Hamburg Port Authority

WE KEEP

THE PORT AT ITS DEPTH

Safe waterside access to the Port of Hamburg

Today and in the future

Legal notice

Editor

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Contents

Preliminary remarks

The present plan forms the basis for a new strategic direction for water depth maintenance at the Port of Hamburg. It describes the path from a fixed strategic plan to an adaptive management system. This transition is based on the recognition that, at the Port of Hamburg and on the tidal Elbe, the highly changeable basic conditions of the natural water system require constant adjustments in sediment management. This means that the basic conditions cannot be established firmly in advance for ten or twenty years. Moreover, the Hamburg Port Authority (HPA) can only design part of the overall sediment management plan by itself. Tasks in many of the areas can only be tackled successfully if players from politics, public administrations, associations, environmental organisations, research institutions and port industries become involved. This is because these tasks are often outside of the administrative, thematic, or regional scope of the HPA or would require a broad societal consensus.

Therefore, the Hamburg Port Authority has identified areas for action and set management goals and will operate and continue to develop sediment management along these corridors. For this purpose, it will rely on transparent reporting to document and communicate regularly progress and adjustments within the individual areas for action. It will indicate which factors it can work on directly, where it can act as a driving force and in which areas it can only serve as one among many partners.

Besides long-term development, we also aspire to handle transparently the opportunities and the duties entrusted to the HPA as the key player in water depth maintenance at the Port of Hamburg.

The three main areas for action in this management system are: the clean-up of pollutants in the Elbe, the water depth maintenance in itself, including dredging and disposing of dredged material and, lastly, river engineering. All activities described below serve directly or indirectly to guarantee the waterside access to the Port of Hamburg in the long term, thus providing a reliable port for shipping, which is an especially sustainable and resource-efficient mode of transport. The port is located near the markets and equipped with excellent transport links to the hinterland.

In the coming years, this management system will continue to evolve thanks to innovation: new measures will be added, and other activities will be discontinued. The HPA will provide transparent information on this and, together with its partners, it will develop, organise and improve on sediment management to ensure that it is sustainable.

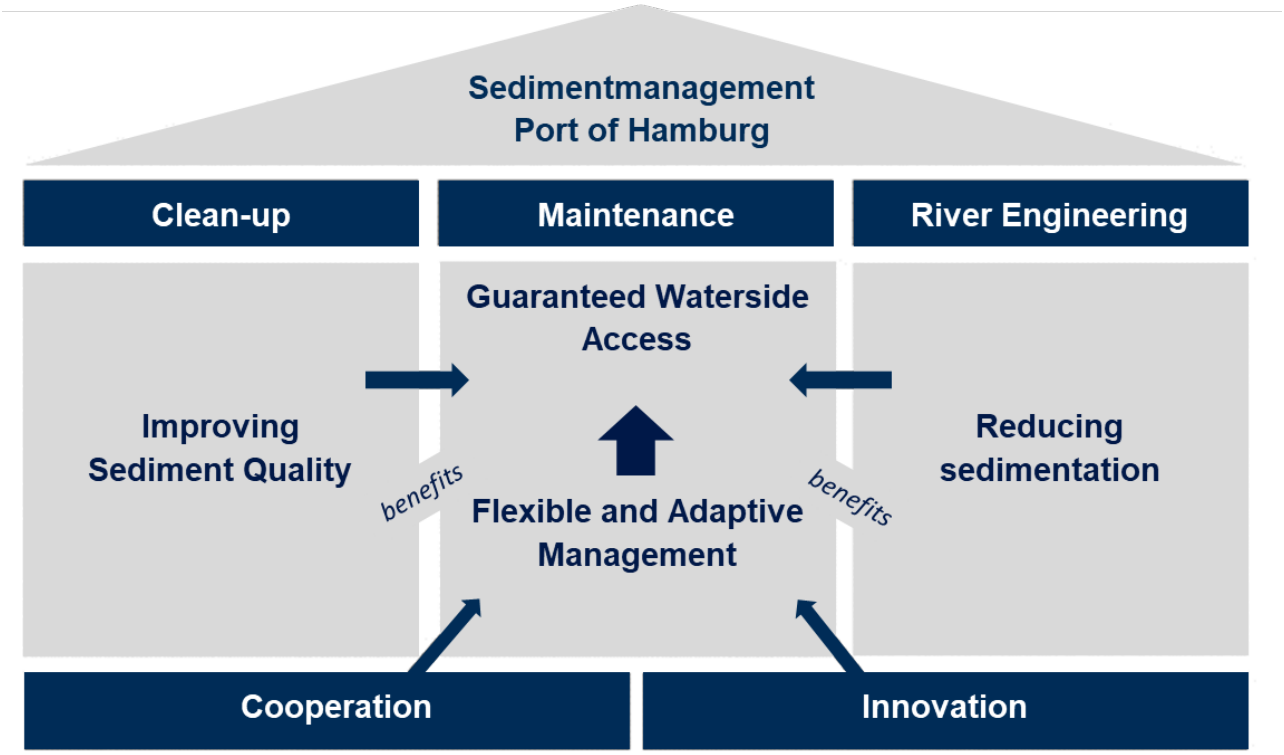

Fig. 1: Activity fields for sediment management in the Port of Hamburg.

1. Introduction

The Port of Hamburg is the most important German sea port and of paramount importance for the German export economy. Roughly €50 billion in gross value added is generated by the port each year in Germany, and almost 600,000 jobs depend on it[1]. Its location deep in the hinterland enables it to transport goods almost all the way to the markets in an eco-friendly and inexpensive manner. This, together with excellent inland waterway, rail and road links, make the port location indispensable for Germany. You can find out more about how this all fits together and about the importance of the port for Germany in an explanatory film.

Explanatory film on the significance of the Port of Hamburg

The Port of Hamburg can only be successful in the long term, however, if it is ensured that the water depths required for navigation will be available throughout the year, from the North Sea to the berths. For the ships to be able to reach the Port of Hamburg, they need to rely on having sufficient water under the keel. This alone guarantees that port enterprises can plan in the long term and do business. To achieve this, fresh deposits (sediments) must be removed regularly from the bottom of the navigation channel, of the access routes and of the berths. Thus, the port's operations depend at a fundamental level on successful water depth maintenance. Within the regional borders, this task is part of the statutory obligation of the Hamburg Port Authority AöR (HPA).

In order to meet this responsibility in the context of national administrative structures and complex, scientific interrelationships, a clear and comprehensive strategy is needed. This overall strategy describes the basic conditions and elements for guaranteeing waterside access to the Port of Hamburg for a planning interval of about ten years, thereby indicating the future direction of this vital duty for Hamburg, the region and for Germany. At the same time, it constitutes a living document, a management system, i.e. it will be adjusted repeatedly to actual conditions of a variable nature; its fundamental direction however is valid for the long term.

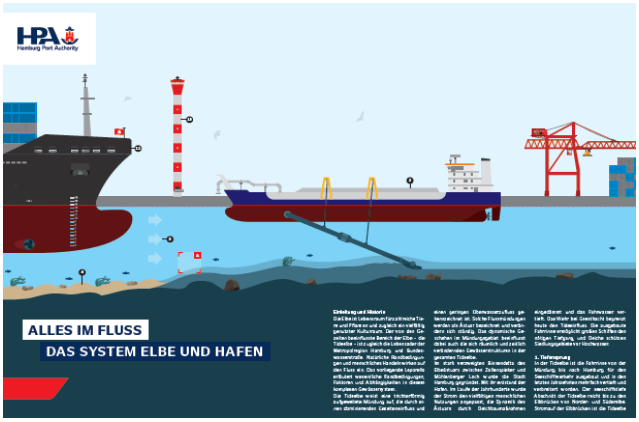

Fig. 2: The workings of the complex system of the Elbe and the port are explained in an infographic (Link).

Suspended sediment and sediments in the river, both from the upper course of the Elbe and with each tide from the North Sea, are in constant motion toward Hamburg, where they are deposited in the extensive, calmer-water areas of the port. In an extreme case, the floor of the river can rise by several meters within few months. In order to provide sufficient water depths for navigation however, in the Hamburg area the HPA dredges several million tonnes of Elbe sediment each year in quantities that can vary by a multiple of four or even more. The HPA determines precisely where dredging is needed using ultramodern survey vessels, which are deployed daily.

The greater portion of the dredged material is silt, a mixture of fine-grained natural deposits, as is the case in most tidal waters. In some areas coarse-grained sand must also be removed, in particular in the main Elbe stream. The weaker the currents, the finer the grains of the deposits.

And so, sediments are a natural and ecologically important component of this waterbody. Therefore, they should be allowed to remain in the waters even if they must first be dredged. They will be relocated to another site in the waterbody. Four disposal sites areas are currently available on

[1] ISL 2021

the Elbe and in the North Sea: At Neßsand on the regional border of Hamburg, at St. Margarethen and at Neuer Lüchtergrund (both relocation sites of the WSV, which the HPA can use jointly to a minor extent) and also in the North Sea at Tonne E3. All of these options are subject to different restrictions and requirements as far as timing, quantities and quality.

The amount of sediment deposited in the berths and shipping lanes of the Port of Hamburg depends on the hydrological situation and also on the interplay of freshwater flow and tidal phenomenon. This amount can undergo extreme changes within short time periods, e.g. due to dry periods or high water levels in the catchment area of the Elbe. There are also long-term trends, such as the widening of the tidal range. Natural changes, the transformation of the Elbe estuary by human activities and also climate change will all contribute to this. Long-term and short-term trends in the hydrological situation also have a combined impact on the scope of the maintenance dredging operations required for nautical and economic reasons.

The silt in the tidal Elbe contains types of pollution typical of the Elbe, such as heavy metals, as well as organic contaminants in concentrations that vary widely depending on the site. These are mainly the product of historical sources (e.g. mining, hazardous industrial waste) in the upper catchment area of the Elbe. Therefore, the HPA takes samples regularly and analyses the dredged material. The samples have shown that, over the course of the years, the concentrations have decreased greatly, and today they are largely so low in Hamburg that it is environmentally sound for the silt to remain in the waters; hence it can be relocated. If the sediments are too heavily polluted, then they are treated and subsequently reused or deposited on land by the HPA. In a special system for preparation of the contaminated dredged material called METHA (“Mechanical System for Separation of Port Silt”), the HPA separates contaminated silt from uncontaminated sand and drains it, thus making it reusable, in order to save limited landfill space.

Without water depth maintenance, the port basin and access routes would be filled with sediment within a few months, and the port would soon only be navigable to a very limited extent. Sediment management (see Fig. 1) is based on three main pillars:

- The actual maintenance with its components of surveying, dredging, relocation, depositing and land treatment.
- The clean-up of contamination sources with the aim of improving sediment quality and expanding options for deposit or use of the sediments and/or reducing their impact.
- River engineering measures with impact on the currents for reduction of sedimentation.

Since the basic conditions are subject to constant change due to natural and human-induced factors, the management of sediment must offer a flexible and adaptable response and when possible be able to take anticipatory action. This applies especially for the central areas of maintenance, i.e. relocation and land treatment.

The Hamburg Port Authority carries out its duty of guaranteeing the water depth in the port by responding to a complex tension between the ecological requirements of the natural environment of the tidal Elbe and the demands of various types of use. The system interactions extend from the source of the Elbe to its estuary, thus far exceeding the scope of administrative responsibility of Hamburg and the HPA. For this reason, compromises must be reached repeatedly in dialogue with stakeholders and administrations along the Elbe, and subject to legal constraints, that can guarantee and map out needs-based utilisation of the tidal Elbe as an economic area and as a natural habitat at the same time. The film explains how this works.

Explanatory film on the HPA’s water depth maintenance.

2. Mission and responsibilities of the HPA

The Hamburg Port Authority (HPA) is a public institution subject to the technical and legal oversight of the Hamburg Ministry for Economic Affairs and Innovation (BWI). Since 2005, it has run the port management of the Free and Hanseatic City of Hamburg and been legally responsible for the development and conservation of an efficient infrastructure in the Port of Hamburg. This also includes guaranteeing the waterside access to the port in the long term.

In order for vessels to reach the Port of Hamburg, the port's waterways and the navigation channel of the Elbe must be kept navigable without interruption from the North Sea to Hamburg itself. The HPA carries out this task within the regional borders of Hamburg. From Wedel to the Elbe estuary at Cuxhaven, the Federal Waterways and Shipping Authority (WSV) is responsible for the water depth maintenance, which is an agency of the Federal Ministry for Transport and Digital Infrastructure (BMVI). Granting approvals beyond the regional borders of Hamburg for the disposal of dredged material is within the scope of responsibility of the respective Federal States andof the Federal Government.

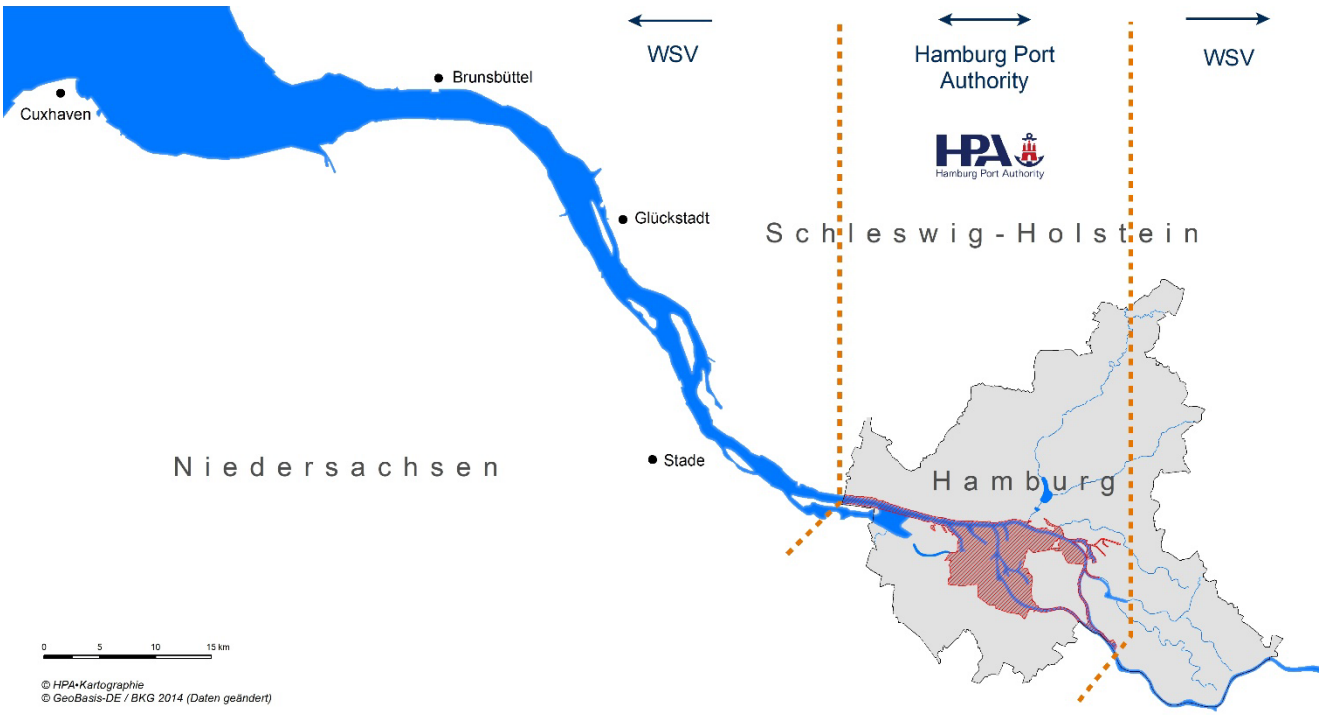

Fig. 3: Responsibilities in the tidal Elbe.

3. Management objectives

Water depth

The essential goal is guaranteeing, as needed, the water depth required for navigation in the port and the Elbe in the area for which the HPA is responsible. This management strategy is based on the goals set below.

I. Reduction of quantities

The quantities of sediment accrued that must be relocated to guarantee the waterside accessibility remain high. This is caused by natural factors and by human intervention. The goal of this management approach is to reduce the quantities in the long term through sustainable discharge of excess sediment from the upper tidal Elbe, through minimisation of sediment and dredging cycles and through river engineering initiatives. Moreover, the amount of contaminated material that must be disposed of on land must be reduced by clean-up of the sources of contaminants along the course of the Elbe and by subsequent extraction of highly polluted sediments in Hamburg.

II. Cost efficiency

The HPA must adhere to the principles of economic sustainability. Hence, the HPA is responsible for keeping the Port of Hamburg navigable and also for accountability in management of taxpayers' money. And so, for all individual measures of this management system, in addition to the efficacy in guaranteeing the waterside accessibility, the efficiency of the resources allocated is crucial.

III. Environmental protection

The Elbe has always been a natural landscape and economic space at the same time. When maintaining the waterside accessibility for navigation, the balance between economic utilisation and conservation of the natural habitat must also be ensured. Today the HPA is already making a great effort to perform the task entrusted to it with the least possible environmental impact. The weighing of alternative measures from this standpoint is a basic principle of this management system. To this end, the HPA relies on cooperation, in addition to collaboration with its own experts; thus, it engages in dialogue with external experts and regional representatives in river engineering management and sediment management and with the Tidal Elbe Forum resp. its successors.

4. System and dependencies

4.1 Tidal Elbe system

Between the weir at Geesthacht and its mouth in the North Sea, the Elbe is subject to the influence of the tides. It is therefore also called the tidal Elbe. The alteration of ebb and flow tides poses a special challenge to maintaining the waterside accessibility of the port, since the tidal forces, the currents, transform the river constantly. Along with the water, the sediments are also in constant motion.

Fig. 4: Satellite image of the tidal Elbe.

The estuary of the Elbe is the largest in Germany. This type of river estuaries, expanded by the ebb and flow tides into a funnel shape, only form on coasts with strong tidal phenomena that constantly transform them. The rivers carry along great quantities of suspended matter and sediment on their natural path downstream until it is finally deposited in the tidal flats. Channels and sandbanks shift constantly within the borders set by the dyke. The estuary of the tidal Elbe is a highly dynamic transitional zone between river and sea; thousands of tonnes of sediment are in continuous motion. Most sections of the estuary are specially protected as habitats. Upstream from estuaries an inland delta is often formed, as also occurs on the tidal Elbe. More than 800 years ago, the Port of Hamburg arose in the multi-branched bifurcation area between Mühlenberger Loch and Geesthacht.

In the inner estuary, the powerful ebb and flow of the tides operates like a pump. While in a natural estuary the sediment is mainly carried along toward the sea, in the lower Elbe transport in the opposite direction is also possible depending on the hydrological situation at any time: The mostly stronger incoming tide carries fine, sandy material upstream. The weaker ebb tide carries only a portion of this out again to the North Sea. This phenomenon, which occurs also in many other estuaries, is called “tidal pumping”.

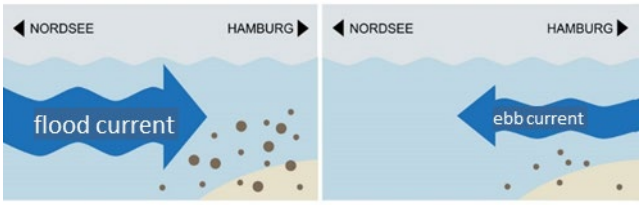

Fig. 5: The “Tidal Pumping” phenomenon.

At the same time, fine-grained sediments from the upper course of the Elbe are carried downstream. The sediments are deposited wherever the current slows down. This occurs especially in the wide port basin and in the lateral areas of the river where the current is weak.
When the Elbe above Hamburg carries a lot of water, i.e. when it has a so-called high freshwater flow, then the force of the river can mobilise a greater portion of the sediments and carry them off toward the North Sea. At the same time, the incoming tide is weakened. The freshwater flow depends on the precipitation in the catchment area of the Elbe and is subject to very significant fluctuations, intensified by water abstraction and reservoir retention. In periods of climate change, the outflow regime in the catchment area of the Elbe also changes due to extreme weather events (droughts, intense rains).

4.2 Quantities of sediment

The quantity of the sediment that is deposited in the port basins and the navigation channel and that must be removed again by the HPA and Federal Waterways and Shipping Administration (WSV) depends on numerous factors and can fluctuate widely. The freshwater flow, – i.e. the flow resulting from precipitation that reaches Hamburg from upstream in the Elbe catchment area – is the most important influencing factor with short-term impact, and it is accorded a special importance: The less water flows down the Elbe, the greater the need for dredging in Hamburg.

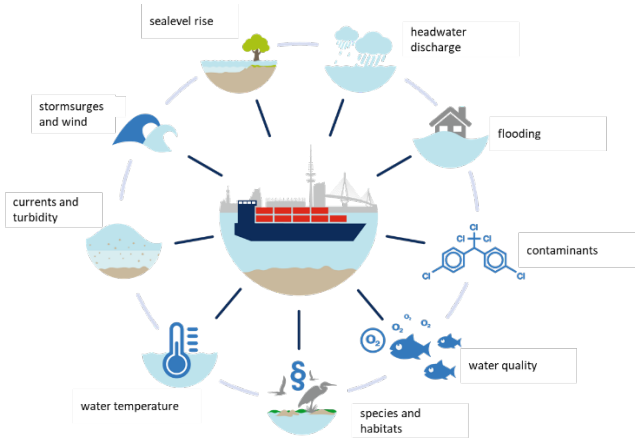

Fig. 6: Factors influencing the water depth maintenance.

The cause of this is an increase in return transport with the incoming tide, which is held in check only to a lesser extent due to the weak outward flow. Sediment cycles are the result whenever dredged material is not carried far enough downstream. The shape of the body of water, on the other hand, determines, in principle, the level of sedimentation in the long term. Due to the expansion of the waterway and to the loss of tidal water areas (dyking, blockage of tributaries, filling in of water areas), but also due to enlargement of individual areas in the port and an increased nautical need for depth, the level has risen higher and higher over the decades.

In the tidal Elbe, the quantities of dredged material vary greatly. Thus, in Hamburg in 2011 roughly 1 million tonnes of dry matter were dredged, while in 2015 it was roughly 5 million tonnes.

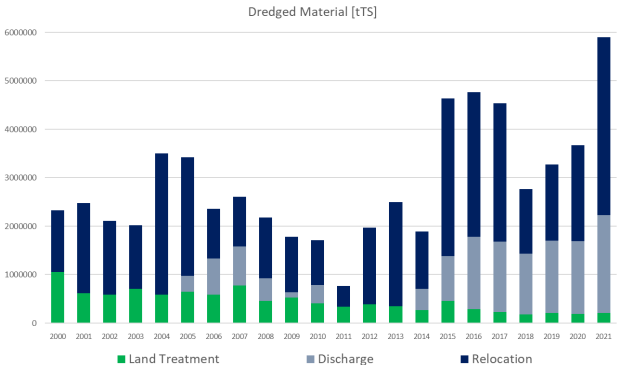

Fig. 7: Evolution of quantities of dredged material HPA 2000 – 2020.

4.3 Quality of sediments

The quality of sediments in the tidal Elbe is also subject to fluctuations according to specific sites and time periods. Pollution such as heavy metals or organic contaminants can adhere especially well to fine-grained suspended sediments. Most contaminants have been and continue to be carried off downstream with the suspended sediment, thus reaching the tidal Elbe and the North Sea, where they deposit as sediments and mix with uncontaminated material from the mouth of the river. The highly varying freshwater flow has a decisive impact on the ratio of the mixture and thus the concentration of the pollution, as well as the quantities of sediment.

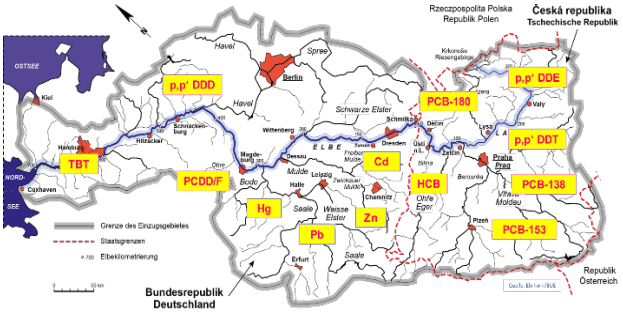

Fig. 8: Sources of contaminants on the course of the Elbe (for example).

The pollution has its origin largely in historic sources from mining, industry, waste water, as well as agriculture. It is found in the entire catchment area of the river and as far away as the Czech Republic. In the lateral area, such as the groynes of the upper and mid Elbe, there are still large quantities of contaminated sediments that could be set in motion again, e.g., in the event of flooding as in summer 2013 or by local maintenance measures. Thus, since the 1990s, pollution has decreased greatly and has stabilised at a level that is much lower, but nevertheless this level is still too high for unrestricted use and the strict targets of marine protection. Even though the river's waters have been very clean for a long time, the older sediments constitute the long-term memory of the industrialised Elbe region.

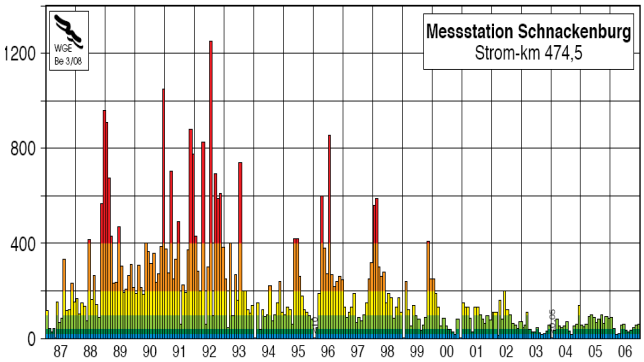

Fig. 9: Evolution of the suspended sediment loads in Schnackenburg with the example of HCB (data in µg/Kg).

5. Management and solutions

The term “sediment management” describes the management of the sediment dynamics in a body of water, in this case in the Elbe. It is the HPA’s task, as enshrined in law, to manage the sediment dynamics so that the depths required for navigation can be provided in a reliable manner. Besides dredging and relocation in the waters or depositing on land, this also includes improving the sediment quality and reducing the quantities of sediment to be dredged. With the goal of guaranteeing waterside accessibility, the HPA has set up a sediment management system that consists of three main pillars: Clean-up, maintenance and river engineering, where clean-up and river engineering in the end serve to expand the leeway for action in the central pillar of maintenance. Close collaboration with all relevant interest groups, administrations and technical experts, as well as consideration of innovative approaches, constitute the foundation for successful work on the three pillars.

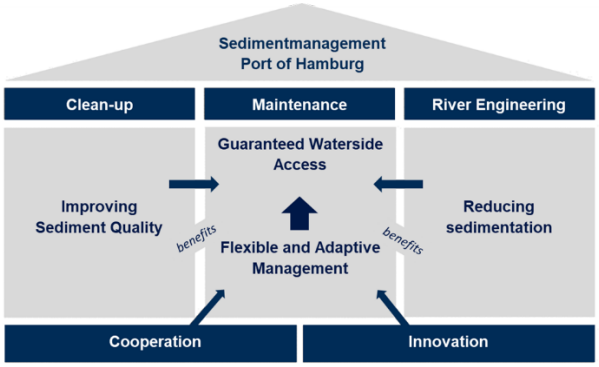

Fig. 10: Activity fields for sediment management in the Port of Hamburg.

5.1 Maintenance

Surveying

The riverbed changes constantly due to tidal phenomenon and to the currents of the Elbe, as well as the transport of sediments that these stir up. To find out whether the navigation channel or the port basin continues to have sufficient depth, the river bed is surveyed regularly with state-of-the-art special vessels and remote-controlled floating drones, and hydrographic measurements are taken.

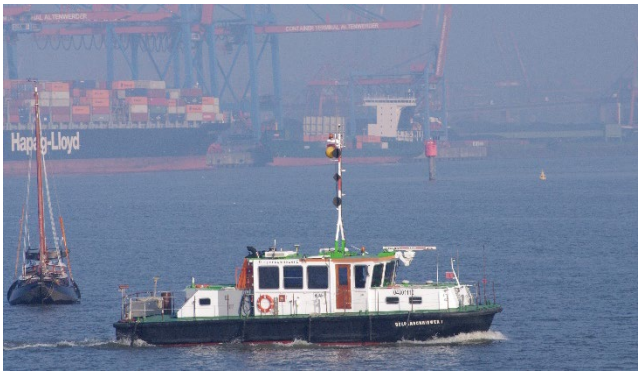

Fig. 11: The survey vessel *Deepenschriewer I.*

Where the required water depth is adversely affected by freshly deposited sediments, the sediments are dredged. Hence, the survey data are not only the basis for safe navigation, but also for planning and controlling the necessary maintenance dredging.

Dredging

If the surveys indicate that the water depths fall short of what is required, then these areas must be dredged to the extent necessary. Dredging is carried out in accordance with the characteristics of the sediment and with local circumstances using trailing suction hopper dredgers (“hopper dredgers”), rope grab dredgers or hydraulic dredgers on pontoons, or the bed-leveller, or the water injection equipment.

Fig. 12: Trailing suction dredger Bartolomeu Dias

The equipment is chartered partly from the Hamburg Fleet, a subsidiary of the HPA, or it is deployed as needed in the context of contracts awarded after competitive bidding procedures conducted at the European level. An expert report from 2018 confirmed that the strategy is the most economically appropriate option for compliance with applicable restrictions and framework conditions. Even the costly deployment of the trailing suction hopper dredgers is easier to arrange from the economic standpoint by awarding contracts to third parties as needed, because in comparison with operating one on its own there are no downtime costs, machine failures can be replaced easily and the specialised equipment best adapted to the task can be deployed.

Relocation and disposal

Before the sediment is dredged, the HPA analyses it for contaminants. Most of the material is inoffensive and can be relocated. This means that the sediments are extracted from the riverbed at sites where they interfere with navigation and disposed of into the waters at another site.

The so-called relocation or transfer takes precedence in sediment management, and sediments must be left in the water body whenever possible. This is partly due to ecological and hydromorphological reasons, since the sediments are a natural component of the Elbe, and partly because it is the most cost- and resource-efficient solution.

There are currently four disposal sites available for the dredged material, which largely consists of silt: At Neßsand on the regional border of Hamburg, at St. Margarethen and at Neuer Lüchtergrund (both relocation sites of the WSV, which the HPA can use jointly to a minor extent), as well as in the North Sea at Tonne E3 in the region of Schleswig-Holstein.

Fig. 13: Neßsand, an island in the Elbe

Since 1995, dredged material has been relocated near the island of Neßsand in the Hamburg section of the Elbe river. This has been possible since the 1990s due to the improvement of the sediment quality, which continues to the present day, resulting from the discontinuation of industry and wastewater treatment along the mid and upper Elbe. The material is relocated in sole dependence on the tides so that it is ensured that the greatest possible amount of sediment is carried off downstream with the ebb tide.

To strike a balance between the different protection and maintenance goals and the necessities of water depth management, the relocation of sediments in the Hamburg area is confined to the cold season. In Hamburg, water depth management is based on an action strategy agreed among the different ministries and agencies[2], which implements the requirements of the basic legal conditions.

In order to guarantee the accessibility of the Port of Hamburg in the summer months as well, since 2005 the HPA has brought fresh sediment into the North Sea to the so-called Tonne E3. The goal of bringing sediment into the North Sea is to maintain the port as needed while discharging excess fine sediments from the upper tidal Elbe in a sustained manner in order to relieve the system of the burden of fine sediment in the long term.

[2] https://www.hamburg-port-authority.de/fileadmin/user_upload/Rahmen_Umlagern_2012_final.pdf

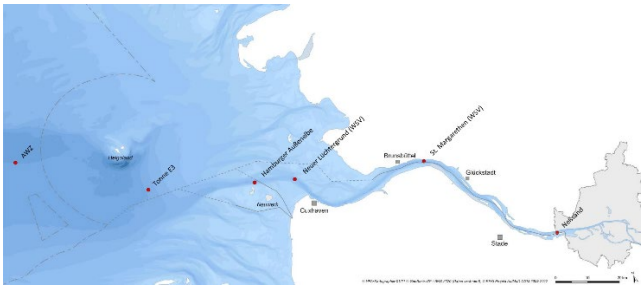

Fig. 14: Location of relocation options currently in use or under study.

Tonne E3 is roughly 25 km northwest of the Hamburg island Scharhörn, in the sedimentation area in which fine-grained silt occurs naturally at a depth of roughly 35 m (the so-called “silt drop area”). The conditions at the site have been selected based on the existence of a strong similarity between the natural sediments and the dredged material so that the greatest possible amount of the dredged material remains there.

The relocation of dredged material from Hamburg is possible thanks to approvals from Schleswig-Holstein. The most recent approvals, valid as of 2016 and renewed in 2019, permit fresh sediments from the federal waterway of the Elbe and also from the most important navigable port areas to be relocated at Tonne E3, provided that they meet strict quality requirements.
To this end, before dredging, the sediments in Hamburg are sampled and analysed by certified laboratories for their contamination rates. Only when it has been demonstrated that the sediments are clean enough is clearance granted to relocate them in the North Sea.

At Tonne E3, an unprecedented monitoring programme, combined with a working group involving other German Federal States, guarantees that any possible environmental impacts can be kept with safe limits. For this purpose, regular measurements and sampling voyages are conducted. Chemical and biological analyses are conducted regularly at roughly 150 stations, directly at the disposal site and at distances of up to 12 km. These include examination of the sea floor, waters, fish and seabed fauna, such as snails and mussels. The stability of the sediments is observed using water depth measurements in combination with analyses of the sea floor. Moreover, sea floor samples are analysed for pollution at different coastal measurement points in Schleswig-Holstein and in Lower Saxony. All measurements up to now have confirmed that negative effects outside of the immediate disposal area, such as measurable drifting into protected areas or onto the coasts, can be ruled out. Moreover, after relocation a rapid regeneration of the fauna adjusted to the changes can be observed.

Fig. 15: Sampling at Tonne E3

Since 2021, the HPA also uses parts of two disposal sites of the Federal Government in the tidal Elbe, although only for dredged material from the federal waterway, in particular from the meeting area that is newly to be maintained near Wedel. The St. Margarethen disposal site is situated in the area of the maximum turbidity zone, roughly 50 km downstream from the regional boundary. From there, too, material is transported back to Hamburg, but this takes significantly longer than from Neßsand. The Neuer Lüchtergrund disposal site is situated right in the mouth of the Elbe, around 100 km downstream. From this site, there is no additional return transport, making this option an especially valuable addition in terms of the intended discharge. The basis of the relocation operation is two comprehensive impact forecasts that also take into account proportionately dredged material from Hamburg from the delegated section. Both relocation options are strictly limited in terms of quantity.
In order to successfully reduce ecologically detrimental cycle management in the future, in 2021 a disposal site to be newly set up in Hamburg, in the outer Elbe, was studied comprehensively. The intention is to relocate sediments of a suitable quality here as well in order to be able to dispense with the return transport into the inner estuary. This potential relocation site is located near the island called Scharhörn, but it is at the edge of the Elbe waterway outside of the National Park.

Land treatment

A small portion of the mainly older sediments in the port's own areas are combined with too many contaminants, in particular from the upper course, and must be treated and disposed of on land. Especially when sediments from neglected deposits must be included in dredging operations, treatment on land is usually unavoidable. The quantity of sediments treated on land has declined in recent years. The reasons are: changes in nautical needs, improvement of the quality of freshly deposited sediments and progress in the gradual removal of contaminated sediments from neglected deposits. Where contaminated sediments from neglected deposits have been properly removed, the fresh sediment has largely become so clean in the meantime that it can remain in the waters, and so it can be relocated.

Fig. 16: METHA system in Francop.

The HPA has developed a system for treatment of contaminated dredged material on land that reuses the greatest possible amount pursuant to the Closed Substance Cycle Waste Management Act (KrWG) and guarantees safe removal for the remaining material, thus conserving resources.

Explanatory film on the land treatment system:

Since March 1993, the large-scale system called METHA ("Mechanical System for Separation of Port Silt") has been in operation for treatment of contaminated dredged material. In the early 1990's, it was the first processing plant in the world for purification of dredged material, an innovative project of the HPA, and today it remains a model for comparable systems, such as the one in the Port of Antwerp. The material is processed so that part of the sediments can be reused. Of course, this conserves resources, for example building sand or sealing materials such as clay, as well as valuable landfill space.

Treatment consists of two phases: First, the clean sand is separated from the sediment by centrifuge. It can be used as building material. The more highly polluted, cohesive silt is drained mechanically and then mostly used as sealing compound at the landfill for dredged material in Hamburg or deposited there. The HPA studies periodically other options for reuse, such as in the ceramic industry as clay substitute or as material for dyke construction. Each year roughly two hundred thousand tonnes of sediment are treated in the METHA system.

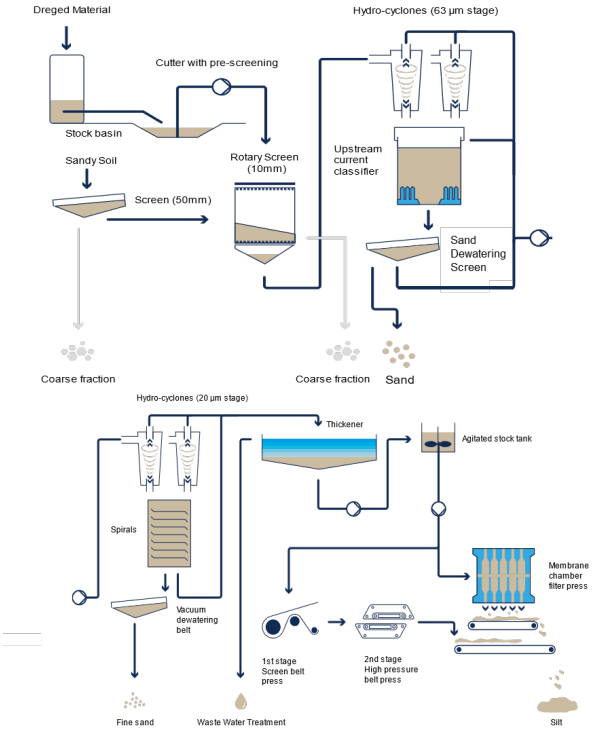

Fig. 17: How the METHA system works.

A portion of the contaminated dredged material is also taken to drainage areas. The water runs off through drains or evaporates. This leaves dry material that is disposed of at the landfill for dredged material in Hamburg.

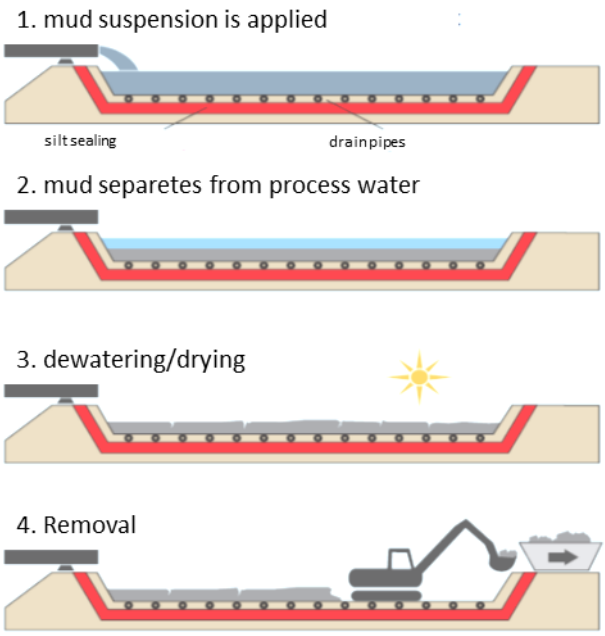

Fig. 18 Process principle of the drainage areas.

The drainage areas are used especially at quantity peaks and for special types of contaminants (oily sediment is dehydrated in special drainage areas equipped with special seals).

After treatment in the METHA system or the drainage areas, contaminated dredged material must be deposited safely. In Hamburg, two landfills for contaminated port sediment are currently being run: in Francop (where new deposits are no longer admitted) and in Feldhofe. Smooth ship traffic and operation of the port are only ensured if sufficient landfill capacity is available for treated dredged material from the Elbe.

Fig. 19: Feldhofe landfill for dredged material.

5.2 Clean-up

Hamburg assumes extensive responsibility for the cleanliness of the Elbe that is not limited to treatment of contaminated dredged material in the Port of Hamburg. In the context of the project for decontamination of the Elbe sediments (ELSA[3]), the HPA assists in identifying sources of contaminants as well as in planning and implementing clean-up projects and in transfer of know-how on environmentally sound handling of contaminated sediments. Although the quality of the Elbe and its sediments has improved significantly, there are still major challenges for the entire national and international community of the Elbe river area with regard to attaining a “good status” of the Elbe as is required according to the Water Framework Directive and the Marine Strategy Framework Directive. To achieve this, clean-up operations must also be carried out on neglected sources of contaminants along the course of the river so that the water system becomes cleaner, and less contamination is carried with the sediment into the tidal Elbe and into the North Sea. Apart from the benefits for water and marine protection, cleaner sediments make possible a truly sustainable and worthwhile use of the dredged material in the tidal estuary and on the coasts, in particular in times of rising see levels.

[3] ELSA - Clean-up of contamination of the Elbe sediments

5.3 River engineering

Over the long term, the quantity of sediment is also to be reduced through river engineering measures, i.e. calculated structural modifications of the riverbed. Therefore, the more tidal space (or “tidal volume”) that is available for the water, the less sediment is stirred up by the tide and carried along and hence the less sedimentation in the Hamburg area. This approach of giving back more space to the river is also followed intensively in other European estuaries (e.g., in the rivers Scheldt, Weser, Ems, Humber, Loire and Severn). The HPA researches and works intensively with different partners to further expand understanding of the system. Thus in the River Engineering and Sediment Management Forum (FOSUST), measures have been identified that have been analysed jointly in the subsequent Tidal Elbe Forum, and that are now available to the competent administrations for further specification or for implementation at the planning level[4].

The HPA is currently carrying out its first large-scale river engineering pilot project in the tidal Elbe, the intertidal area of the Kreetsand Shallows. Roughly 30 hectares of new tidal space, which will at the same time serve as tidal habitats of special ecological value, will be created.

Fig. 20: Kreetsand Shallows under construction.

[4] see Tidal Elbe Forum

6. Areas for action

Water depth maintenance is the central pillar for guaranteeing waterside accessibility, as in most seaports throughout the world. All activities are oriented toward this core task. Water depth maintenance always needs several options in order to be able to respond flexibly to the nautical needs and to the underlying environmental conditions.

More options for water depth maintenance however does not mean that an increasing quantity of dredged material is transported. On the contrary: The selection of the right relocation site in consideration of the contributing natural factors such as the freshwater flow can achieve an efficient reduction of quantities dredged while at the same time reducing environmental impacts. This results in greater safety for navigation and increased cost-efficiency. In order to improve the basic conditions for maintenance, the quality of the sediments in the Elbe catchment area must be improved at the same time. This expands leeway for action when dealing with sediments, since in particular the quality of the sediments (which has improved greatly) - and how they are perceived by the public - decides, in the end, on the options for dealing with them. This would make it easier to use sediments in a worthwhile manner as valuable natural resources for use with additional benefit, for example to protect the coasts, thus working to forestall the consequences of climate change and of the rise in sea levels. River engineering measures must be developed since they have a beneficial impact on the tide dynamics, the sediment quantities and also the ecological conditions of the waters. Innovations increase the efficiency and, in the end, the sustainability for guaranteeing the accessibility of the Port of Hamburg. Close collaboration within the region lays the foundation for societal acceptance.

Currently we do not have reason to assume that one of the challenges, such as the clean-up of the Elbe or the implementation of river engineering measures can be resolved comprehensively in the short term. Coordinated efforts of the entire river area community are required for this. And so the task of water depth maintenance is a continuous learning process that requires constant analysis and adaptation to existing and evolving framework conditions.

Water depth maintenance

U1: Maintenance with schedule

U2: Appropriate use of the Neßsand relocation site

U3: Finding a safe, long-term option for disposal in the North Sea

U4: Use of further relocation options in the tidal Elbe

U5: Safe, appropriate use of treatment and disposal on land

Clean-up of the Elbe

E1: Establishment of a comprehensive sediment management system

E2: Clean-up measures

E3: Information and early detection

River engineering

S1: Preparation of the “Kreetsand” pilot project

S2: Planning and implementation of river engineering measures (creation of tidal space)

S3: Planning and implementation of measures to control the currents

Innovation

I1: Nautical depth

I2: Logistics and transport

I3: Modelling of currents and transport of suspended sediment

I4: Maintenance and climate change

I5: Reuse of the dredged material

Collaboration

Z1: Tidal Elbe Forum

Z2: Exchange of ideas among specialists and public relations work

6.1 Water depth maintenance

Each and every one of the proven building blocks of water depth maintenance at the Port of Hamburg – surveying, analysis, forecasting, dredging, monitoring, relocation in the waters or on land – will still be necessary in the future. In this respect, the need for maintenance is determined by the highly varying quantities of sediments. Since 2005, the port can also be maintained over large areas during the high-sedimentation summer months thanks to the option of relocating dredged material in the North Sea at Tonne E3. At the same time, the tidal Elbe and especially the relocation site Neßsand is effectively unburdened by relocation of sediment into the North Sea.

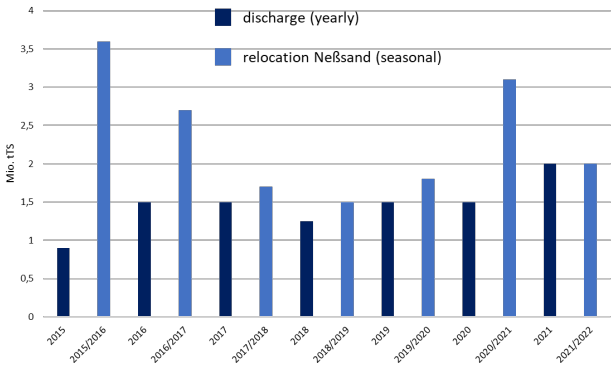

Fig. 21: Annual quantities Tonne E3, and seasonal (season = November to March) evolution of the quantities relocated to Neßsand, in millions of tonnes of dry material.

In order to be able to maintain the accessibility of the port even in periods of very high sedimentation or very low freshwater flows, it will be indispensable in the future to continue on this path of consistent discharge of fine sediment. The existing options for action are insufficient given the extreme hydrological conditions that have already lasted for over six years. This is illustrated by the fact that relocation of material to Neßsand 2020/2021 had to be increased significantly once more due to insufficient disposal capacities. Applicable maximum quantity limits, time limitations and the public perception, which do not take sufficiently into account the overall contamination existing in the Elbe and the impacts that are actually possible, impose limits on the existing frameworks for action. As a result, it has not yet been possible to implement specialised concepts for joint management of the tidal Elbe to a sufficient extent. The required maintenance must be postponed repeatedly, which limits ship traffic or operation of individual port businesses and which in the end also has a negative impact on the confidence and trust placed in Hamburg as a port location.

Therefore, the goal of water depth maintenance is to have available the maximum possible different options for relocating sediment that are guaranteed in the long-term so that the Port of Hamburg can be maintained in a flexible manner in accordance with its needs. In the interest of sustainability, the HPA must be able to utilise the best relocation option for the dredged material in each case, depending on the basic conditions (needs, sediment quality, hydrological situation, ecological factors, basic technical and legal conditions).

The future maintenance of the HPA is guided by the following assumptions, which have proven over the preceding years to be technically correct and generally accepted:

I. Sediments are a natural component of the water body and when possible, must remain in the water body.

These assumptions are already determining how the HPA operates today. Only if the pollution of the sediments to be dredged does not meet applicable environmental quality requirements, i.e. if it is impossible for the sediments to remain in the waters according to permit regulations, are they dredged from the water, treated on land and deposited or reused. Moreover, sediments are only dredged if there is a nautical, strategic or project-related requirement (for example, in the event of building works, overall maintenance or clean-up).

II. The quality of the sediments, and not their origin, must determine how they are handled and where they are relocated to.

The first important step was taken when the final approval was obtained for relocation of dredged material from the Port of Hamburg to the North Sea at Tonne E3. For the first time since 2016, this step enabled sediments to be relocated from the federal waterway and from parts of the port waters and hence from port areas essential for transport.

Provided that they meet the strict quality requirements that ensure that there is no negative impact on the marine environment outside of the placement site.

To be sure, the tidal Elbe is an integrated system that must be regarded and maintained as such – nevertheless it is not only the objective expert analysis, but also the responsibilities and administrative boundaries that influence handling of sediments. Dredged material from Hamburg is persistently addressed as “poisonous mud”, even though the quality of the fresh Elbe sediments today permits them to remain safely in the waters. Apart from actual clean-up activities for real improvement of sediment quality, in particular, doing additional communications work in the form of information and dialogue in order to keep the discussion on objective terms and implement the maintenance approaches in keeping with the existing system, is essential.

III. In a dynamic natural body of water, maintenance operations must be able to respond equally flexibly and adaptively.

This assumption is of decisive importance for the future of the port and the tidal Elbe and requires consistent implementation. A cost-efficient and sustainable management of the dredged material in a hydrodynamically complex system such as the tidal Elbe requires a high degree of flexibility and understanding of the system. Different relocation areas are better-suited or less-suited, depending on the natural conditions. In particular when there is low freshwater flow in the Elbe, when the natural force of the river is not sufficient to clear away sediment, then the sediment must be relocated into areas of the tidal Elbe where the ebb tide is dominant or into the North Sea. This is the only way to extract fine sediments from the estuary while minimising small-scale sediment and dredging cycles, as well as saving resources and the environment.

IV. The monitoring of the effects contributes to constant improvement in understanding the process and the system.

When implementing a flexible maintenance strategy, an accompanying monitoring programme is required that enables timely detection of effects and rapid corrective reactions when needed. In the context of an adaptive sediment management system, all aspects of the activity are continually analysed and adjusted as needed. This type of monitoring serves to promote understanding of the system in a targeted manner and constitutes an important basis for future maintenance strategies and decision-making.

In light of these assumptions, the packages of measures outlined below should be implemented.

Package of measures U1: Maintenance according to schedule

The regular tasks of water depth maintenance are based on a forecast scenario of quantities and corresponding capacity planning, which are verified and adjusted regularly while the maintenance campaign is underway. In order to improve the forecast of the transport and sedimentation processes related with the natural flow conditions and thus to further improve the certainty of planning in the coming years, an operational model for transport of suspended matter and sediment in the Elbe is being developed jointly with the Federal Waterways Engineering and Research Institute (BAW). This model will enable us to deduce the direct effects of all relocation activities, as well as indications for joint optimisation of maintenance.

At the Port of Hamburg, maintenance of the heavily used berths is carried out at regular intervals. This offers security to enterprises and creates trust. Moreover, it minimises increases in shoals at an early point. The goal is maintenance according to schedule – in the customers’ interest. Current experiences with this approach have appeared highly promising. This is enabled by regular deployment of

a so-called bed leveller, a powerful silt plough. This machine can remove silt from the berths whenever they are not occupied, regardless of the season and of the deployment of the large-scale hopper dredger. The silt plough moves the sediment over a short distance into a storage area without liquefying or appreciably stirring up the silt in the process. This low-turbulence technique has advantages for the ecology of the waters and also for the hopper dredgers, which are deployed at a later point. The latter can pick up the dredged material efficiently from the so-called silt capture channels and relocate it. Thanks to this procedure, the berths could be kept well at depth in the high-sedimentation months, in spite of continuing high sedimentation. This approach, consisting of nearby relocation, storage areas and efficient dredging and relocation operations has proven effective and will continue to be expanded. For this purpose, the Hamburg Fleet has constructed an efficient, low-emission bed leveller.

Package of measures U2: Appropriate use and preservation of the Neßsand relocation site

The Neßsand relocation site, which has been in use regularly since 1995, will also be an important component of the maintenance strategy of the Port of Hamburg during the winter months in the future and hence must be preserved. Even if other relocation sites further downstream can also be increasingly used, there are still some areas of the port that can be maintained only with small-scale equipment that should not be deployed for long-range transportation. Nevertheless, the objective is to limit relocation to Neßsand to an operational minimum by ensuring sufficient discharge.

The relocation near the island of Neßsand is subject to an action strategy agreed between the Hamburg Ministry for the Environment and the HPA, which ensures that all relevant environmental requirements are met. The HPA regards this agreement, together with its future technical updating, as the basis for responsible action in the Hamburg area.

At the same time, future adjustments of the quality criteria for relocation to Neßsand must take into account the respective contaminant situation from upstream and also the quality requirements for marine protection. Freshly settled sediments must be able to be relocated in the waters to the necessary extent in the future as well. A temporary increase in concentration of contaminants in the sediment that can be traced, for example, to breakdowns or improper conduct in the area of upstream residents, and that cannot be influenced by Hamburg, must not lead to an existential threat to the Port of Hamburg. The risk-sharing community of Elbe river basin must be jointly responsible for taking all necessary measures to prevent this type of damage scenarios and in the event of damage, for jointly seeking solutions that do justice to the importance of the Port of Hamburg for Germany as an economic region.

The HPA takes its responsibility seriously and makes the ecological impacts of relocation in the Hamburg section of the Elbe river transparent by conducting studies and making forecasts of impacts as well as through monitoring and reporting. Relevant environmental data are available to interested members of the public for rapid access in a comprehensible arrangement.

Fig. 22: Islands in the Elbe, Hanskalbsand/Neßsand.

Since 2014, the extremely low flow conditions have meant that the incoming tide carries the sediments back to the Port of Hamburg within a short time. This makes additional relocation options urgently necessary so that the relocation site at Neßsand must be utilised only when flow quantities are sufficiently high. This is the only way to reduce cycle dredging and prevent or minimise the ecologically undesirable accumulation of fine sediments in the upper area of the tidal Elbe (cf. Package of measures U4).

Since the concentration of contaminants combined with the sediments by mixing processes in the path from the tidal Elbe to the mouth of the Elbe in the North Sea is decreasing, in principle, considering the contamination aspects, the

aim must be to travel the shortest possible relocation distances along this contamination gradient since it will be that much more likely that the relocated dredged material matches the quality and composition of the sediment at the disposal site. This is also useful from the economic standpoint, since the transport distance determines the (fuel- and cost-) efficiency of relocation. In the end, short routes have ecological benefits also in light of equipment emissions. The weighing of the use of different relocation sites must also take these aspects into account.

The efficacy of small-scale relocations is determined strongly by hydrological conditions. When freshwater flows are low, the proportional return transport of the sediments is high. At such times, in the ideal case, it is necessary to travel to relocation sites situated further downstream. Under conditions with very high freshwater, the distance of the Neßsand relocation site can be sufficient. However, to guarantee predominant discharge of the sediments with the tide toward the North Sea; unless, in consideration of return transport, dredging performance, cost-efficiency, use of energy, emissions and contamination gradient, a useful relocation site for partial amounts.

The use of the Neßsand relocation site is restricted to certain seasons of the year. To strike a balance between the different protection and maintenance goals and the necessities of water depth maintenance for guaranteeing navigation, various specifications have been made by the HPA and BUKEA in a joint framework for action[5]. These stipulate that in principle no relocations are to be carried out between 1 April and 6 November. With increasing understanding of the system and in light of a more extensive consideration of basic ecological conditions, in the future instead of setting a fixed date flexible, methods must be developed that are aligned with the system involving use of hydrological and ecological measurements. Hence, the actual conditions are to be taken into account more extensively in the assessments.

Package of measures U3: Finding a safe, long-term option for disposal in the North Sea

The goal of the HPA is to be able to utilise a disposal option in the North Sea that is reliable in the long term. The disposal of dredged material from Hamburg in the North Sea at Tonne E3, which has been underway since 2005, in spite of the time-limited approval in each specific case and the limits on the quantities disposed, has proven to be an indispensable component of maintenance of the Port of Hamburg, and this is not only true in the summer months. This option enables the HPA to achieve complete discharge of the fine sediments that are brought there from the inner estuary. This contributes substantially to minimising the siltation of port areas vital for traffic, in particular in the summer months when there is intense sedimentation, while at the same time unburdening of sediment the ecologically valuable areas of the upper tidal Elbe.

Moreover, the extensive monitoring conducted in parallel from the beginning has not detected any long-term detrimental impact on the marine environment outside of the immediate disposal site. The location of the disposal site in a natural silt area of the Elbe plume also contributes to this.

If there were no reliably usable disposal sites in the North Sea (or in the lower tidal Elbe), this would quickly lead, under unfavourable hydrological conditions, to restrictions on ship traffic with serious consequences in the Port of Hamburg. Therefore, it is the task of a responsible management for the accessibility of the port to guarantee the existing option and to study and exploit alternative or complementary disposal options.

The vicinity of the Exclusive Economic Zone (EEZ) is also under consideration as a possible alternative or complementary option to Tonne E3. This has already been assessed as one of the high-priority options based on the work of the Forum for Dialogue. The Forum estimated that this area is to be classified, based on its ecological and morphodynamic conditions, as of roughly similar value to the silts drop area near Tonne E3. The HPA has handed in an application for approval pursuant to the German High Sea Prohibition Act (HoheSeeEinbrG) and is thus breaking new ground as far as regulatory approval.

[5] https://www.hamburg-port-authority.de/fileadmin/user_upload/Rahmen_Umlagern_2012_final.pdf

Package of measures U4: Use of further relocation options in the tidal Elbe

A study by the German Federal Institute for Hydrology (BfG) analysed from a technical perspective whether it is also possible, in order to unburden the fine sediment dynamics in the inner estuary, to relocate sediment from the Hamburg dredging district within the tidal Elbe but significantly downstream from Neßsand (*Impact forecast 686/690*[6]). According to the study, the area of the maximum turbidity zone (brackish water zone), where the natural turbidity is already very high and the background pollution, compared with the North Sea, is more similar to the pollution typical of the Elbe, has been evaluated to be suitable. This option also has the advantage of shorter routes, lower emissions and greater operational flexibility. This type of calculated sediment management also helps to prevent sediment deficits and losses of tidal flat areas near the mouth of the river and on the coast.

Following this approach, since early 2021 the HPA has made proportional use of an existing federal disposal site near St. Margarethen in the maximum turbidity zone for dredged material from the delegated section. The fine material relocated there however tends to largely be carried back towards Hamburg, although this return transport takes three times longer than for Neßsand, so that on this route the sediment cycle can successfully be slowed down significantly.

Since the end of 2021, an additional federal disposal site for material from the Hamburg delegated section is in use, at Neuer Lüchtergrund in the mouth of the Elbe. Dredged material disposed of there is discharged completely by the tides, thus unburdening the upper estuary just as effectively as discharge into the North Sea at Tonne E3[7].

The proportional use of both relocation sites is based on extensive impact forecasts of the German Federal Institute for Hydrology (BfG), which demonstrate with technical certainty that no significant detrimental impacts on the protected assets are to be expected. An accompanying monitoring on site will verify the forecasts on an ongoing basis.

An additional disposal option is being planned in the area of the Hamburg outer Elbe. Since February 2022, the expert reports required for this option have been available. For up-to-date information on this option, please see HPA website.

Packages of measures U2, U3 and U4 should not be interpreted as alternatives. Sustainable sediment management in keeping with the system requires all options that can be utilised according to the experts. This is the only way to effectively reduce the overall quantities of dredged material and impacts in the short term. More options for relocating dredged material does not imply that the quantities will be greater. Data models document that enough targeted discharge of fine material can reduce the overall quantities of dredged material within a few years - as well as the emissions related with transport [8] - even if the hydrological conditions remain unfavourable.

Package of measures U5: Safe, appropriate use of treatment and disposal on land

As a rule, land treatment and disposal of sediment must be reserved only for more highly contaminated sediments. Only if sediments that must be dredged are too contaminated to allow them to remain in the waters will the HPA dispose of them on land. Therefore, its declared goal is to minimise land treatment and deposit and someday to do away with it entirely.

The HPA removes contaminated sediments from neglected deposits only if this is required for nautical reasons or in the course of clean-up, building or other investment measures This could also include dredging operations in the context of implementation of river engineering measures or for the general repair and creation of tide volume or shallows in areas of the port at depths for inland navigation. This saves landfill space in the Hamburg area and limits costs. The

[6] Impact forecast VSB 686/690
[7] Impact forecast VSB 730/40

[8] e.g. by up to one third less CO_2 than in 2021!

Tidal Elbe Forum for Dialogue has also arrived at the recommendation to limit land disposal,

In specific, this goal must be reached in two ways: Firstly, the City of Hamburg and the HPA are working, in the context of initiatives involving other German Federal States, to improve the sediment quality (clean-up measures, see the next chapter). In addition, the HPA contributes in Hamburg to the clean-up of the Elba by step-by-step extraction of contaminated sediments from neglected deposits. Fresh sediments can then mostly be relocated when these areas are next due for maintenance. This ensures that contaminated sediments from neglected deposits do not have to be removed as often in the future.

To ensure the sustainability of disposal of dredged material in Hamburg, including adopting precautions against the risk of breakdowns or of short-term inputs from upstream due to high water levels, the HPA aims to provide sufficient treatment and landfill capacities.

Fig. 23: Silt deposit Francop and the METHA system (2014).

The METHA system, in combination with drainage areas, continues to be the right technique to prepare dredged material for reuse or disposal. The use of treated dredged material in dyke building or other manners of reuse are still being pursued, even though up to now these have shown only slight potential in terms of quantity.

In any case it is clear: On the contrary to many demands, the treatment and disposal on land of dredged material that can be relocated does not constitute an ecologically sound or economically feasible alternative. The costs of this are too high and the capacities of land treatment are insufficient and cannot be expanded.

6.2 Elbe clean-up

The goal of this area of action is to actively promote and implement clean-up measures in the entire Elbe basin. This is the only way to continue to improve the quality of the sediment arriving in Hamburg and of the dredged material accruing with it during maintenance.

The contamination of the Elbe with inorganic and organic pollutants improved significantly in particular in the 1990s, especially in bodies of water. The remaining contamination in the Elbe sediments however continues to present a great challenge for water depth maintenance. According to expert assessment from the Elbe river basin community, transport of pollutants could be reduced once more by up to 40% if reasonable clean-up measures were implemented.

Package of measures E1: Establishment of a comprehensive sediment management for the Elbe

One prerequisite for a calculated and efficient clean-up of the Elbe is comprehensive sediment management across boundaries for the entire Elbe basin. As early as 2014, suggestions for good sediment management practices in the Elbe catchment area to achieve trans-regional goals for action had been offered by the International Commission for Protection of the Elbe (IKSE). This also includes measures to reduce pollution along the course of the river up to the Czech Republic, which will help to comply with environmental requirements, such as the European Water Framework Directive (WFD) and the European Marine Strategy Framework Directive (MSFD). In light of the scope (in geographic, ecological and financial terms), a regional assessment of

measures is not sufficient: possible remote impacts of pollution, measures and activities must always be kept in sight. As a result, the successful implementation depends to a significant extent on a comprehensive vision that determines benefits and costs within the river basin community and allocates these fairly.

Despite its intense efforts and the funds provided, in the ELSA project Hamburg was obliged to discover that a lot of time and persuasion is required to implement effective clean-up measures in the catchment area of the Elbe. In light of severe environmental accidents in the Czech Republic, the HPA must have an analysis conducted of the extent of any possible legal claims of Hamburg against the upstream residents to contribute actively to further improvement of the pollution situation with a view to the entire river system. An expert report (Köck/Reese 2018) comes to the conclusion that faults must be detected in the previous implementation of the WFD and also that there is an option to clarify the legal issues before the Federal Administrative Court (BVerwG) in order to assert a disadvantage of the downstream residents derived from previous shortcomings in implementation. The possibility of an EU infringement complaint would also have to be considered.

As a guiding, supportive tool, and for a fairer distribution of burdens related with the clean-up of sources of contamination in the Elbe, the HPA advocates for the establishment of a solidarity fund throughout the river basin for joint financing of measures by the government and countries.

Package of measures E2: Clean-up measures

For years now, Hamburg has supported targeted clean-up of sources of contamination. In the context of the project for decontamination of the Elbe sediments (ELSA[9]), Hamburg, together with its partners the HPA/BWVI and BUKEA, provides funds and expertise for adopting and implementing clean-up measures. The project has been extended to 2027, in light of the management cycle pursuant to the WFD.

Up to now, the work of the ELSA project served to identify hazardous waste deposits (so-called “hot spots”) in the Elbe catchment area. This information is now available. Now we must follow through with the next steps toward implementation of clean-up measures. It has not yet been possible to implement any projects jointly with the German Federal States, the German Federal Government or the Czech Republic. In light of this, the aim of the HPA is to initiate beneficial clean-up projects in Hamburg, in the German catchment area and also in the Czech Republic and to accompany them actively in order to unburden the Elbe of contamination in the long term.

There are some positive signs in this regard: The sediment management strategy of the International Commission for Protection of the Elbe (IKSE) for the entire catchment area, which is now available, designates areas for action in Germany and the Czech Republic. In the Czech Republic, there are specific plans for clean-up measures of different sites along the Bilina and on the Czech section of the Elbe that are to be carried out in the short term. These are based on the experts’ studies and clean-up recommendations initiated and accompanied primarily by the ELSA project. For the coming year, a direct collaboration is also in the works between the ELSA Project and the Czech Elbe enterprise (Povodi Labe) on feasibility of the clean-up of barrages.

Clean-up measures in the German catchment area continue to be a key component of work in the river basin. The recommendations for action of the community of Elbe river basin (FGG Elbe) and of the International Commission for Protection of the Elbe (IKSE) have as yet only been able to be implemented to a limited extent. Therefore, the goal is to complete the sediment-related clean-up measures required under the European Water Framework Directive (WFD), which can be expected to result in a measurable decline in transport of pollutants into the tidal Elbe and the North Sea.

In the process, apart from the German Federal States, the Germany Federal Ministries for Transport and Digital Infrastructure (BMVI) and for the Environment (BMU) will assume a significant role. In April 2019, at the Federal Government/Federal States Workshop, three specific pilot measures were introduced, which come under the scope of

[9] ELSA - Clean-up of contamination of the Elbe sediments

responsibility of the BMVI. These constitutes an important building block that must be implemented as soon as possible.

In Hamburg, the clean-up of existing hazardous waste is also being continued. For this purpose, different sections of port waters containing sediments from neglected deposits are being cleared. At the same time, the tide volume and valuable shallows are being restored. Hamburg leads the way in this regard with its good example.

Package of measures E3: Information and early detection

Another goal of the HPA is to prevent new contamination of the Elbe sediments through registration of hazardous substances.

A negative example for this is the release of PCB that took place early in 2015 in Ústí nad Labem. During sandblasting work on a railway bridge, major portions of the paintwork were not collected professionally and made their way directly into the waters. 87 kg PCB were released in this manner. In November 2016, after great media attention and political intervention, clean-up operations were carried out, although by that point most of the PCB had spread through the river. This case makes it clear that there continues to be a need for explanation. Work carried out professionally would have prevented this environmental catastrophe. Here the ELSA project, jointly with the competent official agencies, intends to carry out more extensive preventive work in the future.

In May 2018, greatly elevated contents of organic pollutants were measured once again at the Schmilka measurement site near the border. In the December sample, values even many times higher had already been detected on the Czech side of the border, in particular for HCB (3,500 µg/Kg). An origin of the pollutants in maintenance measures in the Czech port areas cannot be ruled out. Even if these pollutant peaks have thinned out on their way to Hamburg to the extent that they are almost unrecognisable, these improper inputs always contribute to the reduction of pollution contents in sediments originating upstream remain significantly behind what would otherwise be possible.

It is important that corresponding risk assessments are also conducted for maintenance measures in the upper course of the Elbe that take into account the remote effect of possible remobilisation of pollution deposits in the sediments. Sediments that are allowed to remain in the waters at that location often have many times higher contamination concentrations than dredged material that must be treated and disposed of on land in Hamburg.

These examples make it clear that an effective early warning system for identification of instances of environmental damage is needed. The existing measurement sites must be utilised, maintained and expanded. This also includes the research platform recently set up in Tesperhude by the Helmholz Centre Geesthacht (HZG), which has served since February 2020 as an additional permanent measurement site in the area of the tideline above the weir at Geesthacht.

6.3 River engineering

The goal is to create new tide volume or recover lost tide volume along the Elbe while at the same time minimising the loss of water areas due to building and development projects in Hamburg.

As early as 2005, within the conceptual framework of Natura 2000, there was a consensus that river engineering measures could contribute to improve the hydromorphological conditions in the tidal Elbe, thus serving both economic interests (reduction of sedimentation/quantities of dredged material) and also interests in conservation of natural habitats and of the waters (valuable shallows, expansion of the estuary habitat).

This was made possible thanks to the findings from applying the hydronumerical 3D model of the Federal Waterways Engineering and Research Institute (BAW), which confirms that an increase in the tide volume, especially in the Hamburg area, would lead to a reduction in the transport of sediments stirred up by the tides, also called “tidal pumping”. In

the meantime, different options for measures to generate tide volume have been studied and their impact estimated. In the final analysis, the overall possible impact on the key tide figures and on sediment transport turns out to be less than initially assumed, and the resistances on site are also noticeable; in principle, the creation of tidal shallows continues to be considered as useful however, in particular if additional ecological or societal utility can be achieved with this type of measures.

Numerous examples from other European estuaries also support this approach, such as those of the Schelde (B/NL), the Severn (UK), the Loire (F) and the Humber (UK). In the meanwhile, this approach of giving back more space to tidal rivers has also been firmly established on the Weser and the Ems and enshrined in plans for measures.

Over the past several decades, the loss of tide volume (e.g., due to building of dykes, bifurcation of tributaries, hydraulic filling and port development), together with measures to expand the navigation channel has contributed considerably to the hydromorphological situation today.

Package of measures S1: Preparation of the "Kreetsand" pilot project

The Kreetsand pilot project, which cost roughly €80 million, is a tidal shallows with an area of roughly 30 ha that is being built on a voluntary basis on the Hamburg North Elbe. Thus the HPA blazes a trail that should be continued jointly with neighbouring states on the tidal Elbe in the future. In 2022, the construction of the Kreetsand Shallows is to be completed. Thanks to this project, the HPA achieves a significant positive balance in the development of water areas during recent years. The HPA's experiences with this project serve as a valuable basis for planning of additional measure on the tidal Elbe.

Fig. 24: Kreetsand Shallows under construction (2021, aerial photograph: Holger Weitzel)

Package of measures S2: Planning and implementation of river engineering measures (creation of tidal space)

In the context of the "Tidal Elbe Forum[10]", founded in December 2016 and partly funded by the HPA, additional possible river engineering measures were examined and considered with participation of all relevant interest groups. As an initial step, a preliminary choice among a pool of roughly 25 possible measures was made. This choice included the re-establishment of the tidal connection of the Alte Süderelbe and the Dove Elbe, the connection of a gravel pond in East Hamburg, the reconnection of the Binnenelbe at Borstel and the Haseldorf marshland. As a second step, the feasibility and efficacy of the pre-selected measures was studied jointly with experts called in to provide their reports.

Then, in 2020, a prioritisation of measures was communicated to the competent administrations by the German Federal Government and the German Federal States as an agreed recommendation for implementation.

The HPA is aware of its special responsibility and acknowledges that it is using all the possibilities within its competence to support the implementation of additional river engineering measures. In this context, approaches from the Weser and the Ems or from other countries (such as the Netherlands or Belgium), where so-called "working with nature" projects[11] are planned and carried out, can provide good models for our region.

[10] www.forum-tideelbe.de

[11] Pianc

Package of measures S3: Planning and implementation of measures to control the currents

In addition to river engineering measures to increase the tide volume, measures to exert localised influence on sedimentation by controlling currents in the Port of Hamburg are also to be studied under the current conditions. This also includes appropriate hydrological adjustments when carrying out port development measures. Even if this type of measures dos does not reduce the overall occurrence of sedimentation, they can nevertheless lead to localised improvements at the main focal points of maintenance.

6.4 Innovation

In a dynamic system such as the tidal Elbe, every action must be adapted to underlying conditions that are always in flux if it is intended to be successful in the long term. Without continuing development, without innovation, there can be no sustainability. In order to expand the leeway for action for sediment management in this context, research and development is required. In this respect, innovation refers not only to technological developments but also to new methods and management approaches.

Package of measures I1: Nautical depth

Before dredging operations are conducted, the need must be determined precisely. The hydrography of the HPA conducts multi-beam echo surveys, area by area, in the entire port area in the context of traffic safety surveys utilised for approval of the nautical depths of the port waters. The methods used for this reliably detect the transitional boundary between the aqueous phase and riverbed. In phases in which high concentrations of suspended sediment are near the riverbed, however, this transition is fluid. And hence, the physical characteristics (density, viscosity) of the boundary identified, as well as the question of whether this boundary is still navigable with nautical certainty, acquire a great significance.

The optimisation of nautical requirements and also of required maintenance dredging operations touches on safety-related questions and hence requires an intensive and interdisciplinary scientific treatment. The experts of the HPA are currently in close coordination with other tidal ports around the world, and in particular, they cooperate with the Ports of Rotterdam and Antwerp on a joint research project. In addition, their expertise is also being expanded together with the relevant departments of regional universities and with the Federal Waterways Engineering and Research Institute (BAW).

The aim is to use scientifically validated methods to define the material characteristics of the sediment and of suspensions that can be described as safely navigable. Beside this, measurement procedures and equipment required in this respect for determination in nature are to be developed and corresponding ship simulations conducted using the model. The first practical tests to date also show very promising results.

Package of measures I2: Logistics and transport

Technical innovations also have an impact on dredging technology and transport. Today the HPA already has in place a points system based on densities in its contracts. This ensures that the contractors have an elevated interest in efficient completion of the work, i.e. in transporting the maximum amount of solid material and achieving high densities in the hold. At the same time, these requirements result in the use of state-of-the-art dredging technologies. The more efficient the dredging operations, the fewer trips are needed, the less energy used and the lower the emissions – an economic and ecological advantage. Apart from this, an incentive system is currently being developed to reduce air emissions during the dredging and transport processes. In 2021, CO_2-neutral recycled fuels were used for the first time for relocation to the North Sea, which saved more than 30,000 t CO_2.

A flexible and adaptable maintenance also requires a strategy for equipment and logistics that is equally flexible. Today, numerous pieces of equipment, most of them highly specialised, are used according to the specific task. These range from the simple hydraulic dredge on a pontoon to the suction dredgers (hopper dredgers) in different sizes (between 1,000 to 18,000 cubic meters). The necessary tasks are carried out using own equipment and also chartered equipment. For large-scale dredgers, in particular, it is customary internationally and also the most cost-efficient option to commission these as needed.

And so, as for other ports in the North Range, it was not reasonable and cost-efficient for the HPA up to now to maintain its own hopper dredger. In contrast to the operation of a single large-scale dredger, the big dredging companies have an extensive pool of equipment so that in the event of an occasionally possible equipment breakdown (and also for cases of quarantine) a replacement can be provided in a timely manner. This is crucial due to the strict time limitations often imposed for dredging.

In addition, the equipment must be in use constantly so that it is amortised. Up to now this has not been possible in Hamburg under the varying deployment conditions in the different areas of the port, the different transport distances (16 to 160 km), and under the restrictions existing for maintenance (e.g. exclusion periods). The use of quantity options existing under public procurement law, as well as the framework contracts for peak coverage make it possible today, however, to enjoy a high degree of flexibility and cost-efficiency in deployment of the equipment.

An analysis revealed that purchase of own large-scale equipment is currently not cost-efficient under the existing restrictive framework conditions. If these relocation options are adopted on a long-term basis due to stable, lastingly usable relocation options for dredged material, such as through long-term guaranteed relocation options in the lower tidal Elbe or an alternative long-term disposal site in the North Sea, then the HPA will re-examine its strategy for equipment and adjust it as needed.

This would also entail, apart from needs-based adaptation of the equipment pool (dredgers), scrutinising the logistics chain and transport techniques and optimising them as needed. For longer transport routes to the North Sea, it must be studied whether decoupling dredging and transport could lead to reduction of costs.

The cost-efficiency of construction of an own bed leveller (silt plough) has already been proved in a business case. Since 2016, the continuous deployment of a leased device has proven to be a success. The Hamburg Fleet is currently constructing an efficient, low-emission device, which is scheduled to be deployed in 2022.

A key function is also carried out by the so-called “hopper remote monitoring”, which was developed for Hamburg’s needs at its own initiative. At intervals of a few seconds, all relevant parameters, such as density, depth and position, are measured and communicated in real time. And so, within a short time, the deployment of dredgers can be optimised. In addition, the data are used for modelling and forecasting sediment transport behaviour by the Federal Waterways Engineering and Research Institute (BAW) (see I3).

Package of measures I3: Modelling of currents and transport of suspended sediment

In the future, it will continue to be necessary to gradually expand knowledge of the tidal Elbe system. Modelling and field measurements will provide assistance with this. The 3D model under continuing further development by the Federal Waterways Engineering and Research Institute (BAW) is a powerful tool available for the tidal Elbe.

The modelling (forecast) of sediment transport processes is currently being expanded by including human intervention in the sediment dynamics (e.g. dredging operations). This can serve to optimise the maintenance of the tidal Elbe carried out by the HPA and the WSV, as well as to improve planning of deployment of dredgers and to determine their impacts in a more targeted manner.

The modelling and its validation continue to be based on field measurements, however. In 2020, the Helmholtz Centre Geesthacht (HZG) added a permanent measurement

point in the area of Tesperhude above the weir at Geesthacht to the existing measurement network and measurement programme. Available data from all measurement stations can be used, e.g., to achieve a better balance between loads of suspended sediments and pollutant loads that are brought from the Elbe catchment area to the tidal Elbe.

By taking part in international research projects, the HPA continually works to expand the state of knowledge and the process understanding related with how to deal with sediments in the water and on land.

Package of measures I4: Maintenance and climate change

In the short- and mid-term, it will be a special challenge to adjust to climate change. Even though forecasts and climate scenarios continue to differ greatly, it is already clear that the tide parameters will undergo changes due to the rising sea levels. Moreover, the trend toward drier summers in the Elbe catchment area will make maintenance more difficult in Hamburg. More precise research is required on the extent to which climate change will also have an impact through other influencing factors, such as changes in intensity or frequency of storms (flood tides) and/or inland flooding events, or shifting of habitats. For this purpose, the HPA is in close contact with international climate experts.

Hence the expansion of options for action for maintenance is also necessary in order to be able to respond in good time to the impacts of climate change. We must start today to prepare for the initial steps.
At the same time, more relocation options can also contribute to a significant reduction in quantities of dredged material in general and hence also to a reduction in emissions. Thus, calculations using a data model illustrate that CO_2 emissions could be reduced by 30% within a few years compared to today (2021).

Package of measures I5: Reuse and recycling of dredged material

Treated dredged material, also called “METHA material”, is already being used successfully to a great extent as certified sealing material at the landfills for dredged material. Material-engineering analyses have also confirmed the suitability of this material for landfills of Classes I and II. Additional options for use at landfills or as surface sealing must also be developed.

The same is true of the use of treated dredged material in dyke building. Here too natural resources such as clay can be saved. Material-engineering and biomechanical analyses have confirmed the suitability of the material. From the standpoint of the environmentalists, suitability has been confirmed taking into account the site-specific conditions (quality of ground and surface waters). Plans are currently being made for the first time to use the material in dyke building.

The HPA holds competitions for ideas for reuse of METHA material, e.g., as alternative construction materials (e.g. pellets) in order to study the market potential. The opportunities for reuse must be exploited optimally.
Apart from reuse, further research is also being conducted on process optimisation for treatment and disposal, for example, for use of flocculants or treatment of landfill gases.

Apart from the reuse of treated dredged material in the context of waste management regulations, fresh dredged material can also be reused constructively. Thus, the HPA always fills up eroded coast segments on the Elbe riverbank with sand, as needed. Underwater erosion areas can also be stabilised with dredged material. Thus, beginning in 2019, valuable shallows in front of the Elbe island Neßsand were restored. In principle, use for long-term protection of the coasts is also conceivable, since in many coastal areas today there is a lack of sediment, which will tend to increase further due to climate change and the rise in sea levels. Excess dredged material accruing in the inner estuary can also be reused beneficially so that tidal flats and coastal flood lands can rise along with the sea level.

6.5 Cooperation

In a societal climate where sound planning and decision making is contingent more than ever on broad acceptance, smooth cooperation of all stakeholders is a basic prerequisite for success and sustainability. For a topic as complex as sediment management it is indispensable to enable frequent exchange of ideas and information and, when possible, to strike out on new paths together. This lays the foundation for mutual comprehension and for the acceptance of all different justified interests.
The HPA has employed this method for a long time now. Some good examples of this are the implementation of Natura 2000 in the Elbe estuary (integrated management plan), the management approaches for the tidal Elbe and for river engineering and sediment management, international projects such as TIDE or more recently the River Engineering and Sediment Management Forum (FOSUST) and then the Tidal Elbe Forum, which, last but not least, provides recommendations and findings that serve as important bases for the HPA's actions.

Package of measures Z1: Tidal Elbe Forum

To achieve the goal of a sustainable development of the tidal Elbe, collaboration among the three regions of Hamburg, Lower Saxony, Schleswig-Holstein, and the Federal Government, as well as exchange of ideas with small groups, municipalities, associations and organisations from the region has been institutionalised. For this purpose, the regions of Hamburg, Lower Saxony and Schleswig-Holstein, together with the Federal Government, agreed to set up a cooperative structure with the name of Tidal Elbe Forum (www.forum-tideelbe.de). The Tidal Elbe Forum began its work in 2016 and concluded it in 2020 with a comprehensive report on its findings. HPA and Stiftung Lebensraum Elbe provided the major portion of the funding for this.

The trust that had already been established among the relevant regional interest groups in the course of its forerunner the "Forum on River Engineering and Sediment Management Tidal Elbe" (www.dialogforum-tideelbe.de), was consolidated and strengthened in the Tidal Elbe Forum. On this basis, a structured, technical dialogue on matters of estuary management was conducted, which acknowledged the justified demands of the different users of the Elbe and took the tidal Elbe as a whole into account.

The most important goal was to identify and prioritise river engineering measures that promote the sustainable development of the tidal Elbe. In this process, the improvement of the hydrological conditions was a paramount criterion. In early 2018, a preliminary selection was made and then assessed (see Package of measures S3). In-depth studies of the prioritised measures were examined for feasibility.

Fig. 25: Press conference on the kick-off of the Tidal Elbe Forum in December 2016

Regular symposiums and transparent information in the region make the work available to a wider audience.

The competent administrations are currently studying how the Forum's successful work can be continued. Of course, the HPA will also take part constructively in a follow-up process.

Package of measure Z2: Exchange of ideas among specialists and public relations work

The bilateral exchange of ideas and collaboration on specific topics are continued as previously and expanded as needed, i.e. with the Federal Waterways Administration and its specialised organisations, the public administrations of Hamburg and neighbouring regions, and other ports of the tidal Elbe, or also at the scientific level both nationally and internationally.

In parallel to the exchange of technical ideas, extensive PR work aims to present the topic in a comprehensible manner, thus increasing acceptance of flexible and adaptable sediment management. On this topic, the HPA has long been in dialogue with associations and individuals in the region and seeks to raise awareness and promote understanding of its activities with extensive material such as films, its website, brochures and flyers.

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