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TIDE TIMES

Tidal River Development

The Interreg IVB North Sea Region Programme

Investing in the future by working together for a sustainable and competitive region

European Union
European Regional Development Fund

INTRODUCTION

Dear friends of TIDE:

A start has been made!

After a long time of preparations and meetings with so many intensively involved partners contributing to shape the outline of the project , TIDE has now set off to enhance Europe's state of the art in management of its beautiful, precious and economically important estuaries.

Focusing on North Sea Region estuaries under a strong tidal influence, protected by European directives and serving as fairways to important seaports, TIDE has gathered some of the leading European experts from universities, port authorities, waterways administrations and others, to find multi-beneficial solutions for future sustainable estuary development. Acknowledging the great importance of this challenging task, TIDE was approved by the Interreg IVB North Sea Programme in 2009.

Among the first working steps of TIDE are the collection of existing knowledge and the identification of knowledge gaps on estuarine functioning and estuarine ecosystem services. Based on this and with the assistance of regional working groups, state-of-the-art governance solutions can be identified and transferred to other European estuaries through conferences, workshops, lectures, TIDE on-the-road events and information materials.

The project was officially started in February 2010 with a Kick-Off Conference in Antwerp. As an introduction to the project, as well as documentation of the presentations and discussions held during the Antwerp conference, I am proud to present the first issue of *TIDE Times!* Through this publication TIDE will continue informing the public over the next three years about its progress, achievements and developments in the field of estuary management.

Sincerely yours,

Manfred Meine
Hamburg Port Authority
TIDE Project Lead Partner

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THE ORIGINS OF THE TIDE PROJECT

Heinz Glindemann – Hamburg Port Authority

The driving force for the Hamburg Port Authority to bring estuary-experts together in one project were the significant changes which have taken place at the river Elbe over the last decades. Anthropogenic changes such as dyking and siltation of river branches and side banks are major drivers of the increase in tidal range and the massive loss of shallow water areas at the tidal river Elbe. As a consequence of these changes, dredging necessities in the port of Hamburg have increased considerably (Figure 1).

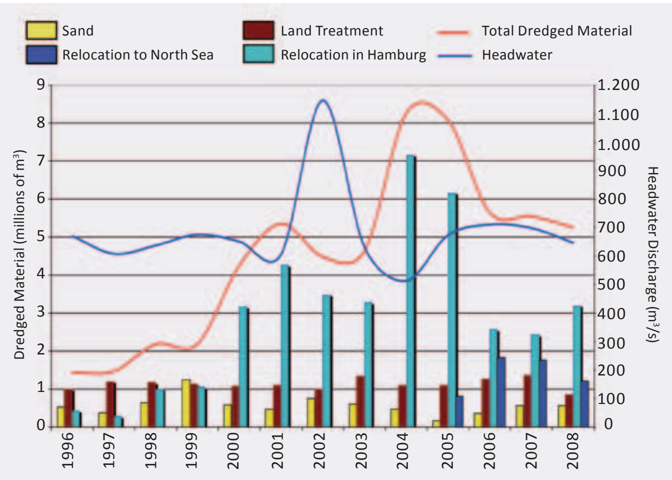

Figure 1.
Development of the volume of material dredged from the port of Hamburg (red line) and freshwater discharge (blue line) during the past decades. Credit: Hamburg Port Authority.

The first inter-estuary exchanges took place during meetings within the CEDA (Central Dredging Association), where experts studied and compared problems at different estuaries. It became clear that more scientific background was needed and most importantly, that the estuary systems needed an integrated management approach to solve their problems.

Discussions in the EU Estuaries working group of experts to provide guidance for the implementation of the Bird and Habitats Directive made it even clearer that a European exchange of experience and knowledge was necessary to compare the challenges of the different estuaries and to get new ideas for the right management strategy. Therefore, a small group under the leadership of the Hamburg Port Authority began looking around for competent partners resulting in the TIDE partnership, which includes the river Elbe (DE), the river Weser (DE), the river Humber (UK) and the river Scheldt (BE/NE).

The criteria for selecting the partner estuaries in TIDE were:

- Shipping channels leading to large seaports inland
- Strong tidal influence
- Massive sediment transport
- Designated NATURA 2000 sites

The involved partners belong to port authorities, universities, and environmental and public agencies (Figure 2).

The aims of TIDE are to identify knowledge gaps in hydrology, morphology and ecology, and integrate planning in local policy while ensuring that NATURA 2000 and Water Framework Directive requirements are met.

We are glad to have all on board and look forward to a fruitful future for the estuaries!

TIDE PARTNERS

ELBE | DE

Hamburg Port Authority (Lead Partner)
Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN)

SCHELDT | NL, BE

Rijkswaterstaat
Flemish Authorities Department of Mobility and Public Works
Antwerp Port Authority
University of Antwerp

WESER | DE

Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN)
Free Hanseatic City of Bremen
University of Bremen

HUMBER | UK

Institute of Estuarine and Coastal Studies, University of Hull (IECS)
Environment Agency

Figure 2.
TIDE project partner institutions.

The TIDE project will be implemented between January 2010 and December 2012. A budget of 3,7 million € is available, sponsored by 50 % by the European Regional Development Fund, financed through the Interreg IV B North Sea Programme, and by 50 % by input of the partners.

Project Advisory Board

TIDE has designated an Advisory Board whose members represent different types of expert knowledge and bring outside perspectives from other estuaries. They will advise TIDE in its various activities and promote the project within their own networks.

Heinz Glindemann – Hamburg Port Authority (DE) (Chairman)
Jean Berlamont – Hydrolics Lab, Catholic University Leuven (BE)
Beatrice Claus – WWF Germany (DE)
Victor de Jonge – Honorary Professor at IECS UK, Ems specialist (NL)
Wivina de Meester – Former Minister of Finance / Health in Flemish and Federal BE Governement (BE)
Tony Edwards – Humber Industry Nature Conservation Association (UK)
Harro Heyer – German Federal Waterways Engineering & Research Institute, Coastal Division Director (DE)
Louis-Alex Romana – IFREMER, Former Director GiP Seine Aval (FR)
Michael Schirmer – Dyke Association Weser (DE)
Hans Heinrich Witte – German Federal Administration of Waterways and Navigation, President (DE)

COMMON CHALLENGES

THE VALUE AND EVOLUTION OF ESTUARIES

Long ago, many large and important cities were established in freshwater tidal zone of estuaries, in part because it was the most inland point that could be reached by ships. Estuaries were ideal, sheltered locations for the establishment of international trade and economic hubs. As societies and human welfare developed, the demand for more supplies and trade, hence ship dimensions, grew accordingly. Deeper fairways were then needed. But a deepening of the system results in tide amplication, especially if the estuarine mouth is funnel shaped. Furthermore, land reclamation also has a strong impact on tide amplification. So while ports continue to provide shelter against the surf, the issue of increasing tidal wave has become a global cause for concern, paralleled by a growing need for safety against floods.

Estuaries are also ecologically valuable, as they are unique sea-river corridors providing migration routes for many species between marine and fresh water habitats. They serve as shelter, as nursery, spawning, and feeding grounds, as resting sites or as permanent living habitat for many species. This biological productivity originates in the fact that estuaries receive the input from the whole adjacent river catchment. But estuarine habitats have witnessed a long history of degradation. Land winning, fairway deepening, increasing emissions have all had their impact on habitat quantity and quality.

The legal and global economic framework, combined with the growing threat posed by sea level rise, are increasingly challenging. Endangered ecosystem functions such as flood regulation, coastal protection, water purification, habitat structure and diversity need to be addressed in an integrated way.

THE TIDE ESTUARIES

The Schelde is the longest of the four TIDE estuaries, but it has the smallest river catchment area (Figure 3). The catchment area of the Elbe is by far the largest and is about 3 times larger than that of the Weser. Each estuary hosts at least one major port. The ports of Hamburg (Elbe), Antwerpen (Schelde), Bremen/Bremerhaven (Weser) and Immingham, Grimsby, Goole and Hull (Humber) jointly add up to about 500 million tons of traffic turnover per year. All estuaries have protected sites and ongoing restoration projects of various kinds.

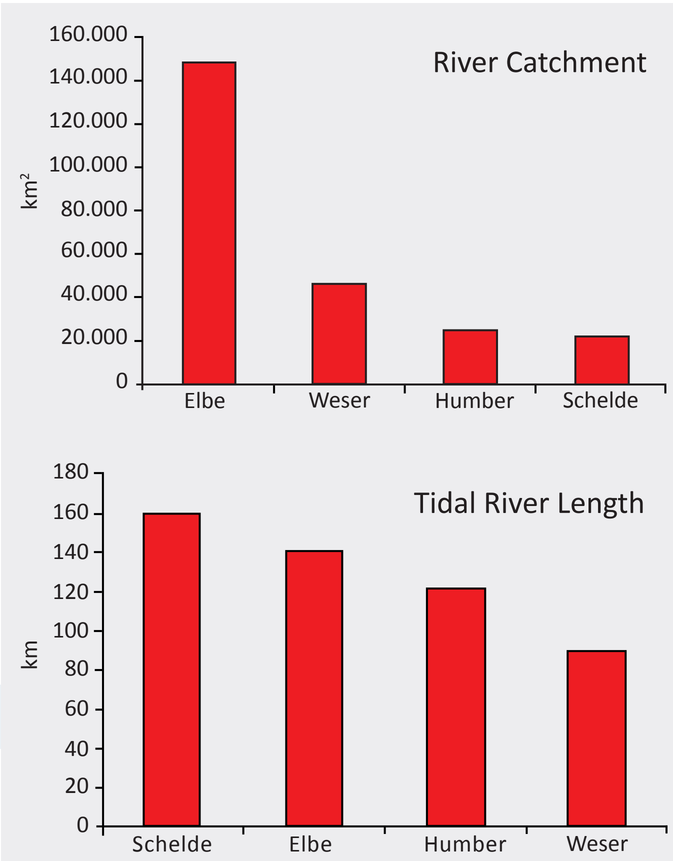

Figure 3.
River catchment area (above) and length (below) of the TIDE estuaries.

TIDE ACTIVITIES

SCIENCE AND ITS STRUCTURAL FRAME

Coordinator: University of Antwerp

TIDE will advance scientific knowledge about estuary functioning by analysing and integrating geomorphological, hydrodynamic and ecologic data for each estuary and conducting an interestuary comparison.

TIDE's structural framework is centered around the concept of ecosystem services (see page 14). This unifying concept makes it possible to clarify to a broader public what benefits we get from ecosystems and to make a link between ecology and economy, as the ecosystem services can be valued in economic terms.

Through this holistic approach, TIDE will define and describe the ecosystem services provided by each estuary and the benefits we receive from them (Figure 4), estimate their importance and quantify them. Only then can these services be linked to the habitat needs and conditions necessary to ensure their provision, and thus the management measures required.

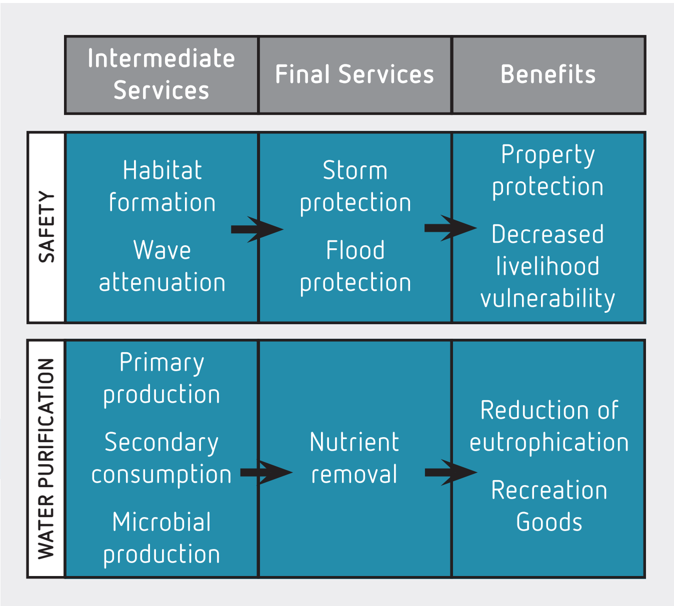

Figure 4.
Example of an estuary's intermediate and final ecosystem services and the benefits we draw from them.

INTEGRATED MANAGEMENT AND GOVERNANCE

Coordinator: IECS, University of Hull

TIDE estuaries have a variety of development and management plans, sectoral strategies, EU Directives and other regional and national policies to comply with. However, none of them has properly integrated plans and the institutional structures do not support holistic management solutions. TIDE's goal is to develop an integrated management planning framework for estuaries, building on existing structures and using a multi-manager sectoral framework.

TIDE will use Regional Estuary Working Groups involving partners and stakeholders with management, scientific or other interests to bring together a range of information and expertise about each estuary.

Through these groups TIDE will develop a range of »good practices« based on governance structures from each estuary. Building on this and a common set of goals, TIDE will produce a *Generic Integrated Estuarine Management Plan,* which will be rolled out in each estuary and refined based on the findings (Figure 5). This will result in *Site Specific Integrated Estuarine Management Plans* for each estuary which address issues more prevalent in some estuaries than others, include specific tools on a sectoral basis and activities to promote better integration.

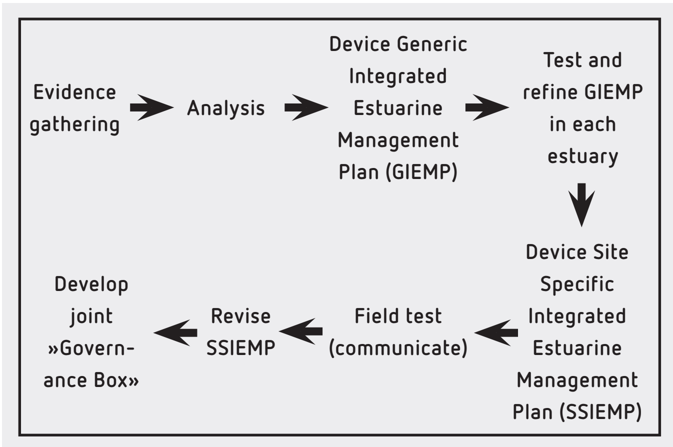

Figure 5.
Summary of the process TIDE will use to develop a framework for better integration of existing sectoral strategies.

PRACTICAL MEASURES

Coordinator: NLWKN

Even the best science-based planning will only lead to a sustainable and integrative management of the estuarine ecosystem if it is successfully turned into practice. Many management measures often do not reach the expected ecological effectiveness because of faults and uncertainties regarding selection, planning or implementation.

Based on a collection of practical experience regarding management, restoration, mitigation and compensation measures relevant to the four estuaries, TIDE will deduce recommendations for their optimised handling (Figure 6). This will be done by compiling examples of both successful and non successful practical measures, assessing their impact, legal framework, cost-effectiveness, and public acceptance.

This compilation of proven measures will serve both as a learning and support tool during the process of planning and implementing a number of pilot projects in the TIDE estuaries.

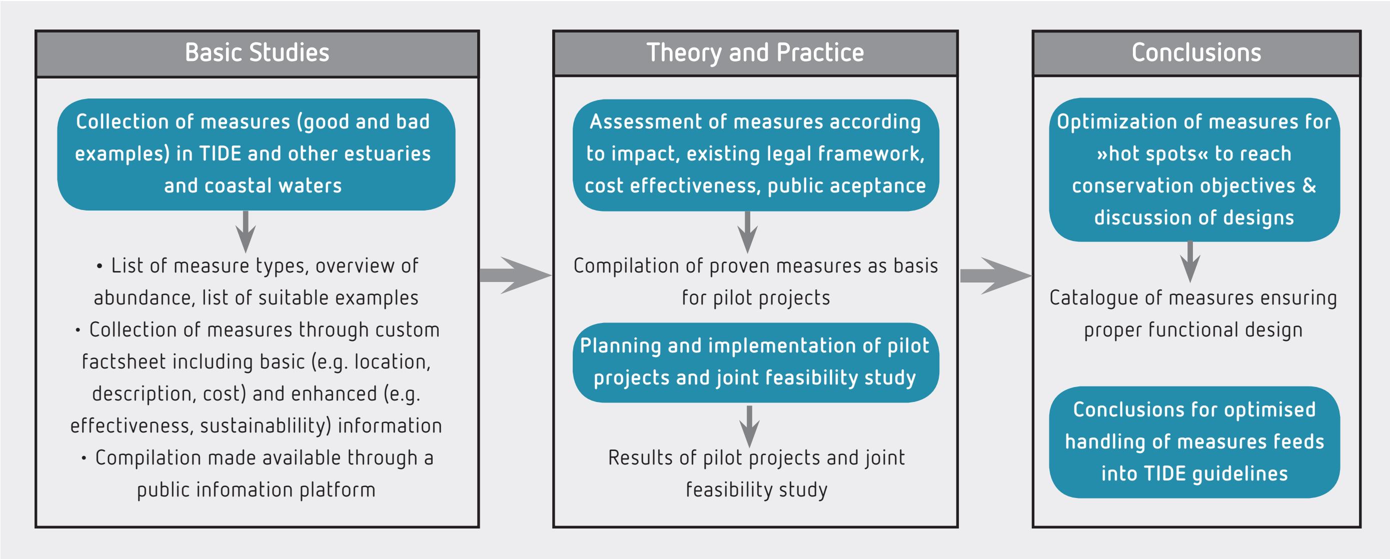

Figure 6.
Flowchart of TIDE activities leading to contributions concerning practical mitigation and other practical management measures.

The measures will be optimised for »hot spots« (e.g. intertidal areas, Flood Control Areas) to reach applicable conservation objectives and a catalogue will be developed which highlights proper functional design. Conclusions for an optimised handling of practical measures will be made available through TIDE guidelines to other estuary managers, experts and decision-makers.

TIDE COMMUNICATION

Coordinator: External Project Coordination Office

Core to the TIDE approach is the collection and exchange of experience on available expertise in estuary management among the North Sea Region partners as well as with experts from former and current related projects, other estuaries and other areas dealing with integrated management. TIDE will hold the following five transnational meetings, which offer opportunities for exchange of experience and knowledge among partners and with invited speakers and guests:

- Antwerp | February 2010
- Bremen | September 2010
- Seine-Aval | June 2011 (date not fixed yet)
- East Riding of Yorkshire | 2012 (date not fixed yet)
- Hamburg | October 2012 (date not fixed yet)

TIDE experience will be synthesized in a joint toolbox documenting tools for assessment, governance and measures. This »TIDE Toolbox« will be presented to other planners, managers scientists and decision-makers of other estuaries and related ecosystems through »TIDE on Tour« seminars.

TIDE on Tour

Interested to receive a Tide on Tour presentation at your institution? Contact the External Project Coordination Office at ct@sustainable-projects.eu or visit us online at
www.tide-project.eu

Related Research

- **ComCoast (Combined Functions in Coastal Defence Zones)** – Combining safety and spatial use in the coastal defence zone to achieve a more gradual transition zone
- **EstProc (Estuary Processes Research Project)** – Estuary hydrodynamic and sediment processes and biology-sediments interactions
- **Harbasins (Harmonised River Basins Strategies North Sea)** – Compatibility of management strategies and international cooperation for the North Sea's coastal waters, estuaries and river basins
- **MR Mo ToWFO (Managed Realignment Moving Towards Water Framework Objectives)** – Indicators and measures to ensure that managed realignments in estuaries do not go against WFD objectives
- **New! Delta (European Sediment Network)** – Sustainable development of ports and port-related activities in North-West European estuaries and coasts, in balance with the European Natura 2000 network
- **OMReG (Online Managed Realignment Guide)** – Collection of coastal habitat creation projects, focus on lessons learned from implemented schemes
- **Safecoast (Sustainable Coastal Risk Management in 2050)** – Contexts and approaches to coastal flood and erosion risk management
- **SedNet (European Sediment Network)** – Sediment issues in European strategies and new tools for sediment management

ACCESSIBILITY: AN EXAMPLE FROM THE RIVER ELBE

Manfred Meine – Hamburg Port Authority

THE TIDAL ELBE RIVER

The Tidal Elbe River is the main artery for Northern Germany and especially for the Hamburg metropolitan region. As the port of Hamburg, located about 130 km upstream from the river mouth, is the largest German seaport this federal waterway is one of the most important and most frequented fairways within Europe. In addition to fairway dimensions, safety and navigation aspects are important for port accessibility.

At present, the Elbe fairway is 13,5 m deep, and a deepening of about 1 m to 14,5 m is currently planned. The necessary approval procedures are based on a comprehensive legal framework considering various relevant criteria. However, the accessibility of the port is also a function of the maintenance conditions. For its ecologic and economic development the reduction of maintenance dredging and the isolation of pollutants are of significance. Therefore, integrated sediment management is needed for a sustainable development of the region.

HYDRO-MORPHOLOGICAL DEVELOPMENT

The morphological diversity of the Elbe estuary is mainly governed by tidal action and is naturally characterized by substantial sediment transport linked to the continually changing riverbed and banks. Natural erosion and sedimentation processes continuously take place in this very dynamic system. Large modifications were observed during past decades, especially at the river mouth.

Within 30 years, a loss of 100 million m³ of soil expanded the river mouth, which enabled more tidal energy to enter the system. Also, the natural development of the estuary was altered by anthropogenic measures such as land reclaiming, dyking, dredging and other hydraulic engineering. These measures have continuously affected the characteristic landscape and the hydro-morphological situation. Natural developments in the river mouth as well as sea level rise have also contributed to a considerable change in the system. The combined effect of the changes and the lack of any mitigation within the estuary have led to an increase of the tidal energy further upstream, associated with a deformation of the tidal curve (Figure 7). This resulted in a steeply ascending flood tide and a more gently falling ebb tide. This effect caused a considerable flood current dominance in the upper parts of the estuary (Figure 8).

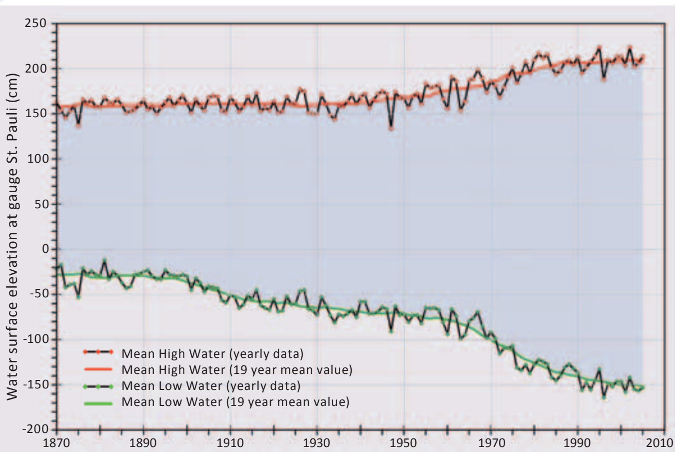

Figure 7.

Development of mean high and low water as annual values in the past centuries at the tide gauge St. Pauli in Hamburg, Germany. Credit: Hamburg Port Authority.

Both the natural and anthropogenic changes along the Tidal Elbe River eventually resulted in an increase of upstream sediment transport (so called »tidal pumping«) causing soaring siltation rates in the fairway and the port of Hamburg. Associated with the alteration of the system, the amount of dredged material and therefore also the maintenance costs necessary to keep the areas navigable have risen rapidly in past years.

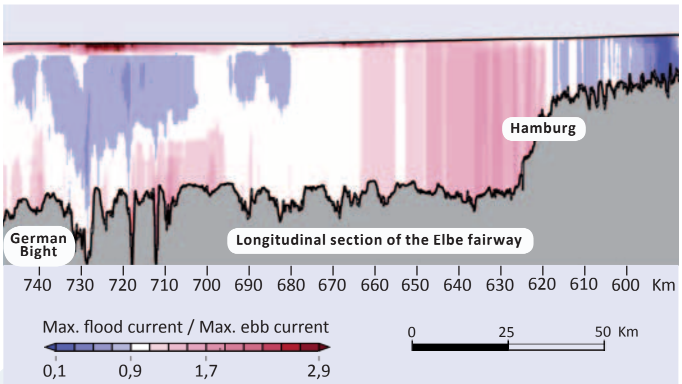

Figure 8.

3D-Simulation of the flood/ebb current dominance at the Tidal Elbe River: the flood dominated system causes upstream sediment transport (»tidal pumping«). Credit: Federal Waterways Engineering and Research Institute (BAW).

A CONCEPT FOR SUSTAINABLE DEVELOPMENT

The tidal Elbe river is of outstanding ecological significance. More than 90 % of its water surface and foreshore areas are designated NATURA 2000 sites. On the other hand, the river is one of the busiest shipping channels in the world. In order to fulfill both ecological and economical services, an integrated management strategy is necessary. In this context, the Hamburg Port Authority and the Federal Administration of Waterways and Navigation have developed a concept for a sustainable development of the Tidal Elbe River as an artery of the metropolitan region. The concept outlines new strategies for relocating sediment and proposes sustainable river engineering measures. Three main objectives are considered:

- Dissipation of incoming tidal energy by hydraulic engineering constructions, especially within the mouth of the estuary
- Establishment of flooding areas in the upper parts of the estuary
- Optimization of sediment management considering the whole system

3D-modeling of measures within the mouth of the Elbe estuary (e.g. reducing the cross-section) indicate a significant benefit for the system through reduction of the tidal energy entering the estuary. However, the river engineering concepts and the effects to the system have to be further examined.

To reduce the tidal pumping effect and the associated upstream sediment transport plans are in place to create additional shallow-water areas connected to the tidal system. Some of these flooding areas may also be developed as storm tide polders to help improve flood protection in coming decades.

As a pilot project for this new kind of river engineering the Hamburg Port Authority is presently developing a 42 ha foreland into a tidal flooding area (pilot project »Kreetsand«). Here a former spoil area will be excavated and connected to the river system within the next years (Figure 9).

Furthermore, an adapted relocation strategy has been designed which intends to relocate fresh, non-contaminated sediments in areas where there is less possibility for them to return to the place where they were dredged, i.e. relocation in ebb-current dominated areas. Therefore ecological system analyses are carried out to define the best relocation sites for the dredged material.

Also under examination is whether sediment traps in combination with hydraulic engineering measures could be part of the future sediment management concept. A pilot sediment trap installed near Wedel (west of Hamburg) is already being tested. The aim is to capture the sediment carried in from the North Sea before it can reach the port and mix with contaminated sediments from upstream.

NEXT STEPS

An enhanced understanding of the estuarine system is needed. In order to study the hydro-morphological and ecological interrelations in the estuaries more data have to be collected and modelled, monitoring concepts have to be optimised and in situ tests will be carried out.

A more integrated approach is required to adapt dredging and relocation strategies. Thus, the exchange of know-how and best practice will be the key activities of the TIDE-Partnership.

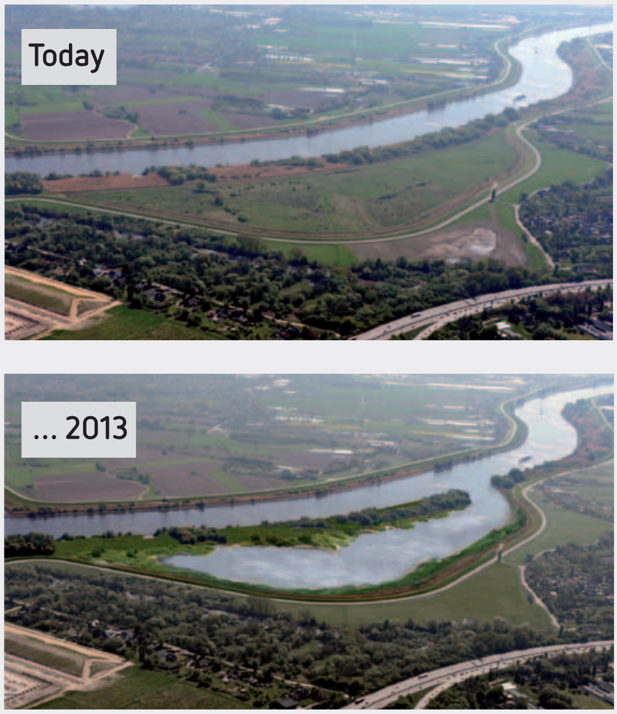

Figure 9.
Hamburg Port Authority's »Kreetsand« pilot project: creation of 42 ha shallow-water area at the Elbe River. Credit: Hamburg Port Authority.

FLOOD RISK PROTECTION IN THE SCHELDE ESTUARY

Stefan Van Damme & Patrick Meire – University of Antwerp
Yves Plancke & Youri Meersschaut – Flemish Authorities Department of Mobility and Public Works

THE SIGMA PLAN AND FLOOD CONTROL AREAS

Safety against floodings is of utmost importance in estuaries, given sea level rise and tide amplification between the estuarine margins. The Schelde has a lively memory of safety issues.

After being struck by a serious flood disaster in the 1950s, the Dutch constructed a massive safety plan around the Dutch part of the Schelde estuary, called Westerschelde. This plan, the Delta plan, still stands as a worldwide example of skill. After a major flooding in 1977, the Belgian government initiated the ›Sigma Plan‹ to protect the Flemish part of the Schelde estuary from tidal surges. Hydrological models predicted that if no measures were taken, the return period of high tide topping over the dikes would increase as a result of sea level rise and deepening of the navigation channel. The flood risk would increase from an already unsatisfactory return period of once every 369 years to once every 72 years by 2050 and to once every 23 years by 2100.

The actualisation of the Sigma plan offered three options:

- Heightening and strenghtening the dikes
- Installing flood control areas (FCA's)
- Constructing a storm surge barrier

In order to allow navigation, the planned storm surge barrier would need to be as high as the cathedral of the city of Antwerp (120 m). Furthermore, a cost benefit study showed that building the costly storm surge barrier would give by far the least economic return. Flood control areas on the other hand offer the opportunity to enhance estuarine ecosystem services. When there is no risk of flooding, the storage volume of the flooding area can be used to allow water to enter and leave through a sluice system, according to the tide. The position and design of the sluices determine the rate and timing of water movement. In this way, the tidal amplitude in an inundation area can be tuned according to the services or habitats preferred.

Flood control areas with such controlled reduced tidal regimes are called FCA-CRT's. Taking into account predicted ecosystem services such as aeration of the water and removal of nutrients from the system through burial and denitrification resulted in an economic return of FCA-CRT's that was slightly better than the return of strengthening and heigthening the dikes. It was thus decided to upgrade the Sigma Plan with a combination of dike enforcements and FCA-CRT's.

THE LIPPENBROEK PILOT PROJECT

The Lippenbroek area (10 ha) was selected as a pilot site to test the functioning FCA-CRT's (Figure 10). In Lippenbroek monitoring is carried out: 1) to investigate whether there is a loss of storage volume due to sedimentation when the entering water leaves sediment behind, and 2) to explore the potential of FCA-CRT's in terms of ecosystem service delivery. The test site showed a beneficial impact of FCA-CRT's on ecosystem service delivery. It also showed that this positive effect was hardly hampered by sedimentation in the long run. Further developments concerning design, functioning and landscape management now lay ahead, as several areas have been designated for CRT application.

MANAGEMENT STRATEGY

In 1999, Flanders and the Netherlands agreed to set up a common strategy for managing the Schelde estuary. In 2002, both parties signed a memorandum of understanding which defined a long term vision strategy. One of the objectives is the preservation in the Western Schelde of a dynamic flood and ebb channel network, the so-called »multi-channel system«. However, the present trend, a continuation of past natural morphological evolutions combined with human interference (land reclamation and polder building, dredging and other river works) may jeopardise this objective.

An expert team appointed by the Antwerp Port Authority stated the need for morphological management in order to

Figure 10.

Water inflow at the Lippenbroek pilot site, testing the functioning Flood Control Areas – Controlled Reduced Tide (FCA-CRT's).
Credits: Cecilia Torres, s.Pro (left top & right), Tom Maris, University of Antwerp (left bottom).

steer the estuarine morphology. In a first phase, sediment from dredging works could be used to reshape eroded sandbars where needed, in order for the flood and ebb flows to maintain the multiple channels.

SEDIMENT DISPOSAL

Since 2002, this new disposal strategy is being investigated as a pilot project on the Walsoorden sandbar in the Western Scheldt. Extensive research was initially conducted in 2002 and 2003, combining several tools: desk studies with maps on the historical morphological changes, field measurements, physical scale model tests and numerical models. Research conducted at Flanders Hydraulics Research concluded that none of the results obtained contradicted the feasibility of the new disposal strategy at the Walsoorden sandbar, although final judgement would only be possible after the execution of an in situ disposal test.

In 2004, 500.000 m^3 of sand were disposed in one month with a diffuser in relatively shallow water at the seaward end of the Walsoorden sandbar. The experiment was monitored, both morphologically as well as ecologically. One year after the in situ disposal, it was concluded that the test was a success from the morphological viewpoint. The ecological monitoring revealed no significant negative changes in trends.

In 2006, a new disposal test was executed, using the traditional dumping (»clapping«) technique with hopper dredgers and disposing again 500.000 m^3 over a period of 3 months. The new experiment was again thoroughly monitored. Due to larger currents in the disposal area, a higher percentage of the material was transported towards the Walsoorden sandbar. This morphological evolution was seen as positive within the objectives of the disposal strategy. From the ecological viewpoint, again no significant negative changes in trends have been identified.

NEXT STEPS

Given the success of both in situ tests, this new strategy for morphological disposal will be incorporated into the dredging and disposal operations during future deepenings of the navigation channel. This new strategy will introduce benefits for both the economy (deepening and maintenance of the fairway) and the ecology (keeping the sediment in the estuary, creating new valuable areas without endangering the multiple channel system).

Further research work was carried out in 2007–2008 on precisely how to embed this strategy in the future dredging and disposal policies as well as on the possible use of the strategy on other locations. During execution, an intensive monitoring programme will monitor the morphological and ecological effects of the disposed sediments, allowing adjustment of the strategy if necessary.

However, this is only part of a morphological management of the estuary, which will also have to include morphological dredging and modifying the hard bordering at some locations. Safety has been targeted in the Schelde in multiple ways. However, a holistic vision and management on the morphology of the whole estuarine system is still not available. The task of TIDE is clear.

NATURE CONSERVATION AT THE TIDAL RIVER WESER

Jochen Kress – City of Bremen

THE WESER AND ITS NATURE

The Weser estuary is, behind the Elbe, the second largest in Germany with a length of approximately 90 km. Along it are situated the twin ports of Bremen/Bremerhaven, which are again the second largest in Germany with a turnover of 74,5 million tons in 2008. The tidal influence reaches up to Bremen (approximately 65 km inland) up to the Hemelinger Wehr, a barrier which was built in 1906 to enable shipping in the adjacent southern areas of the Weser. The tidal range is growing from the Outer Weser up to Bremen and reaches there about 4,4 m compared to 30 cm prior to the first Weser deepenings. Most of the Weser belongs to the Federal State of Lower Saxony, minor parts to the Free Hanseatic city of Bremen.

As all European estuaries, the Weser estuary still consists of ecological assets of high value and importance (Figure 11). Major parts of the estuary are protected under Natura 2000 provisions. Compared to other estuaries there are still many areas of mudflats in the Outer Weser which are protected as »estuary habitat« according the Habitats Directive (Figure 12).

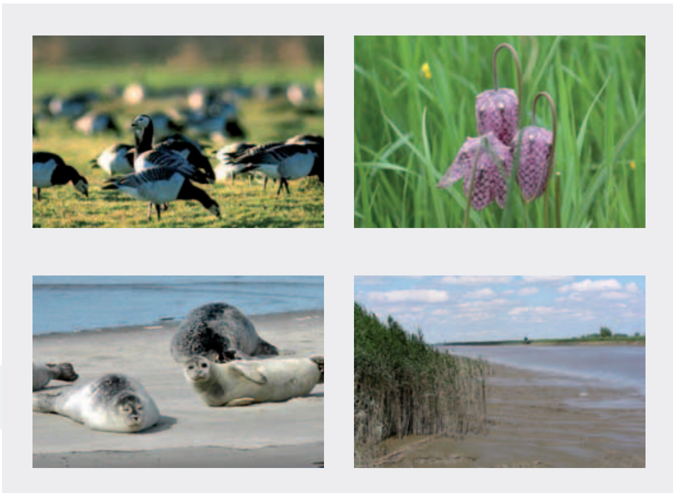

Figure 11.

Natural assets of the Weser estuary. Clockwise: barnacle goose, checkered daffodil, seals, reed and mudflats along the Strohhauser Plate. Credit: NLWKN.

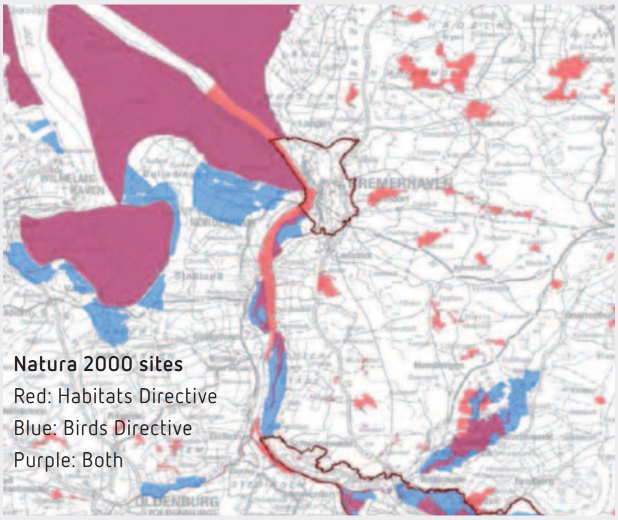

Figure 12.
Natura 2000 areas in the Weser region. Credit: NLWKN.

AN INTENSELY USED ESTUARY

The Weser has been used by man for centuries. The ports have further developed shipping, which has remained one of the main uses ever since. Since the first corrections to the river fairway at the end of the 19th century, the Weser has been deepened multiple times. The current depth between Bremerhaven and Bremen is 16,12 to 11,10 m below mean sea level. The next deepening is already in schedule with another 1,2 m up to Bremerhaven and 0,6 m up to Bremen.

But what is good for shipping is often a problem in terms of nature conservation (e.g. loss of shallow water areas) and coastal protection. The tidal range has been increasing substantially with an increased risk of high storm surges. Other detrimental effects are artificial embankments instead of sand beaches (Figure 13), high tidal velocity, high nitrate concentrations, the loss of former side arms (one channel system) and generally speaking the loss of habitat diversity. The protection against increasing storm surges has been another major concern and in the meantime dikelines form the outer border of the estuary itself. The natural hinterland which was flooded in the past has been split from the estuary.

WHAT HAS BEEN ACHIEVED?

In the effort to maintain the ecological status the former Weser island »Große Luneplate« was developed as a centre for ecological compensation in the Weser estuary in an area of approximately 460 ha (Figure 14). Here development of a polder area behind the dike and associated of high value grassland for nature conservation are being implemented.

To fulfil the Natura 2000 requirements, a planning process was initiated by the nature conservation authorities of Bremen and Lower Saxony, which integrates the needs of the different uses in the estuary in a combined management plan.

WHY TAKE PART IN TIDE ?

The partners of the Weser estuary (the city of Bremen, the University of Bremen and the Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency) have chosen to take part in the TIDE project for a variety of reasons. The most important of them is the valuable opportunity for TIDE partners to learn from each other in terms of present estuarine management proceedings.

Based on this exchange of available practical experience regarding measures planned and implemented within the estuaries of the Humber, Schedt, Elbe and Weser, recommendations for an optimised selection, planning and implementation of measures in estuaries will be formulated. In addition, different pilot projects will be implemented in the Weser estuary focusing on the regeneration of shore areas, the enhancement of shallow water areas and the development of natural sublitoral hard substrate ecotopes in the outer Weser estuary.

Figure 13.
Development of artificial embankments which lead to a loss of natural habitat. Credit: Andreas Tesch (bottom).

Figure 14.
The Luneplate in the Weser estuary under development as a habitat area. Credit: bremenports.

ESTUARINE MANAGEMENT OF THE HUMBER

Krystal Hemingway & Nick Cutts – IECS, University of Hull

THE HUMBER ESTUARY

The Humber Estuary is a complex macro-tidal coastal plain estuary located on the northeast coast of England, bordering the North Sea. It has an area greater than 30.551 ha and a catchment draining over 20 % (24.472 km^2) of England, thereby providing the largest single input of freshwater to the North Sea from the English coastline. Major tributaries flowing into the estuary include the rivers Ouse, Wharfe, Aire, Don, Trent and Hull (Figure 15). The total length of tidal waters within the system is 313 km, with the greatest distance of tidal influence being 147 km from the outer estuary at Spurn Head to Cromwell Weir on the Trent. The river has a mean tidal range of 5,7 m, with a maximum of 7,4 m near Hull, which then decreases to 5,6 m at Trent Falls, where the rivers Ouse and Trent converge to form the Humber estuary.

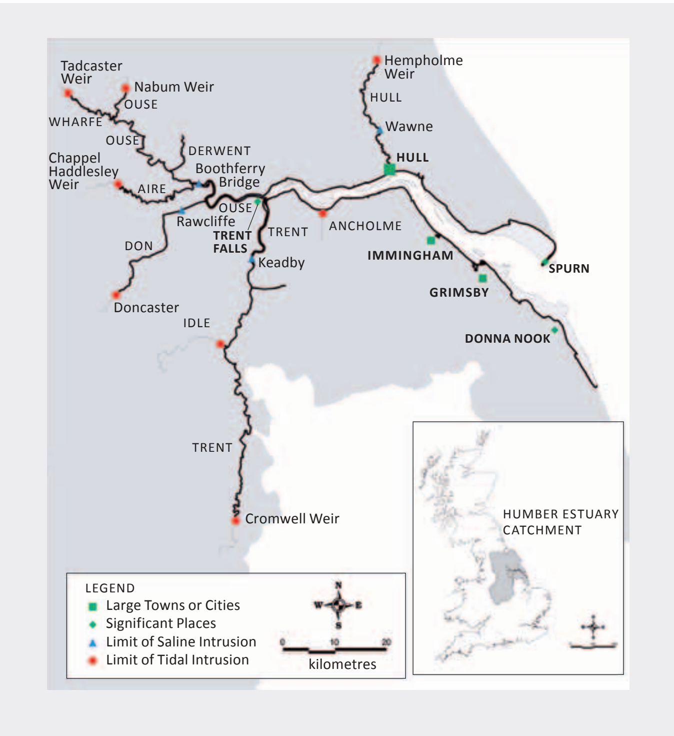

Figure 15.

Map of the Humber Estuary and surrounding catchment. Credit: IECS, University of Hull.

The erosion and accretion of sediments are an important feature throughout much of the estuary, as is the changing position of the main channel. The low-lying nature of the hinterland means that artificial flood defences are present along the majority of the estuary's length, constraining the natural development of intertidal mudflat and saltmarsh in response to relative sea level rise.

The hinterland provides good grade agricultural land, as well as land for industry, in particular the chemicals sector, with much of this industry at least in some part dependent on the presence of the estuary. The estuary supports the UK's largest ports complex (predominantly the ports of Hull, Immingham, Grimsby, Goole) and is the feeder into smaller ports and wharves along the Rivers Trent and Ouse. The Humber handles around 14 % of the UK's trade which translates into 40,000 ship movements each year.

The entire area of the Humber Estuary as well as parts of the tidal river tributaries is designated as a Special Area of Conservation, a Special Protection Area and a Ramsar site, which together form the Humber Estuary European Marine Site (EMS) and places it within the Natura 2000 Network as well as the UK's MPA network. These designations now act as substantial driver for integrated management of the estuary, which in addition to nature conservation, includes economic and social management aspects but under a wider remit of public safety.

HABITAT LOSS AND GAIN

The Humber Estuary has been subject to substantial anthropogenic modification for over 2,000 years, with the gradual draining of the Humber headlands area, as well as land claiming in the estuary margins. In addition, channel morphology within the estuary and its tributaries has been modified for flood defence purposes as well as navigation. As such, the estuary is classified as a Heavily Modified Water Body (HMWB), and is currently subject to a process known as coastal squeeze, whereby ongoing relative sea level rise in conjunction with the presence of extensive immovable coastal and fluvial defence embankments entails the gradual loss of intertidal habitat.

Over the last 200 years, as a result of anthropogenic modification, namely embanking of the estuary and associated land claiming, there have been substantial losses of intertidal habitat in the Humber Estuary (Table 1). However, in recent years there has also been an increase in some components of intertidal area, both as a result of natural system responses as well as from habitat creation schemes including managed realignment projects. These managed realignment schemes addressing coastal squeeze are being initiated by the Environment Agency as part of their flood defence remit, with additional schemes provided as compensation sites for direct habitat loss as a result of developments, largely from the ports sector.

Loss of subtidal habitat has not occurred on the same scale. However, parts of the bed of the estuary are subject to modification through maintenance dredging work. This process is now regulated and monitored, and only occurs in limited areas of the estuary, with sections of the fairway dredged in the middle estuary. This dredge material is disposed of within the Humber system to ensure no loss of material from the Humber over the longer term.

Estuary Location	Mud	Sand	Salt-marsh	Dune	Reed	Lagoon	Subtidal
Inner	225		110		420	20	
Middle	1.770	300	200		50		20
Outer	690	400	110				10
Coast	400	600	100	100			
Total	**3.015**	**1.300**	**520**	**100**	**470**	**20**	**30**

Table 1.

Areas of habitat lost over the last 200 years on the Humber Estuary (ha).

ESTUARINE MANAGEMENT

The over-riding management goal for the Humber is the maintenance of public safety. This is of prime importance given the low-lying nature of the hinterland, and associated flood risk. This management is the responsibility of the Environment Agency, who is charged with the maintenance of effective flood protection measures, a duty carried forward through its Humber Flood Risk Management Strategy. In most instances, this entails the maintenance of existing defence alignments, but where the possibility exists, the Environment Agency has developed a series of managed realignment schemes (Figure 16) as part of its Flood Risk Management Strategy. These schemes also address intertidal habitat loss due to coastal squeeze. However, a component of the strategy addresses flood management capacity needs in the Upper Humber, whilst some schemes, at least in part, address the direct loss of intertidal habitat resulting from ongoing flood defence works on the estuary.

On the Humber estuary, the Environment Agency employs a policy of a 1:1 ratio of habitat loss to creation for coastal squeeze, and a 1:3 ratio for habitat loss to creation for direct construction related losses from defence improvement works. The provision of a suitable management plan for flood protection taking due regard of nature conservation values and designations has been initiated by the Environment Agency, with the plan (known as a Coastal Habitat Management Plan or CHaMP) currently undergoing a periodic review and revision. In addition to the Flood Risk Management Strategy, the outer estuary is included within the Shoreline Management Plan for the East Yorkshire and Lincolnshire coasts. This plan focuses on coastal protection needs and management options, and is of importance given that the adjacent coastline to the Humber is one of the fastest eroding in Europe. This management plan is currently undergoing periodic revision.

A further series of compensatory managed realignment sites have also been identified by Associated British Ports (ABP) – the main ports operator in the Humber – to address current and planned port expansion. These sites have been developed through the Environmental Impact Assessment (EIA) and Appropriate Assessment (AA) processes, in conjunction with ABP's operational strategy for fairway management which has been developed with the nature conservation importance of the estuary in mind. These management strategies for flood protection and port development provide examples of a comprehensive sectoral approach to management in the Humber.

In addition to the above, the presence of industrial, residential and recreational activities around the estuary entails a range of management plans which have been implemented for the estuary on a sectoral basis. These – and the sectors they represent – have largely been included within the overarching Humber Management Scheme (HMS), established through the European Marine Site designation. Management of these sectors is carried out through the suite of relevant authorities, with the aim of ensuring that the conservation objectives of the European Marine Site (EMS) are met, and that any changes to either EMS activities or conditions are addressed and incorporated. The ultimate aim of the HMS is to ensure that subject to natural change, the favourable condition of the EMS is maintained through sustainable management.

THE TIDE CHALLENGE

The challenge to the TIDE partners is to build on the existing management framework already developed for the Humber, and following that, to trial the framework in other estuaries in order to develop an integrated management approach that can be applied across north-west Europe coastal margins. As part of this framework, it is hoped to develop a series of management tools that will form part of an integrated management ›toolbox‹.

The ultimate aim is to undertake a process of 'joined-up environmental thinking' for estuarine management, whereby integration occurs across a range of sectors and scales. We hope to develop a strategy to move away from the traditional sectoral management approach to an integration of use and user in estuaries, taking into consideration the requirements of current European management drivers and tools. In doing so, the project aims to ensure the provision of both economic and ecological services. It also aims to deliver a framework for the sustainable management of critical environmental processes, areas and species whilst allowing ongoing and developing economic activity against a background of flood safety.

Figure 16.

Example of habitat creation through managed realignment at Paull Holme Strays, Humber estuary. Credit: IECS, University of Hull.

THE ECOSYSTEM SERVICES APPROACH

Patrick Meire & Stefan van Damme – University of Antwerp

The structural framework for TIDE's scientific activities is based on the concept of ecosystem services. Since the formalization of this concept in the 2004 Millenium Ecosystem Assessment, the idea has received increasing attention in the academic world, as well as with managers and politicians.

›Ecosystem services‹ are defined as the collective benefits that humankind receives from the multitude of resources and processes that are supplied by natural ecosystems (Figure 17). The strength of the concept lies in its capacity to make explicit and quantify the different services delivered by ecosystems and to make it possible to translate these services into monetary terms. The EU has embraced this concept in many of its policies and the United Nations Environment Program's ›The Economics of Ecosystems and Biodiversity‹ (TEEB), a major international initiative to draw attention to the global economic benefits of biodiversity has also had substantial influence on policies, even though it has not yet been completed.

The major issues in the TIDE estuaries are: accessibility of ships to ports and fairways, safety against floods and a good ecological status. These issues are directly linked to the fields of geomorphology, hydrodynamics and ecological functioning and how we manage those. Geomorphological management (e.g. deepening, dredging, sediment management, managed retreat, disposal strategies) clearly influences accessibility, safety and ecological functioning. Managing hydrology (storing storm water and managing fresh water discharge) impacts safety and ecological functioning. Nature restoration and conservation obviously has an impact on ecological functioning.

Although estuary management is a complex task which requires scientific support, the goals for accessibility or safety are in themselves quite easily formulated, as a required depth and width of the fairway or in an allowed risk of inundation. The formulation of ecological goals, however, is far more complicated. How do we define the number of birds we want in an estuary or the surface amount of marsh land? How do we take global change or global economic development into account when formulating these goals?

When taking this into account, formulating a consistent integrated set of goals for an estuary becomes a very challenging task. Therefore, TIDE will seek to translate the different goals into ecosystem services, in light of this concept's strong integrating capacity. This is seen as a necessary translation step in order to make ecology comparable with accessibility and safety matters. It is a crucial step to reaching economic quantification of ecologic values on equal terms with accessibility and safety, which is capital for managers and decision makers.

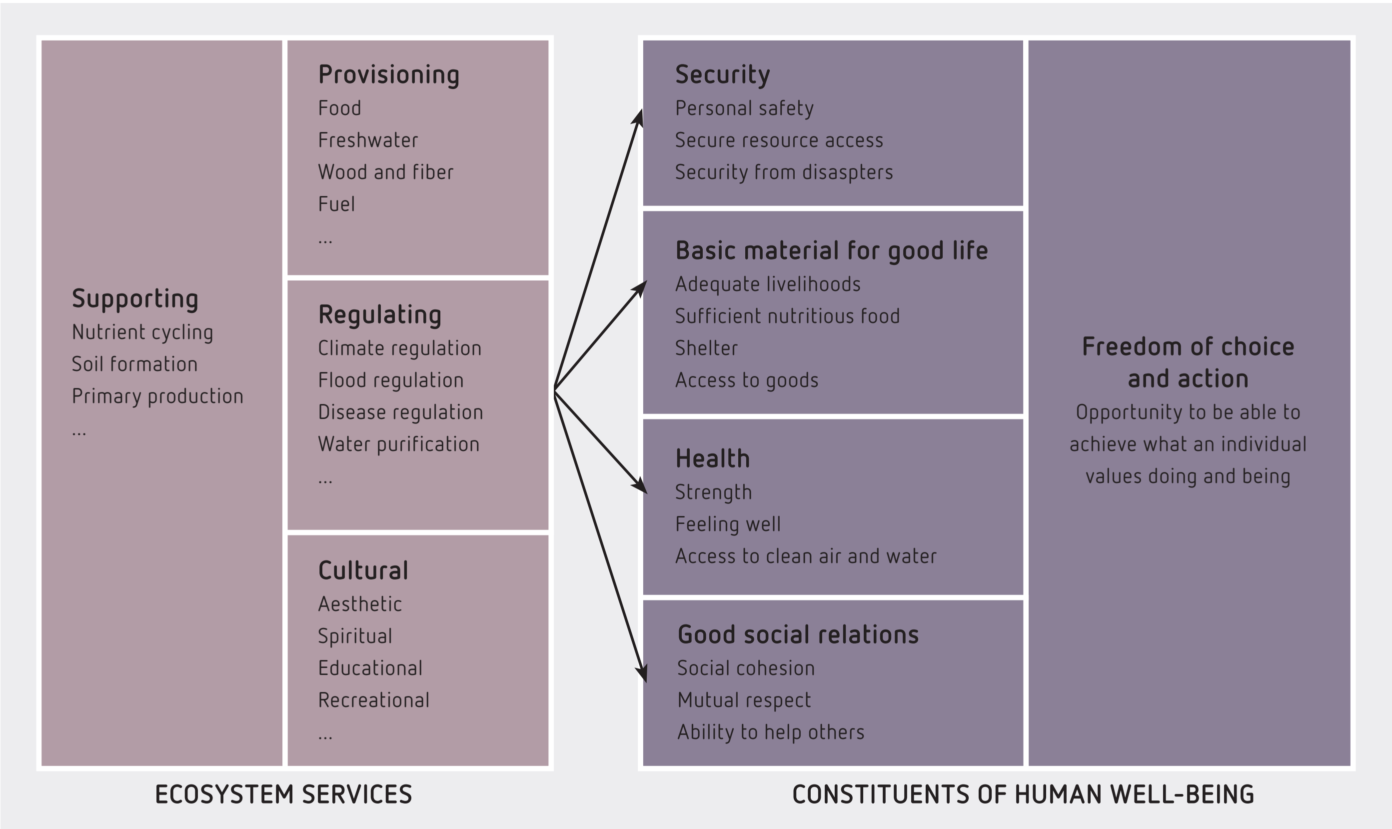

Figure 17.
Ecosystem services provided by nature and resulting benefits in terms of human well-being. Adapted from the Millenium Ecosystem Assessment.

TIDE: THE BIG IDEA!

Mike Elliott – IECS, University of Hull

The TIDE project is focused on how we can maintain and protect ecological goods and services while at the same time delivering economic goods and services. As a subtext here we could ask ›how does a port stay within its environmental responsibilities and yet still be a viable business?‹. For each of the four TIDE estuaries, the project aims to:

- Define and measure ecological goods and services
- Define and measure the economic goods and services
- Indicate how we protect, maintain and deliver these services
- Indicate the uses and users
- Determine the conflicts between these uses/users
- Indicate the management structures and plans
- Create these where they don't exist
- Suggest systems in estuaries for implementing these
- Communicate these to stakeholders
- Educate stakeholders where necessary/possible

This approach includes the need to use the best natural and social sciences for management of our estuaries and tidal rivers, especially as we manage to protect critical processes, areas and species, and for the production of ecological and economic goods and services. Of course, private companies also manage to prevent prosecution and to look after shareholders (some port authorities in Europe are private companies while others are state bodies). We have to manage many activities but have many tools for doing this and many public bodies to carry out that manaement (Figure 18).

Hence, to get sustainable and successful management we need to harmonise within and between sectors, stakeholders, regulators, mediums, estuaries, regions, countries, outcomes and implementation. This is because the Humber, Elbe, Weser and Scheldt are regarded as multi-user spaces and so there are many things that we need to manage (and by whom):

- Habitats (nature conservation agencies)
- Environmental quality (environmental protection agency-type organisations)
- Water space usage (port authorities)
- Navigation (port authorities)
- Infrastructure (municipalities/federal state)
- Energy extraction (private companies)
- Biological extractions (fisheries bodies)
- Estuarine water extraction (private energy companies)
- Upstream water abstraction (water supply companies)
- Land space usage (municipalities/federal state)
- Erosion and flooding control (environmental protection agencies, municipalities, etc)
- Industry (EPA/private companies)
- Recreation and tourism (agencies)

Above all, estuaries within Europe are managed to protect the features designated under EU directives, for example their habitats and species and their conservation objectives. Hence we need to build these elements into an iterative environmental management system which treats the environment as an entity to be managed as a whole (Figure 19).

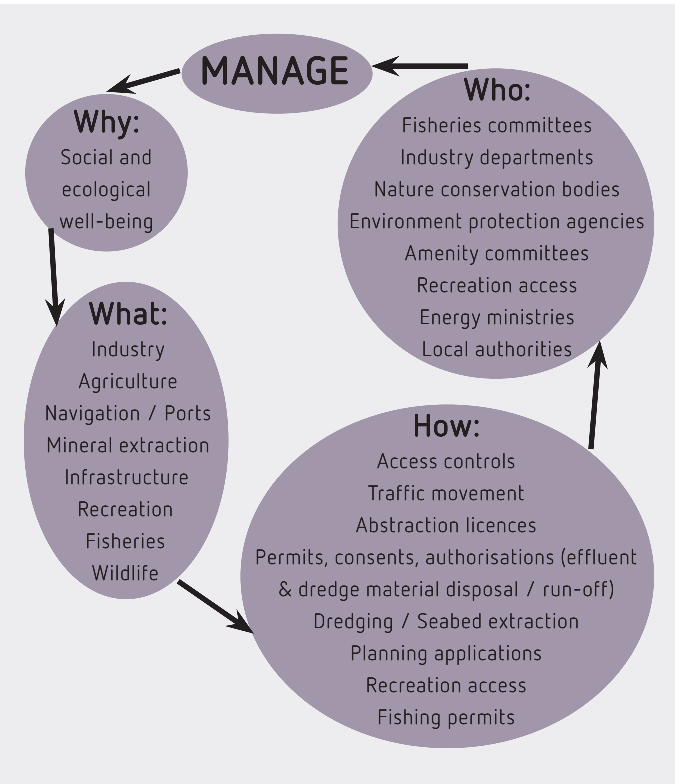

Figure 18.

The basis of estuarine management. Adapted from McLusky & Elliott, *The Estuarine Ecosystem: ecology, threats and management*, OUP, 2004).

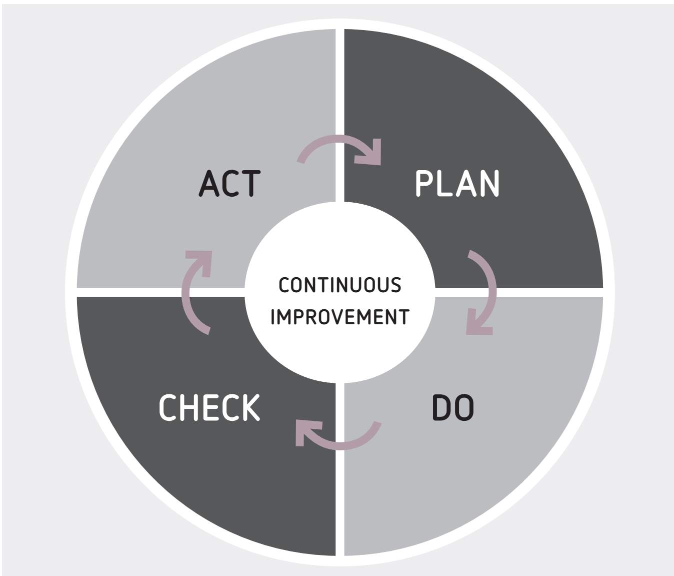

Figure 19.

The basis of an environmental management system. Adapted from Hyde and Reeve, *Essentials of Environmental Management*, 2005.

The management of any entity relies on defining an outcome and having tools to achieve that outcome. In the case of environmental management, this relates to setting objectives (as the desired outcome) and making these objectives quantitative – what may be called indicators against which monitoring can be carried out (Figure 20). It is an axiom of management that ›you cannot manage something unless you can measure it‹. The monitoring of change then needs to be carried out against a set of predefined actions – i.e. at the outset there is the need to define what managers will do if change is detected. The TIDE project will involve the use of Environmental Integrative Indicators which aim to bring together the hydromorphological features of estuaries, the anthropogenic pressures within systems and the environmental consequences of those pressures.

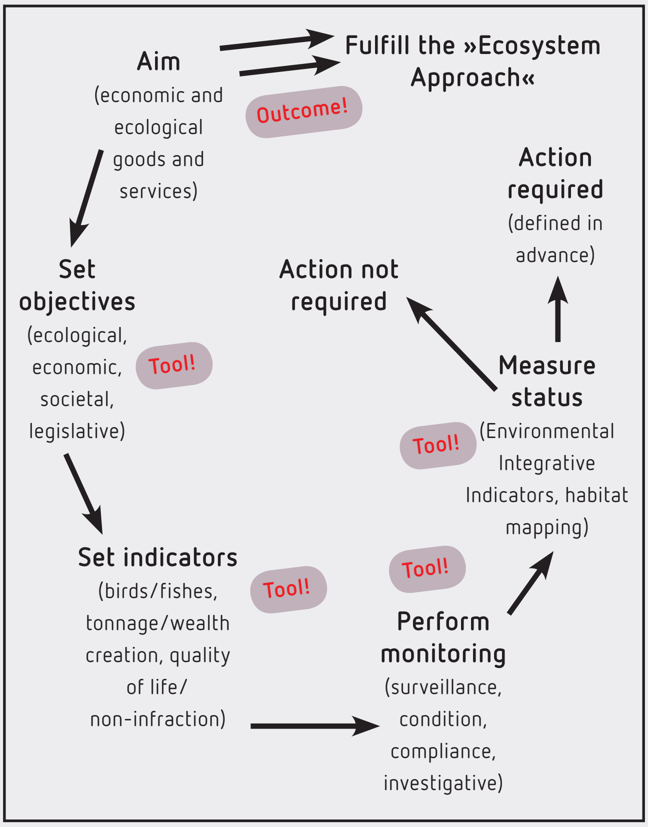

Figure 20.
An environmental management framework.

In showing that TIDE is an integrative project which can treat an estuary as a system which needs management, we are learning from business systems which rely on objectives. These need to be set and then we need to know when they have been met.

This in turn relies on the objectives (and their indicators) being SMART: Specific, Measurable, Achievable/Appropriate/Attainable, Realistic/Results focussed/Relevant and Time-bounded/Timely. It is thus no surprise that, again using an idea modified from business management, the organisation of an environment can be analysed by conducting a P.E.S.T analysis. This is a simple analysis of an environment's Political, Economical, Social and Technological organisation. Therefore we manage our estuaries for both ecology and economy (the reason), using both technology and administrative bodies (our tools), within both laws and governance (legislative drivers) and for both society and politics (social drivers). Hence we need to find ways of sustainably managing these natural and social systems. This can be summarised in the so-called seven tenets that our actions must follow (Table 2).

Seven Tenets of Sustainable Environmental Management	
Environmentally sustainable	That the measures will ensure that the ecosystem features are safeguarded
Technologically feasible	That the methods and equipment for ecosystem protection are available
Economically viable	That a cost-benefit assessment of the environmental management indicates sustainability
Socially desirable / tolerable	That the environmental management measures are as required or at least are understood by society as being required
Legally permissible	That there are regional, national, European or international agreements and/or statutes which will enable the management measures to be performed
Administratively achievable	That the statutory bodies such as governmental departments, environmental protection and conservation bodies are in place and functional to enable the successful and sustainable management
Politically expedient	That the management approaches and philosophies are consistent with the prevailing political climate

Table 2.
Seven tenets that any actions to achieve sustainable environmental management should follow.

The TIDE project will use the best available science to measure the natural and social features and to determine the capacity of the estuaries to support both ecological and economic features. Hence we will need *Joined-up Environmental Thinking*, which requires:

- Ecological integration (habitat integrity, fit-for-purpose)
- User/use integration (and a move from a sectoral approach)
- Management integration (across the prevailing legal and administrative aspects
- Monitoring integration (with joint programmes for cost-effectiveness)
- Environmental integration (from site-based to wider study, as sites are influencing and being influenced by remote events)
- Scientific integration (responses to multiple stressors at several levels of biological organisation)

A SHIFTING PARADIGM

Toon Tessier – Antwerp Port Authority

A CHANGING VIEW ON DREDGING AND DISPOSAL

It is an established opinion that dredging and the disposal of sediment affect the hydrodynamic regime and morphology of the system, causing disturbance of the estuarine natural balance, increase of flood risk and destruction of habitats. Ports receive most of the blame for the occurrence of these phenomena. However, it is also a fact beyond any doubt that many other interventions such as massive land reclamation in the past couple of hundred of years have played a far more important factor in canalising the system and reducing the diversity of estuarine habitats.

Many ports now believe that dredging work and disposal of dredged material do not necessarily need to have a negative impact and that, on the contrary, when carefully designed as part of a holistic approach, these human interventions can actually make a positive contribution towards reducing undesirable effects on the natural system.

THE NEED FOR A NEW PARADIGM

The ports taking part in TIDE strongly believe that the project will offer many opportunities to see how fruitful this working hypothesis may be. To make this possible, a paradigm shift is urgently needed.

Not so long ago, the dominant perception in ecological circles was that the best way to conserve nature is for human intervention to be kept to a minimum. For too long a time, this perception was fed by the fact that for most of the time, human intervention was really nothing else but »working against nature«. This perception is now slowly beginning to change. Instead of sticking to the old paradigm »nature untouched = nature best«, a growing group of conservationists supported by scientists believes that the new paradigm »working with nature = nature conservation« has to be given a fair chance in the debate. After all, why should an estuary, an ecosystem whose history is so closely interwoven with human history, differ that much in principle from many other terrestrial wildlife habitats in Europe which depend on constant human intervention for their survival?

THE CHALLENGE TO COME

Given all this, many ports do support the need for a global management scheme to produce the framework for specific human interventions. The most basic challenge is to develop that management strategy in the following years. The goal of such a strategy is to generate a flexible geometry conserving the morphological diversity, complexity and mobility of a multiple channel system. The operational targets are:

- Controlling the propagation of the tidal wave
- Increasing self-erosive actions of the current at sills
- Maintaining and improving the diversity of biotopes.

Keys to these targets are morphological dredging, morphological disposal, modification of hard bordering that obstructs natural river flow, and construction of soft (reversible) measures that can be easily adapted if necessary.

THE WALSOORDEN: A PILOT PROJECT

It seems to be an enormous task to change the still dominant view on estuaries. Fortunately, in recent years a number of experiments have shown that »working with nature« is really more than a nice slogan.

The pilot project at the shoal of Walsoorden on the Western Scheldt is an example of the interesting possibilities ahead in terms of morphological management (Figure 21). Here dredged material was disposed near the seaward tip of the shoal with the expected advantage that the material will stay in this location instead of returning to the sills. This disposal strategy is also expected to help improve the distribution of the currents near the shoal, sustain the multiple channel system of the estuary and decrease the flood velocity on the shoal, thus improving its ecological potential.

Figure 21.

Aerial view of the shoal of Walsoorden on the Western Scheldt River, where a pilot project is trying new approaches to morphological management and disposal of dredged material. Credit: Stefaan Ides, Antwerp Port Authority.

GOVERNANCE AND MANAGEMENT ASPECTS OF THE EMS ESTUARY

Victor N. de Jonge – AREA, The Netherlands

THE EMS ESTUARY

The Ems estuary is a coastal plain estuary that crosses the Wadden Sea at the border between The Netherlands and Germany (Figure 22). The freshwater tidal river has a length of ~107 km, including a ~ 70 km estuary, and covers a surface area of ~ 475 km^2 (excluding the outer delta).

Approximately 40 % of the lower reaches (the area seaward of Eemshaven) and as much as 80 % of the Dollard comprise intertidal flats. The estuary's tidal prism – the change in water volume between high and low tides – is at the inlet ~ 10^9 m^3. The tidal range varies from ~ 2,3 m in the tidal inlet to over 3,0 m near the towns of Delfzijl and Emden and ~ 3,5 m near Papenburg.

THE MAIN PHYSICAL PROBLEM

The main physical problem in the Ems is the human-induced increase in tidal range and the deformation of the incoming tidal wave between Knock and Papenburg, which is important because it leads to an extremely strong accumulation of mud in the upper part of the estuary system, high levels of suspended particulate material (SPM) and a high estuarine turbidity maximum (ETM) (Figure 23)

THE MAIN ECOLOGICAL PROBLEM

Due to the altered hydraulic conditions, a deterioration of the light regime has also occurred in the Ems estuary and its fresh water tidal river since the mid 1950s. The estuarine turbidity gradient in the 45 km distance between the town of Emden in Germany and the North Sea has increased two- to three-fold due to channel deepening and annual channel maintenance dredging (Figure 24). In addition, river canalizations and stepwise river deepenings upstream of Emden (45 km upstream of the sea) have resulted in a nearly tenfold (110 to > 900 mg·l^{-1} SPM) increase of the ETM since the 1950s. The latter changes not only impact the river part of the system but also half of the estuarine part up to where the estuary starts to cross the international Wadden Sea. Data for 1992–1993 show the same concentration pattern as in 2005–2006, strongly suggesting that the changes in SPM gradient are structural and not due to natural inter-annual fluctuations in precipitation, tidal characteristics or wind speed.

Since primary production in the water column is mainly limited by the availability of light, the deteriorated light conditions and the increased light extinction coefficient result in the proportional decrease of primary production. Another effect is that during the May to October period, the oxygen concentrations decrease to between 0 and 2,5 mg·l^{-1}, which renders the migration of invertebrate and fish species with gills impossible. Measurements in the highly turbid Ems estuary have demonstrated that the extremely low summer oxygen concentrations are directly correlated with sediment concentrations reaching values of > 50 kg·m^{-3}. Factors such as decreased freshwater discharge, increased depth and decreased vertical mixing stimulate the upstream accumulation of sediment and organic material, contributing to these oxygen deficits.

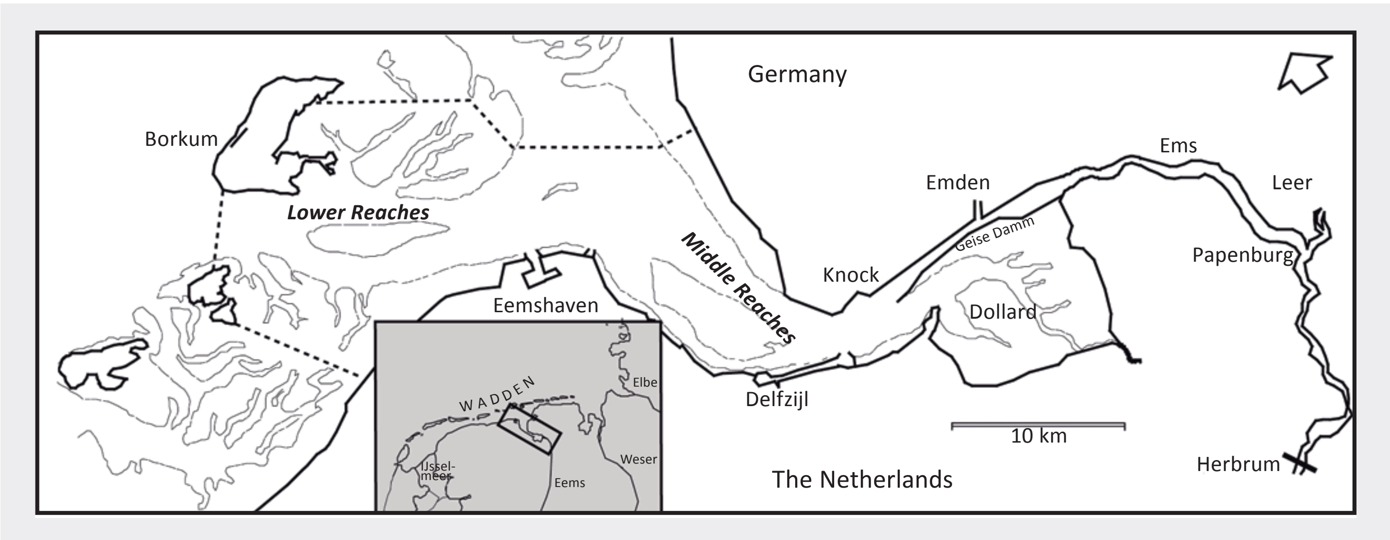

Figure 22.

Map of Ems estuary. Dashed lines indicate the hydraulic watersheds between the estuary and adjacent tidal basins of the Wadden Sea. Credit: Victor de Jonge.

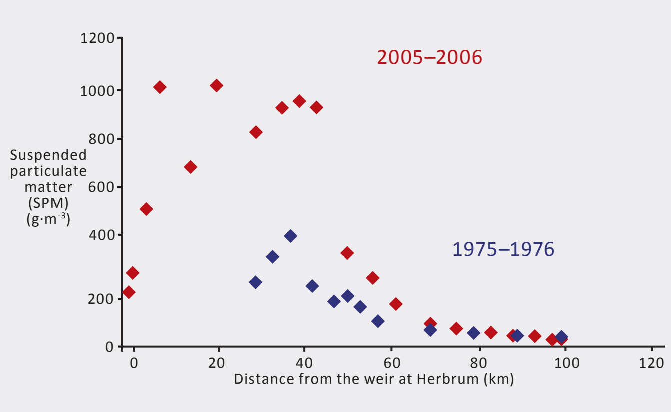

Figure 23.

Mean annual concentrations of suspended matter at the water surface in 1975–1976 (blue) and 2005–2006 (red).

Figure 25.

A Norwegian Cruise Line ship at the harbour of the Meyer shipyard in Papenburg. Credit: Victor de Jonge.

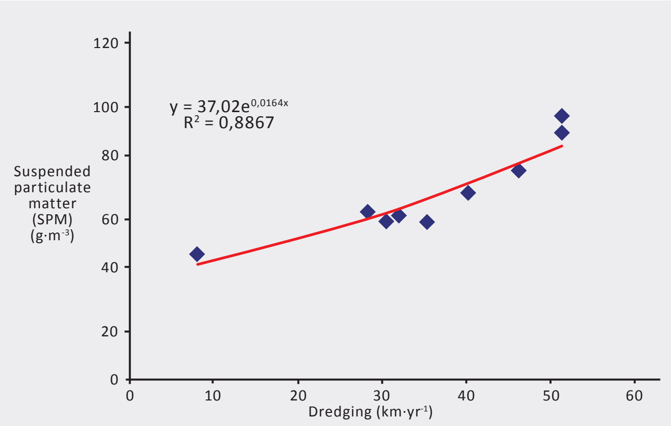

Figure 24.

Relation between channel maintenance dredging (length per year over which modifications took place) and mean estuarine suspended matter concentrations between Emden and Borkum.

THE MAIN ECONOMIC PROBLEM

The Meyer shipyard in Papenburg designs and builds luxury cruisers (Figure 25), which are conveyed down the Ems to the sea. Since 1984 the river has undergone a series of artificial deepenings. After the last deepening, it became clear that further improvements and adaptations for passage of ever bigger ships were no longer possible. The recent generation of cruisers requires water depths more than the river can offer, even considering nearly continuous dredging operations. For that reason a barrier was built which combines the possibility to-dam up the river water when a cruiser must be conveyed, with the flood prevention in the local area during storm surges.

The Jos Meyer shipyard is one of the main local employers and a major economic driver. For the company there are many reasons to keep the shipyard where it is, including history, local trustable employees and supplier companies, and an excellent political lobbying network. However, the price for maintaining the current situation is that a) the government (tax payers) must finance the required water infrastructure, and b) the environmental conditions of the river in terms of landscape aspects, suspended matter loads and oxygen concentrations have continued to deteriorate since the mid 1980s.

A POSSIBLE GOVERNANCE SOLUTION

The present problems are partly due to historical decisions on step-by-step increases of the river depth and the executed river canalisations by German authorities for the German river Ems. The consequences of this are measurable in the non-disputed Dutch territory (main part of the Dollard) and the majority of the disputed area (main part of the Ems estuary), which is mostly under joint Dutch-German control.

Another part of the problem relates to the consequences of the 1960 Border Treaty between Germany and The Netherlands, which led to the Permanent Boundary Water Committee. A Committee for the Ems was created but did not receive sufficient mandate to guarantee a powerful and integrated cross-border cooperation on matters concerning the entire Ems river basin. Its task is restricted mainly to maritime affairs and advising the treaty partners on related matters. Since the ›1996 Additional Protocol‹ and the adoption of the EU Water Framework Directive in 2000, some further efforts have been put in place towards environmental cooperation, but their success remains thus far unclear.

The Netherlands and Germany should charge a strong and powerful cross-border (regional) committee with clear tasks including guidance for adjustments to the socio-economic development of the Ems region, an immediate improvement of the estuarine and river environment and landscape, and the protection of the regional cultural heritage. These developments should be in line with the status of the international Wadden Sea – Ems estuary included – as a UNESCO world heritage site. Grounded on the Brundtland Commission's view on ›sustainability‹ (1987), this could then lead to a more rational development and adaptation of regional cross-border economic activities in the Ems region and other relevant measures (including for instance further harbour specialisation).

A good example of how to look at the present problems might be given by the situation around the Scheldt estuary on the border between The Netherlands and Belgium, where in spite of strong and different national interests, developments have been made to the benefit of both the economy and the environment.

PLANNING ESTUARY RESTORATION IN THE USA

Charles (»Si«) Simenstad – University of Washington, USA

STRATEGIC RESTORATION

Rehabilitation of ecosystems in extensively developed estuaries is difficult enough given the legacy of historic modifications and contamination, but restoration of ecosystem processes and recovery of at least some of the goods and services provided by natural estuarine ecosystems is particularly challenging. I provide here four vignettes of restoration planning and implementation in extensively developed estuaries of the West Coast USA that provide some potential 'lessons learned' about the need to be more strategic, as time and opportunity to achieve some level of rehabilitation, much less restoration, diminish in the face of continued development pressures and external forces such as climate change.

While there are many examples of complete or near-complete restoration of estuarine ecosystems and the fundamental processes that support them, extensively developed coastal landscapes often constrain our capability to accomplish the »build it and they will come« goals of most restoration projects. Rapidly achieving equivalency to natural (»reference«) ecosystems that will be self-sustaining in the long term is often futile given the limited opportunities to fully recover natural ecosystem processes, conditions and functions required at the watershed scale. Rather than seeking to re-create original conditions, the only feasible goal we can strive to attain is thus to establish sites that are self-regulating and integrated within their landscapes.

In this context, rehabilitation (managing natural processes and functions to provide ecosystem functions, goods and services) often is the only option. Thus, in most circumstances we should accept active restoration – human intervention to substitute or accelerate natural processes with engineered solutions – instead of the more preferable passive restoration. Strategic restoration is designed to maximize the contribution of each restoration project to regional, management area, ecosystem, or target species goals, and provide for the greatest contribution to the persistence and/or recovery of populations. This requires taking into account limiting factors such as:

- Landscape configuration
- Restorability of fundamental ecosystem processes
- Spatial patterns of demography, dispersion, and dispersal of key species
- Barriers to transport and dispersal of energy, organisms and important resources
- Equal weight given to the landscape context as well as the content of restoration projects.

LESSONS LEARNED

Based on personal experience with restoration initiatives in four west coast North American (USA) estuaries, (1) South San Francisco Bay, (2) Puget Sound, (3) Puyallup River estuary, and (4) Duwamish River estuary – I suggest that, while there are convincing arguments for rehabilitation in these highly altered systems, we need to approach it strategically with different expectations, planning and performance measures.

While there are many differences in the historic, cultural and, particularly legal/regulatory drivers for restoration between the USA and comparable situations in Northern Europe, the motivations are often the same: mitigation for lost resource and ecosystem function from on-going development and recovery of ecosystem goods and services that have been lost or degraded by prior activities. In the USA, comprehensive restoration actions in large, developed estuaries such as the TIDE estuaries has been driven by a combination of regulatory mitigation (e.g. US Clean Water Act), recovery of threatened or endangered species (e.g. US Endangered Species Act) or non regulatory restoration initiated by local governments, non governmental organizations and private citizens.

The following are lessons from the restoration initiatives in these four west coast estuaries.

1. South San Francisco Bay (South Bay Salt Ponds Restoration Project)

- Anything is possible, e.g. one person's constraints is another person's opportunity, where what was once considered to be unfeasible has turned into the potential of over 6,600 ha of restored estuarine wetland (Figure 26).
- The estuary's response to restoration may alter the structure and composition of component ecosystems in a way that may not be part of the historic template.

Figure 26.

A salt pond (#3, West Bay) currently being planned for restoration under the South Bay Salt Pond Restoration Project, San Francisco Bay, California, USA. Credit: Charles Simenstad, University of Washington.

- Monitoring and science (particularly modeling) to predict pattern and rate of restoration is required to be adaptive, but also helps in communication with stakeholders.
- Peer review and stakeholder involvement from the beginning of the process is invaluable.

2. Puget Sound (Pudget Sound Nearshore Ecosystem Restoration Project

- Change Analysis and Strategic Needs Assessment guidance documents helped identify the greatest need/benefit for restoration and preservation along the ~4,000 km of Puget Sound's shoreline.
- Analyses of a geospatial database facilitated inference about:
  - Relationships between nearshore ecosystem structure and the processes that create and sustain shoreline geomorphology and function
  - Landscape analysis of adjacent and cumulative effects among stressors and restoration actions
  - Planning restoration and preservation portfolios
  - Exploration of future change effects on alternative restoration and preservation strategies.

3. Puyallup River Estuary

Extensive industrial and urban development of this estuary (Commencement Bay) suggests that:

- Although you can't restore historic estuary structure, it is possible to strategically enhance function for target species such as endangered Pacific salmon (*Oncorhynchus* spp.) if ecosystem processes (e.g., river flow, sedimentation) are still intact.
- Spatially-explicit identification of salmon habitat needs can lead to new, more strategic restoration and rehabilitation targets (Figure 27) .
- Legacy contaminants will continue to be a stressor vis-a-vis recontamination of rehabilitation sites.

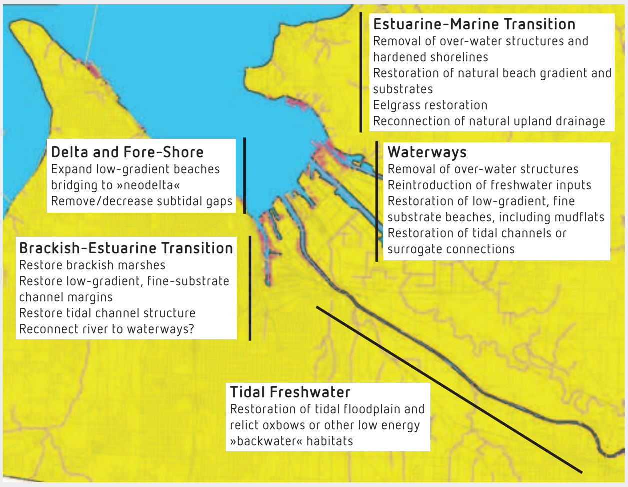

Figure 27.

Strategic actions to restore and rehabilitate juvenile Pacific salmon habitats in Commencement Bay, Puget Sound, Washington, USA. Credit: Charles Simenstad, University of Washington.

4. Duwamish River Estuary

In an estuary that has lost ~98 % of its tidal wetlands over a century of development, rehabilitation of less than 7 ha of tidal ecosystems by 13 projects since 1988 has provided some important lessons:

- Small but strategic changes can produce significant ecosystem benefits if positioned appropriately in the estuarine landscape and designed to maximize landscape linkages, as evidenced by the documented functional response by fish and wildlife (Figure 28).
- The developed landscape can offer an experimental tableau for testing alternative restoration approaches, performance standards and monitoring.
- Initiatives in urban estuaries offer the opportunity for expansion of public understanding, appreciation and even direct involvement in restoration
- As is the case with some resources, such as at-risk anadromous salmon, we cannot afford NOT to ensure that watershed restoration and all other measures toward salmon recovery are not compromised by failure to rehabilitate their estuarine habitat.

A MESSAGE FOR THE TIDE PROJECT

Figure 28.

Main intertidal basin of Herrings House restoration site shortly after reinundation by tide, lower Duwamish River estuary, Puget Sound, Washington, USA. Credit: Curtis Tanner, USFWS.

Integrating over these experiences, some important »take home messages« should be applicable to the TIDE project:

- The need to acknowledge system constraints and understand and work with extant ecosystem processes.
- The value in being strategic in approach and deployment of restoration and rehabilitation actions that maximize environmental benefit.
- Planning and designing rehabilitation and restoration for landscape connectivity, both proximally as well as at regional scale.
- Being more innovative, integrating both active and passive restoration.
- Deploying and managing adaptively.

- Looking to the future for both constraints as well as opportunities (e.g., climate change, population growth, development).
- Employing interdisciplinary science and engineering teams to confront the complex issues of rehabilitating highly developed landscapes.
- The importance of employing models – conceptual to hydrodynamic, sedimentological, and ecological – to test hypotheses responses and support adaptive management.

Ultimately, the challenges of rehabilitating estuarine ecosystems in urbanized and industrial estuaries in the USA and northern Europe are the same: managing expectations and using the best scientific and technical tools to ensure that the results are strategic. We should be encouraged to optimize the credibility and dissemination of efforts in this direction by: using external peer review and other ›lessons learned‹ mechanisms; producing white papers and other guidance documents that provide timely dissemination of results to the broader restoration community; contributing to applied science publications; and, collaborating in international forums at all scales through workshops and international meetings.

A NEW VISION FOR THE LOIRE RIVER ESTUARY

Pierre Bona – GIP Loire Estuaire

THE LOIRE ESTUARY

The Loire River extends over 1000 km with a catchment covering a fifth of France. Its flows varies dramatically from 150 to 6200 m^3/s. Its estuary extends over 100 km and passes through the city of Nantes, located some 55 km away from the sea and built on high ground, and through areas of unprotected low-lying agricultural land, mainly used for cattle grazing (Figure 29).

Figure 29.
Upstream view of the Loire estuary. Credit: Gerpho.

RIVER ALTERATIONS

For the past two centuries, the Loire estuary has undergone a series of major public works to maintain safe shipping conditions to the Port of Nantes. Initially, the estuary was shallow with a multi-channel and island system. It was deepened and transformed into a single channel to help the tide propagate upstream more efficiently.

However this has resulted in an alteration of estuary hydro-sedimentological processes, with some negative impacts on the various users of the Loire River:

- Low water levels have dropped dramatically, which has resulted in an increase in the tidal range in Nantes from 3 m to more than 6 m within the past 100 years
- The salt intrusion has progressed upstream
- Turbidity has developed in extent and concentration

RESTORATION PLAN

Faced with such problems, it was decided in the 1990s to initiate an ambitious study and monitoring programme, as part of the ›Plan Loire‹, to improve the understanding of the estuarine processes, set common objectives for the future of the estuary and define a possible restoration scheme.

The stakeholders decided on a new common vision for the estuary, based on more balanced objectives between economy, urban development, environment and amenities. The study programme has shown that it is possible to restore the hydrosedimentological processes by modifying the estuary morphology, while providing better conditions for its users.

The proposed restoration scheme is based on two main actions: the recreation of mudflats along the downstream part of the estuary and the filling up of deep sections in the navigation channel, downstream of Nantes. Both will reduce the tendency of the Loire to trap fine sediments in its internal estuary while restoring key ecological functions.

PILOT PROJECT

The GIP Loire Estuaire, who is the project manager for this restoration programme, is a partnership organisation created by the main estuary stakeholders in 1998 to advance and capitalize on knowledge in the downstream part of the Loire river. The GIP Loire Estuaire is now considering the creation of a 100 ha mudflat in the estuary, as part of a pilot project, before implementing this type of intervention in a larger scale (500 ha). The new mudflat will be created by digging into areas of unprotected low-lying agricultural land, used for cattle grazing, and/or reed beds of high ecological value (Figure 30).

Figure 30.

Downstream view of the Loire Estuary showing, on the right side, one of the two sites considered for the mudflat recreation pilot project. Credit: Gerpho.

To come up with the best project possible with the least impact on the various users, the GIP Loire Estuaire has initiated a working group bringing together the main users and stakeholders with an interest on the project site (farmers, regulatory bodies, harbour authorities, land owners, environmental organisations, etc). This group has provided useful input into the design process and will be consulted at a later stage to check whether its requirements have been properly addressed by the design. The implementation phase of this pilot project is planned for 2012–2013. A monitoring programme will then be implemented over a period of a few years before it can be decided to extent the mudflat recreation programme to larger areas.

The GIP Loire Estuaire is also working on the global restoration scheme for the Loire estuary by studying additional morphological actions. Some further field and modelling work still needs to be conducted to fully understand the estuarine processes in the Loire but the context for this restoration programme is favourable: there is political support, a river catchment framework is in place to set general restoration actions and the main stakeholders share common objectives for the estuary.

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