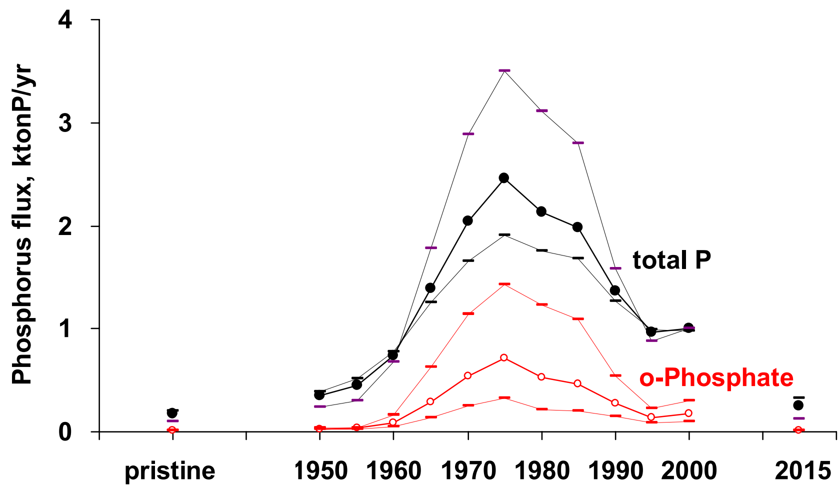

Figure 16: Total fluxes of total phosphorus and o-phosphate from the upstream Scheldt and Rupel river basin by mean (dots), wet or dry hydrological conditions (bars). (in ktonP/yr)

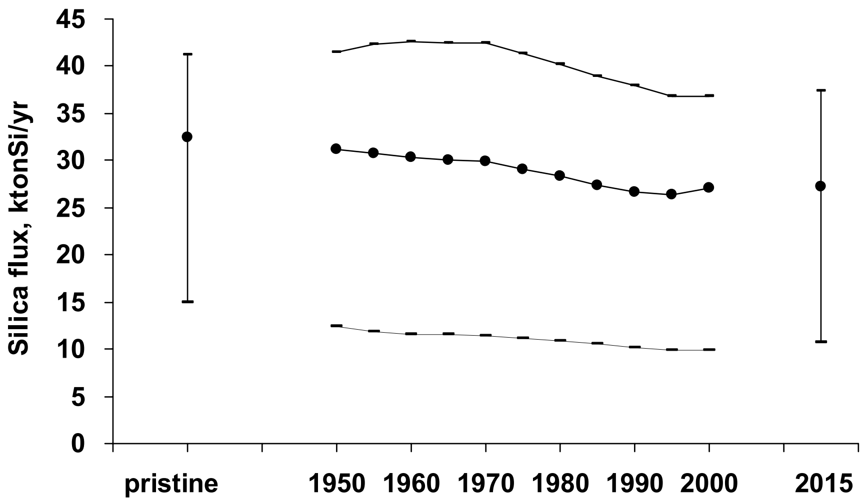

Figure 17: Total fluxes of dissolved silica from the upstream Scheldt and Rupel river basins by mean (dots), wet or dry hydrological conditions (bars). (in ktonSi/yr)

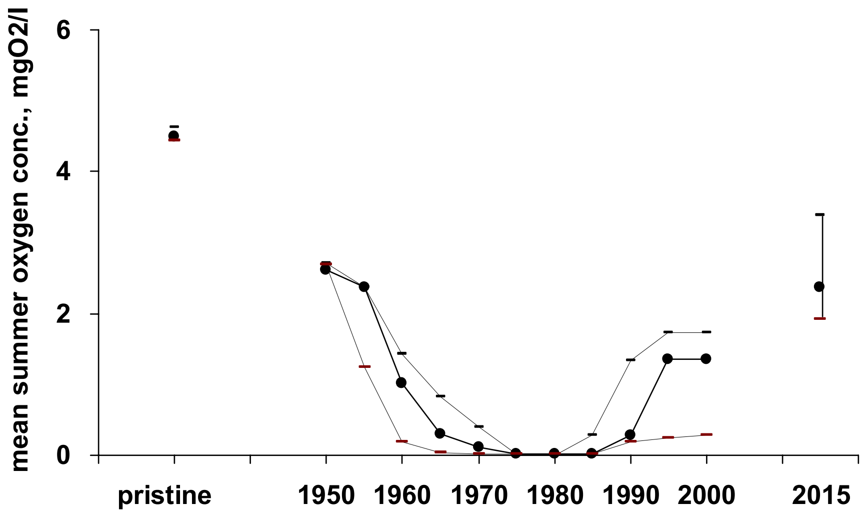

Figure 18: Mean summer level of oxygenation in the outlet of the Scheldt and Rupel river

Except for nitrate, the '2015' scenario meets the pristine scenario. This is an indication that the present legislation is adequate. Only the diffuse input of nitrate needs further attention.

4.2.1.4 Reconstruction of estuarine emission

Introduction

Estuaries cannot merely be considered as a stretch of river. They are transitional zones between the catchment and the sea in which intense biogeochemical processing takes place (Meire et al., 2005). The watershed emissions as reconstructed with the Riverstrahler model (see previous section) can therefore not be extended to the coastal zone without taking into account the specific reactions and transformations of the Scheldt estuary. The results of the Riverstrahler model have served as input in the OMES ecological model of the Scheldt estuary.

The OMES model

The estuarine OMES model is a simplified simulation box compartment model using fixed dispersion coefficients, which allows predicting chemical and biological alterations that can take place in dissolved substances that reside in the estuary. The model is described in Soetaert & Herman (1995 a, 1995 b & 1995 c), and has since then been improved by recalibrating on data of 1980-2002, implementing the lateral input of tributaries in a better way, and reformulating the transport in the upper compartments. The Riverstrahler results for the different scenarios have been used as input for the OMES model. In that way the effect of specific estuarine processes could be reconstructed for the present and historical immission scenarios.

Results

The results for chlorophyll a have for some scenario's been plotted in Figure 19 tot Figure 22. The run for 2001 shows that the model is able to represent the seasonality pretty well, but the maximum values at bloom periods (August) could not fully be reproduced (Figure 19). This indicates that the model approach is not fully apt to reconstruct phytoplankton bloom peaking values.

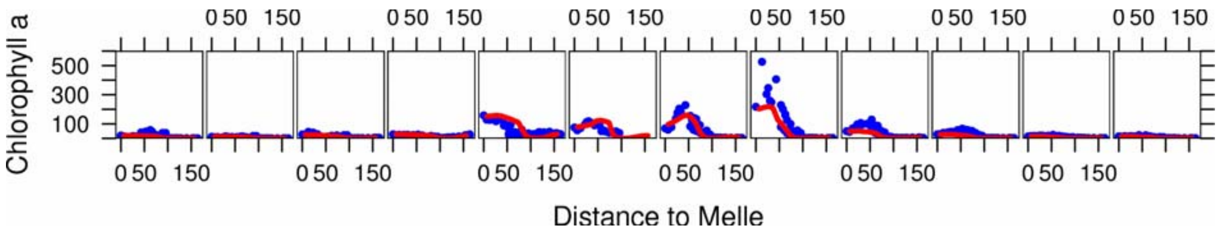

Figure 19: Chlorofyll a (mg.m-3) model results for the '2001' present scenario (red line) against data of 2001 (blue dots), from January (1st plot) till December (last plot); distance to Melle in km.

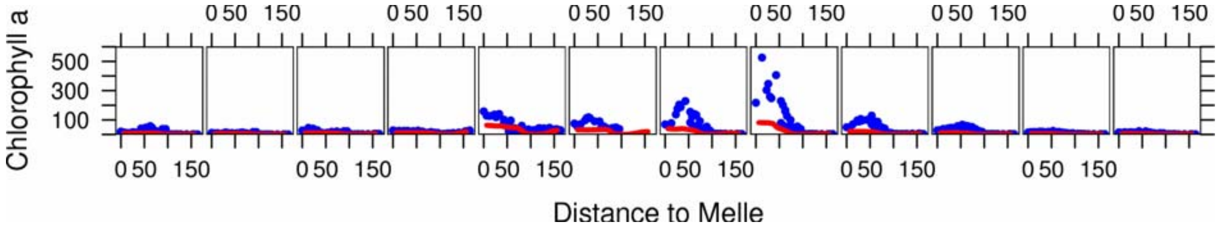

Figure 20: Chlorofyll a (mg.m-3) model results for the 'pristine' scenario (red line) against data of 2001 (blue dots), from January (1st plot) till December (last plot); distance to Melle in km.

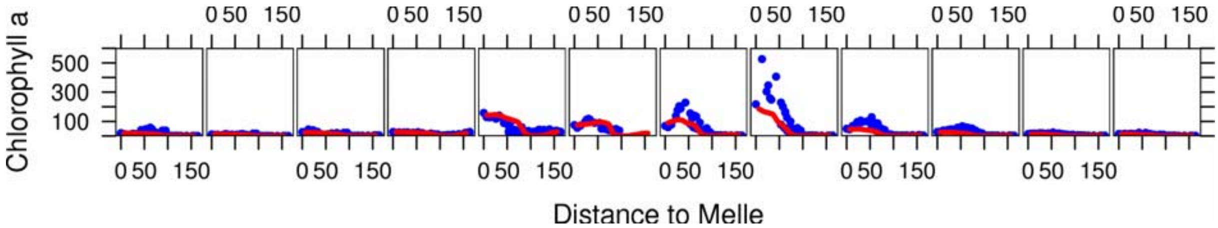

Figure 21: Chlorofyll a (mg.m-3) model results for the '1950' scenario (red line) against data of 2001 (blue dots), from January (1st plot) till December (last plot); distance to Melle in km.

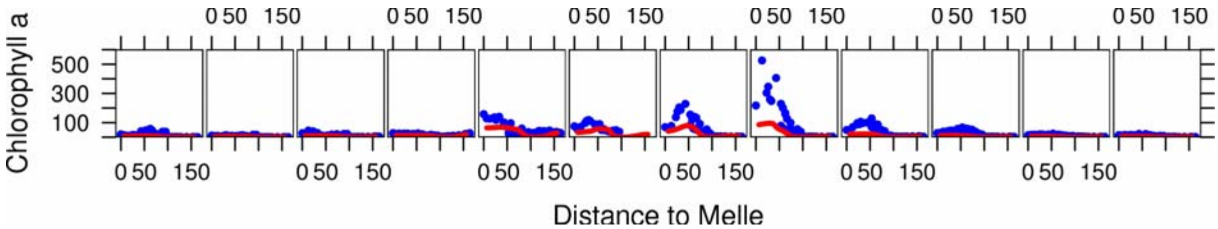

Figure 22: Chlorofyll a (mg.m-3) model results for the '2015' future scenario (red line) against data of 2001 (blue dots), from January (1st plot) till December (last plot); distance to Melle in km.

The chlorophyl a concentrations (yearly averaged) at the mouth of the Scheldt estuary were reconstructed for the different scenario's, and a comparison with the available data was made (Figure 24). The actual chlorophyll a data were also collected and these are represented in Figure 23 and Table 11 (source: BMDC website, 2005). These data are also incorporated in Figure 24.

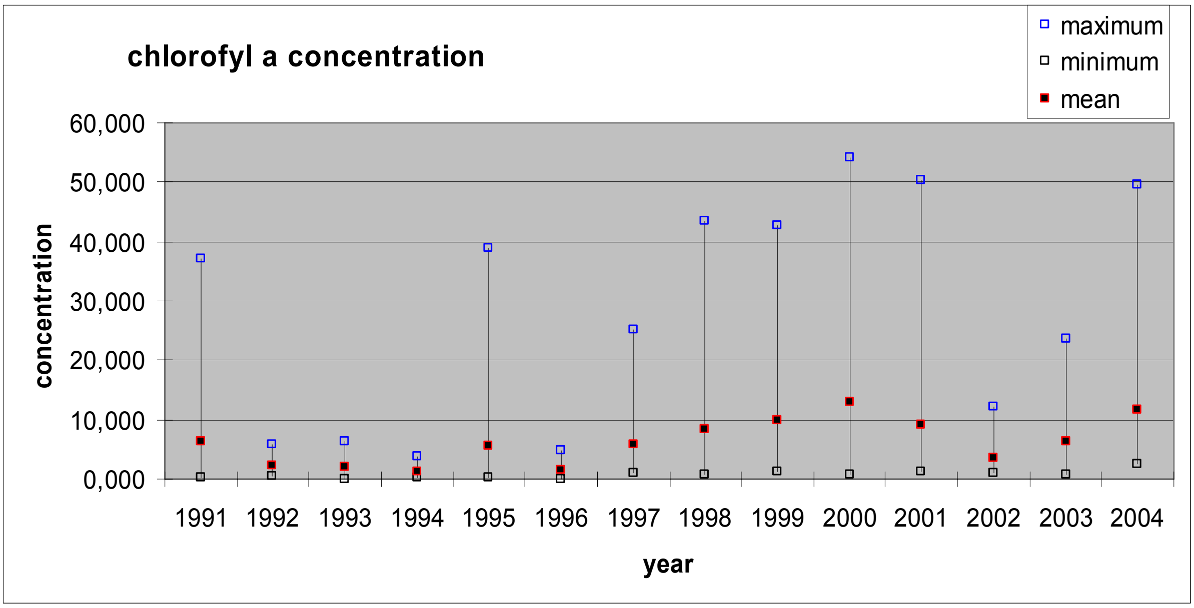

Figure 23: Actual measured values of mean, minimum and maximum chlorophyll a concentration (µg/L) for different years.

Table 11: Mean, minimum and maximum chlorophyll a concentrations for the years 1991-2004 (BMDC website, 2005).

year	mean	maximum	minimum
1991	6,427	37,080	0,300
1992	2,22625	5,780	0,430
1993	2,1132	6,380	0,100
1994	1,278696	3,910	0,260
1995	5,662051	38,780	0,380
1996	1,4825	4,800	0,100
1997	5,746156	25,180	1,020
1998	8,26425	43,490	0,820
1999	9,963898	42,600	1,330
2000	12,97336	54,050	0,780
2001	9,170688	50,267	1,176
2002	3,4795	12,241	1,127
2003	6,441571	23,758	0,723
2004	11,7155	49,640	2,440

These results show that the difference between the pristine state and the bad conditions in the period 1970-1985 is in fact not very big, especially if the scatter on the actual data is considered, which makes it difficult to derive classification limits. A classification based on chlorophyll only is therefore not advisable.

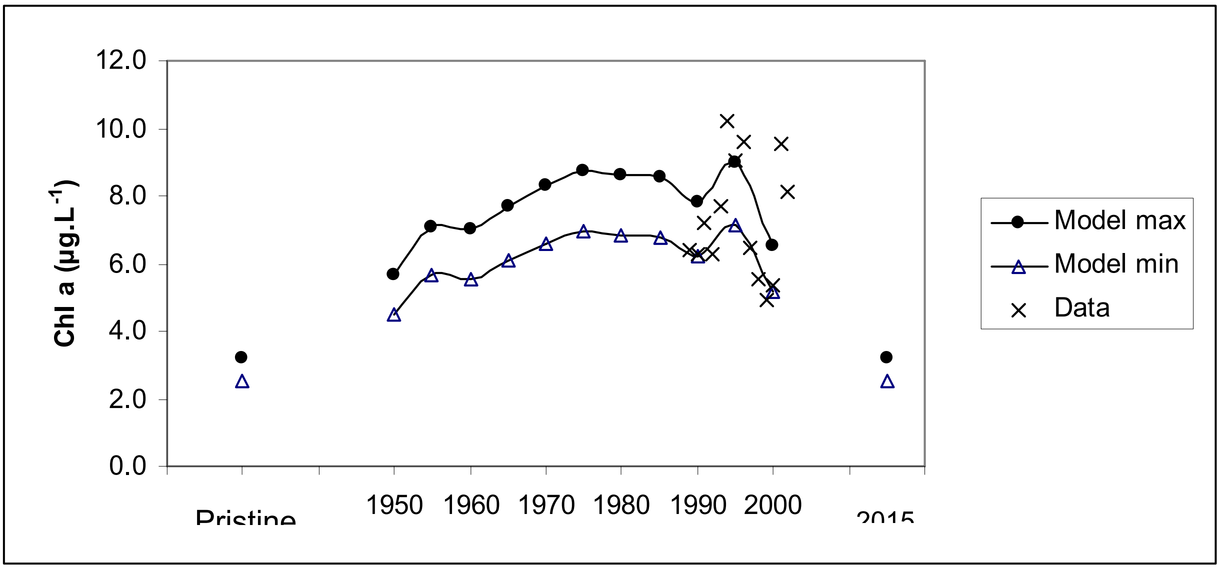

Figure 24: Chlorophyl a concentrations (yearly mean) at the mouth of the Scheldt estuary, as modelled with the OMES model with a maximum and a minimum estimate, and compared with yearly averaged data

The '2015' run for nitrogen confirms that in the future only a slight improvement of the nitrogen status is expected. Ammonium concentrations will drop consistently (Figure 25), but the nitrate concentrations (the dominant fraction) improve only slightly (Figure 26).

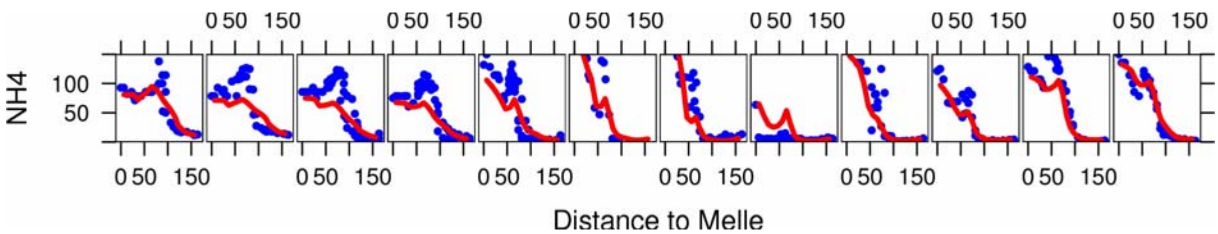

Figure 25: Ammonium (mmol N.m-3) in the '2015' scenario (all European Directives implemented) against data of 2001 (blue dots) , from January (1st plot) till December (last plot); distance to Melle in km.

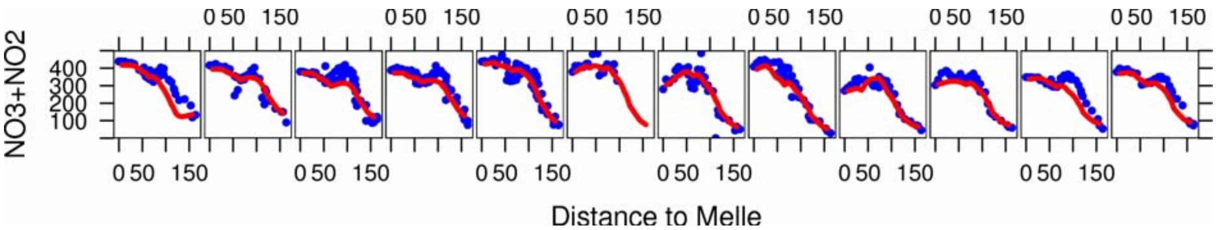

Figure 26: Nitrate plus nitrite (mmol N.m-3) in the '2015' scenario (all European Directives implemented) against data of 2001 (blue dots) , from January (1st plot) till December (last plot); distance to Melle in km.

4.2.1.5 Conversion chlorophyll a – primary production

The modelled chlorophyll a values need to be converted to primary production values, to allow plotting the latter against the expected benthic biomass data (according to the relation given above). Apparently, for the Belgian coastal waters, no relation between primary production and chlorophyll a concentration is available in literature. A relation was however found for Dutch coastal waters (Bot & Colijn, 1996) and since these authors used a sampling station in the southern part of the Dutch coastal waters, it could be argued that the environmental conditions are similar to the ones in the Belgian coastal waters. The following equation described the relation given in Figure 27: ln PP = 1.27 ln (chl a) + 1.04 (R^2 = 0.91). Because primary production values are expressed per m^3, a correction needs to be made to be able to express primary production per m^2 (needed for relation between primary production and macrobenthic biomass). This was done by using the light attenuation data for that area. Constant light transparency during the year has been assumed with the light attenuation value set at 0.3 m^{-1} and correcting for self-shading by adding 0.015 m^{-1} per mg chlorophyll/m^3 (Bot & Colijn, 1996).

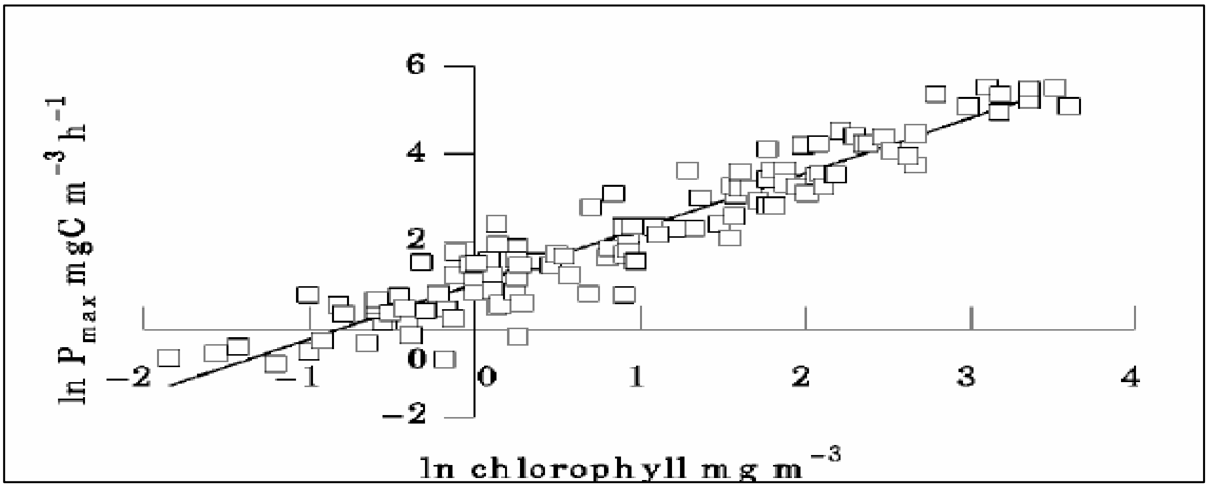

Figure 27: Relation between chlorophyll a and primary production in the Dutch coastal waters (Bot &Colijn, 1996).

Using this relationship, the modeled (system-averaged) chlorophyll a concentrations were transposed to modeled primary production values for the mouth of the Westerschelde (Figure 28).

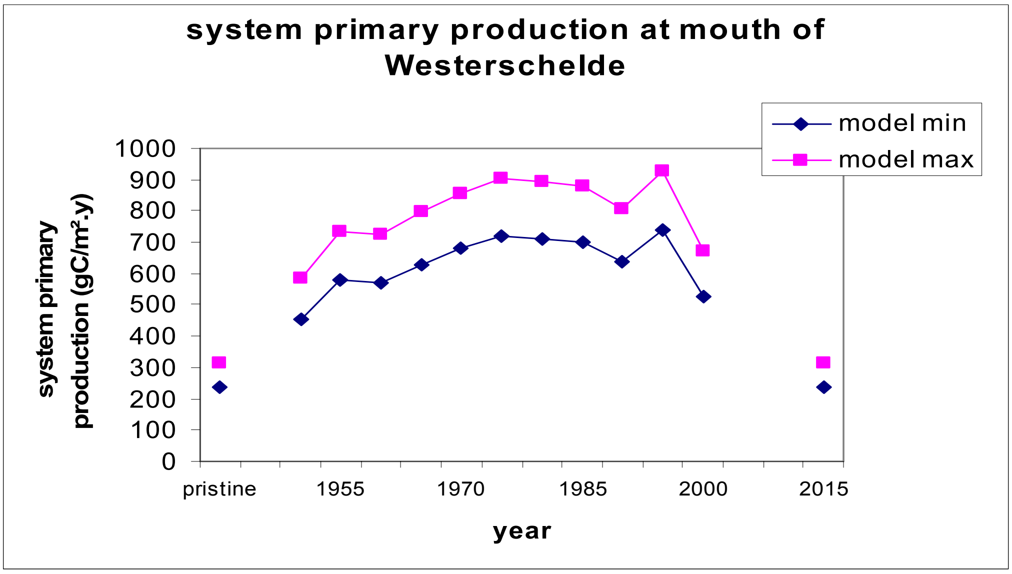

Figure 28: Modelled primary production at the mouth of the Westerschelde.

When the chlorophyll a values collected by BMDC (i.e. coastal chlorophyll a data) are equally transposed to primary production and plotted on the same graph, it can be seen that the chlorophyll a concentration and primary production values show a greater fluctuation than the trend shown for the situation at the mouth of the Westerschelde (Figure 29).

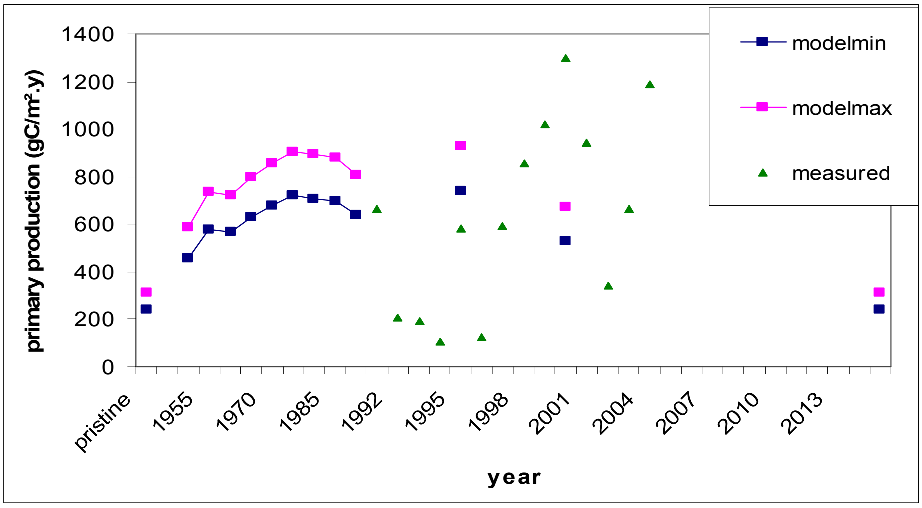

Figure 29: Primary production according to the modeled and measured chlorophyll a concentrations.

4.2.1.6 Relation primary production – benthic biomass

When the modeled maximum and minimum values for primary production are plotted on the graph, representing the modeled relationship between benthic biomass and primary production, the corresponding benthic biomass can be deduced (Figure 30). This is done for both the year 2000 and for the future scenario of 2015.

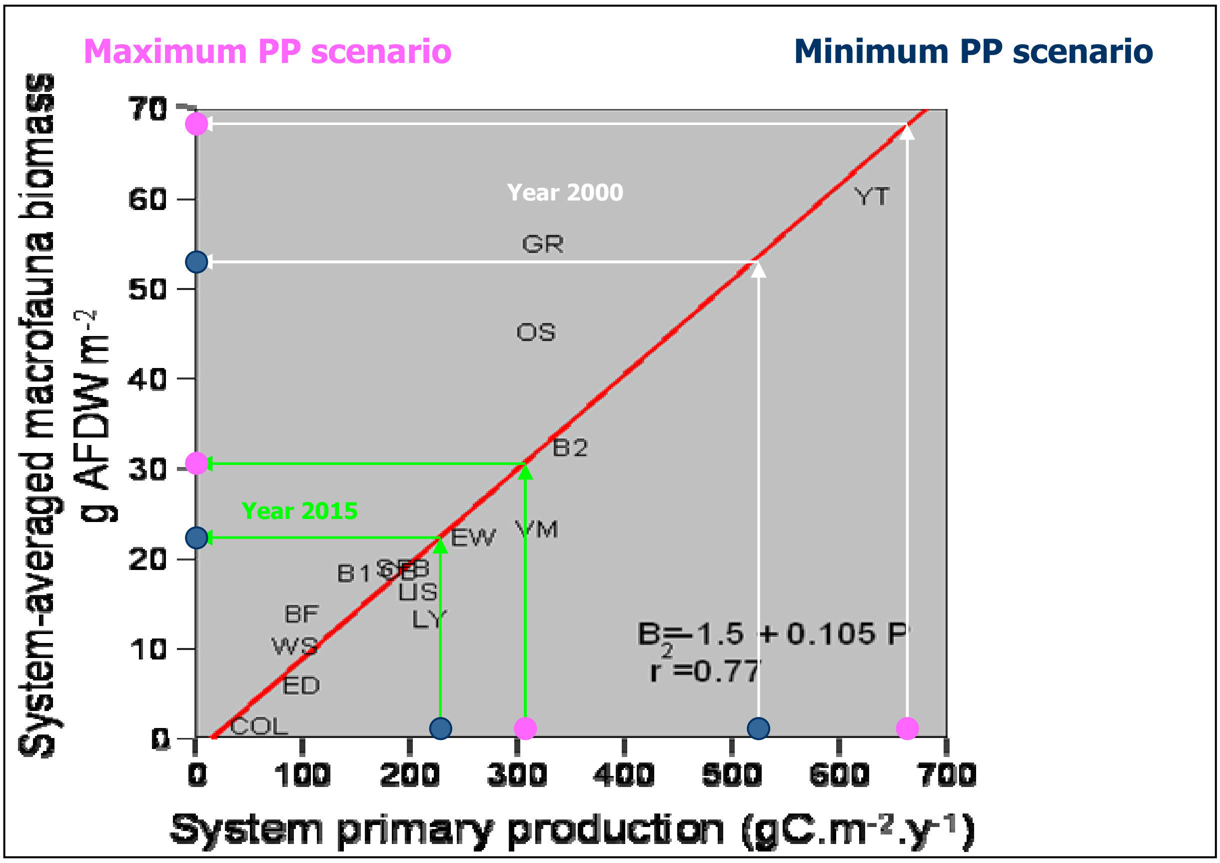

Figure 30: Modelled primary production for 2000 and 2015 and the corresponding macrobenthic biomass values.

Then a compilation of all literature on macrobenthic biomass data of the Belgian coastal area (including the mouth of the Westerschelde) was made and additional biomass data from our own database were added to this compilation (Table 12). The average macrobenthic biomass at the mouth of the Westerschelde estuary was 2.58 g AFDW/m² and 5.33 g AFDW/m² for the coastal area. When this mean value of 5.33 g AFDW/m² is plotted on Figure 30, it can be seen that it is well below the modeled biomass values of the years 2000 and 2015. There could be several explanations for this feature:

a. The biomass data from the literature and from the database are not representative for the actual biomass values.
b. The model gives values for the situation at the mouth of the Westerschelde and should be extrapolated to the coastal zone situation because there's an overestimation of the biomass in the coastal zone.
c. The model only incorporates human pressures resulting in nutrient release, but other pressures could have an effect on the macrobenthic biomass (e.g. dredging, fisheries,...) and this should be accounted for in the model.
d. The model needs further adaptation in order to reconstruct primary production in a better way.

Explanation a doesn't hold true when the available biomass information is investigated in depth. The highest macrobenthic biomass value found in literature is that from Van Steen (1978) and in this study only very rich mussel beds were sampled. Mussel shells obviously increase the value of macrobenthic biomass. When the mean biomass value was calculated based on our own measurements (Erdey, 2000), a value of 2.98 g AFDW/m² was found. The samples that accounted for this value were all taken in October, which is generally known as a month with the highest biomass values of the year. The maximum values found in this study varied between 10 and 14 g AFDW/m², so it can be concluded that the biomass values given in Table 12 are definitely no underestimation of the macrobenthic biomass in the Belgian coastal zone.

Table 12: Compiled macrobenthic biomass data for the Belgian coastal zone and the mouth of the Westerschelde estuary (near Vlissingen).

	Macrobenthic biomass (g AFDW/m²)	
	coast	**Off Vlissingen (Westerschelde-marine)**
Erdey (2000)	2.98	
Govaere (1978)	2.01	
Van Steen (1978)	10.74	
Vanosmael (1977)	5.60	
Hostens (2003)		0.24
Craeymeersch et al. (1992)		2.5
Hummel et al. (1988)		5
Average	5.33	2.58

Explanation b will probably hold some truth, because it was already mentioned above that there appear to be great differences in the chlorophyll a patterns of the coastal area and the mouth of the estuary. Adapting the model to fit this coastal chlorophyll a trend better, could also prove to give better results for the extrapolated macrobenthic biomass values. In the study of Erdey (2000) the sampling of macrobenthic biomass was accompanied with the sampling of the water to determine the chlorophyll a concentration. When this mean chlorophyll a value is transposed to primary production, using the relation of Bot & Colijn (1996), this primary production value can be plotted against the actual mean biomass value of Erdey (2000) and this shows that this point agrees well with the trend between primary production and biomass determined for transitional waters (Figure 32) confirming that the relationship of transitional waters is useful for the Belgian coastal waters.

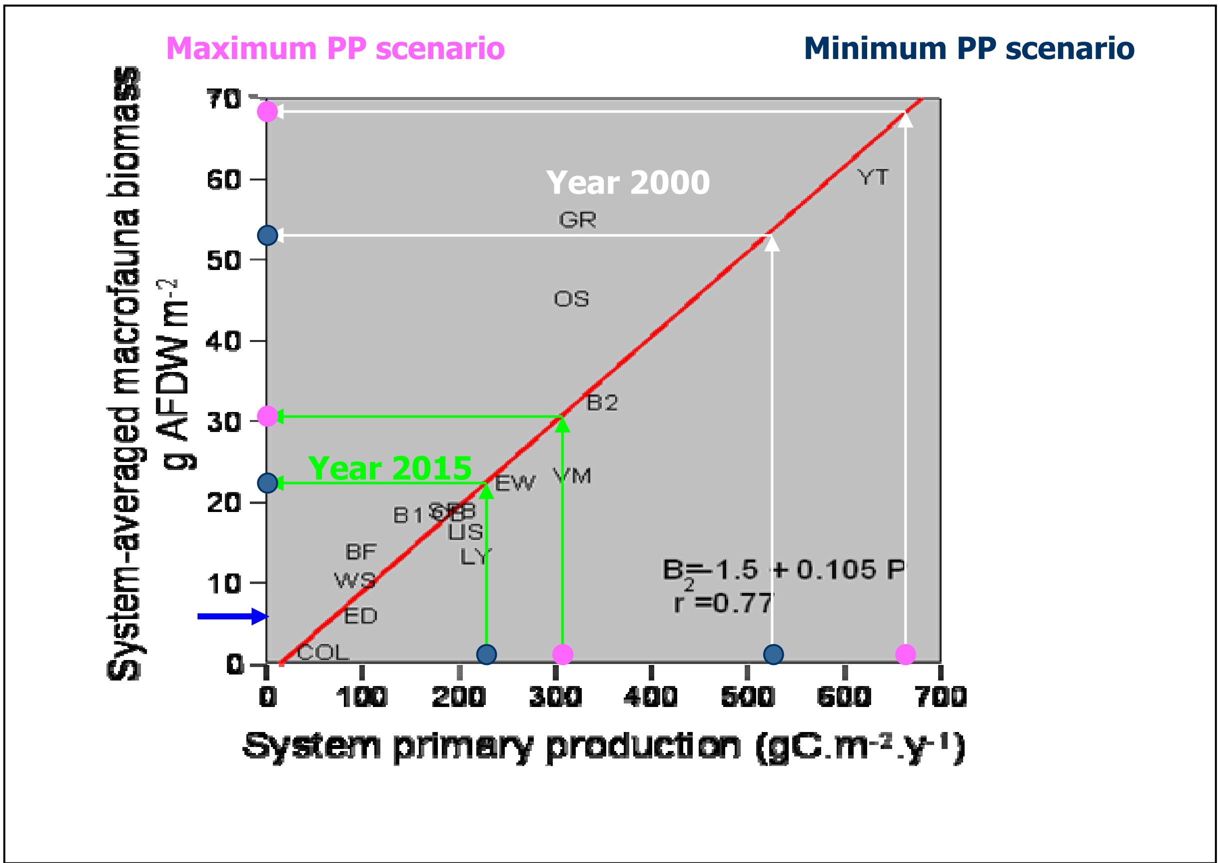

Figure 31: Actual biomass and extrapolated primary production (based on measured chlorophyll a values) for the Belgian coastal zone.

The blue arrow on the left side of the graph corresponds with the mean value of macrobenthic biomass found in literature for the Belgian coastal area.

Explanation c is also very likely because it is generally known that the Belgian Continental Shelf (including its coastal area) is very intensively used by man. It is therefore possible that the biomass values measured now are only representing an impoverished state of the actual biomass. The GAUFRE project tried to give a comprehensive overview of the different anthropogenic pressures of the BCS (Maes et al., 2005) and it could be possible to use this information to establish a pressure gradient for the Belgian coastal zone.

Explanation d (model improvement needed) may also be true. Altering the coefficients α (maximum light utilization coefficient) and θ (C/Chl a ratio) within acceptable ranges, i.e. within the range of available literature values, together with using Chl a data that were analysed with different methods, caused multiplicative effects that could decrease the net primary production with a factor 10. This means that the formulas of primary production on which ecological modeling is based need fundamental reconsideration. Therefore it is advised to reassess the proposed method when more detailed studies on primary production have been performed.

A classification of a transitional water at the level of the ecosystem was developed using the relation found between primary production PP and macrobenthic biomass B (B = -1.5 + 0.105 P, R^2 = 0.77). This relation can also be expressed as a B:PP ratio of 1:10 and this ratio is reached when the ecosystem is in equilibrium. Deviations from this ratio seem to indicate an ecosystem which is under some kind of stress (Escaravage et al., 2004). Results from mesocosm experiments (Prins et al., 1995) and numerical models (Herman & Scholten, 1990) on the relation between phytoplankton production and different levels of benthic grazing were used to create different ecological status classes for transitional waters. Higher ratios (points situated above the equilibrium relation in Figure 32) are usually the result of a higher grazing pressure from the benthos (e.g. due to the introduction of new grazing benthic species in the system) (Nichols et al., 1990; Alpine & Cloern, 1992), while lower ratios (points below equilibrium relation) are the result of a lower grazing pressure (e.g. due to a high pollution stress or significant morphological changes in the system) (Rybarczyk & Elkaim, 2003). The results from the experiments and models expressed extreme bad B:PP ratios as 1:1 and 1:100. These ratios are therefore used in the classification tool as the boundary for a "bad ecological status". Two limits for a "poor ecological status" (in systems where overgrazing and phytoplankton escape leads to states of critical unbalance) were derived from the models and these are 1:2,5 and 1:40. Because the Westerscheldt is characterized as a heavily modified water body, classification for such waters do not have to consider the "good" and "high" ecological status (which are considered as unattainable goals for such waters), but the "good and maximal ecological potential (GEP and MEP respectively). The interval delimited by the 1:5 and 1:20 ratios corresponds with areas where systems are properly functioning (GEP). The MEP is situated around the 1:10 ratio (line of optimal functioning) and was arbitrarily extended on both sides of this line at half distance (2:15 and 1:15) from the outer limits of the GEP (Figure 32).

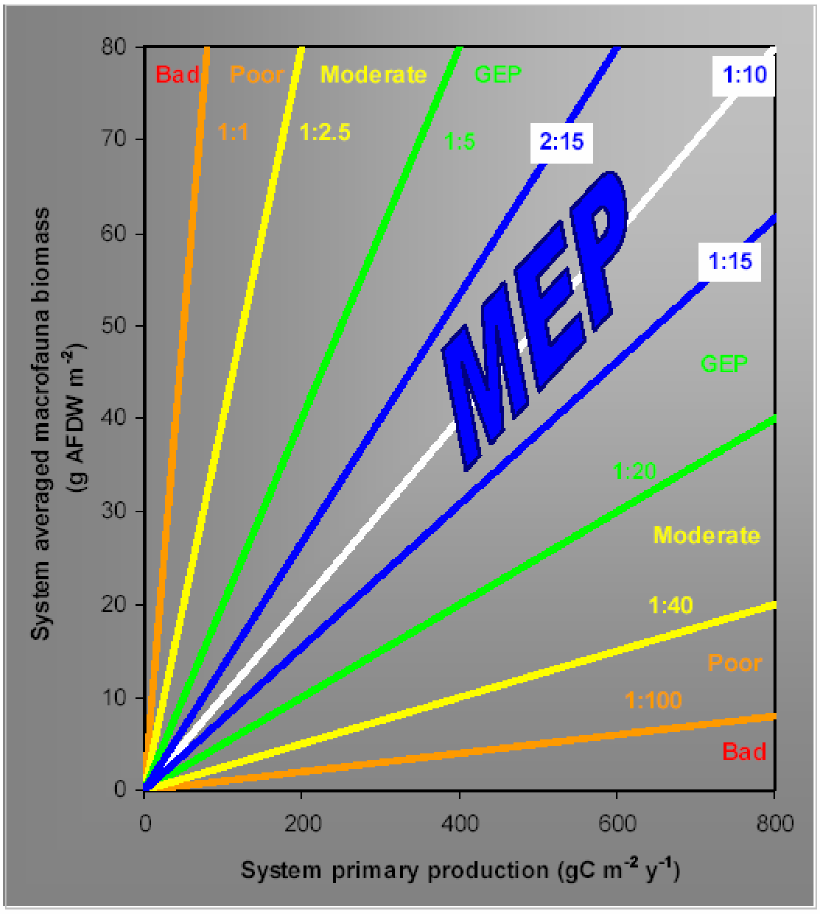

Figure 32: Macrobenthic classification at the scale of the ecosystem, developed for transitional waters (Escaravage et al., 2004).

Due to the absence of similar data from experiments and numerical models for the Belgian coastal zone, the same class boundaries for "bad", "poor" and "moderate ecological status" of the transitional waters is adopted for the coastal waters. Because the Belgian coastal zone is not characterized as a heavily modified water body, boundaries should be set for "good" and "high ecological status" instead of GEP and MEP. Because the 1:10 ratio is seen as the ratio at which the ecosystem is in balance, we chose a narrow interval around this line as the delineation of "high ecological status", corresponding with 3:25 and 2:25 ratios as outer limits. The "good ecological status" is therefore characterized by the intervals between 1:5 and 3:25 and 2:25 and 1:20.

It is now possible to investigate the ecological status of the Belgian coastal waters at ecosystem level. Therefore we need sampling data for both macrobenthic biomass and primary production. In the study of Erdey (2000) the sampling of macrobenthic biomass was accompanied with the sampling of the water to determine the chlorophyll a concentration. When this mean chlorophyll a value (1.096 mg.m^{-3}) is transposed to primary production, using the relation of Bot & Colijn (1996), this primary production value (87.99 gC.m^{-2}.y^{-1}) can be plotted against the actual mean biomass value of Erdey (2000) and this shows that this point agrees well with the trend between primary production and biomass determined for transitional waters, although there's a discrepancy (Figure 33).

Based on these data from Erdey (2000) the ratio B:PP for this system is 1:29 and this corresponds with a "**moderate ecological status**" (ecological score of 0.6). Because the point lies under the equilibrium line this could indicate that the moderate status is not the result of overgrazing of the phytoplankton by the macrobenthos, but could be explained by the impact of pollutants or physical impacts.

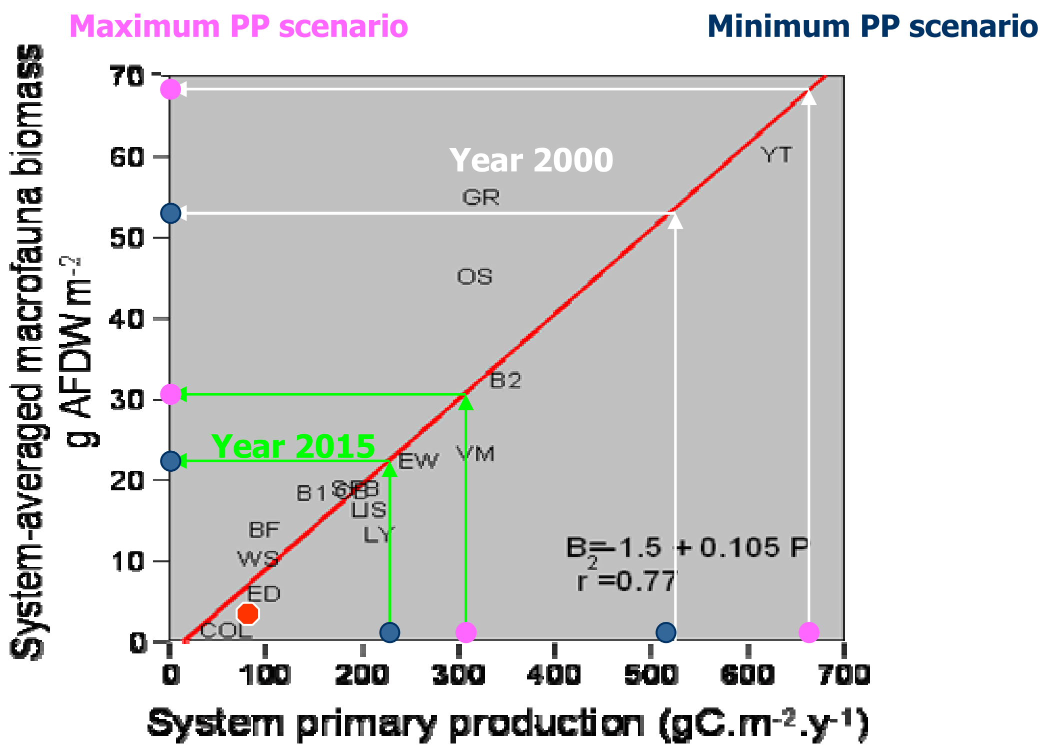

Figure 33: Actual biomass and extrapolated primary production (based on measured chlorophyll a values) for the Belgian coastal zone.

The red dot in the lower left part of the graph represents the chlorophyll a and its corresponding biomass value measured in October 1999 and described by Erdey (2000).

4.2.2 Macrobenthic classification on the habitat level

In this level the size, shape and spatial relationships of ecotopes or habitats are evaluated, because they influence the dynamics of populations, communities and ecosystems.

In the Westerscheldt study (Escaravage et al., 2004) this level is assessed using the areal proportion of several habitat types (mudflats, sandflats, shallow areas and mussel bank areas). The MEP (and other ecological class statuses) for these indicators is set by looking at historical data of the areal proportion of these habitats in 1900, with introduction of a correction factor because it's not feasible to restore all mudflats and shallow subtidal areas of that time.

Unfortunately such data (surface area of habitat types in coastal waters of Belgium) are not available at this time. Habitat maps for a part of the Belgian coastal area were developed during the HABITAT project (Degraer et al., 2002) and these will be adapted and extended for the whole coastal area during the MESH project (EU InterregIIIB: www.searchmesh.net). These maps could be used to calculate the proportions of each habitat type in the Belgian coastal zone, however no historical data exist to establish class boundaries for the different ecological statuses.

Another important aspect to consider is that the Belgian coastal area are very open systems, where natural sediment transport has a great influence on the habitat types which occur in the area. So, if data on the proportion of the habitat types for historical times would be available, it would still be very difficult to assign changes in these proportions to anthropogenic impacts. For this study we therefore chose not to include the habitat level in our classification of the Belgian coastal areas.

4.2.3 Macrobenthic classification on the within-habitat level

The Belgian coastal zone comprises three different macrobenthic communities and three macrobenthic species associations (transitions between communities), which are each characterized by different habitat specifications (based on typology defined by Van Hoey et al. (2004) and described in the section on typology above, see Table 13). Based on these habitat specifications (sediment type, mean grain size, mud content and depth), 6 habitats are defined: near-shore shallow muddy sand, well-sorted mobile sand, medium-coarse sand, deep muddy medium sand, offshore deep medium sand, near-shore shallow fine sand. Developing a macrobenthic classification of the Belgian coastal zone based on the habitat types within this zone is ecologically more meaningful than a classification of the whole zone as one type (which is in accordance with the current WFD). So, while the whole Belgian coastal zone is classified as having a moderate ecological status (see above) for macrobenthos, here we describe a more detailed macrobenthic classification for the different habitats and species associations occurring in the area. In the typology paragraph 3.5 the Zwin area is also mentioned as a different habitat type within the Belgian coastal area. Unfortunately there are no suitable data on macrobenthos for this area available at this time. The only data available were taken to detect impacts of the oil spill that was caused in the Belgian coastal area in 2003 on the macrobenthos. No pre-impact data for comparison are available. Therefore it was concluded not to include the Zwin area in this analysis. When more data become available a classification of this habitat type can be done as well. At the end phase of the project it was mentioned by the end users that the beach habitat(s) should also be included in the analysis (they were left out because we thought that the WFD didn't include the beach area as a coastal water area), but at that phase of the project it was impossible to do the classification again for this area as well due to a lack of time (such classification depends on a thorough macrobenthic community analysis of the beach area which wasn't available at the start of the project).

For each habitat the number of coastal macrobenthic samples belonging to these habitats is determined and the maximum densities and species richness is calculated (Table 13).

Table 13: Habitat characteristics of the species assemblages found in the Belgian coastal zone (Van Hoey et al., 2004) and maximum densities and species richness counted in the coastal samples.

	Abra alba – Mysella bidentata community	*Nephtys cirrosa* community	*Ophelia limacina – Glycera lapidum* community	Species association 3	Species association 5	Species association 7
Sediment type	FS	MS	MS	MS	MS	FS
Mean grain size (µm)	219	274	409	268	333	219
Mud content (%)	5.8	0.4	0.3	1.9	0.2	<0.1
Depth (m)	-13	-12	-15	-14	-16	-2
	Near-shore shallow muddy sand	**Well-sorted mobile sand**	**Medium to coarse sand**	**Deep muddy medium sand**	**Offshore deep medium sand**	**Near-shore shallow fine sand**
Maximum density (ind/m²)	17516	7417	3928	16956	945	439
Maximum species richness (#/m²)	40	34	11	20	12	9
Number of samples	49	21	10	30	12	10

The Belgian dataset with coastal samples is not that substantive (132 samples); it was difficult to obtain good reference data that can be used in such a classification. We have used the samples of the time period 1994-2001 as reference samples. We realize that this dataset is not ideal as reference collection because they already represent an altered state of the coastal waters, but at this time we see no alternative, because no older samples are available for the coastal area. The most recent samples (from 2002 onwards) were then used to determine the actual (recent) ecological status of the different habitats. Another possibility to determine the reference condition could be to use all data from 1975-1994 of the whole Belgian Continental Shelf as reference data and to use the coastal data from 1994-2002 to assess the ecological status. However, it is uncertain whether these open sea data are representative for the coastal situation, which is more turbid due to wave action and is also more influenced by pollutants and coastal fishing. We therefore recommend that other examples of similar coastal systems (with similar habitats) with undisturbed conditions should be searched which could be used as reference condition. For now only the available samples were used to give an estimate of the ecological class of each habitat.

The **first indicator** that should be considered on the within-habitat level is the **number of species**. Escaravage et al. (2004) used a huge dataset of samples from 1975 to 1999 as reference conditions to determine their MEP class for the Westerscheldt. Class boundaries for the good, moderate, poor and bad status are based on a literature review (see Escaravage et al., 2004). This method allows the scaling of the species richness of the samples of each habitat against the reference condition (high/MEP ecological status) and also considers the total surface area which is sampled.

The **second indicator** that should be considered on the within-habitat level is the **species list per habitat**. This indicator makes a distinction between species occurring in at least 90% of the samples (subindicator 1), between 90% and 50% of the samples (subindicator 2) and in less than 50% of the samples (subindicator 3). Escaravage et al. (2004) used a permutation technique to determine the minimum required number of species in the > 90%, 90-50% and < 50% species list as a function of the number of species in the species list of any habitat (Figure 34).

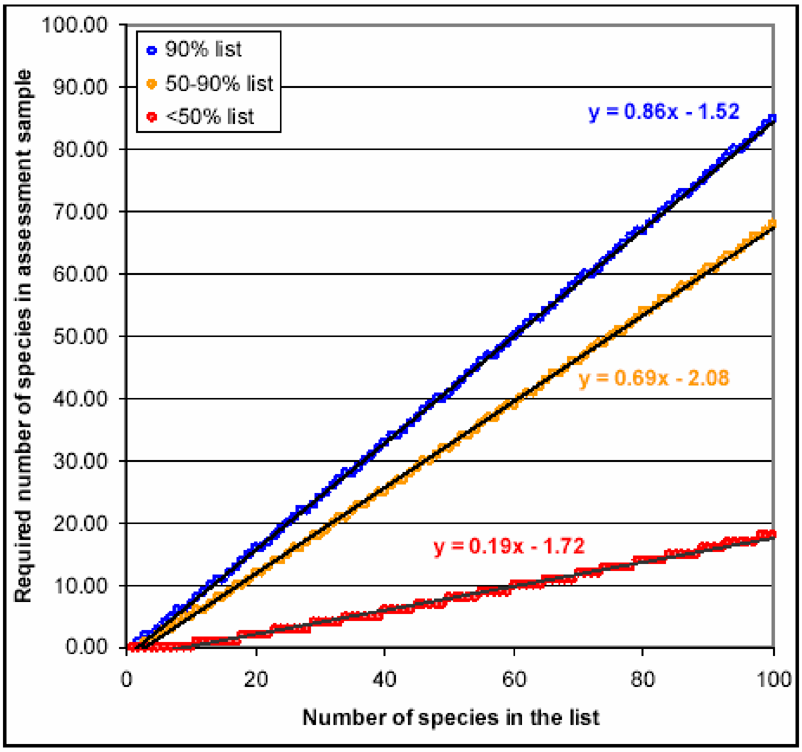

Figure 34: Minimum required species in the > 90%, 50-90% and < 50% species list as a function of the number of species in these lists (Escaravage et al., 2004).

The **third and fourth indicators** to be assessed on this level are the macrofauna density and biomass. The average biomass/density and their standard deviations have to be calculated for each habitat. The 5% confidence interval around the average deviation ($\pm$ 1.96 $\sigma/n^{0.5}$) represents the boundaries for the high ecological status. As a consequence, the width of this interval (i.e. the tolerance for the assessment) depends on the number of samples taken. Departure from the high ecological status could then be assessed by comparing the average and standard deviation in the assessment sample with those in the reference. Because there are no biomass data available for the Belgian coastal area, we only use the density indicator for this study.

The indicator scores for each of the habitats within the Belgian coastal area are given in Table 14. The integration of different indicators and subindicators is done by averaging the individual (sub)indicator scores, resulting in an overall indicator score for the within-habitat level. The determination of the Water Framework Directive class is done by comparing this overall score with the NIOO class boundaries mentioned in Table 15.

Table 14: Indicator and subindicator scores found for all habitats in the Belgian coastal zone. The integration of the (sub)indicators is given by "overall indicator score" and the corresponding Water Framework Directive class is given as well. The average WFD class is the average ecological class when all scores of the different habitats are averaged.

	Near-shore shallow muddy sand	**Well-sorted mobile sand**	**Medium to coarse sand**	**Deep muddy medium sand**	**Offshore deep medium sand**	**Near-shore shallow fine sand**
Number of species	0.35	0.53		0.35	0.82	1
<50% species list					0.54	
50-90% species list	0.41			0.15	0	
>90% species list	0.47	0.60		0.55		0.64
Density	0.52	0.60		0.53	0.47	0.80
Biomasa	No biomasa data available					
Overall indicator score for within habitat level	0.44	0.57		0.40	0.46	0.81
Remarks		Reference dataset smaller than assessment dataset ➔ evaluation unsure	No assessment dataset available ➔ evaluation impossible			Reference dataset smaller than assessment dataset ➔ evaluation unsure
WFD class	Moderate	Moderate		Poor	Moderate	High
Average WFD class	Moderate (average overall indicator score equals 0.54)					

It should also be mentioned that the samples that were used for the assessment (samples from 2002 until now) are almost always taken at stations near the harbour of Oostende (Figure 35) and it is known that this area is under relatively high human pressure due to the vicinity of the harbour (with higher pollution levels and an increased mud content due to dredging activities). The macrobenthos found at these stations is almost always impoverished in terms of diversity and density. This is also reflected in the status of the habitats of the Belgian coastal zone (mostly poor to moderate ecological status, except for the near-shore shallow fine sand habitat). To allow a more accurate classification at the within-habitat level more assessment samples which are more evenly spread along the Belgian coastline should be taken into account.

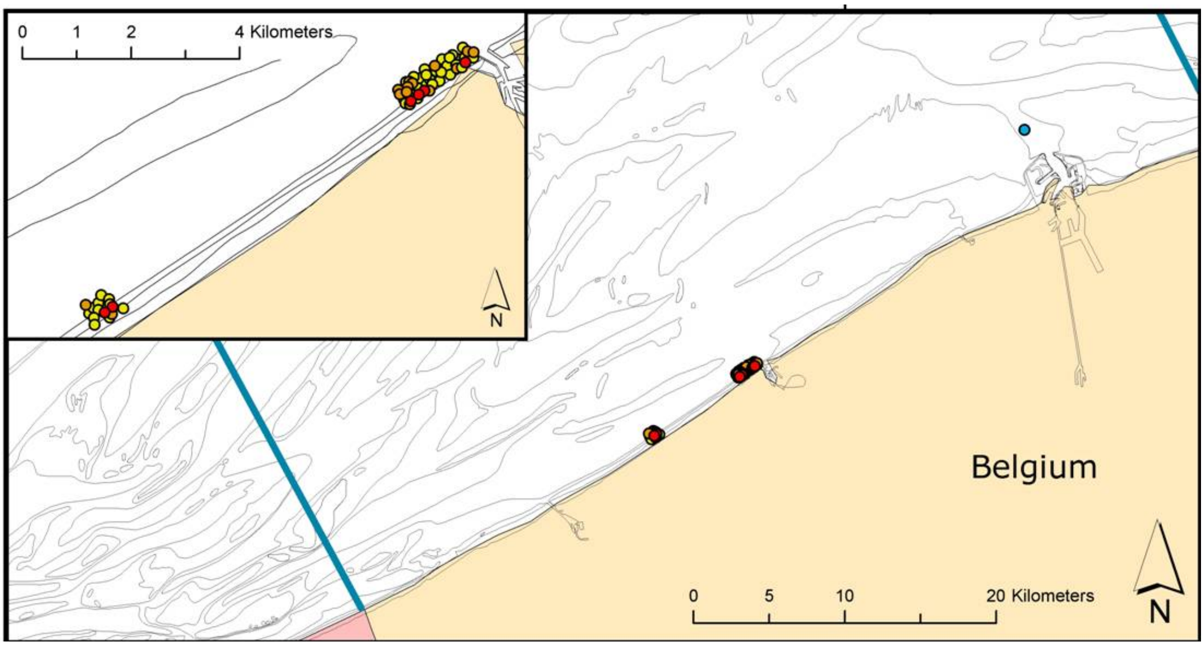

Figure 35: Overview of the distribution of the samples used for the macrobenthic classification at the within-habitat scale.

Table 15: The five classes of ecological status for the WFD assessment with the numerical values attributed for the integration of the subindicators.

WFD classes	High	Good	Moderate	Poor	Bad
Class boundaries	1 ≥…≥ 0.8	0.8 >…≥ 0.6	0.6 >…≥ 0.4	0.4 >…≥ 0.2	0.2 >…≥ 0

The overall score for the whole water body (including scores from the ecosystem, the habitat and the within-habitat levels) can be calculated as follows: overall score $ECO^3_{BEN} = [(1 * IND_{ecosystem}) + (2 * IND_{habitat}) + (2 * IND_{within\text{-}habitat})]/5$. This gives a moderate ecological status for the whole water body (Belgian coast) (Table 16). Although the indicator score on the habitat level could not be calculated for the Belgian coastal data (due to absence of relevant data) the overall score is in this case determined as follows: $ECO^3_{BEN} = [(1 * IND_{ecosystem}) + (2 * IND_{within\text{-}habitat})]/3$. This doesn't reflect the actual overall score but should be regarded as a first attempt to classification of the macrobenthos in the Belgian coastal strip.

Table 16: Determination of the overall ecological status for the whole Belgian coastal waters.

	Weighing factor	Ecological status	Ecological score
Ecosystem scale	1	MODERATE	0.60
Habitat scale	2	Not available	Not available
Within habitat scale	2	MODERATE	0.54
Whole water body		MODERATE	0.56

4.2.4 Other macrobenthic classification methods

On a European level an intercalibration exercise is being held for coastal water classification in the framework of the Water Framework Directive (Coast NEA GIG exercise). Several member states of the European Union are already in an advanced stage of developing a classification system for their coastal waters and the intercalibration exercise aims at combining all available macrobenthic data from coastal waters to test the agreement of these classification methods. Similar exercises are being held for phytoplankton and macroalgae.

The Marine Biology Section also delivered its macrobenthic data from the 1 nautical mile zone to the leaders of this exercise. The results of the different classification systems can later be used to screen our own classification results. Belgian coastal waters belong to the NEA 1 eurotype according to this intercalibration group. Other member states, collaborating in the exercise, with the same eurotype are the UK, the Republic of Ireland, Spain, Norway, France, the Netherlands and Denmark. All participants were asked to send all available macrobenthic data that met certain criteria (Table 17).

Table 17: Criteria for macrobenthic samples to be included in the intercalibration exercise.

Criteria for macrobenthic samples to be included in the intercalibration exercise
0,1 m² sample size abundance data 1 mm sieve mesh subtidal samples depth < 30 m grain size: % 63 µm sediment should be defined

Belgium sent 132 sample data that met these intercalibration criteria (i.e. the same samples that were used for the classification method mentioned in

Paragraph 4.2.3). 5 classification methods were tested in the exercise: the method of Denmark (DKI), the UK (IQI), Spain (m-AMBI) and the Norwegian classification system (NQI). All these indices are multimetric and their composition is explained in Table 18. As you can see all these classification methods use the AZTI Marine Biotic Index (AMBI; Borja et al., 2000) as the sensitivity element in their assessment. It has been shown that this AMBI can be used to detect different impact sources (pollution, heavy metals, industrial and mining wastes, sewerage works, ...) (Borja et al., 2003). The classification method described in Paragraph 42.3 (hereafter called the NIOO method of Herman & Ysebaert (2004)) doesn't use the AMBI. In this classification method the influence of anthropogenic stressors is assessed on the three levels of assessment. On the ecosystem level deviations of the PP:B equilibrium ratio point at an unbalanced ecosystem functioning. This indicator is rather robust and doesn't allow the determination of the specific impact, because the deviation is a result of the integration of the whole spectrum of disturbances. It mostly has a strong signal function. On the habitat level, changes in the surface areas of habitats are the result of morphological or hydrodynamic changes (dredging, dumping,...). At the within-habitat level community shifts (changes in abundance or species composition) are induced by changes in the sediment composition or water chemistry and/or temperature. It would be a worthy addition to the NIOO method to include an indicator that scales the dominance levels of predefined taxonomic and/or functional groups (such as AMBI) at the within-habitat level to increase the sensitivity of the NIOO method and to enhance the intercalibration between the NIOO method and the NEAGIG classification methods.

Table 18: Specifications of the different classification methods used in the NEAGIG intercalibration exercise.

Method	Multimetric index	Composed of:	Reference
Danish method	DKI	Shannon's H AMBI Species number Number of individuals	Rosenberg et al. (2004)
UK method	IQI	AMBI Species number Number of individuals	Miles (in preparation)
Spanish method	m-AMBI	AMBI Shannon's H Species number	Borja et al. (2000, 2004a, 2004b, 2006), Bald et al. (2005), Muxika et al. (2006)
Norwegian method	NQI	AMBI Simpson's eveness Number of taxa	Rygg (2002; 2006

All samples were given a score between 0 and 1, which is an indication of their ecological status: bad, poor, moderate, good or high. The class boundaries for the different classification methods were determined following the intercalibration exercise, which maximise the agreement between statuses (Table 19). However, these boundaries may change after further analyses using revised assessment methods and including data from other member states. Boundaries have been set using data for type NEA1/26.

Table 19: Class boundaries determined for each member state classification method.

Method	Bad	Poor	Moderate	Good	High
Denmark	0-0.16	0.16-0.35	0.35-0.58	0.53-0.67	0.67-1
UK	0-0.2	0.2-0.41	0.41-0.63	0.61-0.71	0.71-1
Spain	0-0.2	0.2-0.39	0.39-0.55	0.53-0.77	0.77-1
Norway	0-0.25	0.25-0.36	0.36-0.5	0.63-0.72	0.72-1
Netherlands (NIOO)	0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1

Averaging these scores per classification method gives the average global score for the whole Belgian coastal area (Table 20).

Table 20: Average global score for the whole Belgian coastal area according to the different NEAGIG classification methods.

Classification method	Average ecological score	Corresponding ecological status
DKI	0.566	Good
NQI	0.667	Good
IQI	0.653	Good
m-AMBI	0.589	Good

Separating the most recent samples (from 2002 onwards) from the rest of the samples, gives the same samples that were used to assess the ecological status according to the NIOO method of Herman & Ysebaert (2004). This allows comparison between the 5 different classification methods (4 NEAGIG methods and the NIOO method) for the 6 habitat types occurring in the Belgian coastal area. The figures below give an overview of the average ecological score that was obtained for each habitat according to the different classification methods. The scores seem to correspond well, except for the medium to coarse sand habitat and the near-shore shallow fine sand habitat. The Danish (DKI) and Spanish classification (m-AMBI) always give lower ecological scores than the other three methods.

Table 21: Average ecological scores that were obtained for each habitat according to the different classification methods

method	score	ecological status
Near-shore shallow muddy sand		
NIOO	0,44	Moderate
DKI	0,59	Good
NQI	0,69	Good
IQI	0,68	Good
M-AMBI	0,6	Good
Well-sorted mobile sand (not 100% reliable, see table 14)		
NIOO	0,57	moderate
DKI	0,53	Moderate/good
NQI	0,64	good
IQI	0,63	good
M-AMBI	0,53	Moderate/good
Medium to coarse sand		
NIOO		NA
DKI		NA
NQI		NA
IQI	0,27	poor
M-AMBI	0,19	bad
Deep muddy medium sand		
NIOO	0,40	moderate
DKI	0,52	moderate
NQI	0,64	good
IQI	0,62	good
M-AMBI	0,53	Moderate/good
Offshore deep medium sand		
NIOO	0,46	moderate
DKI	0,47	moderate
NQI	0,62	moderate
IQI	0,58	moderate

M-AMBI	0,49	moderate
Near-shore shallow fine sand (not 100% reliable, see table 14)		
NIOO	0,81	high
DKI	0,52	moderate
NQI	0,64	good
IQI	0,62	good
M-AMBI	0,51	moderate

When all scores per habitat are averaged, this gives the overall indicator score for each method (see Table 22 and Figure 36). These scores are relatively similar for the different classification methods and give a moderate to good ecological status for the Belgian coastal area.

Table 22: Overall ecological score that was obtained for all habitats according to the different classification methods.

method	**score**	**Ecological status**
NIOO	0,56	Moderate
DKI	0,53	Moderate/good
NQI	0,65	Good
IQI	0,57	Moderate
M-AMBI	0,48	Moderate

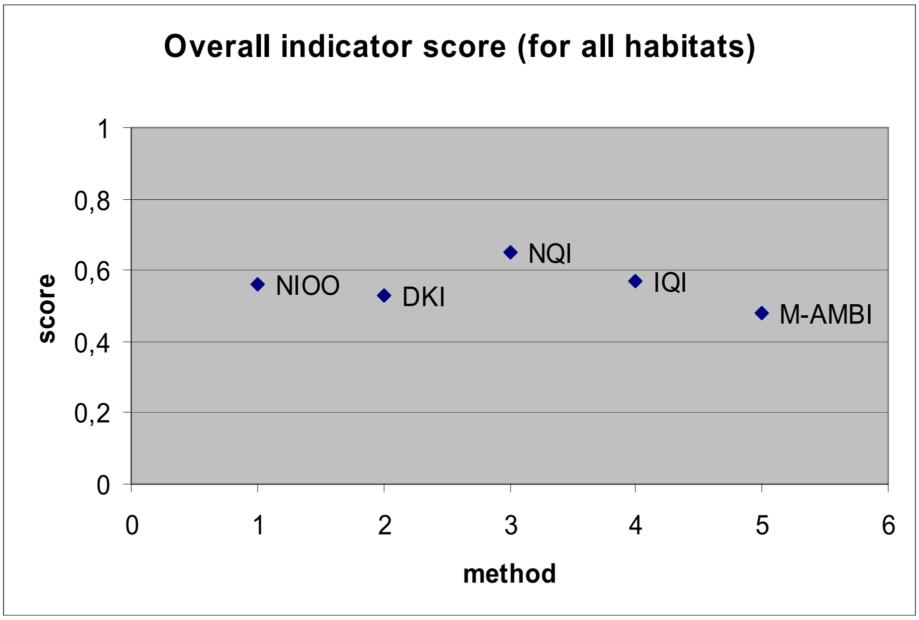

Figure 36: Overall ecological score that was obtained for all habitats according to the different classification methods.

For the class boundaries of each method see table 26 above.

For the purpose of NEAGIG reporting the following information on the Belgian classification method can be provided:

- The Belgian classification method was not used in the NEAGIG intercalibration exercise because it wasn't developed fully at the start of the exercise. The method was therefore not tested with different national datasets. However the results of the Belgian classification method were screened against the results of the other national classification methods afterwards.
- The Belgian classification method is partly based on a classification method developed for transitional waters by Ysebaert & Herman (2004) and Escaravage et al. (2004). The method is temporarily called the "NIOO method".
- Determination of reference conditions is described in paragraph 4.3.
- Class boundary setting is described in Table 19.
- Results of the comparison of the results of the different national classification methods on the Belgian data is described in Tables 20, 21 and 22 and in Figure 36.
- It should be mentioned that the description of the NIOO method and the class boundaries chosen could be changed after the finalisation of the

intercalibration exercise (June 2007). All results should therefore be considered with care.

4.2.5 Development of a phytoplankton classification method for the Belgian coastal waters

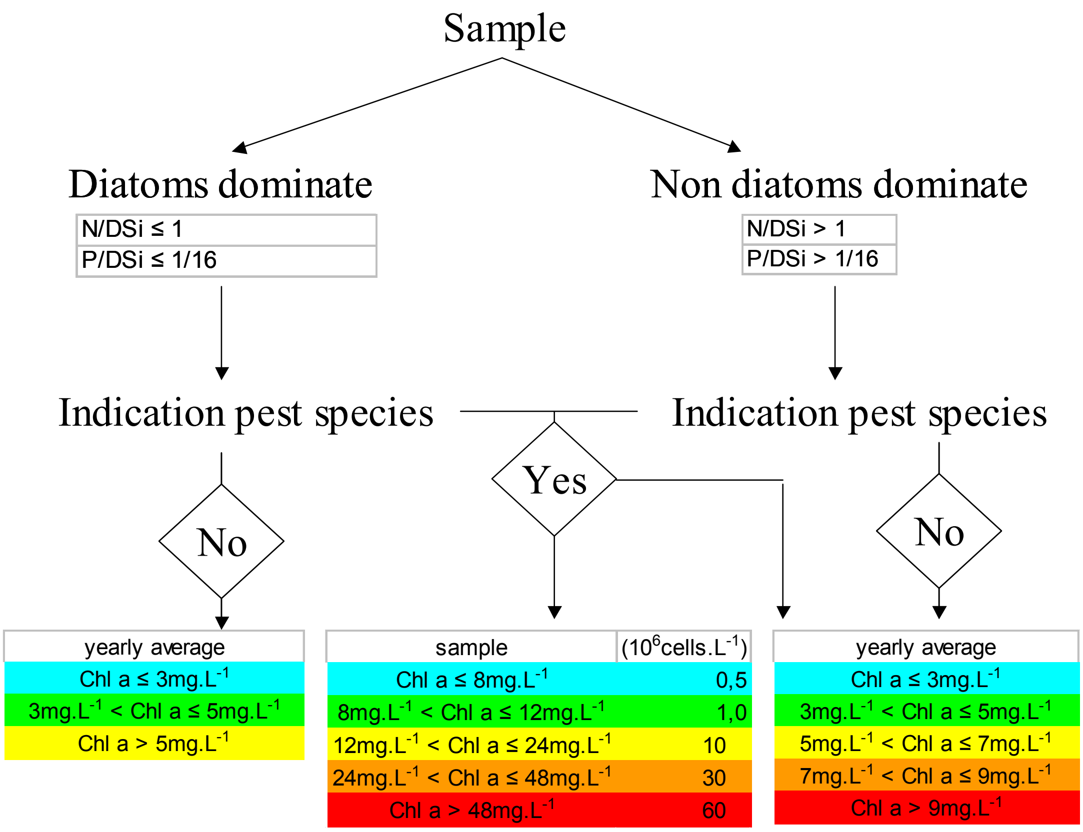

Figure 37: Classification procedure for phytoplankton in the coastal area

The phytoplankton classification in case of pest species occurrence was based on the Dutch classification system, which is fully compatible within the presented functional approach. If the pest species classification part would be actualized by the Dutch, then this actualization can be adapted accordingly in our classification.

The reconstruction of the yearly Chl a concentrations for different historical or future scenarios as explained in the previous chapter, provides not only a basis for the construction of a classification of benthos, but also of phytoplankton in the coastal zone (Figure 37). Indeed, the pristine scenario cannot but stand for a very good status. The scenario '1950', as well as the future '2015' scenario were shown to be of still good quality, whereas the seventies and eighties were notorious for their bad quality. This allows to define classes of quality, as is shown for the yearly average values of Chl a in Figure 37. This scheme shows that the yearly averages are, however, not sufficient to evaluate the quality status in an adequate manner. It is of utmost importance to consider the phytoplankton community composition. It has been shown that dominance of diatoms is more favourable for the food chain than dominance of non diatoms (Schelske et al*.,* 1983; Smayda, 1990; Smayda, 1997). If diatoms dominate, the primary production is more easily transmitted towards higher trophic levels, leading to a beneficiary secondary production. Therefore, production on itself cannot lead to an unsatisfactory status, as long as the oxygen content of the water or the sediment is not affected by the production. In order to watch over this condition however, the oxygen classification as presented by Borja et al. (2000) should be taken into account as well. If non diatoms prevail in the community, then the bacterial food web is likely to take over, resulting in the manifestation of eutrophication nuisances. Special care is needed with respect to harmful pest species such as Phaeocystis or dinoflagellates causing 'red tide'. If any indication for the presence of such species is available, it is recommended to follow the Dutch classification, which is specifically aimed at this aspect. In this system the number of cells of the pest species is taken into account, plus the actual Chl a concentration (van der Molen, 2004; Figure 37).

Dominance of diatoms or non diatoms can be determined by cell counts in a known cell volume after which the results are transformed into biomass by using the formulas of Menden-Deuer & Lessard (2000). The group with the highest biomass dominates the community. Because it is in this method sometimes necessary to determine the cells onto species level, an easier method to have indications of dominance is to look at the nutrient ratios where dominance of diatoms is in nutrient limiting systems indicated as shown in Figure 37.

4.3 Description of the reference condition

Since the classification method presented is based on a reconstruction (modelling) exercise of the pristine ecological condition in the Westerscheldt and the coastal waters at the mouth of this estuary, the values found for "the high ecological status" correspond to this pristine situation and can be used as reference conditions at the system level.

The reference condition for phytoplankton is a situation where diatoms preferably dominate the plankton community. In that case the primary production can be maximal as far as no negative feedback on oxygen would harm the diversity. If non diatoms would for one reason or another (due to natural variation) dominate, then the reference condition is determined by low Chl a values (yearly average < 3 $mg.L^{-1}$). No indication of pest species is available in the reference condition, or if there would be some hazardous indication, then the instant Chl a concentration cannot exceed 8 $mg.L^{-1}$, and the cell number of the pest species cannot exceed 500 000 $cells.L^{-1}$.

The system averaged macrobenthic biomass (B) should be related to the primary production (PP) according the equation given by Escaravage et al. (2004). A B:PP ratio of 1:10 corresponds with an ecosystem in balance and this ratio can be used as the reference condition for primary production and macrobenthic biomass at the system level. This ratio was determined by using a historical dataset of the Dutch delta area (Herman et al., 1999), which was complemented with additional data from other estuaries found in literature by Escaravage et al. (2004).

The reference conditions for macrobenthos at the habitat level are different for the different habitats (with their specific macrobenthic communities) within the system and are also dependent of the sample size. Reference conditions for the macrobenthic communities at the within-habitat level were established using historical data available at the Marine Biology Section (University of Ghent). Values found for macrobenthic species richness and density in the reference dataset and the species composition of these reference samples were used to establish maximum expected values for the different metrics within this level.

These reference conditions should however be treated with care, since the dataset used to establish this reference conditions is relatively recent (1994-2001). Older data are not available for the Belgian coastal zone. In the future it would be advisable to search for other, more reliable methods to establish reference conditions for macrobenthic communities in the Belgian coastal zone (see also paragraph 4.2.3 above).

5. CONCLUSION

Objective of the current research project was to make up the typology of the Belgian Coastal Waters, to describe the reference condition and to make up the classification system. Doing this, the results form the basis to fulfill the obligations with respect to typology and classification of Belgium in the framework of the Water Framework Directive.

According to the systems proposed in the WFD for making the typology, only one type can be distinguished in the Belgium Coastal Waters: Euhaline, shallow, mesotidal, not sheltered and sandy. The Zwin Nature Reserve (Flemish competence) differs from this type with respect to the mean salinity of the water (polyhaline).

A proposal was also made to use more practical subdivisions (i.e. division in waterbodies or habitat types) of this one type so more detailed and ecologically meaningful classifications could be determined for the macrobenthos.

In this report, a method was explained through which it is possible to quantify a classification on system scale. This method was strong in showing differences between historic scenarios. On a spatial scale however, the considered system, the coastal zone as defined in this work, is probably too restricted for the method to be applied upon. This is probably the reason why discrepancy was found between the measured and modeled Chl a results in the coastal zone. The classification is furthermore based on yearly averaged system values. The measured Chl a values and derived primary production values, as shown in Fig. 21 and 23 are averages of 1 to max 6 sampling stations. This is too few. In fact the coastal zone as it is defined here is too small to be fit for the proposed method, which has otherwise such strong potential to quantify system scale classification. Therefore it is advised that on the system scale, the coastal zone should be considered on a vaster spatial scale. Scoring is therefore as such not yet possible.

The macrobenthos was also classified on a more detailed, within-habitat scale, which is in accordance to the recommendation made in the typology section. In this way the preliminary ecological status of the macrobenthos was not only determined at the system scale (= classification for whole Belgian coastal type) but also at the within-habitat scale (= classification for different habitat types or waterbodies within Belgian coastal type). This classification was done by using the oldest part of the available data (1994-2001) as a reference dataset to establish reference conditions and class boundaries for each habitat type. The most recent samples (from 2002 onwards) could then be used as assessment dataset to classify each habitat type. These results should also be considered with much care, because the reference dataset is not that "historical" and the data in this dataset will already reflect human impacts during this period. However, other reference data are not available for the Belgian coastal zone and comparable data from other countries with similar habitat conditions were not found during this study. The classification at the within-habitat level should therefore be seen as a first trial and it needs to be considered again in the future when more data or information are available.

6. RECOMMENDATIONS AND FURTHER RESEARCH

This chapter deals with recommendations to policy makers and suggestions for further research in order to optimize the classification of the Belgian coastal waters and to be able to formulate measures to ameliorate the ecological condition of the Belgian Coastal Waters.

Improvements for the use of the classification method include:

- A better modeling of estuarine primary production.
- Combining the approach for the Scheldt estuary with the same approach applied on the Seine estuary. This will allow to refine the reference condition for the coastal zone, as for now it has been considered that only the plume of the Scheldt has a major influence on the coastal quality, which is not the case.
- A more detailed study should be performed to test the relationship between benthos and primary production in coastal systems.

It is advised that on the system scale, the coastal zone should be considered on a vaster spatial scale.

Recommendations for monitoring network:

- Ideally the monitoring network should include monitoring sampling points in each of the distinguished habitats (6 marine habitats, beach habitat(s) –which still need to be distinguished- and Zwin habitat) to be able to follow up the within-habitat classification for macrobenthos.
- From a practical point of view it could be more advisable to only locate monitoring sampling points in certain priority habitats (for instance the habitats which are clearly linked to the true macrobenthic communities and not to the macrobenthic transitional species associations).
- The monitoring network should be distributed evenly along the Belgian coast to ensure geographical representation.
- A major difficulty with the classification of macrobenthos at the habitat and within-habitat level is the fact that coastal waters are very dynamic and open systems. Habitats (and their associated macrobenthic communities) change over time, which makes it difficult to implement a good monitoring network. It could therefore be necessary to change the location of the monitoring sampling points after a certain time period. There is a lot of progress made on habitat mapping in Europe (MESH

project) and this information could be very valuable when choosing future monitoring networks.

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8. ANNEXES

ANNEXE A

LEGAL MATTERS IN THE COASTAL ZONE

In this annex we will look deeper into legal matters with respect to the marine zone (seaward bound part of the coastal zone), marine pollution, navigation and sea harbors.

A.1 Beaconing of marine zones

Different territories can be distinguished in the marine zone:

- The territorial sea (up to 12 sea miles);
- The corresponding zone (up to 24 sea miles);
- The fishery zone;
- The exclusive economic zone; and
- The continental shelf.

The treaty of the United Nations with respect to the right of the sea (Montenego Bay, 10 December 1982) fixes the competences of the countries with respect to different marine territories.

In June 1998, this treaty has been accepted in Belgium (published in the BS in September 1999).

The boundary of the **Belgian territorial sea** had been fixed before: in the treaty of 8 October 1990 with France and in the treaty of 18 December 1996 with the Netherlands. The law of 6 October 1987, the width of the territorial sea has been fixed at 12 sea miles, in accordance to the treaty of the United Nations with respect to the right of the sea.

The **corresponding zone** for Belgium has been fixed in the law of 22 April 1999 with respect to the exclusive economic zone. This law is concretizing the competences of Belgium in this zone.

The **fishery zone** for Belgium has been laid down by the law of 10 October 1978, which was changed, by the law of 22 April 1999 with respect to the exclusive economic zone. Outside the Belgian territorial sea, a national fishery zone has been fixed. The boundary of the fishery zone is the same as this of the exclusive economic zone.

The **exclusive economic zone** is that zone in which the country has rights about: 1. Exploration and exploitation, preservation and management of the natural riches, the waters and the seabed and 2 other activities for economic exploration of the exclusive economic zone. Other countries can use this zone for navigation, flying over and putting in cables and pipelines. These rights are set by the treaty of the United Nations of 10 December 1982 and were accepted by the Belgian authorities in the law of 18 June 1998.

The law of 22 April 1999 with respect to the exclusive economic zone of Belgium in the North Sea concerns the concretization of the competences of Belgium in this zone.

The **Belgian continental shelf** is the zone where Belgium has the competence to explore and exploit non-living and living riches in permanent contact with the seabed. The competences of Belgium on the continental shelf have been described in detail in the law of 13 June 1969 with respect to the exploration and exploitation of non-living riches of the territorial sea and the continental shelf which has been changed by the law of 20 January 1999 with respect to the protection of the Marine Environment and the Law of 22 April 1999 with respect to the exclusive economic zone of Belgium in the North Sea.

In the treaty of 29 May 1991 the boundary of the Belgian continental shelf has been fixed with the United Kingdom and North-Ireland. This treaty has been accepted by the Belgian authorities in the Law of 17 February 1993. The boundary between the Belgian and the Dutch continental shelf has been fixed by the treaty of 18 December 1996 and accepted by the Belgian authority in the Law of 10 August 1998.

A.2 Navigation

Navigation is regulated by federal regulations. The following items have been regulated by federal laws:

- General aspects with respect to navigation: name of the ship and the home port, signs for ships, wrecks, etc., obligations for the for the owner, the operators, captains or captains of vessels.
- Maintenance of the navigation routes and ports.
- Registration of Sea-going vessels.

The safety on sea has been regulated by the international treaty of 1974 and the protocol of 1978 (SOLAS, 1974/78). This treaty contains important provisions that complete MARPOL and have to do have with general safety regulations, which contribute to the prevention of shipping accidents.

Apart from this treaty two European directives have been accepted in Belgium with respect to safety measures for pleasure vessels, roro vessels, fisherman vessels and passenger vessels (respectively, dir. 94/25/EC, regulation 3051/95, dir. 97/70/EC and 98/18/EC).

Finally, directive 79/115/EEC regulates the piloting by North Sea pilots on the North Sea and the Channel. Every Member State has to take measures so that ships can appeal to qualified pilots.

A.3 Marine Pollution

Marine pollution due to navigation

International jurisdiction with respect to marine pollution due to navigation (Marpol-treaty) has been implemented in Belgium by the Law of 17 January 1984. It regulates the operation pollution due to navigation (oil and other pollutants).

The Law of 6 April 1995 with respect to the prevention of the pollution of the sea due to navigation executes the Marpol-treaty. The law includes hard punishments for offences on the law.

The agreement with respect to fight the pollution of the North Sea by oil and other pollutants has been signed in Bonn on 13 September 1983 (being changed on 22 September 1989) regulates the control from air for the identification of pollution and collection of proofs in case of offences on the law. This agreement has been executed in Belgium by the Law of 16 June 1989.

National jurisdiction on the protection of the marine environment has been set by Law of 20 January 1999 (changed by the Law of 3 May 1999). This law includes the prevention and the limitation of the pollution due to navigation and the possibilities for the authorities to take emergency measures for the protection of the marine environment.

Marine pollution due to dumping

Two international treaties are being implemented in Belgium:

- Treaty with respect to the prevention of pollution of the sea due to dumping of waste (London, 29 December 1972, changed by the Protocol, London, 8 November 1996).

- Treaty with respect to the protection of the marine environment of the northeastern Atlantic Ocean (Paris, 22 September 1992).

An agreement has been made between the federal authorities and the Flemish authorities with respect to the protection of the North Sea against disadvantageous environmental effects due to dredging activities and dumping the dredged material.

The law of 20 January 1999 with respect to the marine environment prohibits dumping and detritus combustion in sea. The prohibition of dumping waste in sea does not include dredged material, waste of fishes and other inert materials of natural origin.

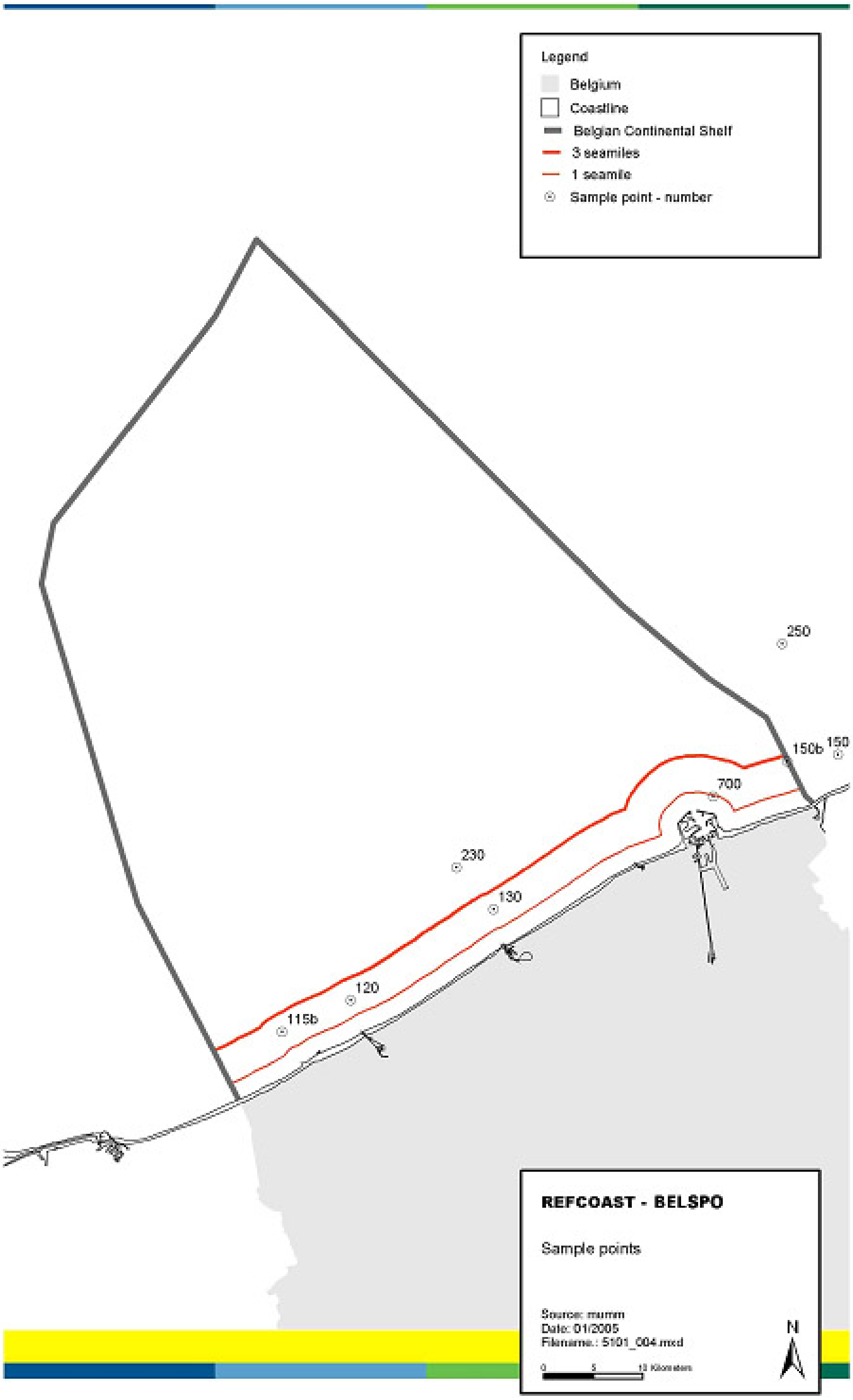
Pollution origination from land

Appendix 1 of the treaty with respect to the protection of the marine environment of the northeastern Atlantic Ocean deals with the prevention of pollution originating from land. The law of 11 May 1995 in Belgium stipulates that the regional authorities are charged with the jurisdiction of the pollution on the proper territory.

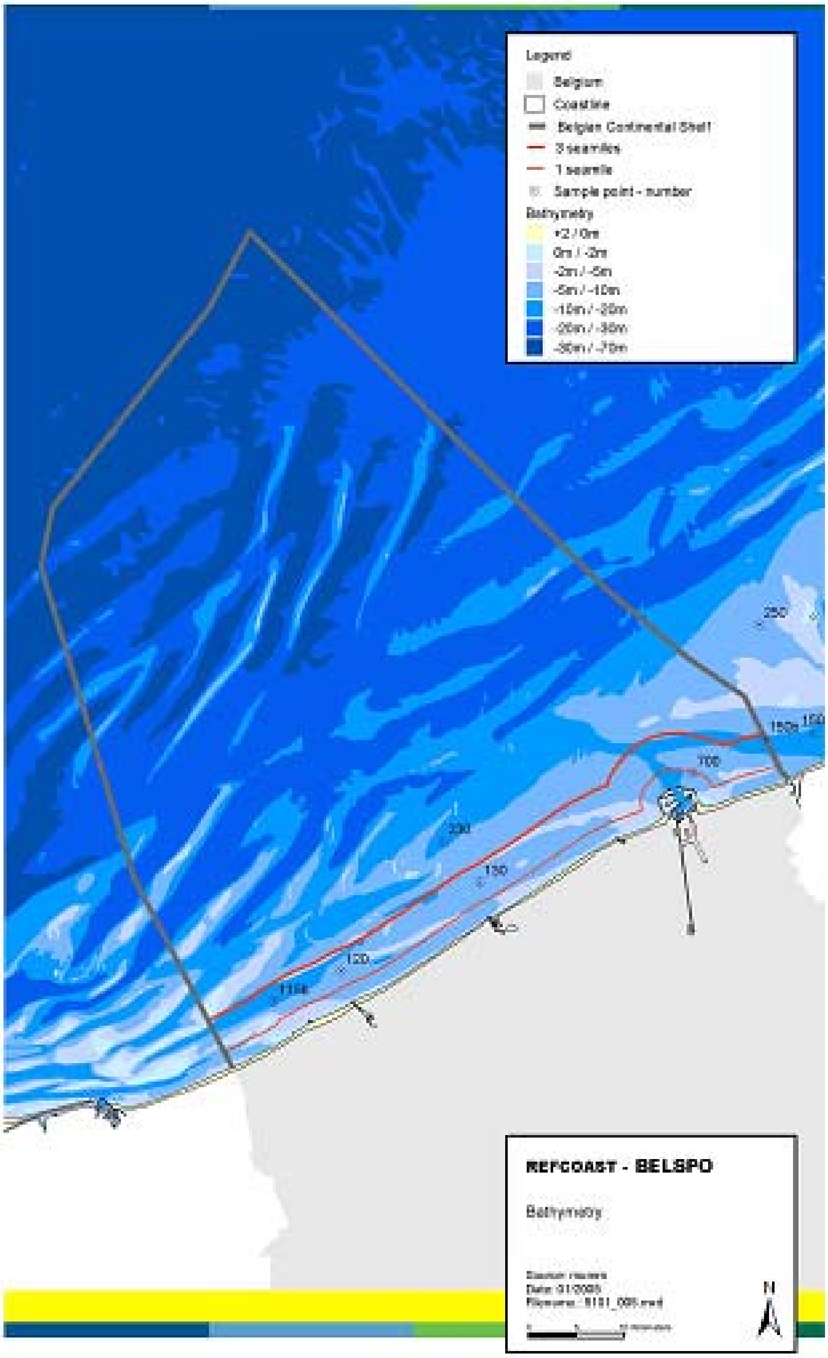
The Law of 20 January 1999 with respect to the protection of the marine environment stipulates that direct discharging of effluent from land to the sea is prohibited.

ANNEXE B

MAPS AS ILLUSTRATION FOR THE TYPOLOGY

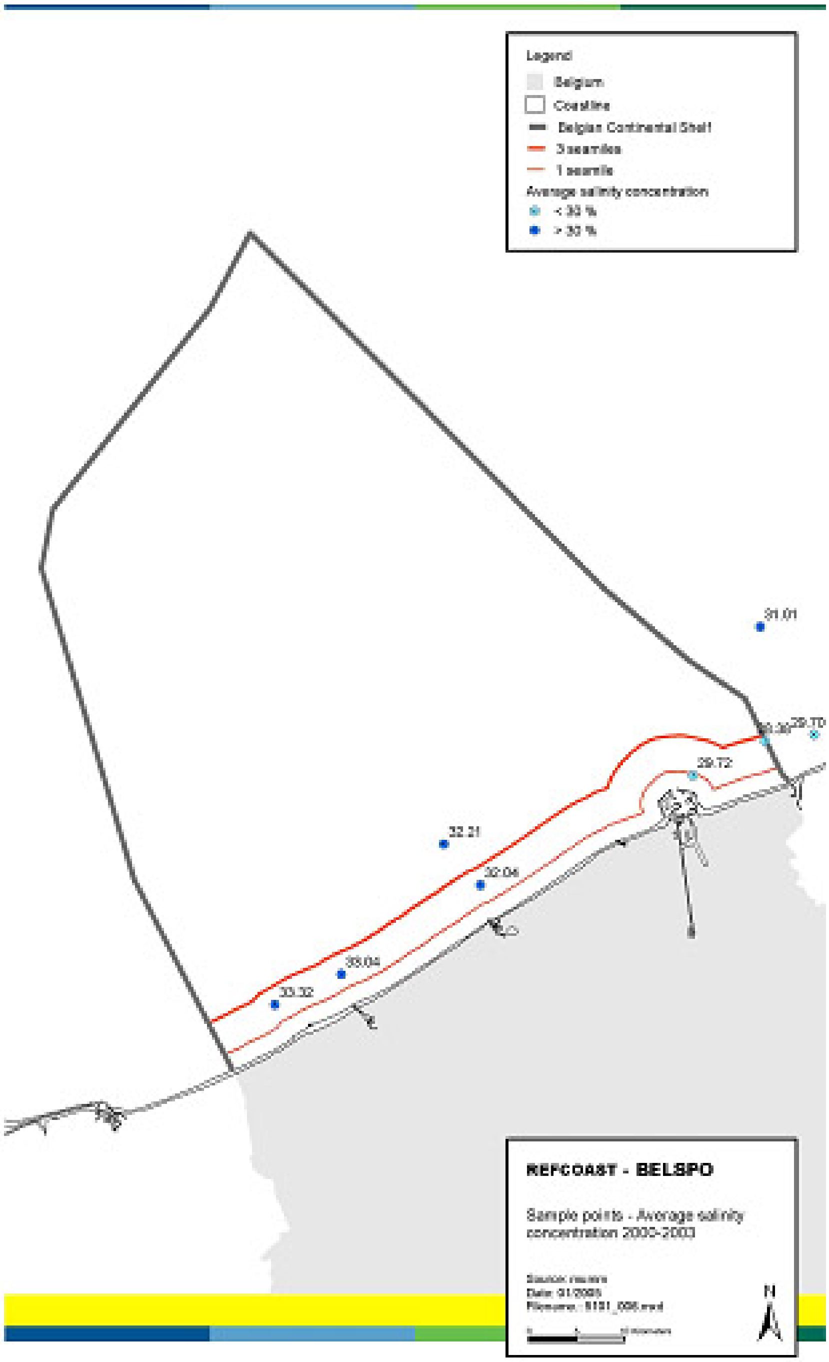


Map 1: Sample points of BMDC form which data of salinity concentration are available



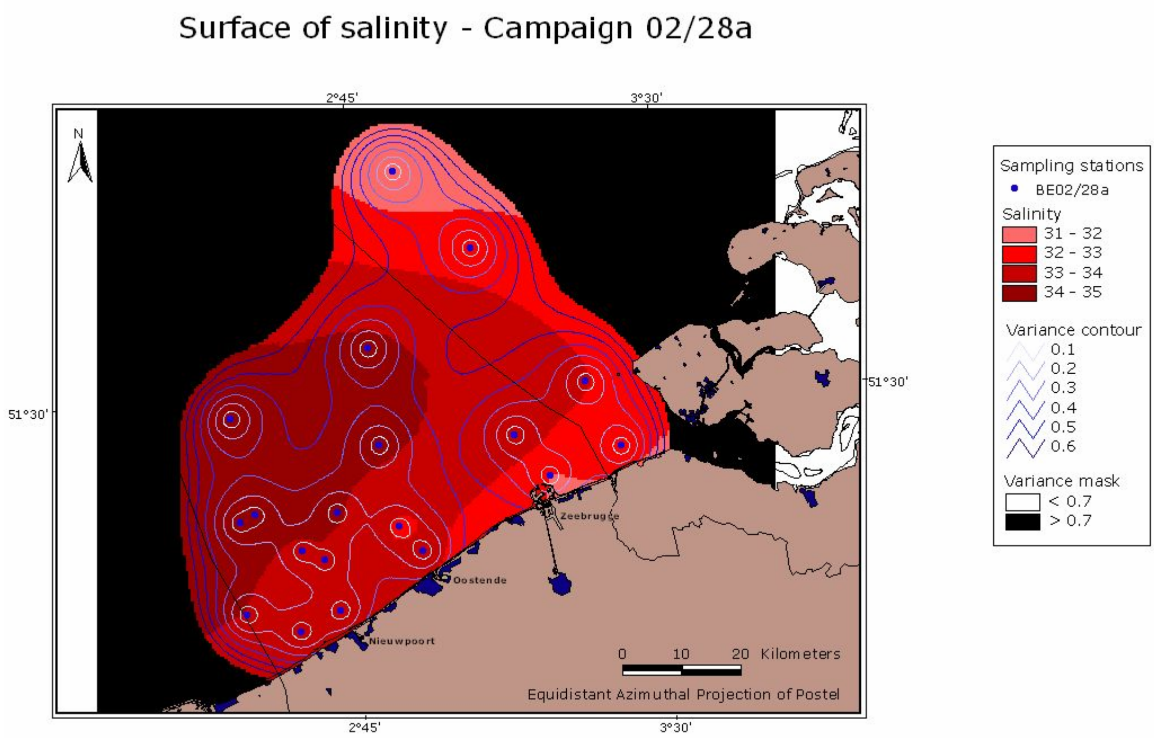
Map 2: Bathymetry of the Belgian Coast

Source: http://www.mumm.ac.be/datacentre/Catalogues/datathemelayers.php

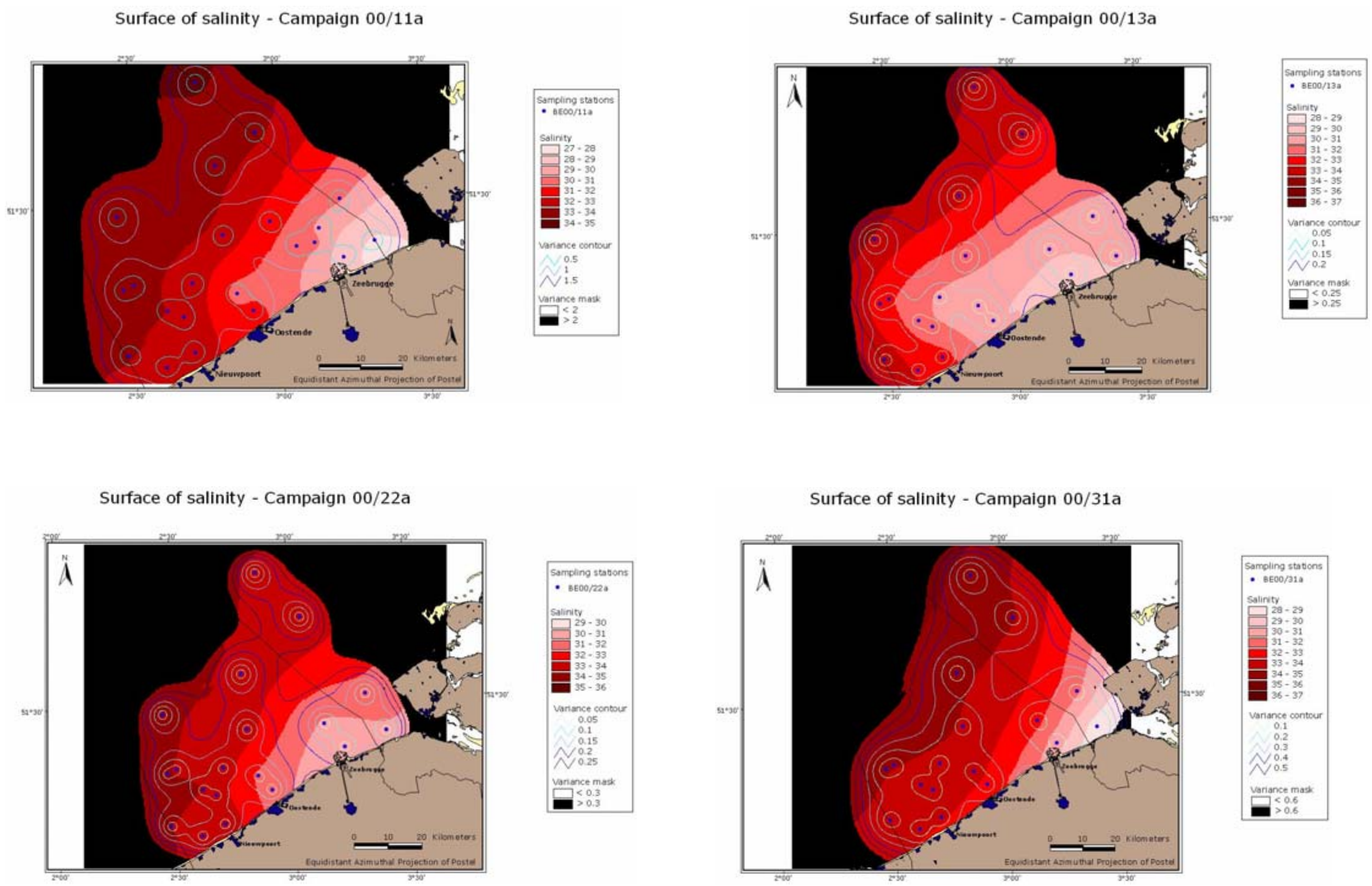


Map 3: Average salinity concentration (pro mille) for the sample points within the zone of 3 nautical miles (sampling events in the years 2000 to 2003)

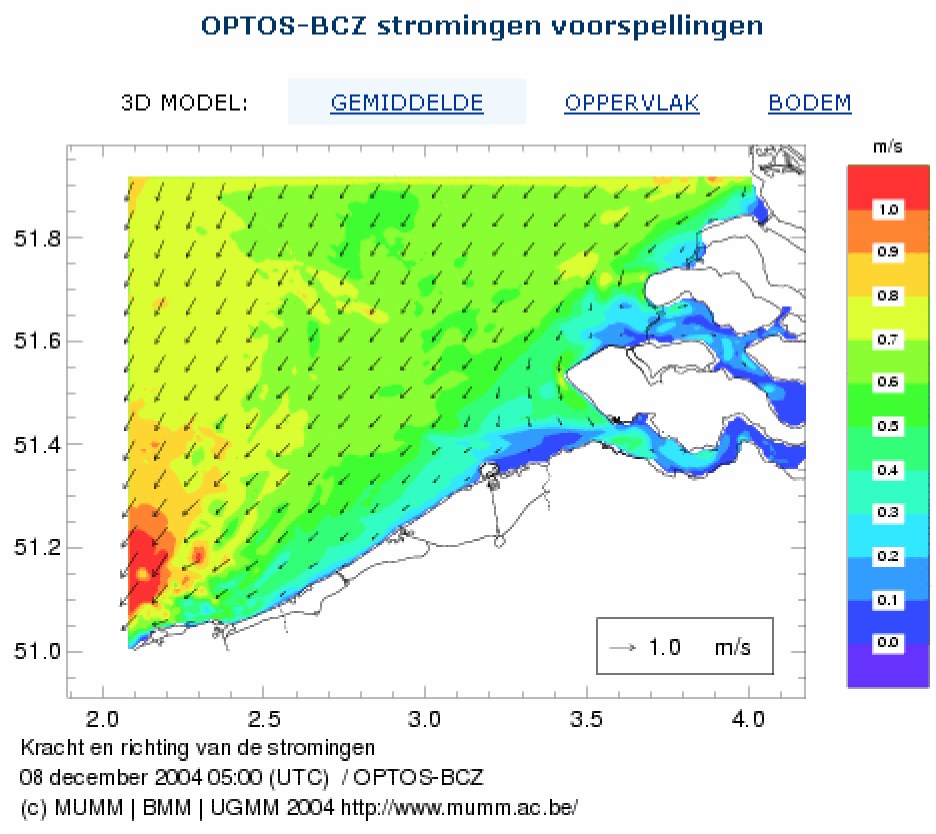
Points indicated in light blue represent a salinity concentration below 30 pro mille; points in dark blue a salinity concentration higher than 30 pro mille.



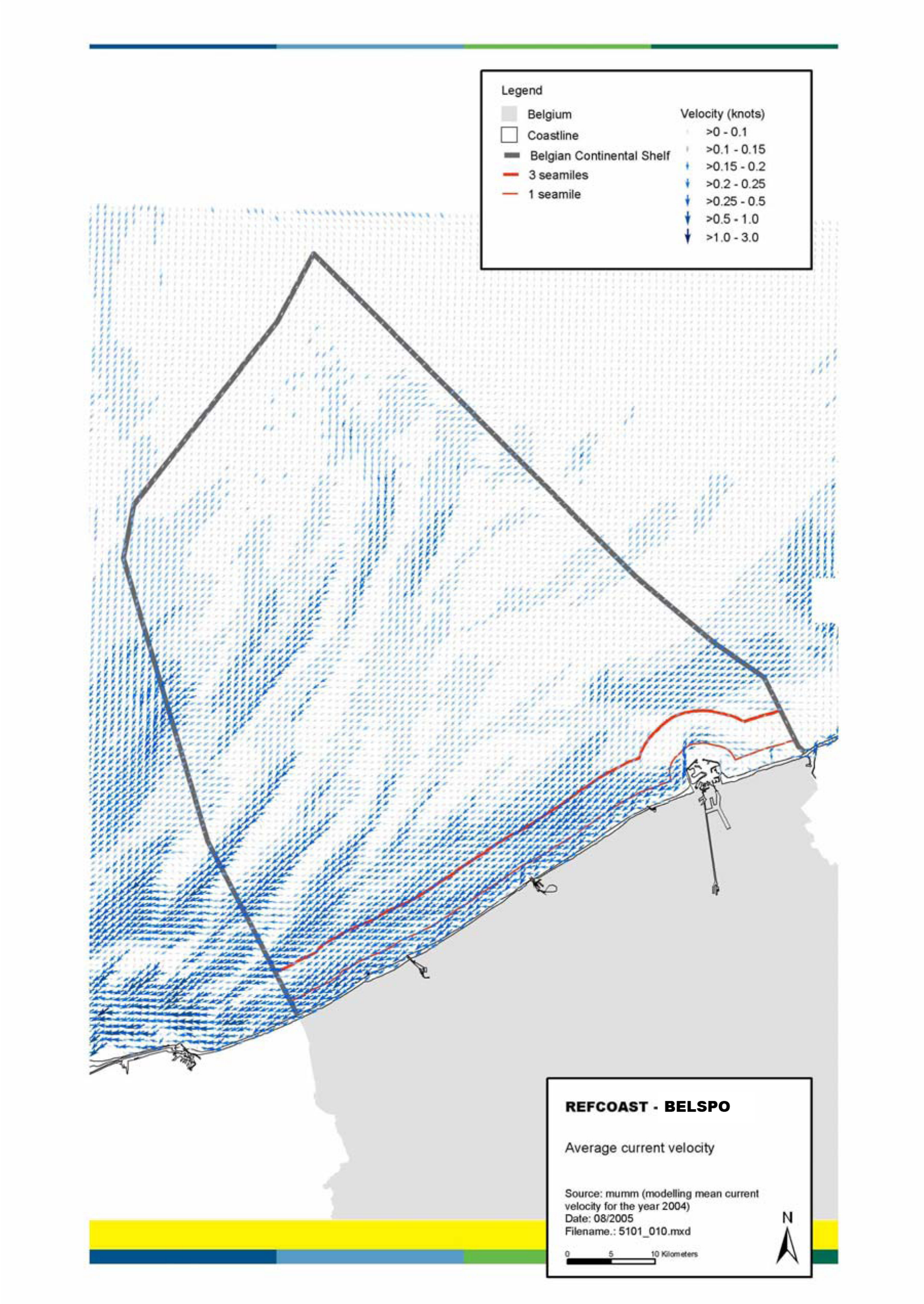
Map 4: Salinity of the Belgian coastal water (December 2002)



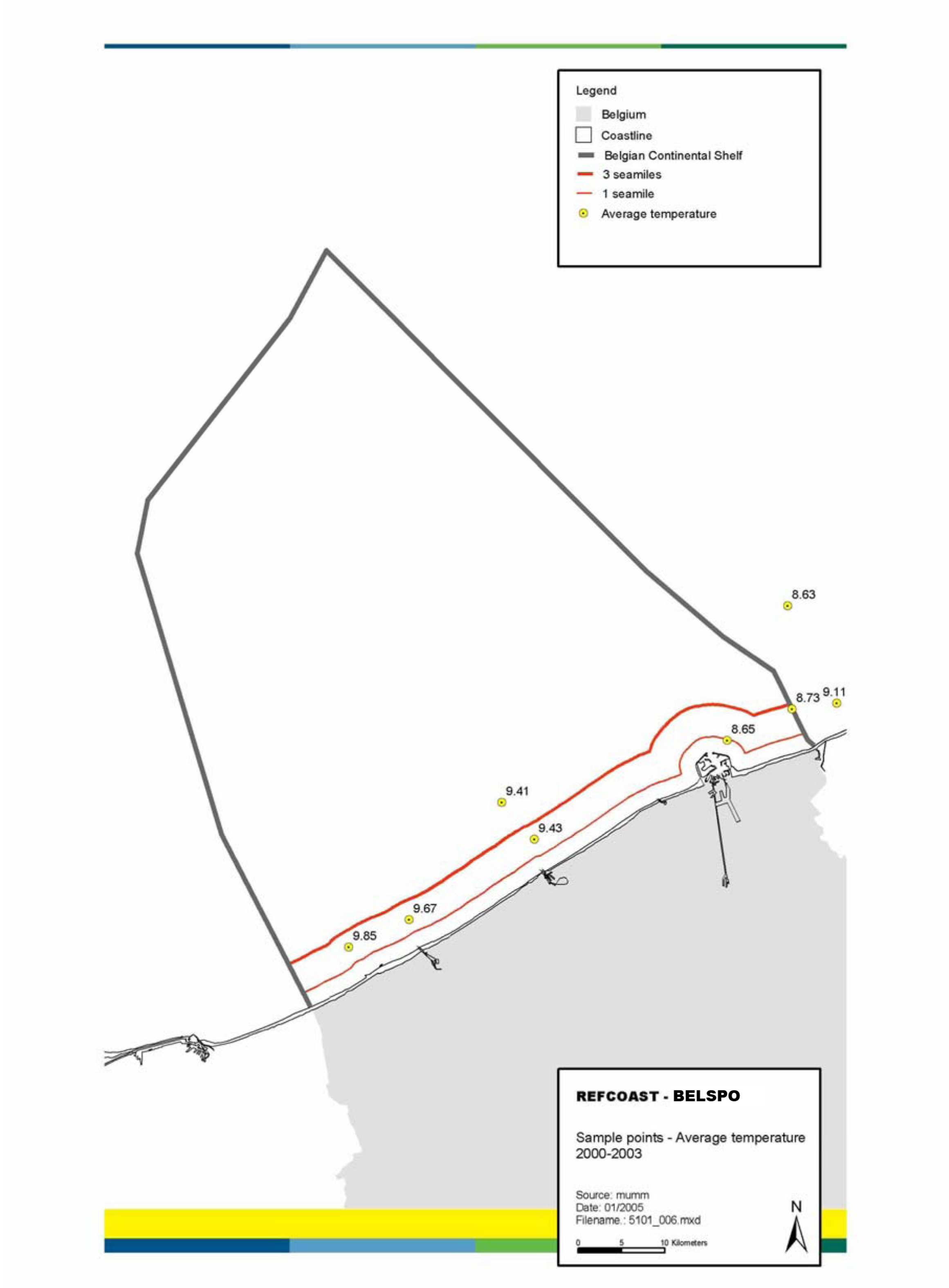
Map 5: Salinity of the Belgian coast water in sampling events in the year 2000 (00/11A: April, 00/13A: May; 00/22A: September; 00/31A: December)



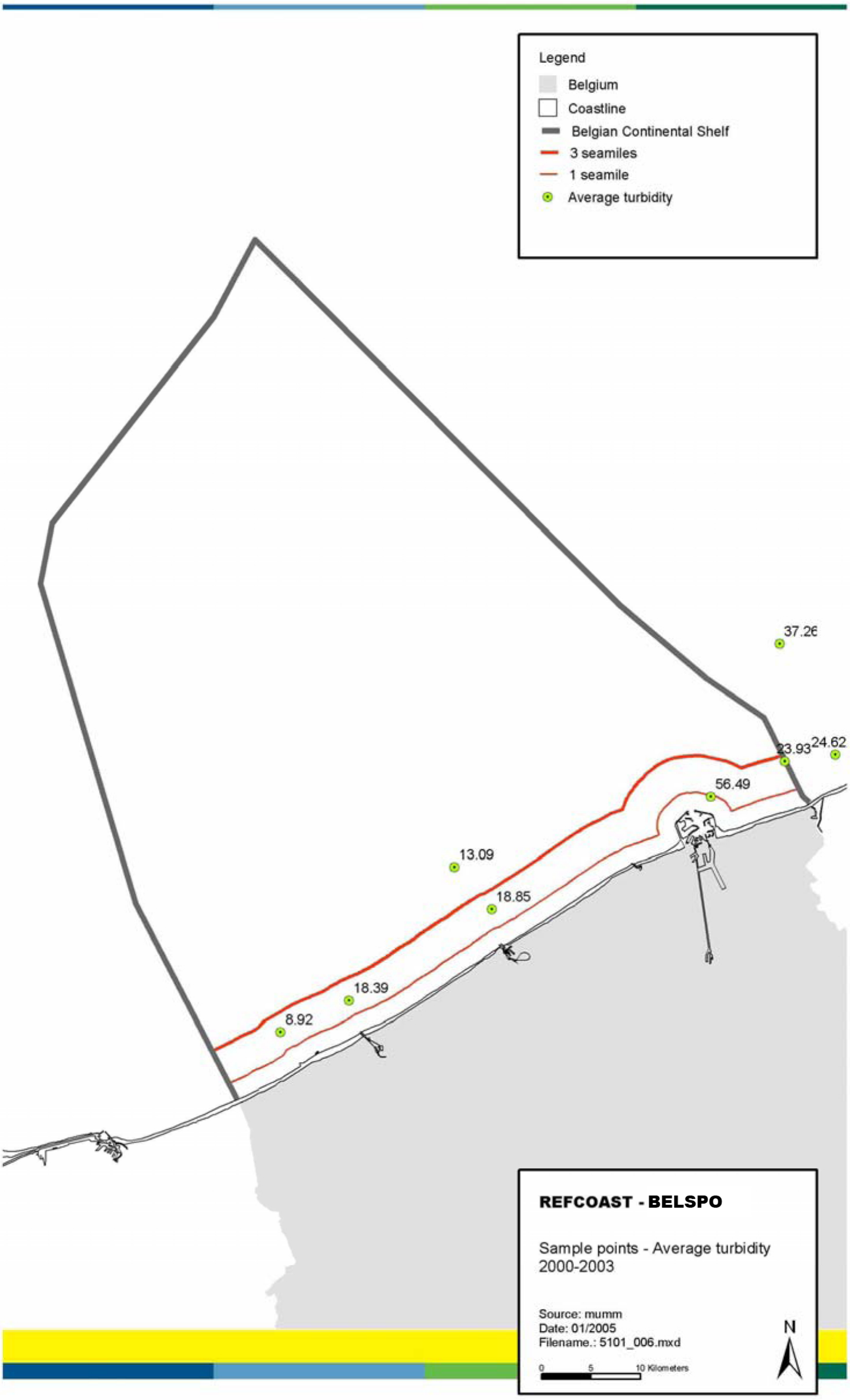
Map 5: Prediction of mean current velocity and direction (maximal current velocity in the period 05 12 2004 until 10 12 2004)



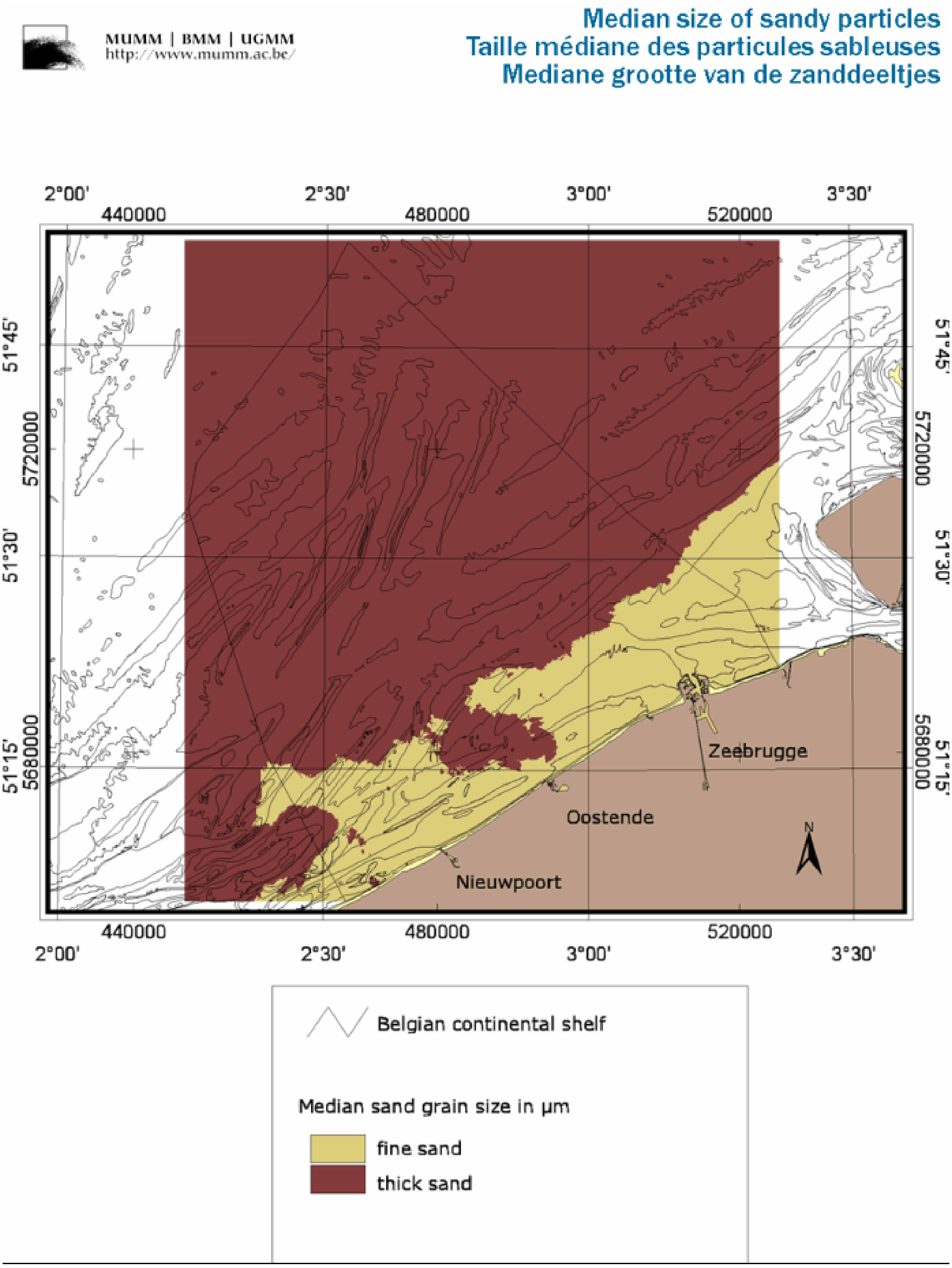
Map 6: Prediction of mean current velocity and direction in the year 2004 (modelled by mumm)



Map 7: Average water temperature during sampling events in the years 2000 - 2003



Map 8: Average turbidity of the coastal waters at the sampling points for the years 2000 - 2003



Map 9: Substratum of the Belgian Coastal Waters

ANNEX C

TOTAL ANNUAL FLUXES OF NUTRIENT AND ORGANIC PARTICULATE CARBON TO THE TIDAL ESTUARINE ZONE

Table 23: Total fluxes of detritic biodegradable particulate organic carbon from the upstream Scheldt and Rupel river basin. (in ktonC/yr)

	Mean hydrology			**Wet hydro**	**Dry hydro**
	Scheldt	**Rupel**	**Total**	**Total**	**Total**
pristine	0.55	1.01	1.55	1.85	1.08
1950	1.06	1.83	2.90	3.30	2.26
1955	1.60	2.59	4.19	4.72	3.21
1960	2.62	5.27	7.89	8.83	6.20
1965	4.73	7.75	12.48	14.10	10.00
1970	5.48	8.89	14.37	16.30	11.61
1975	6.87	8.10	14.97	17.11	12.02
1980	5.76	9.97	15.73	17.73	12.72
1985	5.97	8.89	14.86	16.87	11.95
1990	2.32	7.45	9.77	10.59	8.08
1995	2.25	6.18	8.43	9.10	6.83
2000	2.13	5.13	7.26	7.88	5.81
2015	0.97	1.53	2.49	2.90	1.86

Table 24: Total fluxes of algal biomass from the upstream Scheldt and Rupel river basin. (in ktonC/yr)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	Rupel	Total	Total	Total
pristine	0.14	0.14	0.27	0.36	0.11
1950	0.31	0.17	0.48	0.41	0.38
1955	0.43	0.18	0.60	0.45	0.41
1960	0.37	0.22	0.59	0.58	0.53
1965	0.39	0.26	0.65	0.76	0.61
1970	0.42	0.28	0.70	0.77	0.64
1975	0.46	0.28	0.74	0.82	0.65
1980	0.44	0.29	0.73	0.83	0.64
1985	0.45	0.27	0.72	0.81	0.63
1990	0.40	0.26	0.66	0.74	0.60
1995	0.54	0.22	0.76	0.68	0.55
2000	0.33	0.22	0.55	0.69	0.56
2015	0.14	0.13	0.27	0.37	0.10

Table 25: Total fluxes of total nitrogen from the upstream Scheldt and Rupel river basin. (in ktonN/yr)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	**Rupel**	**Total**	**Total**	**Total**
pristine	0.80	0.99	1.79	2.25	0.95
1950	4.80	5.77	10.57	13.06	5.73
1955	5.88	7.20	13.09	15.88	7.34
1960	6.73	8.93	15.66	18.96	9.56
1965	9.61	11.23	20.83	25.56	14.09
1970	12.80	13.49	26.29	32.56	17.66
1975	18.45	16.15	34.60	44.38	20.77
1980	21.24	19.90	41.14	53.74	24.26
1985	23.22	22.28	45.50	58.75	25.58
1990	22.76	23.98	46.73	61.18	23.88
1995	24.49	25.45	49.94	64.53	24.79
2000	23.96	26.91	50.87	66.23	23.74
2015	21.39	21.99	43.38	58.50	17.15

Table 26: Total fluxes of nitrate from the upstream Scheldt and Rupel river basin. (in ktonN/yr)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	Rupel	Total	Total	Total
pristine	0.46	0.50	0.96	1.25	0.41
1950	3.26	3.15	6.41	8.37	2.79
1955	3.83	3.52	7.34	9.43	3.03
1960	4.39	3.17	7.56	10.18	2.60
1965	5.03	3.18	8.21	12.45	2.28
1970	6.94	4.13	11.08	16.88	3.12
1975	10.91	6.29	17.20	26.55	4.59
1980	14.54	8.55	23.09	35.50	6.47
1985	15.55	10.54	26.09	39.54	7.34
1990	18.92	13.60	32.53	46.43	10.60
1995	21.91	15.69	37.60	51.88	12.96
2000	21.49	19.39	40.88	55.44	14.45
2015	20.57	20.74	41.31	55.98	16.07

Table 27: Total fluxes of total phosphorus from the upstream Scheldt and Rupel river basin. (in ktonP/yr)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	Rupel	Total	Total	Total
pristine	0.07	0.10	0.17	0.20	0.10
1950	0.14	0.21	0.35	0.39	0.23
1955	0.18	0.28	0.46	0.52	0.30
1960	0.25	0.49	0.74	0.78	0.67
1965	0.50	0.90	1.40	1.26	1.78
1970	0.76	1.28	2.05	1.65	2.88
1975	1.10	1.37	2.46	1.91	3.50
1980	0.68	1.45	2.14	1.76	3.11
1985	0.68	1.30	1.98	1.69	2.80
1990	0.42	0.94	1.36	1.26	1.58
1995	0.34	0.63	0.97	0.99	0.88
2000	0.34	0.67	1.01	0.98	1.00
2015	0.11	0.15	0.26	0.33	0.13

Table 28: Total fluxes of dissolved silica from the upstream Scheldt and Rupel river basin. (in ktonSi/yr)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	**Rupel**	**Total**	**Total**	**Total**
pristine	15.43	17.00	32.43	41.25	14.95
1950	15.31	15.90	31.21	41.40	12.41
1955	15.20	15.52	30.72	42.28	11.78
1960	15.02	15.36	30.38	42.62	11.56
1965	14.77	15.28	30.05	42.50	11.54
1970	14.71	15.25	29.95	42.47	11.49
1975	14.26	14.86	29.12	41.31	11.17
1980	13.83	14.47	28.30	40.26	10.89
1985	13.36	14.00	27.36	38.94	10.53
1990	13.04	13.57	26.61	37.94	10.19
1995	12.96	13.44	26.40	36.87	9.91
2000	12.46	14.57	27.03	36.86	9.90
2015	13.49	13.79	27.28	37.33	10.75

Table 29: Mean summer level of oxygenation at the outlet of the Scheldt and Rupel river basin. (in mgO2/l)

	Mean hydrology			Wet hydro	Dry hydro
	Scheldt	Rupel	mean	mean	mean
pristine	5.67	3.34	4.50	4.63	4.43
1950	2.44	2.80	2.62	2.7	2.68
1955	2.91	1.85	2.38	2.36	1.24
1960	2.00	0.02	1.01	1.44	0.18
1965	0.60	0.01	0.31	0.82	0.03
1970	0.21	0.00	0.11	0.39	0.02
1975	0.03	0.01	0.02	0.02	0.02
1980	0.04	0.00	0.02	0.00	0.02
1985	0.03	0.00	0.02	0.28	0.01
1990	0.58	0.00	0.29	1.33	0.19
1995	2.72	0.00	1.36	1.73	0.24
2000	2.70	0.00	1.35	1.74	0.29
2015	1.92	2.82	2.37	3.38	1.92

ANNEX D

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This study has been set up with coordination of the promoter Els Van Cleemput. During the project, we lost her and the project team regrets that she cannot see the final result of the research. Therefore, we want to honour her with the work that we have put in this study and we want to dedicate this report to her.

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