

# Coastal Erosion Indicators Study



## Coastal Erosion – Evaluation of the needs for action

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## MANAGEMENT SUMMARY

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The present report is an assessment study concerned with the feasibility of the development of a number of indicators in the coastal zone in the framework of the EUROSION project.

EUROSION aims at “providing the European Commission with a package of recommendations on policy and management measures to address coastal erosion in the EU, recommendations based on a thorough assessment of the state of coastline and of the response options available at each level of administration.”

To this goal the project will establish a database with relevant data sets, provide information based on the analysis of this data and develop policy recommendations based on the assessments. While the data collection and the development of policy recommendations have been foreseen in the work plan of the project from the beginning, the need for assessment has been identified during the course of the project. GIM has been asked by the consortium to analyse the needs of the main European level clients of the EUROSION project and to define a series of indicators which illustrate the impact of coastal erosion on natural assets in the coastal zone and vice versa.

An important characteristic in the development of potential indicators is the relevance of the indicator at European level for the assessment of European policy questions. Therefore the proposed indicators are not able to provide answers to complex local or regional issues, except that they may identify regions in which more detailed studies at the local level should be started, using more detailed information sources than the ones available to the EUROSION project.

Based on documentation from European Commission services and the European Environment Agency, the requirements for information about processes in the coastal zone have been identified. During this work the focus has always been on coastal erosion and its impact on assets or the impact of a specific process on coastal erosion. This focus is necessary to define a clear boundary line for the objectives of the indicators and to avoid an overlap with other organisations looking to other processes than erosion in the coastal zone, such as land cover changes or the overuse of natural resources.

As a result of the assessment study GIM proposes the development of indicators for the following topics:

- Coastal erosion – presence and changes
- Identification of erosion hotspots
- Climate change – storm surges
- Climate change – sea level rise

The indicators will be integrated in the DPSIR assessment framework and for each of the topics, a series of indicators is proposed which illustrate the impact of erosion on human, economic and ecological values at risk. The necessary processing steps for the creation of the various indicators are presented in technical summary sheets in the annex.

In addition to relevant indicators for coastal erosion, the assessment study has also identified a number of data gaps which currently impede the development of other relevant indicators.

The required resources for the implementation are estimated in the technical indicator sheets (in annex). The estimation includes the processing of the data, the filling of the meta database and a simple illustration of the results in map format.

Not included in the estimate is the production of indicators fact sheets and the design of complex posters.

# 1 THE EUROSION PROJECT OBJECTIVES

EUROSION aims at “providing the European Commission with a package of recommendations on policy and management measures to address coastal erosion in the EU, recommendations based on a thorough assessment of the state of coastline and of the response options available at each level of administration.”

These main objectives of the project can be summarised in two points:

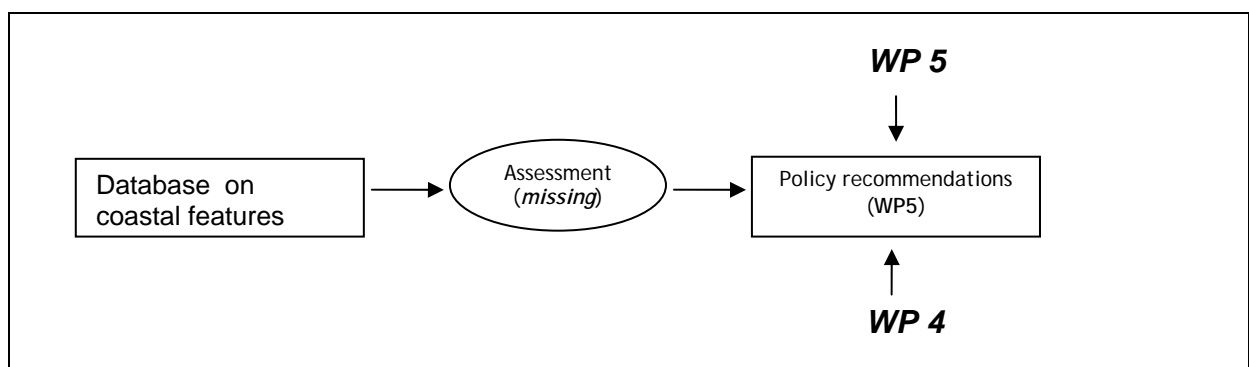
- Data collection and provision of information
- Development of policy recommendations

A huge amount of Europe-wide data are expected to be collected within the framework of EUROSION. These data are expected to be organised in a single database featuring 2 groups of layers: (i) basic layers, and (ii) thematic layers. While basic layers aim at providing the database with a geometrical reference, thematic layers are expected to provide information on features which have directly or indirectly an impact on coastal erosion processes.

While some of these data layers will be retrieved from existing data sources (e.g. administrative boundaries, land cover, land cover changes since 1975, infrastructure, etc.) with a limited added value from the project, most of the other layers will consist of EUROSION self-made processing works meant:

- to fill geographical gaps (e.g. Elevation, land cover changes in the accession countries since 1975),
- update obsolete databases (e.g. Geomorphology, Erosion trends, coastal defence works),
- geo-reference non geographical data (e.g. maritime boundaries, sea level rise, laws and decrees), or
- provide synthesised statistical parameters consistent at the European level (e.g. hydrodynamics, sediment discharges from river basins)

Nevertheless and in spite of this huge amount of data collected by the project, the EUROSION implementation plan does not give a clear picture how these different data will be put together in order to document coastal erosion status and trends in Europe, and thus orient policy recommendations expected from the project. This step – one may call it the “assessment” step – is currently missing and may have a negative impact on the project perception by the members of the Advisory Board, by members of the Steering Group, and finally by the Client.



**Figure 1: The missing link**

Therefore the EUROSION consortium has asked GIM to carry out an assessment of indicators which are relevant for the coastal zone to fill this existing assessment gap. The aim of the indicators is that they

1. can be provided in the framework of EUROSION, i.e. are linked to coastal erosion issues,
2. will assist the policy assessment of the EEA and
3. will eventually lead to the formulation of policy recommendations.

For this goal, GIM has assessed how the different data sets collected by EUROSION and provided in a spatial database can be put together for the analysis of coastal erosion status and trends in Europe and thereby orient the policy recommendations expected from the project.

## 2 CONTEXT OF THE INDICATORS

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In order to assess the general directions and needs for indicators in the coastal zone, GIM has studied a number of documents provided by the consortium itself (e.g. trend analysis, scoping study) or by the EEA which is a main client for the results of the project.

### 2.1 TREND ANALYSIS

The EUROSION consortium has prepared a trend analysis which examines the issues that influence coastal erosion. This report deals mainly with the following topics:

- Accelerated sea level rise (ASLR) – a threat to depositional coasts (beaches, wetlands);
- Changes in sediment supplies – leading to erosion;
- Storms – changes in frequency and strength;
- River delta subsidence – mainly of local effect;
- Human impacts – through infrastructures construction (e.g. dams) which influence sediment flows.

The trends described vary due to the different types of coast and the different intensities of human pressures.

#### Sea level rise

- According to different studies a rise of 10 – 100 cm is expected by 2100. The rise is related to global warming.
- The effect of ASLR is a deficit in sedimentation (if sediment flows cannot keep up with sea level rise) and consequently leading to erosion.
- ASLR will have an effect on river floods and storm surges which will be able to penetrate further inland.
- In Northern Europe the ASLR is likely to be compensated by the post-glacial isostatic rebound of the land masses.

#### Precipitation and evaporation

- Precipitation is likely to increase in Northern Europe by some 2% per decade, while Southern Europe is more likely to experience a decrease in precipitation by some 5% per decade combined with a higher evaporation.

In Southern Europe this will lead to changes in river flow regimes which can have an impact on river deltas, leading to erosion in the deltas.

#### Human impacts

- Between 1960 and 1990 about 100 dams per year have been constructed in Europe. Today over 6000 large dams exist in Europe, most of them in Spain (1200), followed by Turkey, France, Italy and the UK each having more than 500 large dams.

The damming of streams has led to a decrease of sediments being trapped behind the dams and to erosion in river delta which are stripped from their vital input.

- The construction of transport infrastructures and buildings in the coastal zones has put pressure on the coastal zones. Pressures are arising from the conflicting uses for agriculture, industry, ports, tourism and residential use.
- Extraction of material (sand, gas) and groundwater has caused ground subsidence.

### Trends by coastal types

The different types of coasts are likely to respond differently to the ASLR.

- Hard cliffs will be almost stable and not show much accelerated erosion due to ASLR.
- Soft cliffs in contrast will retreat due to ASLR at an increased rate.
- Beaches are in a constant state of flux with sand being eroded or deposited in complex cycles. When the balance of incoming sediments becomes less than the ones being removed by long shore drifts, then the result is erosion.
- Deltas are particularly threatened by ASLR. Delta creation is mainly controlled by sediment supplies from rivers which is influenced by climate change. If runoff decreases in Southern Europe, delta destruction will be the consequence.
- Coastal wetlands are also highly vulnerable to climate change as their location is linked with present sea level. Any change in sea level will provoke a horizontal or lateral shift of their location.

ASLR is likely to effect wetlands (i.e. disrupt) in several ways, through inundation, erosion and saltwater intrusion. However, wetlands are capable of keeping pace with ASLR by growing upward (e.g. sediment trapping) if the rise is slowly enough (< 1 cm/year).

### Regional trends

- Coastal erosion due to ASLR is likely to show some regional trends. These trends are mainly linked to the tidal range, which can be seen as a key factor for the vulnerability of the coast to erosion. In general, the smaller the tidal range, the greater the susceptibility of the coast to sea level rise and therefore erosion.
- Regions with high tidal ranges are the Atlantic and the North Sea.
- Regions with low tidal ranges are the Baltic and the Mediterranean.
- The Mediterranean is also experiencing a reduced water inflow over the last 40 years, due to damming and irrigation leading to a reduced sediment load. Moreover deforestation has influenced the hydrological regime facilitating soil erosion and irregularities in surface runoff.

In addition the Mediterranean region is experiencing a destruction of natural shoreline defences for urban development as well as excessive groundwater pumping leading to land subsidence.

## 2.2 SCOPING STUDY

The objective of the scoping study is to provide a consistent and useful framework for the development of policy recommendations. This was based on a review of generic policy options for coastal zone management and assessment of their implementation by analysing different aspects.

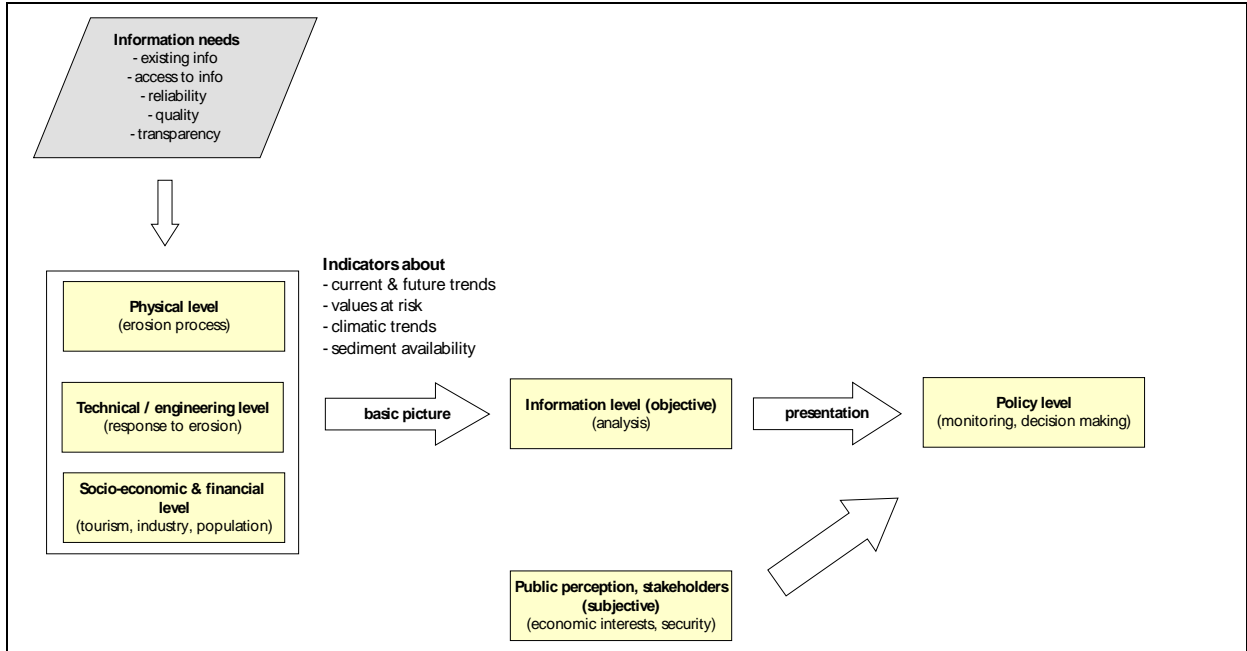
The assessments have been carried out on 6 levels:

1. The physical process level dealing with the process of erosion.
2. The policy level dealing with decision making and policy monitoring.
3. The technical or engineering level concerned with the technical responses to coastal erosion.
4. The socio-economic and financial level concerned with economic impacts of coastal erosion as well as with the economic use (tourism, industry) of them.
5. The public perception and stakeholder level which includes the (sometimes) different view of people concerned on political decisions in coastal zones.
6. The information level which will analyse the basing information and present a synthesis to planners and decision makers to prepare, implement and monitor coastal erosion management.

Figure 2 illustrates the relations between the different assessment levels (in light yellow) (modified from the scoping study) and their relation to the indicator work to be performed. Basic information (grey box) must be made available at the physical, the technical and socio-economic and financial level with the aim to provide a basic picture (as complete as possible) of the situation. The picture will then be analysed at the information level and the results presented to planners and policy makers.

However, policy making cannot be based on objective information alone, but also take into account the public perception and stakeholder communications.

The proposed indicator development fits into this process at the level of the provision of the basic picture. This “picture” (or indicator) is based on information of the physical, technical or socio-economic level(s) and feeds the analysis on the information level.



**Figure 2: EUROSION assessment levels and placement of indicators developments**



## **3 EXPECTATIONS OF THE CLIENT**

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### **3.1 DG ENVIRONMENT**

Two key expectations from EUROSION by the project steering committee have been made explicit:

- Information on erosion rates
- Identification of hotspots.

Furthermore the DG Environment project officer has asked the project to be as specific as possible and to identify concretely which data are missing that would be required for a better support of policy recommendations.

### **3.2 THE EUROPEAN ENVIRONMENT AGENCY (EEA)**

The EEA has published an indicator storyline in which they describe the interest and priorities for indicators related to terrestrial environment. The objective of the indicators to be developed is to gain an understanding of interactions and conflicts through the integration of information and spatial analysis of the data.

Priorities to be addressed in the topic of terrestrial environment and relevant in the framework of EUROSION are:

- Assessment of the state and changes of land use and land cover at European scale;
- Regional assessments of specific areas, starting with urban and coastal zones.

Questions to be addressed by the indicators are:

1. Is the use of land and soil in Europe sustainable?
2. What are the drivers and pressures resulting from the degradation of land and soil?
3. What are the main environmental impacts of land and soil degradation?
4. How effective are the policy responses?

#### **3.2.1 Work already done by the EEA**

In the framework of a Eurostat project on environmental accounting, a number of indicators for the coastal zone have already been tackled (COAST 1 – sustainability of coastal developments).

- Analysis of various issues by distance from the shoreline:
  1. State of land cover by distance and regional sea
  2. Artificialisation pressure
  3. Land cover changes (e.g. LACOAST) for Spain and Romania
- CORILIS method (i.e. smoothing of CLC data)
  1. Dominant landscapes
  2. Percent of artificialisation based on CORILIS
  3. Landscape change matrix (from / to) for main types (agricultural, artificial, natural)

#### **3.2.2 EEA expectations from EUROSION**

When thinking about relevant environmental indicators of the coastal zone, we need to keep in mind that the indicators have to be relevant also in the framework of EUROSION. This means that the

indicator has to be linked to coastal erosion. This excludes a number of indicators listed in the EEA / ETC-TE documents because they are purely land cover oriented.

EUROSION is expected to provide information on indicators for

<b>COAST 4 – coastal erosion</b>	Coastal erosion and propagation trends	S
<i>Modification of the coastline due to natural process and deficits of sediments resulting from management of the rivers. Impacts of the coastal engineering works aimed at protecting, but also impact on the coastline. Coastal erosion causes high impacts on natural areas marine biotopes and on real estate.</i>	Coastal erosion hotspots	S
	Impact of coastal erosion on natural areas (wetlands, dunes, ...)	I
	Impact of coastal erosion on marine biotopes	I
	Impact of coastal erosion on real estate	I
	Protection of coast against erosion by artificial works	R
	Protection of coast against erosion by integrated management	R
	Restoration of eroded beaches	R
<b>COAST 5 – risks in coastal zones</b>	Exceptional climatic events	D
<i>The coast is a very vulnerable system. Due to the interface between the climate, the land and the sea it is prone to natural hazard. Moreover, the concentration of industrial production and high mobility of people and goods by land and sea make the area highly vulnerable to oil spill and other technological hazards.</i>	Occurrence of serious floods & landslides in recent years	D
	Concentration of hazardous industries on coasts	P
	Flow of pollutants (N, P, pesticides) from river basins	P
	Hotspots of oil spills (accidental & illegal)	P/ S
	Hotspots of coastal flooding	S
	Sea level rise index by coastal unit	S
	Cost of restoration after accidents or natural damages	R

**Table 1: EEA / ETC indicator list on coastal issues**

To provide information relevant to these groups of indicators, the following input data should be provided by the EUROSION project:

- Coastal erosion and propagation
- Erosion hotspots
- Sediment flows / delta impact
- Erosion protection by artificial works versus integrated planning and management
- Sea level rise
- Climatic events

### 3.3 CONCLUSIONS

Based on the information provided by the EUROSION reports and the expectations of the clients of the project, a number of issues could be identified as being of high relevance and interest to the project and therefore to the client.

- Presence of coastal erosion and propagation trends

Information about the presence of coastal erosion is provided by the coastal erosion database. Information about propagation trends is limited to the simple presence of erosion. There will be no information about the rate (speed) of erosion available from the database.

- Changes in coastal erosion

Changes in coastal erosion over the last 15 years can be assessed by a comparison of the coastal erosion database version 1 with the version 2 which is being created (updated) in the context of the EUROSION project.

- Impact of coastal erosion on biotopes and human constructions (assets at risk)

The assessment of the impact of coastal erosion will be possible from the data collected within the project, but limited to the statement that a certain asset is under pressure from erosion. Sites under pressure from erosion will be referred to as coastal erosion hotspots.

It will not be possible to establish time series (scenarios) based on erosion rates which predict when a particular site might disappear due to coastal erosion.

- Identification of vulnerable area

The identification of erosion hotspots leads also to the identification of vulnerable areas. Additional vulnerable areas can be classified through the risk of being flooded due to sea level rise or by storm surges.

- Experiences from Integrated Coastal Zone Management (ICZM)

Experiences from ICZM are mainly available from local ICZM projects and therefore not scope of the indicator development task. These aspects are covered by the shoreline management guide produced by a different work package of the EUROSION project. Nevertheless it might be possible to link information on expenses on coastal defence to the changes in erosion (see second point above), thus indicating areas where coastal defence works have been successfully implemented and which budgets have been made available for this.

## 4 DEVELOPMENT OF INDICATORS

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The coast is one of the most valuable natural assets of our continent. This fact is clearly demonstrated by the millions of people who make their way to the coast for a longer or shorter time to enjoy the fresh sea breeze, the sun glittering on the waves, the special, often spectacular, nature of the coast and the delicate mix of natural, cultural and historical elements in the coastal environment. But the coast is also an essential element for many necessary often competing economic activities, as can be seen for example at some of the big harbours on our continent.

The natural coast is a non-renewable resource. That truth lies behind the demand for sustainable use of the coast.

Coastal ecosystems are under threat, nowhere more so than in Europe. According to a recent study by the World Resources Institute 70% of European coastlines are highly threatened, the highest percentage of any region in the world, as indicated by the density of population, roads, pipelines, utilities, cities and major ports. Coastal ecosystems are highly productive and extremely sensitive to such development, and are valuable both ecologically and economically. Coastal waters are the nurseries for most commercial fish and shellfish stocks; coastal tourism is an important source of revenue; and healthy coastal wetlands provide a buffer zone against the impacts of climate change and rising sea levels. As populations continue to migrate from inland to coastal areas, and from rural to urban areas, irreversible impacts on coastlines will occur if we continue to ignore these phenomena<sup>1</sup>.

According to current knowledge, approximately one quarter of the European Union's coast – 16.000 km of shoreline – is currently under threat from erosion despite the development of a wide range of measures to protect shorelines from erosion and flooding.

In order to better understand the interactions, conflicts and potential synergies between the issues that play a role in the coastal zone indicators are being developed by integrating information from different sources on a spatial level as basis for analysis.

### 4.1 THE DPSIR MODEL

Using the unifying framework of Driver-Pressure-State-Impact-Response (DPSIR), observed state changes and impacts in and on the coastal zone generated by changing material fluxes are investigated from the perspective of their individual drivers at European scale.

By integrating the indicators into the DPSIR chain it is possible to develop a kind of indicator story line. The table below presents the several issues of concern in the coastal zone as a series of individual indicators using the DPSIR assessment framework.

Table 2 shows in fact that it is not always possible to define all parts of the DPSIR framework when considering the available data. While the impact of coastal erosion on certain assets is rather straightforward, it is more difficult to assess the impact of e.g. human activities on coastal erosion. Especially at European scale the mostly local effects of e.g. coastal defence works are not or only with high uncertainties detectable in European databases.

Figure 3 illustrates how the indicators proposed by the EEA, the European Topic Centre for Terrestrial Environment and the those identified in chapter 3.3 fit into the DPSIR concept.

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<sup>1</sup> COMMITTEE FOR THE ACTIVITIES OF THE COUNCIL OF EUROPE IN THE FIELD OF BIOLOGICAL AND LANDSCAPE DIVERSITY: European Code of Conduct in Coastal zones, 3<sup>rd</sup> meeting, Geneva, 19 April 1999 – CO-DBP (99) 11

Coastal Erosion Indicators					
	Driving forces	Pressures	State	Impact	Response
<b>ETC/TE</b>					
Coast 3/4	Sea Level Rise Flow of sediments transported by rivers	Capture of sediments by dams in river basin Barriers to drift current: harbours, marinas and other	Coastal erosion, and progradation trends Coastal erosion hotspots	Impact of coastal erosion on marine biotopes/coastal ecosystems Impact of coastal erosion on natural areas(wetlands,dunes,...) Impact of coastal erosion on real estates	Protection of coast against erosion by artificial works / by integrated planning and management Costs of restoration of eroded beaches Progress in coastal management / ICZM
Coast 5		concentration of hazardous industries on coasts	Hotspots of coastal flooding Sea level rise index by coastal index		costs of restoration after accidents or natural damages
<b>EEA/ETC: Other</b>					
		Dominant pressure from land use land uptake by transport infrastructure land uptake by urban sprawl			
	Population density	geographical distribution of the population seasonal population in the coastal zone			
<b>EUROSION</b>					
	1. Indicators which highlight changes in erosion trend patterns in the past 15 years		comparison between CORINE Coastal Erosion (CCER) 1965 and CCEr 2000		
	2. Indicators which measure the impact of coastal erosion on coastal assets			human/economical capital at risk of flooding in case of coastal defence breach, human/economical capital at risk of toppling into the sea, etc.	
	3. Indicators which measure the impact of human activities on coastal erosion processes			major activities concerned here are harbour activities, mining activities, tourism, and to a lesser extent, aquaculture	
	4. Impact of coastal erosion on natural areas			natural habitats (including wetlands) at risk of depletion on a short term (0-10 years), medium term (10-25 years), and long term basis (>25 years), distance changes to the coastline, etc.	
	5. Consequences of climate change on coastal safety		land reclaimed by sea in case of sea level rise, areas potentially affected by a decrease of extreme wave return period, etc.		

Figure 3: Overview of indicators within the DPSIR chain

<i>Topic</i>	<i>Driving forces</i>	<i>Pressure</i>	<i>State</i>	<i>Impact</i>	<i>Response</i>
Coastal erosion	Natural and non-natural processes	Erosion rate	Presence of erosion	Values at risk	Investments made for coastal defence
Flooding	Sea level rise		Flooded area	Values at risk	Zoning, emergency plan, dikes
Human impact on coastal erosion	Tourism	Construction of infrastructure	Constructions within 300 m from the beach		Guidelines for development in coastal zone

**Table 2: Examples for the DPSIR assessment framework in the coastal zone**

## 4.2 MODELLING COASTAL EROSION HOTSPOTS

In the framework of the development of coastal indicators the identification of "coastal erosion hotspots" was found to be of relevant importance (see chapter 3.1). Since the identification will not be possible directly from the coastal erosion database, a modelling approach needed to be defined.

The initial idea was to identify those parts of the coasts that are subject to more than average erosion. However, experience demonstrates that an eroding coast does not necessarily have to be called a hotspot if no assets are at immediate risk and that a "non receding" coast might be considered being a hotspot when existing erosion is continuously compensated through beach nourishment practices.

During the RIKZ/GIM meeting of 29/08/2001 it was agreed that the term "hotspot" should be applied wherever certain levels of risks are reached for human safety, economical assets or for high value natural habitats. Therefore the term hotspot will only be used in the combination of the presence of erosion and an existing impact on an asset (value at risk).

In order to arrive at an overall agreement, a definition based on an objective decision tree (Figure 4) can illustrate how different parameters (erosion trends, coastal defence, morpho-sedimentology, human settlements, infrastructure, natural habitats) are combined and processed to decide whether or not a specific area should be considered as a hotspot.

The importance of the definition and identification of coastal erosion hotspots is also illustrated by the interest expressed by the EUROSION steering committee where two key expectations of the EUROSION project were defined as:

- Information on erosion rates
- Identification of erosion hotspots

### 4.2.1 General Framework

The development of the proposed decision tree needs to be seen within the context of the activities related to the assessment on indicators relevant for the coastal zone. Therefore, the decision parameters that are used are based on the information that is and will become available within the EUROSION project. The combination of information from the different databases allows to define for each investigated zone:

- presence of erosion
- presence of coastal defence works
- morpho-sedimentology type
- distance to areas of economical or ecological value

The main data sources used in the decision tree are :

- The coastal erosion database
- Natura2000
- CORINE Land Cover / LaCoast

#### **4.2.2 Coastal Erosion Database**

The coastal erosion database contains information for a succession of contiguous segments. For each segment the database contains the following information:

- Evolution

The evolution of a coastal segment considered by the project is classified as follows:

- Erosion – retreat of the coast line, towards the land
- Sedimentation - aggradation of the coastline, towards the sea
- Stability – no or negligible change of position of the coast line
- Morpho-sedimentology

The morpho-sedimentological codes used are grouped into 5 main classes:

- Artificial coasts
- Rocky coasts
- Natural Beaches
- Replenished artificial Beaches (here considered separately from natural beaches)
- Muddy Coasts
- Coastal defence works

The presence (Y/N) of works of coastal defence of transversal type (dykes, groins) built on the strand or off-coast is recorded. The nature of the protection works is not specified.

- Geology

The nomenclature for on-shore geology to be collected within the framework of the project will take into account the complementarity with the morpho-sedimentological layer. The geological codes have been modified from the International Geological Map of Europe and the Mediterranean Regions, edited by UNESCO and the German Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover.

This nomenclature (currently under development by the EUROSION project) includes 34 different items within 3 hierarchical levels of increasing details. The most detailed class code should be attached to each (linear) coastal segment.

#### **4.2.3 Additional data sets**

In addition to the use of the information of the coastal erosion database, other data sources need to be consulted in order to identify the presence and nature of the areas that are neighbouring the documented segments of the coastal erosion database. Especially important is the localisation of areas with a specific economic or ecological value that could be threatened by the occurring erosion processes.

The main data sources used are the Natura2000 database for the identifications of natural habitats and the CORINE Land Cover Database for the identification of zones with important urban, rural or economic activities.

Other data sets can be used for the identification of vulnerable areas as soon as they become available or when they are considered to be relevant in a specific context.

#### 4.2.4 Decision Tree

By combining the different data sources, the decision tree shows the different theoretical paths that can be used to identify coastal erosion hotspots. The paths are initially based on Yes/No decisions with regard to the information presented in the coastal erosion database.

- Path 1:

Given presence of erosion and of coastal defence works, a segment can be considered as a hotspot independently from its morpho-sedimentology when it is found that a sensitive zone is at less than 1 km.

This path mainly evaluates the correct functioning of the coastal defence works.

For the morpho-sedimentology code Rocky Coast only Code B is taken into consideration:

Code A = Rocks and/or cliffs made of hard rocks (little subject to erosion)

Code B = Conglomerates and/or cliffs made of material subject to erosion: presence of rock waste and sediments (sand pebbles on the strand)

- Path 2:

When there is a presence of erosion and coastal defence works are installed a segment can be considered as a hotspot when it concerns an artificial beach that is regularly replenished.

Since there probably is a good reason for the beach replenishment, but apparently there is still erosion this is considered as a hotspot without even any consideration of the hinterland.

- Path 3:

When there is a presence of erosion and no coastal defence works are installed a segment can be considered as a hotspot independently from its morpho-sedimentology when it is found that a sensitive zone is at less than 1 km.

This hotspot is considered to be of a lower degree compared to path 1 or 2.

- Path 4:

When there is a presence of sedimentation and coastal defence works are installed a segment can be considered as a hotspot when it is found that a sensitive natural zone (Wetland) is at less than 1 km and that this zone could experience a change in nature (risk of disappearance due to sedimentation) due to the occurring sedimentation processes.

- Path 5:

When there is a presence of sedimentation and no coastal defence works are installed a segment can be considered as a hotspot when it is found that a sensitive natural zone (Wetland) is at less than 1 km and that this zone could experience a change in nature due to the occurring sedimentation processes.

- Path 6:

When there is no or negligible change of position of the coast line and coastal defence works are installed a segment can be considered as a hotspot if it concerns an artificial beach that is regularly replenished and when it is found that a sensitive zone is at less than 1 km.

- Path 7:

When there is no or negligible change of position of the coast line and no coastal defence works are installed a segment can be considered as a hotspot if it concerns an artificial beach that is regularly replenished and when it is found that a sensitive zone is at less than 1 km.

#### 4.2.5 Hotspots

Depending on the expected importance of the impact of erosion and the asset at risk (here defined by CLC data for urban areas and NATURA 2000 data for natural assets) it is possible to classify different degrees of hotspots.



These different degrees of hotspots reflect the basic idea that the impact of erosion is considered differently for the different values at risk. A second aspect that can be deducted (at least partly) from the indicator is whether or not a coastal defence structure is successfully performing its objectives.

#### **1<sup>st</sup> degree**

A coastal segment is defined as a 1<sup>st</sup> degree erosion hotspot when erosion is observed on the shoreline despite of the presence of defence works in combination with values at risk in the hinterland of the coast. In addition to the values at risk, the question needs to be asked if the protective works are performing their work in a satisfying way.

#### **2<sup>nd</sup> degree**

A second degree erosion hotspot is characterised by the presence of erosion (with or without values at risk) but without any protective works at the shoreline. It is assumed that there are reasons for not protecting the eroding coast, maybe due to the fact that the economic value at risk is not in balance with the expenditure for the protective works.

#### **3<sup>rd</sup> degree**

A third degree of hotspots is present in locations where the coastline is in a stable state, while a few beaches are artificially nourished to compensate an apparent erosion problem. While the continuation of the counter measures are successful, a cessation of the beach nourishment would immediately lead to an erosion problem.

#### **4<sup>th</sup> degree**

The fourth degree erosion hotspot is a special case in which accumulation is presenting a threat to existing wetlands.

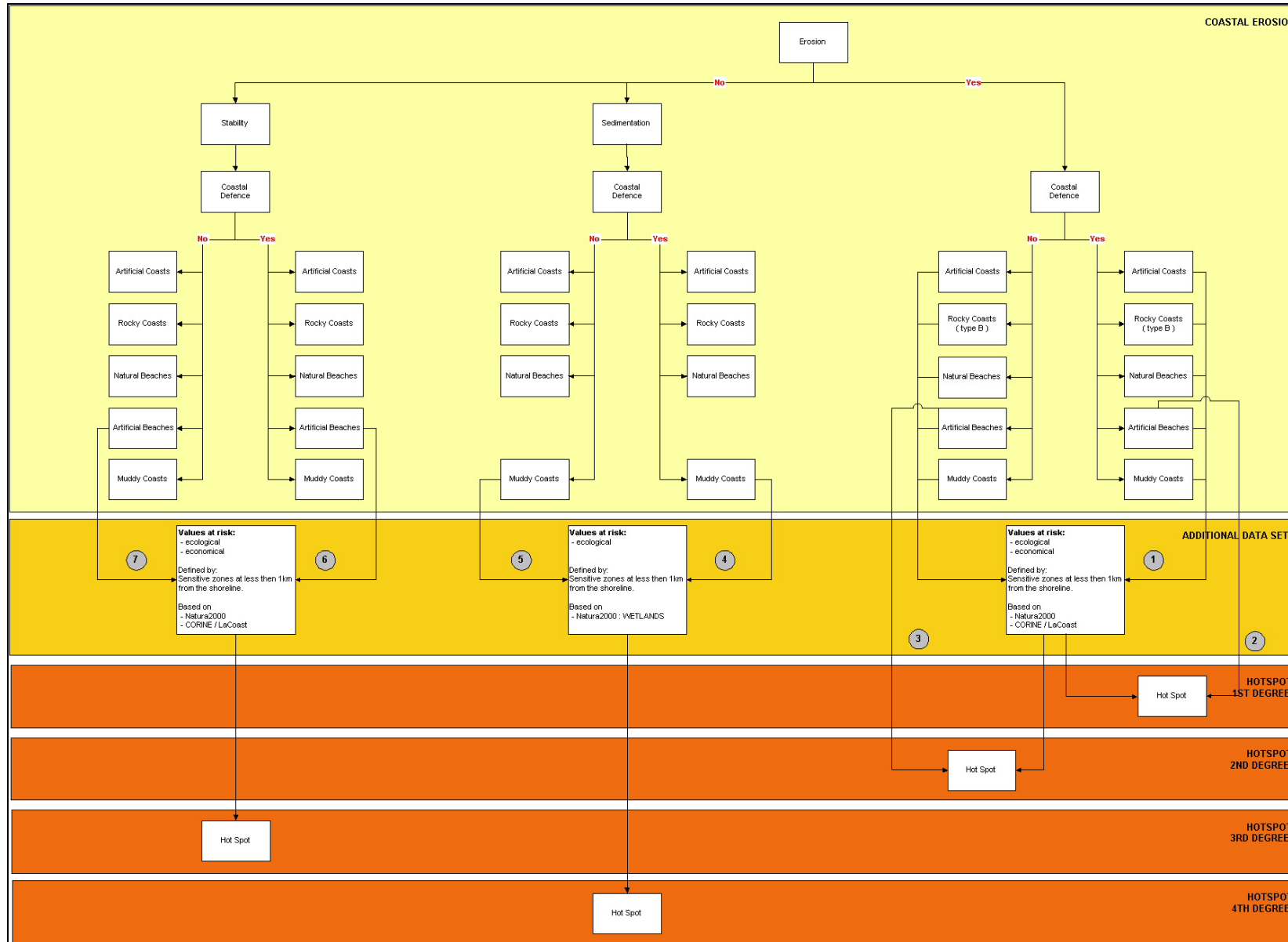


Figure 4: Hotspot decision tree

## 5 PROPOSALS FOR CONCRETE INDICATORS

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The indicators presented in this chapter represent the results of the assessment process and are the proposals for those coastal erosion indicators which have been retained after studying their technical feasibility and political relevance. During the assessment more potential indicators have been considered, but discarded for various reasons (technical feasibility, relevance). Nevertheless the most relevant are shortly summarised in the annex.

The indicators are often part of a group or family of single indicators which illustrate the same topic from slightly different points of view. These different views are nevertheless needed to obtain a fuller picture of the issue under observation.

The methodological implementation of the indicators is summarised in the annex of this report. The list of indicators presented here does not exclude the possibility of defining additional relevant indicators as soon as other data sources become available or when the political attention focuses on a different topic. Nor follows from this list that all of the listed indicators will be implemented by the EUROSION project.

The following indicator topics have been identified to be most relevant in the context of the EUROSION project and technically feasible from the implementation point of view:

- Trends in coastal erosion
- Climate change
- Erosion hotspots

A technical summary sheet with information on the processing methods, required resources and data gaps for each group of indicators is included the annex.

### 5.1 TRENDS IN COASTAL EROSION

A major outcome of the EUROSION project is to respond to policy questions related to specific trends along the European coasts. Therefore, information regarding the presence of and the temporal changes of coastal erosion processes should be considered as being some of the main deliverables of the coastal erosion database. In order to be able to monitor the trends in coastal erosion it is necessary to have access to indicators that assess the difference in the evolutions of the shorelines.

A series of three indicators related to coastal erosion is proposed for implementation. These three indicators illustrate the erosion issue from different view points.

1. Based upon the readily available information at the European level a simple state indicator can be built illustrating those coastal regions in which erosion is present. This indicator focuses merely on the presence or absence of coastal erosion. The impact of the presence or absence of erosion on any other assets is not taken into consideration at this point. Nonetheless this information will serve as basic information for the development of more complex indicators.
2. An indicator of changes and evolution trends in coastal erosion can be created by comparing the first version of the erosion database with the second version which is created within the framework of the EUROSION project. The indicator will be provided at the level of shoreline segments as well as it can be aggregated to other reporting units based on administrative regions, natural coastal units or watersheds.

The policy questions addressed by the indicator are main environmental changes and the presence of specific trends in the coastal zone.

3. When linking the changes in coastal erosion to the evolution of the budgets spent on coastal defence over the past 2 decades, it is possible to highlight regions where positive (resp. negative) changes in erosion pattern may be explained by higher (resp. lower) investments made. Therefore, this indicator can create a more explicit link between the natural erosion process and the level or responses whereby addressing the generic policy question whether the historic policy responses have been adequately. Since the information on budgets spend on coastal erosion will be probably

be available by administrative units only, the indicator regarding the effectiveness of the coastal defence measures will provide information on administrative and not on the level of shoreline segments.

In the DPSIR chain the three indicators could be integrated as shown in the table below. The recorded presence of erosion and the possible changes of the erosion trends provide information on the actual state of the coast, while the combination of the erosion trends with the investments made on coastal segments can be considered as being a response indicator.

#### Integration in DPSIR chain

D	P	S	I	R
		<ul style="list-style-type: none"> <li>• Presence of erosion</li> <li>• Changes in erosion trends</li> </ul>		Investments on coastal protection

## 5.2 CLIMATE CHANGE – STORM SURGES

Increasing atmospheric concentrations of carbon dioxide and other gases released by human activities are generally expected to warm the earth a few degrees (Celsius) in the next century. Such a global warming could have a number of effects on the climate of the earth and the levels of the oceans. The acceleration of sea level rise in the 20<sup>th</sup> century is evidenced and can be seen as a driving force behind exceptional events like storms and floods.

As consequence to global warming the frequency of storm surges will probably and the average duration most certainly increase<sup>2</sup>. The present equilibrium of shorelines will be disturbed because the conditions of their creation will change, this is especially valid for sandy coasts.

These storm surges pose a particular threat to the coastal zones because even though most dikes can cope with a modest increase in sea level, storm surges might be able to top the dams due to a combination of increased mean sea level and extreme wave height.

Catastrophic floods and surges due to extreme climatic events have effected large parts of the European coast in known history. In the 14<sup>th</sup> and 17<sup>th</sup> century 2 catastrophic events have resulted in the loss of more than two thirds of land in the north Friesian Wadden Sea. Likewise the storm surges of February 1962 are in “good” memory of the people of Hamburg when a surge of 4.7 m above mean sea level inundated large parts of Hamburg and killed 300 people.

The occurrence of extreme climatic events like storm surges provides a pressure on those areas that are sensitive to inundation. In addition, the identification of the areas in the hinterland of the dikes that could be subjected to flooding can be used as a state indicator. On the basis of different flooding scenarios the areas at risk of flooding can be delineated. This quantification of potential area under risk of flooding should be evaluated per administrative unit.

In order to estimate the impact of the flooding caused by storm surges it is also necessary to estimate the actual values at risk when flooding of certain areas occurs. Therefore the information on flooded areas has to be related with information on human developments and natural areas that are within the influence zone of the flooding. When using information on land cover and demographic statistics it is possible to have indications of the human developments and number of people affected by the flooding. With information on the location and type of areas with high natural value it is possible to develop information indicating the type of areas that are directly affected or could be threatened by storm surges.

Therefore, the storm surge indicators will provide information on the areas of different types of human developments at risk as well as ecological assets or even human lives.

<sup>2</sup> Brückner, H. (1999): Küsten – sensible Geo und Ökosysteme unter zunehmendem Stress.- In: Petermanns Geographische Mitteilungen 143 / Pilotheft 2000

A step that is still somewhat uncertain in the development of an indicator on storm surges are the storm surge scenarios themselves. Most information on storm surges is not georeferenced, furthermore scenarios for modelling the probability of storm surges occurrences are not available yet. Their creation in the framework of EUROSION is being evaluated.

#### Integration in DPSIR chain

D	P	S	I	R
Climate change	Storm surges	Flooded area	Human / economic / ecological capital at risk	

### 5.3 CLIMATE CHANGE – SEA LEVEL RISE

It is anticipated that climate change will lead to a rise in global mean sea level, primarily because of thermal expansion of ocean water and land glacier melt. Coastal areas could face a significant risk of increased flooding, inundation and erosion as a result of sea level rise. The extent of the rise and local variability in the rate of rise are important issues in planning how to respond. By the "worst case" scenario, global mean sea-level is expected to rise 95 cm by the year 2100, with large local differences due to tides, wind and atmospheric pressure patterns, changes in ocean circulation, vertical movements of continents etc.; the most likely value is in the range from 38 to 55 cm (Warrick et al, 1996<sup>3</sup>). The IPCC has modelled scenarios in which a rise between 9 and 88 cm between 1990 and 2100 is projected. The projected sea level rise will impact mainly on low lying areas such as marshes, tidal flats and deltas. Sea level rise leads through an increased tidal range to increased coastal erosion.

Especially the sensitive ecosystems of the tidal flats (e.g. the Wadden Sea) – an important breeding and nesting area for birds, fishes and other animals – is under threat of being destroyed by sea level rise. An increase in sea level of about 1 m would reduce the area of the Wadden Sea by 50% and would effect about 10 million inhabitants of the Netherlands (67%) and 186 billion Euros of property values<sup>4</sup>.

Apart from direct land loss due to seas rising, indirect factors can generally be listed as the main difficulties associated with sea-level rise. These include erosion patterns and damage to coastal infrastructure, salinisation of wells, sub-optimal functioning of the sewage systems of coastal cities with resulting health impacts, loss of littoral ecosystems and loss of biotic resources. Therefore, increasing sea levels will have impacts on natural coastal habitats as well as on developed and populated areas. Rising sea levels will increase the risk to beaches and dunes from extreme climatic events, and increase risks to coastal roads, houses, ports, industries, etc.

But not all European coastal regions show the same vulnerability to accelerated sea level rise (ASLR). Most of the Mediterranean coast are not very vulnerable to ASLR, as well as the Atlantic coasts of France and Ireland (current exposure to large tides), Lithuania, Estonia and Finland (glacial rebound). On the other hand, the flat and highly developed coasts of England, Belgium, The Netherlands, Germany and Poland are highly vulnerable to sea level rise. Important cities like London, Antwerp, Bremen and Hamburg lie in the potentially affected zone<sup>5</sup>.

The indicators presented here respond to the generic question of what are the main environmental changes in the coastal zones. Specifically making reference to the policy question about specific trends.

<sup>3</sup> Warrick, R.A., C. Le Provost, M.F. Meier, J. Oerlemans and P.L Woodworth, 1996. 'Changes in Sea level'. Chapter 7 of IPCC 1996a, 362-405

<sup>4</sup> Brückner, H. (1999): Küsten – sensible Geo und Ökosysteme unter zunehmendem Stress.- In: Petermanns Geographische Mitteilungen 143 / Pilotheft 2000

<sup>5</sup> Tol, R. (2000): An overview of European vulnerability to impacts of accelerated sea level rise (ASLR).- In: Proceedings of SURVAS expert workshop on European vulnerability and adaptation to impacts of accelerated sea level rise, Hamburg

The first indicator will illustrate the pressure of sea level rise per coastal unit.

Based on the expected sea level rise it is possible to indicate the influence on coastal erosion. Coastal erosion is caused by the action of the sea in combination with other factors such as wind and rain.

The Bruun rule<sup>6</sup> specifies that in a sandy beach region the shoreline retreat is about 100 times the rise in sea level. The second indicator presented will try to define similar recession trends for different coastal morpho-sedimentological types (based on literature search and expert judgement). Applying these recession rates to the current shoreline the effect will be illustrated for each single coastal segment.

Whilst climate change is unlikely to change significantly the total area at risk of flooding, it will increase the risk to which these areas are exposed. Therefore, it is also interesting to indicate which agricultural land, urban centres and areas of internationally-designated environment sites are potentially subject to sea level rise. Unfortunately the existing information base does not provide suitable data for such an assessment. Main requirement for the definition of flooded areas due to sea level rise is a DEM with a vertical resolution in the deci- or even centimetre range to accommodate the different ASLR scenarios.

#### Integration in DPSIR chain

D	P	S	I	R
Climate change	Sea level rise		<ul style="list-style-type: none"> <li>• Shoreline recession</li> <li>• Potential area inundation</li> </ul>	

## 5.4 EROSION HOTSPOTS

The coast line is subject to a continuous modification due to natural processes and deficits of sediments resulting from management of rivers and coasts. The differences that occur in the changes of the coastline make it necessary to identify those areas where this modification results in coastal erosion. In addition special attention has to be given to the areas that are under pressure by coastal erosion whereby causing impacts on natural areas, marine biotopes as well as on economical assets like real estate. Both the area under pressure as well as the neighbouring zones are being looked at. Once identified, these areas (i.e. areas with an economical or ecological asset under pressure by coastal erosion) can be considered to be coastal erosion hotspots.

Theoretically a coastal zone that exhibits anomalously high erosion rates, relative to the surrounding beach could neutrally be defined as an erosion hotspot. However, the available information at European level does not allow to unambiguously detect these specific coastal stretches based on detailed erosion rates only. In addition there is no agreed definition from how many centimetres of coastline recession (per time range) the fact of erosion should be called "hotspot".

By consequence the project proposes to define a hotspot when the investigated coastal zone unit is not only under threat of erosion but can be also linked to certain values at risk within its influence zone. Therefore, the proposed indicator will reply to the request for identification of the actual hotspots for coastal erosion and vulnerable areas in coastal zones as well as address the specific impacts of coastal erosion in the coastal zones in combination with a quantification of the impact in terms of values at risk, either economic or ecological.

Hotspots of coastal erosion can be identified by combining different sources of information. It is proposed to make use of an objective decision tree based on the content of the coastal erosion database.

Through the evaluation of certain database variables (e.g. erosion: Y/N; presence of defence works: Y/N; and coastal morphology) regions with presence of erosion are identified. By overlying these areas

<sup>6</sup> BRUUN, P. (1962). "Sea Level Rise as a Cause of Shore Erosion". Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, 88, 117-130

of potential or actual erosion with information about values at risk (e.g. land cover, protected areas) vulnerable areas are identified.

In case an area with presence of erosion puts pressure on an economic and ecological asset, this area is then called an erosion hotspot. Different degrees of hotspots can be distinguished depending on the decision path influencing the impact of erosion on more or less valuable or probable regions.

By combining the hotspot information with population figures, the urban areas at risk themselves can be classified into classes of importance. The assumption is that a defence work in front of a city with one million inhabitant is more important (in terms of capital at risk) than a defence in front of a small village.

The recorded presence of erosion provides information on the actual state, while the evaluation of the impact of coastal erosion on economic and ecological assets of areas under influence of coastal erosion can be regarded as an impact indicator. Furthermore, through the integration of additional data sources it will become possible to differentiate even different classes of economical risks and values.

#### Integration in DPSIR chain

D	P	S	I	R
		Presence of erosion	Erosion hotspots: impact on economic and ecological values	

Figure 5 illustrates the position of the indicators proposed in this assessment study (highlighted in yellow) within the DPSIR assessment framework. The indicators in the other text fields represent a further aspect of the same indicator series extending to an additional aspect of the DPSIR chain. But with regard to the current input data situation the development of this additional aspect is not feasible.

Coastal Erosion Indicators					
Proposed Indicators	Driving forces	Pressures	State	Impact	Response
Coastal erosion and propagation trends			Presence or erosion changes in coastal erosion between 1985 and 2002	Impact of coastal erosion on existing infrastructure (capital at risk) Impact of coastal erosion on protected land (habitats, biodiversity)	Investments on coastal protection (km of renourished beach, permits for coastal armoring, number of permitted artificial reefs; volume of dredged material disposed)
			rate of coastal erosion		
Erosion hotspots Impact of erosion: values at risk			Presence or erosion	Erosion hotspots Impact of coastal erosion on existing infrastructure (capital at risk) Impact of coastal erosion on protected land (habitats, biodiversity)	
Climate Change : Storm surges	Climate Change	Storm Surges	Flooded areas	human / economic capital at risk	cost of flood defence; permits for coastal armoring, number of permitted artificial reefs
Climate Change: Sea Level Rise	Climate Change	Sea Level Rise	Shore Line recession Flooded areas	human / economic capital at risk	
Impact of human activities in Coastal Zones		increased population + development extention of harbour facilities; tourism		Impact on erosion	

Figure 5: Proposed indicators in the DPSIR assessment framework



## 6 IDENTIFICATION OF DATA GAPS

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The assessment study on the technical feasibility of the development of indicators for coastal erosion has identified a number of concrete data gaps. The study pointed out that for a number of potentially relevant indicators the information base is not yet sufficient to calculate such indicators on the European level.

In order to produce consistent indicators, the information needed for their development is required on a consistent and detailed spatial level. Based on the available information in the coastal erosion database, additional information sources should preferably be as close to the coastal segments of the erosion database as possible. For most of the purely administrative data linked to coast it will be difficult to have access to information on this level of detail.

However, when focussing on the financial aspects of coastal defence measures it is also to be noted that most financial investments are not evenly spread within an administrative unit. Therefore, it could mean already a major improvement if “hotspots” of investments (e.g. restoration cost after damages) were geolocated (e.g. via a point database or linked to the nearest village).

A general problem with the necessary additional data sources is that even when the information is available in structured databases, the data is mostly not georeferenced, i.e. linked to a precise location on the ground for which the information has been collected or for which it is valid.

The missing information listed below is not exclusively related to coastal erosion in particular, but concerns the information about the coastal zone in a wider general context.

The information could contribute to the development of the following potentially relevant indicators:

### 6.1 COASTAL EROSION AND PROPAGATION TRENDS

#### Erosion hotspots by measurement

The identification of erosion hotspots is an important topic in coastal zone management. Nevertheless the identification of erosion hotspots based on quantitative measurements is not possible yet on a European scale.

The proposal for the identification of hotspots made in the context of this study is based on data modelling using the information available in the coastal erosion database. Therefore, it only provides an appreciation of the actual erosion situation along the European coasts.

However, quantitative erosion hotspots could be identified by evaluating if the erosion rate of a particular coastal segment exhibits anomalously high erosion rates, relative to the surrounding coast based on quantitative measurements. The following information would be needed to establish this indicator:

- erosion rates (see also below)
- an international agreement on how to identify erosion hotspots in a local or regional context.

The identification of erosion hotspots in a local or regional context is preferable over mere erosion rates because it takes into account the site specific conditions. Actual erosion of only a few centimetres per year in a very sensitive area could be judged by local authorities to be more important than higher erosion rates in a less sensitive context.

#### Erosion rates

The availability of erosion rates as an average value of centimetres of shoreline recession per year would be a very important information for coastal zone management. This information would permit to establish short, medium and long-term impact scenarios based on erosion rates. To date such information is not collected in a uniform fashion and over comparable time ranges. Although it is not realistic to plan or establish a European wide database on erosion rates for the different coastal

segments, a uniform recording of erosion rates on test zones distributed along the European coasts would provide a valuable indication with regard to the monitoring of coastal erosion processes.

In addition it is also very important to distinguish catastrophic events in which large patches of land are lost to the sea from continuous erosion.

## 6.2 IMPACT OF COASTAL EROSION ON NATURAL AREAS

### NATURA 2000 GIS

The digital boundaries of the NATURA 2000 sites are needed in order to assess the impact of coastal erosion on them. The availability of boundaries allows to more precisely locate protected areas and thus to assess more precisely the impact on them. For areas more distant from the coast scenarios could be build when they would be effected by erosion under a given current erosion rate.

The NATURA 2000 boundaries are currently under production, but not yet available to the project.

## 6.3 IMPACT OF HUMAN ACTIVITIES IN COASTAL ZONES

### Tourism data

The European Code of conduct for coastal zones<sup>7</sup> states that the tourism industry is the world's fastest growing industry, and has been an important part of the economic development of many of the poorer areas of Europe, especially in the South. The growth rate for tourism in Europe is 3.7% per year, projected to continue<sup>8</sup>. The Mediterranean is the leading tourist destination world-wide and 90% of the tourists travelling to the Mediterranean are heading for French, Spanish and Italian coasts.

The sheer speed and scale of tourism development has had a major impact on the environment. In addition although many local people have benefited from the increase in prosperity which tourism brings, the social and cultural effects are significant. In addition over-development and environmental degradation have led to many areas losing their appeal. As tourist numbers drop off the ability to maintain the infrastructure becomes more difficult. Where erosion has become a problem, as has happened in many areas where development has occurred in vulnerable zones, the cost of maintenance can be particularly high and often has to be borne by the local tax-payer.

The impacts of tourism in coastal areas arise from the construction of infrastructure (e.g. hotels, marinas, transport, waste treatment facilities, groynes) and from recreation (golf courses, water sports, thematic parks, beach access and parking, etc.). The problems in this sector differ from other economic sectors in that the degradation of the environment results in the degradation of the industry itself with knock-on effects in other industries.

Detailed information about tourism is required for an assessment of the impacts as well as of the benefits of tourism in the coastal zone. Information that is available at NUTS 5 level (commune level) would already be a major step forward in the analysis of the relationship between tourism and its impact in the coastal zone. For small coastal communes the NUTS 5 level is certainly sufficient, in bigger communes a majority of the generated income should be allocated to the coastal strip, assuming that the coastal hinterland is not as heavily frequented by tourists as the coastal strip.

Concrete information requirements are:

- Number of tourists
- Main tourist season (number of months)
- Income generated by the tourists during this period

<sup>7</sup> COMMITTEE FOR THE ACTIVITIES OF THE COUNCIL OF EUROPE IN THE FIELD OF BIOLOGICAL AND LANDSCAPE DIVERSITY: European Code of Conduct in Coastal zones, 3<sup>rd</sup> meeting, Geneva, 19 April 1999 – CO-DBP (99) 11

<sup>8</sup> European Commission, D.G. Environment, "Consultation on the basis of the Green Paper: A step further towards recognition of Community action to assist tourism," 1995.

Information on tourism could be used to determine areas under pressure. Potential indicators which could be developed from the data are pressure on protected lands, water consumption during the tourist season with a linkage to the overuse of coastal aquifers.

### **Tourism income versus maintenance cost**

Tourism as such has of course not only a negative side. Tourism also provides important opportunities for strengthening local industries such as agriculture and fisheries, traditional crafts, and so forth. Where industries are in decline, tourism ventures can help supplement declining income.

Tourism is for many coastal communes an important source of income. Therefore the comparison of income generated by the tourism industry in a region should be compared with the expenditure for coastal defence in the same region. In fact, in certain parts of the world all expenditures for coastal protection (incl. artificial beach nourishment) are more than compensated by the revenues generated by tourism in the same area.

An example of this are the coasts of Florida where the current investments in of beach nourishment are 30 Mio. US\$ for 27 projects compared to \$17.7 billion in direct tourist spending every year<sup>9</sup>. On the other hand it should be mentioned that U.S. scientists are noting that the state's efforts to control beach erosion have been too late in many cases and ineffective in others.

A comparison of these financial aspects could provide the European decision makes with an additional point of view on the issue of coastal erosion. But the financial viability of actions should nevertheless not obscure the fact that in this vicious circle of more tourists, more development, more growth and more beach nourishment, the environment is often the loser.

### **Increased erosion due to protection works**

Protection works are installed to reduce coastal erosion. In some cases though the installation of protective works has lead to an increase in erosion in a areas adjacent to the defence works. Such information is required at very local level, but nevertheless important to judge the success rate of coastal defence works in general.

## **6.4 COASTAL ZONE MANAGEMENT**

### **Coastal protection by hard and soft engineering**

Information about the type of coastal defence works and especially with regard to the differentiation into hard and soft engineering works is a valuable input to the assessment of changes in coastal zone management. The availability of this information on the same spatial detail as the coastal erosion database (i.e. at segment level) would allow to assess the success and / or impact of different types of defence works. Likewise it could be implemented as a policy response indicator.

The impacts of hard engineering are usually more severe than soft engineering. Hard engineering generally results in long term changes in coastal morphology, particular erosion, alongside protected areas. Soft engineering is generally a more environmentally friendly approach which works towards providing a dynamic equilibrium at the coast. It also generally requires more space thereby reducing coastal squeeze.

### **Initial and maintenance cost of defence works**

Information about the type of coastal defence works in combination with their initial cost and costs for continuous maintenance would allow a cost-benefit analysis of the protection works. Therefore the information must be available on a more detailed level than only the administrative level on which the budget is spent. At this stage it is not clear how much funding is attributed to the different types of defence works under the responsibility of a certain authority.

By separating initial installation cost from costs for on-going maintenance, the differences between hard and soft engineering can be better evaluated.

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<sup>9</sup> Miami Herald 30.07.2002 (<http://www.miami.com/mld/miamiherald/news/state/3760527.htm>)

### **Restoration costs after damage**

The overall picture of costs is not complete without a view on the restoration costs of coastal defences after a damage. These costs are not included in the maintenance cost and are often linked to exceptional climatic events (storms, floods).

The fact that certain parts of the coastline are restored even under high cost are already an indicator for the high value of that part of the coast.

### **Distribution of policy options**

Information about the various policy options in response to coastal erosion (i.e. hold the line, move seaward, managed realignment, limited intervention, do nothing) for the different coastal segments or coastal units is of interest.

A comparison of coastal erosion evolution trends with the management options permits to complete the DPSIR chain and to include the policy response to the erosion phenomenon in certain regions.

## **6.5 RISKS IN THE COASTAL ZONE**

### **Hazardous industries**

Information about the location of hazardous industries and the transport volumes linked to seaports is currently not available in common European-wide databases.

The Eurostat GISCO database contains information about the location of ports, but no information about transport volumes. The combination of these data could be used to assess transport routes and the potential of ship accidents due to traffic density.

The GISCO database is also able to provide information about the location of nuclear power stations (dated 1985), oil and gas pipelines, tanker terminals as well as oil and gas refineries. The drawback of the data is its coarse scale (1:3 Mio) and that most of the data has not been updated recently. Other information about chemical industries is not available.

### **Accidental and illegal discharges of oil at sea**

The EEA has already published a series of indicators on accidental and illegal oil spills at sea. Even though pollution by oil spills have been reduced by 60% since the 1970s, major oil spills from occur at irregular intervals.

A lack of information provided by the indicators published by the EEA is the location of the spills. Georeferenced information about accidents is currently limited to major events and information about illegal discharges (as collected by the International Maritime Organisation) is not available in georeferenced form.

## **6.6 STORM SURGES**

Consequences of climate change are sea level rise and the increase in frequency and height of storm surges. No information about predictions or modelling results of surge occurrences (scenarios) has been located so far.

Spatially detailed information about potential storm surges is important for the identification of coastal areas which are subject to high risks. By combing the information on storm surges with digital elevation models and maps of vulnerable zones (human, economical or ecological areas) maps of potential impacts can be generated.

### **Detailed digital elevation model**

A detailed elevation model with a vertical resolution of less than 1 meter is required for the areas flooded by accelerated sea level rise. The modelling scenarios are predicting changes in sea level in the range of several 10s of centimetres over the next 100 years. This cannot be represented with the current DEMs available at European level. If at all, only a worst case scenario with a rise of about 1 m could be modelled, but with a relatively high uncertainty, due to the precision of the DEM itself.

## 6.7 CONCLUSIONS

A conclusion that can be drawn from the assessment of other relevant indicators and data gaps is that there is an information need for certain indicators at the local or regional level, but the European level data sources are insufficient to supply the required detail. An example are the impacts of human activities on coastal erosion. Most of the impacts e.g. of the construction of coastal defence works are of local effects (erosion and sedimentation) and based on complex interactions that cannot be assessed or modelled with European level data.

A second issue concerns the geolocation of information. A lot of relevant information is collected without a detailed reference about its location. If expenses for coastal protection works are only available at a rather high level of administrative units (e.g. NUTS 2), it is not possible to allocate the cost for the maintenance of particular coastal segments. Such information details could be used also as a criteria in the decision tree for the identification of coastal erosion hotspots.

# ANNEXES

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## ANNEX 1 – TRENDS IN COASTAL EROSION

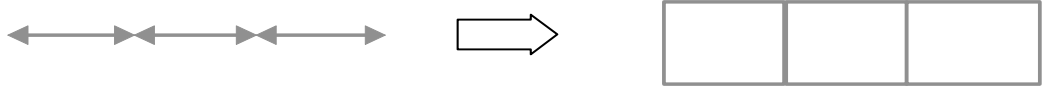
<p><b>Title</b></p> <p>Presence of coastal erosion (state 2002)</p>
<p><b>Interest</b></p> <p>EUROSION – presence of coastal erosion EEA – coastal erosion and propagation trends</p>
<p><b>Objective</b></p> <p>This indicator supports the generic question about the main environmental pressure in the coastal zones. It addresses the concrete policy question related to “What are the specific trends on the coastline?”</p> <p>The identification of the presence of coastal erosion without any judgement about its impact is a straightforward state indicator. The presence of erosion is considered to be neutral. This basic state indicator serves as input to further indicators which look at the impact of erosion and the policy response to it.</p>
<p><b>Reporting unit</b></p> <p>Segment level.</p> <p>The presence of coastal erosion is recorded at the level of the shoreline segments. The results can thus be analysed at this detailed level or aggregated to any bigger reporting unit, such as administrative regions as well as natural coastal units or watersheds.</p>
<p><b>Measurement unit</b></p> <p>Qualitative measurement.</p> <p>The attribute “erosion trends” is analysed and all segments in which erosion is confirmed or suspected are highlighted. Since the database does not provide quantitative measures of erosion rates, the presence of erosion will only be assessed in a qualitative way.</p>
<p><b>Detailed methodology</b></p> <p>In the updated version of the coastal erosion database the attribute “erosion trends” is assessed for the confirmed or presumed presence of coastal erosion. The different values of the attributes are mapped to illustrate the presence of erosion along the European coast.</p> <ol style="list-style-type: none"> <li>1. Display the line data set of the coastal erosion database.</li> <li>2. Select in attribute CETR all segments which have confirmed or presumed erosion.</li> <li>3. Display the selected segments according to a defined legend.</li> </ol>
<p><b>Missing data</b></p> <p>To date (Sep. 2002) the updated version of the coastal erosion database is not available. The coastal erosion database will be updated in the framework of the EUROSION project.</p> <p>Quantitative erosion rates (i.e. measurements of recession of the coastline in centimetres) are not available.</p>
<p><b>Processing cost</b></p> <p>The processing cost will probably be around 5 man days. This includes the data processing, filling of the meta database and an illustration of the results in a map. Filling of fact sheets is not</p>

included in the estimation.

**Update frequency**

The expected update frequency will be in the range of 10 to 20 years. This is related to the effort involved for the collection of the data and the time required in which erosion manifests changes.



<p><b>Title</b></p> <p>Changes in coastal erosion between 1985 and 2002</p>
<p><b>Interest</b></p> <p>EUROSION – changes in erosion trend</p> <p>EEA – coastal erosion and propagation trends</p>
<p><b>Objective</b></p> <p>This state indicator supports the generic question about the main environmental changes in the coastal zones. It addresses the concrete policy question related to “What are the specific trends on the coastline?”</p> <p>Aim of the indicator is to assess the difference in the evolution of the shoreline. The evolution of the shoreline records the prevailing trend in erosion at a specific stretch of the coastline for the past 5 to 10 years. By comparing the coastal erosion database from 1985 (version 1) with the version updated in 2002 major changes in coastal erosion trends can be detected.</p> <p>E.g. which areas have gone from stability to erosion or where has erosion be stopped over the last 20 years. Areas of major change can then serve as input to more detailed regional studies in which the reasons for change are more closely analysed.</p> <p>The analysis of the drivers of the change is not possible from the European database, since the drivers are normally local effects.</p>
<p><b>Reporting unit</b></p> <p>Segment level.</p> <p>The changes in coastal erosion are recorded at the level of the shoreline segments. The results can thus be analysed at this detailed level or aggregated to any bigger reporting unit, such as administrative regions as well as natural coastal units or watersheds.</p>
<p><b>Measurement unit</b></p> <p>Qualitative measurement.</p> <p>The attribute “erosion trends” is compared in the 2 databases. Since both databases do not provide quantitative measures, the changes can only be compared qualitatively.</p>
<p><b>Detailed methodology</b></p> <p>Both coastal erosion data sets (version 1 &amp; 2) are line data sets. Since both line data sets are not 100% identical and have no width, it is not directly possible to compare them automatically without any pre-processing.</p> <p>The following processing steps are necessary to compare the data:</p> <ol style="list-style-type: none"> <li>1. Convert one line data set into a polygon data set (e.g. version 2). This is done by buffering the line data set by a certain width. The width has to be determined from the maximum horizontal geometric difference between the two line data sets.</li> </ol> <p>The buffer needs to be defined on each segment (i.e. the unique segment code). The shape of the buffer at the end of the line segment should be set to flat (i.e. a line rectangular to the line to be buffered), not a half circle.</p> <p>Output: A polygon data set which corresponds to the line data set, but now with a width. This spatial extent allows to compare the 2 data sets.</p> 

2. Rename attributes of polygon data set by adding the year (i.e. 02) to it. Rename the line data set of the other version by adding the respective year (i.e. 85) to its attributes. This is required to avoid the same name of an attribute when both data sets (line & polygon) are combined.
3. Intersect line data set (version 1) with polygon data set (version 2). This step creates a "line-in-poly" data set and allows to assess the attributes (e.g. coastal erosion) of coincident line segments.



4. Assess the differences (change from 1985 to 2002) between version 1 and version 2.
5. Creation of a new line data set with an attribute that indicates the change from version 1 to version 2.

#### Missing data

To date (Sep. 2002) the updated version of the coastal erosion database is not available. The coastal erosion database will be updated in the framework of the EUROSION project.

Quantitative erosion rates (i.e. measurements of recession of the coastline in centimetres) are not available.

#### Processing cost

The processing cost will probably be around 12 man days. This includes the data processing, filling of the meta database and an illustration of the results in a map. Filling of fact sheets is not included in the estimation.

The uncertainty of the processing days is mostly due to questions related the potential software limitations (e.g. buffering of the line data in one output data set or several subsets).

#### Update frequency

The expected update frequency will be in the range of 10 to 20 years. This is related to the effort involved for the collection of the data and the time required in which erosion manifests changes.

<p><b>Title</b></p> <p>Trends in coastal erosion in correlation with budgets spent on coastal defence – changes between 1985 and 2002</p>
<p><b>Interest</b></p> <p>EUROSION – changes in erosion trend, effectiveness of defence works</p> <p>EEA – cost of erosion protection</p>
<p><b>Objective</b></p> <p>This indicator tries to assess the effectiveness of coastal defence works and to highlight regions where positive (resp. negative) changes in erosion patterns may be explained by higher (resp. lower) investments, which create a more explicit (and psychological) link between erosion natural processes and the level of responses.</p> <p>The indicator addresses the generic policy question whether policy responses are adequate. In particular the question about the effectiveness of coastal defence measures.</p>
<p><b>Reporting unit</b></p> <p>Segment or administrative level.</p> <p>The changes in coastal erosion are recorded at the level of the shoreline segments. The budgets allocated to coastal defence will only be available by administrative unit. The level of this unit is not known yet and can be different in the participating countries.</p>
<p><b>Measurement unit</b></p> <p>Qualitative measurement.</p> <p>The attribute “evolution of the coastline” is compared in the 2 databases and correlated with the cost for coastal defence in the same region.</p>
<p><b>Detailed methodology</b></p> <p>Since the budgetary information about coastal defence works will be available by administrative unit, the comparison of the erosion trends in correlation with the budget cannot be done at the level of the segments. The analysis will be done by administrative unit on which the budget information is supplied.</p> <ol style="list-style-type: none"> <li>1. Consider the output of the previous indicator (new line data set with erosion changes) development as input to this analysis.</li> <li>2. Attach to all coastal segments the information to which administrative unit they belong. <p>In a first step it has to be ensured that no segments of the coastal erosion database are laying further seaward than the boundaries of the administrative units. If yes, these segments have to be coded manually with their administrative unit code or the polygons of the administrative units have to be extended seawards to include all segments.</p> <p>By intersecting the administrative data set (polygons) with the coastal erosion database the attributes of both data sets are combined. When a segments extends across an administrative boundary the respective length in each unit will be counted.</p> </li> <li>3. Calculate the total distance of segments by evolution trend in both databases by administrative unit.</li> <li>4. Assess the total distance of segments that have changed in trend by type of trend by administrative unit.</li> <li>5. Correlate the budget spent on coastal defence with the changes in coastal erosion trends.</li> <li>6. Identify areas with a good cost – benefit ratio and less successful areas.</li> </ol>

**Missing data**

To date (Sep. 2002) the updated version of the coastal erosion database is not available. The information about budgets will be requested by a questionnaire sent out to various points of contact. The information will become available for administrative units.

The required information will be requested in the framework of the EUROSION project.

**Processing cost**

The processing cost is around 12 man days, starting from step 2. A time consuming step is the assignment of an administrative unit to each segment and the agreement on a classification of cost-benefit ratios, unsuccessful area, etc.

This estimation includes the data processing, filling of the meta database and an illustration of the results in a map. Filling of fact sheets is not included in the estimation.

**Update frequency**

The expected update frequency will be in the range of 10 to 20 years. This is related to the effort involved for the collection of the data and the time required in which erosion manifests changes. Information on budgets can be updated basically every year, but the manifestation of changes will only be possible on longer time ranges.

## ANNEX 2 – CLIMATE CHANGE – STORM SURGES

<p><b>Title</b></p> <p>Climate change – Storm surges &amp; area flooded</p>
<p><b>Interest</b></p> <p>EUROSION – consequences of climate change</p> <p>EEA – risks in coastal zones – hotspots of flooding, exceptional climatic events</p>
<p><b>Objective</b></p> <p>The indicator responds to the generic question of what are the main environmental impacts in the coastal zones. Specifically making reference to the policy question for specific impacts of climate change. Climate change is one of the most urgent environmental problems with potentially large impacts in the coastal zone.</p> <p>The acceleration of sea level rise in the 20<sup>th</sup> century is evidenced. Sea level rise can impact the coastal zone by floods caused by storm surges. These storm surges pose a particular threat to the coastal zones because even though most dikes can cope with a modest increase in sea level, storm surges might be able to top the dams due to a combination of increased mean sea level and extreme wave height.</p> <p>Catastrophic floods and surges due to extreme climatic events have effected large parts of the European coast in known history. In the 14<sup>th</sup> and 17<sup>th</sup> century 2 catastrophic events have resulted in the loss of more than two thirds of land in the north Friesian Wadden Sea. Likewise the storm surges of February 1962 are in “good” memory of the people of Hamburg when a surge of 4.7 m above mean sea level inundated large parts of Hamburg and killed 300 people.</p> <p>In order to estimate values at risk different flood scenarios are worked out and their influence on the hinterland of the dikes are assessed. The following values at risk can be illustrated:</p> <ul style="list-style-type: none"> <li>• Human developments (land cover)</li> <li>• Population (remapped to CLC)</li> <li>• Natural areas (EUNIS, NATURA2000)</li> </ul>
<p><b>Reporting unit</b></p> <p>Coastal or administrative units, spatially independent units based on flooded land.</p> <p>The reporting will also be depending on the fact whether the damage assessment is made for a specific dike failure or for all Europe in general.</p>
<p><b>Measurement unit</b></p> <p>Polygon data.</p> <p>Area (km<sup>2</sup>) flooded by coastal / administrative unit. → state indicator</p> <p>Human developments at risk (value class). → impact indicator</p> <p>People at risk. → impact indicator</p> <p>Ecological assets at risk. → impact indicator</p>
<p><b>Detailed methodology</b></p> <ol style="list-style-type: none"> <li>1. Obtain data for surge height from a modelling scenario.</li> <li>2. Determine all areas in the DEM which are below a certain threshold. The threshold is defined</li> </ol>

by the height of the surge above mean sea level.

The areas selected represent the flooded areas in case of specific storm surges. This corresponds to the state indicator mentioned above.

In order to assess the impact of the storm surge, the information about the flooded area is overlaid with information about values at risk. Human developments and infrastructure are identified from CORINE land cover (CLC), people at risk are obtained from the data set on population density remapped to CLC and ecological assets are identified from the NATURA 2000 GIS database.

3. Overlay the effected area with the different values at risk (economic, people, ecological)
4. Report the area and location effected by the surge for the 3 different value classes.
5. The results are presented in table form as well as in a map.

#### **Missing data**

A step that is still somewhat uncertain in the development of an indicator on storm surges are the storm surge scenarios themselves. Most information on storm surges is not georeferenced, furthermore scenarios for modelling the probability of storm surges occurrences are not available yet.

Flooding due to storm surges can be modelled more easily than floods due to sea level rise because of the bigger vertical height of surges. This is especially important for EUROSION, since the project does not dispose of a DEM with less than 1 m vertical resolution.

#### **Processing cost**

About 12 days for the first value class plus another 3 for each additional value class, including data processing, meta data and creation of an illustrative map. This results in approx. 22 man days for the processing of all 4 indicators mentioned.

Filling of fact sheets is not included in the estimation.

#### **Update frequency**

The expected update frequency will be in the range of 10 to 20 years or sooner if better input data or different scenarios become available

## ANNEX 3 – EROSION HOTSPOTS

<p><b>Title</b></p> <p>Erosion hotspots – impact of coastal erosion on economic and ecological assets in the coastal zone</p>
<p><b>Interest</b></p> <p>EUROSION – measure of the impact of coastal erosion on economical assets at risk, impact on natural areas</p> <p>EEA – impact of coastal erosion on biodiversity / real estate.</p>
<p><b>Objective</b></p> <p>The indicator replies to the request for identification of hotspots of coastal erosion. Furthermore the indicator can be used to locate vulnerable areas in the coastal zone. Finally the indicator addresses the impact of coastal erosion in the coastal zone in combination with a quantification of the impact in terms of values (e.g. capital) at risk.</p> <p>Hotspots of coastal erosion are identified by an objective decision tree based on the content of the coastal erosion database.</p> <p>Through the evaluation of certain database variables (e.g. erosion: Y/N; presence of defence works: Y/N; and coastal morphology) regions with a presence of actual or potential erosion are identified. By overlying those areas of potential erosion with information about values at risk (e.g. land cover, protected areas) vulnerable areas are identified.</p> <p>In case the area in which actual or potential erosion is detected puts pressure on an economic and ecological asset, this area is then called an erosion hotspot. The pressure is identified here as vicinity to an asset. Different degrees of hotspots can be discerned depending on whether the erosion is impacting on more or less valuable regions or the actual probability of the accelerated erosion to have an impact at all (i.e. whether the sites should be called a hotspot or not).</p> <p>By combining the hotspot information with population figures, the urban areas at risk can be further classified into classes of importance. The assumption is that a defence work in front of a million inhabitant city is more important (in terms of capital at risk) than a defence in front of a small village.</p>
<p><b>Reporting unit</b></p> <p>Coastal segment or administrative unit.</p>
<p><b>Measurement unit</b></p> <p>Point data.</p> <p>Qualitative information about the presence of accelerated erosion in combination with economic and ecological assets at risk. Economic and ecological assets at risk will be illustrated by a specific indicator each.</p>
<p><b>Detailed methodology</b></p> <ol style="list-style-type: none"> <li>1. Determine areas with presence of erosion from the coastal erosion database and the decision tree. This leads to an identification of a number of coastal segments.</li> <li>2. Assess the hinterland of areas with presence of erosion with respect to economic assets or ecological assets. Buffer the coastal segments of accelerated erosion by a defined width (e.g. 500 m).</li> <li>3. Overlay the buffered segments (i.e. the areas with presence of erosion) with the CLC</li> </ol>

database to assess economic risks (urban /economic areas at risk) and with the NATURA 2000 GIS database to assess ecological areas at risk.

4. If economic and ecological assets are detected within the buffer, the coastal segment is classified as erosion hotspot according to the degree defined in the decision tree.
5. To even further the assessment and determination of the capital at risk, population figures remapped to CLC can be used to determine the importance of an urban area. Since land cover information from the CLC database is neutral in the definition of urban areas with respect to their importance, the number of inhabitants can provide this additional information.

This will allow assessing the value of an urban asset under pressure from erosion.

Output of these processing steps will be a series of three erosion hotspot indicators with respect to different assets under pressure.

### **Missing data**

Information about erosion hotspots is not available from the EUROSION database. Therefore this information has to be modelled. The modelling process is summarised in a decision tree based on the content (attributes) of the coastal erosion database.

The availability of the population density database remapped to CLC to the project has to be confirmed and whether the data is a format directly accessible by a GIS (e.g. shapefile or raster data set). The database has been produced by the JRC under contract for Eurostat GISCO.

The NATURA 2000 GIS database with digital boundaries of the protected sites are currently not yet available to the project. The production of the data is contracted out by DG Environment. In case the NATURA 2000 GIS database is not available the location of the protected sites can be approximated by a point and a buffer according to the area of the site.

### **Processing cost**

About 20 days for the first value class plus another 3 for each additional value class and as well 5 days for the integration of population data (step 5), including data processing, meta data and creation of an illustrative map. Filling of fact sheets is not included in the estimation. This results in a total of approx. 30 man days.

The automation of the decision tree in the processing flow will be a major milestone of the first 20 man days.

### **Update frequency**

The update frequency depends on the availability of new data. While for the erosion and land cover database an update cycle of 10 years will not be underestimated, the database on protected sites is under constant change.



## ANNEX 4 – CLIMATE CHANGE – SEA LEVEL RISE

<p><b>Title</b></p> <p>Climate change: Sea level rise (I) by coastal unit</p>
<p><b>Interest</b></p> <p>EUROSION – consequences of climate change EEA – risks in coastal zones – sea level rise</p>
<p><b>Objective</b></p> <p>The indicator responds to the generic question of what are the main environmental changes in the coastal zones. Specifically making reference to the policy question about specific trends. Climate change is one of the most urgent environmental problems with potentially large impacts in the coastal zone.</p> <p>The acceleration of sea level rise in the 20<sup>th</sup> century is evidenced. The IPCC has modelled scenarios in which a rise between 9 and 88 cm between 1990 and 2100 is projected. Sea level rise can impact the coastal zone through increased erosion or floods.</p> <p>The indicator presented here will illustrate sea level rise by coastal units / coastal segments (colour coding of the shoreline).</p>
<p><b>Reporting unit</b></p> <p>The reporting unit will be most probably by administrative or coastal units.</p> <p>The reporting per segment will not be possible due to the lack of detailed sea level rise information.</p>
<p><b>Measurement unit</b></p> <p>Line and point information.</p> <p>The impact can be measured in absolute amount of rise [cm] for the shoreline.</p>
<p><b>Detailed methodology</b></p> <ol style="list-style-type: none"> <li>1. Obtain information about sea level rise scenarios. The data should be available for a more detailed regional breakdown than regional seas. While it is obvious that a segment level will not be feasible, an output by NUTS 3 regions would already represent a valuable result.</li> <li>2. Link the SLR information to the coastal erosion database.</li> <li>3. Display the shoreline data set according to the expected rise with the target time scale.</li> <li>4. Map the worst case flood scenario by assuming a 1 meter SLR and determine all areas with an elevation less or equal to 1 m above mean sea level.</li> </ol>
<p><b>Missing data</b></p> <p>Sea level rise scenarios for the next 100 years are not available from the EUROSION database, only historic records.</p> <p>A detailed DEM with a vertical resolution of &lt; 1 metre is required to assess various scenarios of sea level rise and the areas under pressure from flooding. Since the project will only dispose of a DEM with 1 m vertical resolution, only the worst case, long-term scenario (1 m rise in 100 years) of flooded areas could be illustrated.</p>

**Processing cost**

About 12 days, including data processing, meta data and creation of an illustrative map. This estimate does not include the SLR scenarios. Filling of fact sheets is not included in the estimation.

**Update frequency**

Updates of the indicator are possible with new basic data. This concerns either new sea level rise scenarios, a better spatial (regional) detail of these scenarios or even a DEM with a higher vertical resolution (although this is not very likely to happen).

<p><b>Title</b></p> <p>Climate change: Sea level rise (II) – shoreline recession (worst case scenario only)</p>
<p><b>Interest</b></p> <p>EUROSION – consequences of climate change</p> <p>EEA – “erosion hotspots” even though no values at risk are assessed</p>
<p><b>Objective</b></p> <p>The indicator responds to the generic question of what are the main environmental pressures in the coastal zones. Specifically making reference to the policy question about specific trends. Climate change is one of the most urgent environmental problems with potentially large impacts in the coastal zone.</p> <p>The acceleration of sea level rise in the 20<sup>th</sup> century is evidenced. The IPCC has modelled scenarios in which a rise between 9 and 88 cm between 1990 and 2100 is projected. Sea level rise can impact the coastal zone through increased erosion or floods.</p> <p>Coastal erosion is caused by the action of the sea in combination with other factors such as wind and rain. The Bruun rule specifies that in a sandy beach region the shoreline retreat is about 100 times the rise in sea level.</p> <p>The indicator presented will try to define similar recession trends for different coastal morpho-sedimentological types (based on literature search and expert judgement). Applying these recession rates to the current shoreline the effect will be illustrated by colour-coding the single coastal segments.</p>
<p><b>Reporting unit</b></p> <p>Coastal segments.</p>
<p><b>Measurement unit</b></p> <p>Line information.</p> <p>Estimated shoreline recession in meters</p>
<p><b>Detailed methodology</b></p> <ol style="list-style-type: none"> <li>1. Access information about sea level rise from previous indicator.</li> <li>2. Define shoreline recession rules for different types of coastal morphology.</li> <li>3. Add the estimated value for SLR to coastline data (new attribute).</li> <li>4. Add the estimated recession factor to coastline data (new attribute).</li> <li>5. Multiply SLR and recession factor to determine the absolute value of coastline retreat per segment.</li> <li>6. Illustrate recession distance in a map by colour-coding the distance in 5 classes (max.).</li> </ol> <p>Optional steps:</p> <ol style="list-style-type: none"> <li>7. Buffer each segment by the absolute value calculated in step 5.</li> <li>8. Create new coastline.</li> </ol>
<p><b>Missing data</b></p> <p>Sea level rise scenarios for the next 100 years are not available from the EUROSION database, only historic records.</p> <p>Recession rates for coastal segments, similar to the Bruun rule, are not available in the database. Their development and agreement would be a very time consuming task.</p>

**Processing cost**

Not assessed, due to unclear input data situation.

**Update frequency**

Not assessed.

## ANNEX 5 – IDEAS FOR ADDITIONAL INDICATORS

The indicators presented on the following pages have been considered during the assessment of the feasibility of indicators in the coastal zones, but they were considered to be not feasible due to non-availability of data or for other reasons.

<p><b>Title</b></p> <p>Coastal erosion and propagation trends – rate of coastal erosion</p>
<p><b>Objective</b></p> <p>The indicator supports the generic question about the main environmental changes in the coastal zones. It addresses the concrete policy question related to “What are the specific trends on the coastline?” The indicator can only be calculated for the French coast.</p> <p>The rate of coastal erosion at which certain parts of the shoreline are retreating serves as an important input for the identification of erosion hotspots. Furthermore the quantification of erosion rates allows to make more concrete assessments about values at risk over different time spans (short, medium, long-term).</p> <p>On a more local scale the erosion rate can be compared to the existing methods for combating erosion in the vicinity and their impact can be evaluated.</p>
<p><b>Reporting unit</b></p> <p>Segment level.</p> <p>The speed of coastal erosion is recorded at the level of the shoreline segments. The results can thus be aggregated to any bigger reporting unit, such as administrative regions as well as natural coastal units or watersheds.</p>
<p><b>Measurement unit</b></p> <p>Line data.</p> <p>Meters of landward movement of the shoreline.</p>
<p><b>Detailed methodology</b></p> <p>No detailed analysis necessary for the identification of erosion hotspots.</p> <p>Erosion rates are classified into a number of ranges (meter / year). Number of classes are to be discussed. For each class a degree of severity is defined upon expert judgement.</p> <p>A new attribute with the erosion speed severity is added to the data set. Coastal segments falling into the most severe class are classified as erosion hotspots.</p>
<p><b>Missing data</b></p> <p>Information on the rate of erosion is not available. Definition of erosion hotspots based on erosion rates are not available.</p>
<p><b>Processing cost</b></p> <p>Not assessed.</p>
<p><b>Update frequency</b></p> <p>Not assessed.</p>

<p><b>Title</b></p> <p>Impact of coastal erosion on protected land (i.e. biodiversity)</p>
<p><b>Objective</b></p> <p>The indicator answers to the generic question of specific impacts of increasing pressure on the coastal zone. The concrete policy question addressed is “What are the impacts on coastal biodiversity?”</p> <p>It is clear that there are not only impacts in the coastal zone leading to erosion, but coastal erosion certainly has an impact on the environment in the coastal zone. The indicator assesses the impact of coastal erosion on land protected by a specific legislation.</p> <p>The impact of coastal erosion is expressed by the rate of erosion and therefore the risk of the protected area to be destroyed due to its land being washed away by action of the sea. The impact can be differentiated in short, medium and long-term effects.</p> <p>The impact of coastal erosion can be significant in the case of steep cliffs which are used by birds for nesting.</p>
<p><b>Reporting unit</b></p> <p>Segment level.</p> <p>The speed of coastal erosion is recorded at the level of the shoreline segments. The results can thus be aggregated to any bigger reporting unit, such as administrative regions as well as natural coastal units or watersheds.</p>
<p><b>Measurement unit</b></p> <p>Polygon data.</p> <p>Area of protected land subject to erosion in short, medium and long-term.</p>
<p><b>Detailed methodology</b></p> <p>The processing has to solve a number of issues in order to provide the desired input for the development of an indicator.</p> <ol style="list-style-type: none"> <li>1. Identify those protected areas which are either directly situated on the coast or which are in the influence zone of erosion hotspots. The maximum influence zone of erosion is determined by the maximum yearly erosion rate in the database multiplied with the maximum range of years for long-term assessment of impacts (e.g. 10 m/year * 100 year = 1 km max. influence zone).</li> <li>2. Buffer the coastline by the width of the max. influence zone (e.g. 1 km).</li> <li>3. Overlay buffer zone and protected areas and select all protected areas which are fully or partly within the buffer zone (i.e. 1 km from the coastline).</li> <li>4. Create a separate attribute in the coastal erosion database which contains a numeric value of the erosion rate for each segment (if not already existing).</li> <li>5. Add 3 new attributes with the distance of coastal erosion that will be reached on short, medium and long-term. Therefore short, medium and long-term need to be transformed into number of years. The erosion rate /year is multiplied with the respective number of years and the result is stored in the new attribute.</li> <li>6. Buffer each segment of the coastal erosion data set with the distance that coastal erosion will reach under a specific time range (short, medium and long-term).</li> <li>7. Intersect the protected areas (identified in step 1) with the buffer zone of a specific time range.</li> <li>8. If a protected area intersects with the buffer zone, determine the area common to both input data sets. This area is the area lost due to coastal erosion during the specific time range in</li> </ol>

question. If a protected area does not intersect with the buffer zone, then this site is not effected by erosion during the examined time range.

When assessing the sites impacted on the long term, then all sites identified in step 1 should be effected.

**Missing data**

The required information about the rate of erosion does not exist to date.

**Processing cost**

Not assessed.

**Update frequency**

Not assessed.

<p><b>Title</b></p> <p>Impact of coastal erosion on existing infrastructures (capital at risk)</p>
<p><b>Objective</b></p> <p>The indicator answers to the generic question of specific impacts of increasing pressure on the coastal zone. The concrete policy question addressed is “What are the impacts on coastal infrastructures and investments?”</p> <p>It is clear that there are not only impacts in the coastal zone leading to erosion, but coastal erosion certainly has an impact on the land in the coastal zone. The proposed indicator assesses the impact of coastal erosion on capital investments made in the coastal zone.</p> <p>The impact of coastal erosion is expressed by the rate of erosion and therefore the risk of the infrastructures to be destroyed due to its land being washed away by action of the sea.</p> <p>By considering the LACOAST data, regions of with a high pressure from urbanisation can be identified. Therefore LACOAST data can be used to identify regions with a high potential for continuous urbanisation in the coastal zone in the future.</p> <p>These area subject to urban sprawl can be compared to areas subject to accelerated coastal erosion and eventually leading to areas in which new development will be under immediate threat by erosion.</p>
<p><b>Reporting unit</b></p> <p>To be discussed.</p>
<p><b>Measurement unit</b></p> <p>Polygon data.</p> <p>Surface of built-up area subject to erosion. Capital at risk?</p>
<p><b>Detailed methodology</b></p> <p>It is proposed to calculate the current indicator for the French data only. The French CCEr database contains information on erosion rates which are not collected in the other countries.</p> <ol style="list-style-type: none"> <li>1. Identify those urban areas which are either directly situated on the coast or which are in the influence zone of erosion hotspots. The maximum influence zone of erosion is determined by the maximum yearly erosion rate in the database multiplied with the maximum range of years for long-term assessment of impacts (e.g. 10 m/year * 100 year = 1 km max. influence zone).</li> <li>2. Buffer the coastline by the width of the max. influence zone (e.g. 1 km).</li> <li>3. Overlay buffer zone and urban areas and select all urban areas which are fully or partly within the buffer zone (i.e. 1 km from the coastline).</li> <li>4. Create a separate attribute in the coastal erosion database which contains a numeric value of the erosion rate for each segment (if not already existing).</li> <li>5. Add 3 new attributes with the distance of coastal erosion that will be reached on short, medium and long-term. Therefore short, medium and long-term need to be transformed into number of years. The erosion rate /year is multiplied with the respective number of years and the result is stored in the new attribute.</li> <li>6. Buffer each segment of the coastal erosion data set with the distance that coastal erosion will reach under a specific time range (short, medium and long-term).</li> <li>7. Intersect the urban areas (identified in step 1) with the buffer zone of a specific time range.</li> <li>8. Assign to each urban land cover class a monetary value per surface area unit (e.g. km<sup>2</sup>).</li> <li>9. If an urban area intersects with the buffer zone, determine the area common to both input</li> </ol>



<p>data sets. This area is the area lost due to coastal erosion during the specific time range in question.</p> <p>10. Multiply the area lost with its monetary value to determine the capital lost within this time range.</p> <p>Use Bruun rule to extend indicator to all European coasts?</p>
<p><b>Missing data</b></p> <p>The required information about the rate of erosion does not exist to date.</p> <p>Information about monetary values of urban areas has not been determined yet.</p>
<p><b>Processing cost</b></p> <p>Not assessed.</p>
<p><b>Update frequency</b></p> <p>Not assessed.</p>

<p><b>Title</b></p> <p>Impact of human activities in coastal zones – extension of harbour facilities</p>
<p><b>Interest</b></p> <p>EUROSION – impact of human activities EEA – no link in COAST 4 or 5</p>
<p><b>Objective</b></p> <p>The indicator relies on CORINE land cover information from LACOAST (1975), CLC90 and CLC2000. The area occupied by harbour facilities in the coastal zones are extracted from the databases and compared. In addition the transport volume for the same years will be assessed.</p> <p>Change in surface area and increase in transport volume are summarised in one value that can be used to assess the impact of human activities in the coastal zone.</p>
<p><b>Reporting unit</b></p> <p>Coastal unit, administrative unit</p>
<p><b>Measurement unit</b></p> <p>Change of surface occupied by harbour facilities</p>
<p><b>Detailed methodology</b></p> <ol style="list-style-type: none"> <li>1. Intersect the CLC data with another data set to provide each harbour facility with a unique identifier. The ID can be used in subsequent steps to assess the area change for each location separately.</li> </ol> <p>If no unique layer is available, the CLC data can also be intersected with administrative boundaries. The drawback of the boundary layer is that large facilities can extend across borders.</p> <ol style="list-style-type: none"> <li>2. Extract areas related to harbour facilities from the CLC databases. Only harbour facilities within a 10 km stretch from the coastline will be considered.</li> <li>3. Assess the changes in surface area for each facility.</li> <li>4. Aggregate the change information by the desired output unit.</li> <li>5. Link the transport volume information to each facility.</li> <li>6. Multiply the surface change with the change in transport volume</li> </ol>
<p><b>Missing data</b></p> <p>Information about transport volume is not available.</p>
<p><b>Processing cost</b></p> <p>Not assessed.</p>
<p><b>Update frequency</b></p> <p>Not assessed.</p>

<b>Title</b>	Impact of human activities in the coastal zone – tourism
<b>Interest</b>	EUROSION – impact of human activities EEA – no link in COAST 4 or 5
<b>Objective</b>	<p>Mass tourism is a significant stress factor for coastal zones, since they occupy the top position among the most favourite recreational areas. This has often a non-reversible influence on the coastal ecosystems.</p> <p>Permanent constructions have destroyed many natural habitats. In addition many activities have a negative impact on coastal and ocean ecosystems.</p> <p>On the other hand, tourism in the coastal zones is a vital economic factor in many countries. This income source has to be compared to the cost of maintaining coastal beaches and other assets. At which economic and ecological expense is tourism sustainable.</p>
<b>Reporting unit</b>	Not assessed.
<b>Measurement unit</b>	Not assessed.
<b>Detailed methodology</b>	Not assessed.
<b>Missing data</b>	Information on tourist expenditures in the coastal zone, number of nights spent, length of the tourist season.
<b>Processing cost</b>	Not assessed.
<b>Update frequency</b>	Not assessed.

<p><b>Title</b></p> <p>Risks in coastal zones</p>
<p><b>Interest</b></p> <p>EUROSION – impact of human activities</p> <p>EEA – risks in coastal zones – hazardous industries</p>
<p><b>Objective</b></p> <p>Significant parts of the European coast are industrialised. Most intensely developed areas include large deltas and estuaries. Excessive loads of contaminants in the coastal zone are primarily due to industrial and urban waste water discharges.</p> <p>Moreover the siting of hazardous industries along the coast represents a significant potential for harmful impacts (accidents) on the coast.</p>
<p><b>Reporting unit</b></p> <p>Coastal unit</p>
<p><b>Measurement unit</b></p> <p>Line and point data.</p> <p>Number of kilometres of shoreline under pressure from hazardous industries.</p>
<p><b>Detailed methodology</b></p> <p>The GISCO database contains information about the location of nuclear power stations (situation refers to 1985), oil and gas pipelines, tanker terminals, oil and gas refineries as well as ports. The drawback of this data is that it exists at rather coarse scale only (1:3 Mio) and that most of the data has not been updated recently.</p> <p>Data processing includes the following steps:</p> <ol style="list-style-type: none"> <li>1. Extract the location of hazardous industries in the coastal zone from the data sets. The extraction can be done by intersecting the GISCO data with a 10 km buffer along the coastline.</li> <li>2. Identify coastal units in which a cluster of hazardous industries is present. The more industries are located in the coastal zone, the higher the pressure on the coastal unit.</li> <li>3. Map the coastal units according to their pressure index.</li> </ol>
<p><b>Missing data</b></p> <p>No spatially based information about the localisation of chemical industries.</p>
<p><b>Processing cost</b></p> <p>Not assessed.</p>
<p><b>Update frequency</b></p> <p>Not assessed.</p>

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