DREDGING IN RIVERS AND ESTUARIES

Rudolf van den Bosch
Chemin de la Combe, F- 34210 Aigne, France

Keywords: Antwerp, port of; Bremen, port of; Hamburg, port of; Le Havre, port of; Rotterdam, port of; dredging, estuaries, harbors, inland waterway transportation, navigation, pollution, ports, rivers, sediment, silting, waste water-drainage, environment, hydraulic fill, hydrocyclone, density current, barges and lighters, ships and motor vessels, disposal, contamination, heavy minerals (placer deposits), landfill, sewerage and drainage, sea-level rise, bulk cargo, siltation, turbulence, water jets, dredgers, diffusers, separation and dewatering, biological treatment.

Contents

Summary

Navigation is one of the important uses made by humanity of rivers and estuaries. Sediment brought in suspension by currents, tidal action and shipping movements is again deposited in estuaries, river harbors and navigation channels.

Dredging is necessary to maintain drafts, widths and easements around bends in rivers for the passage of vessels transporting cargo and passengers to inland destinations along navigable river reaches. A number of dredging techniques is described, including water injection dredging, maintenance dredging, capital dredging and environmental dredging.

Statistics and examples are given of some major European river and estuarine ports and harbors. These are dependant on constant maintenance dredging for sustainability, capital dredging for improvement to meet increasing demands, and environmental dredging to insure a sustainable environment.

Methods are described for dealing with dredged slurries and for converting some of this usable spoil material into useful materials for construction, as well as for safe disposal of harmful and contaminated dredged materials. Other applications are for landfills, for flood protection works and for agricultural purposes.

1. River Water and Uses

Here, on earth, water is one of the most precious elements, essential and indispensable for human life. Fortunately it is available to humanity, however not everywhere. It is present in the oceans, seas and in lakes, in the form of ice in the polar Arctic- and Antarctic regions, as snow on the mountains, and as ice in the glaciers. From there it melts and runs down as water; it forms currents, brooks and rivers; flowing down, sometimes into lakes, but at last into the sea or ocean.

The heat of the sun evaporates water from the oceans, seas and lakes; and clouds are developed in the air. From time to time the water falls down to the earth as rain or snow. It soaks into the soil and is used for the growing of plants and trees, and for drinking by animals and human beings. The surplus is drained away in currents and rivers, and flows to the sea. By this circulation of water, nature creates a continuous process of refreshment and purification, in which can be found favorable conditions for human.

Humanity can make use of the rivers for several purposes, such as for building of settlements and towns with good communications. Civilization was born on the banks of rivers. Even now eighty percent of the population of the world lives less than fifty kilometers from open water. At many places on rivers and estuaries, dredging equipment was engaged to make the first hydraulic sandfills and to create river-ports.

- ***Drinking Water Use***

At first, the inhabitants of river banks took the water directly from the river. Later on, in areas with a dense population, some buffer storage had to be created, to overcome periods with low river flows. For this purpose weirs or barrages were constructed to form artificial lakes. If the water quality is poor, sometimes river water is pumped over great distances by means of pipelines or conveyed in canals to an area where the soil has a good infiltration capacity. It is infiltrated into the bottom of an aquifer and pumped out of the soil again somewhere else as clean groundwater.

- ***Fishing and Hunting Uses***

Natural water-endowed regions are protected and conserved for these purposes**.**

- ***Navigation Use***

Before roads were constructed, at most places rivers were already used for navigation, in order to reach inland locations. Nowadays, rivers are still used to transport all kinds of commodities, as well as people.

- ***Irrigation of Agricultural Land***

Long before the present era, irrigation systems with dikes and canals have been constructed along the rivers Nile, Tigris, Euphrates, Indus, Yangtze-Kiang and others. Even now, in arid areas irrigation is necessary and wide spread, for agricultural purposes.

- ***Energy from Water-power***

The first watermills drove all kinds of machines by direct mechanical coupling. Nowadays, electric energy is generated by water-power obtained from water stored behind barrages and dams.

- ***Tourism***

On many navigable rivers it is possible to make a cruise and see the country from the waterside. For some countries this kind of tourism makes an important contribution to the economy of the country, e.g. Egypt. Also, leisure-parks, beaches and marina's can be built along river banks.

- ***Mining***

Sand and gravel of good quality can often be found in river beds, and are used as building materials and for the construction of roads. Also minerals, like gold and tin, are often found as *placer* deposits in river beds.

- ***Process and Cooling Water***

Process- and cooling-water is essential for factories, industrial plants and thermal power stations.

- ***Uses for Defensive Purposes***

At many places a river forms a frontier between two countries. As example can be given the following: In Holland, in 1574, the town of Leiden was laid in siege by the Spanish Army. By opening the sluices and piercing the dikes, the river water was released, and it dislodged the enemy from its positions. This was the beginning of the independence of The Netherlands. During the Second World War, again, river water was used to inundate the land for defensive purposes.

- ***Uses for Rendering Agricultural Land Fertile***

During periods of high water, a river can overflow its banks and can leave a thin layer of mud behind on the flood plain. Extensive deposition areas are geologically formed by sedimentation of a river, especially in estuaries. This land is mostly valuable for agricultural purposes, for pasture and for natural reserves. Of course, in using rivers for cultivation, the sediment can cause trouble for navigation. This item will be discussed further in Section 5.

- ***Uses for Sewerage and Drainage of Waste Water***

During long periods in the past, waste water has been drained in an uncontrolled way into rivers. Natural faeces become harmless after several kilometers of travel in flowing water, due to the self- cleaning capacity of the river. But for great cities, with industrial waste water loads dumped in rivers, this cleaning capacity was not sufficient anymore.

Chemical wastes and heavy metals pollute the water and the sediment of the rivers, and end up in the estuaries and in the sea.

Lately, even the politicians became alerted, and in 1972 in London, in 1974 in Oslo, and in 1992 in Paris, inter-governmental conventions were held in order to regulate dumping of wastes at sea for all international waters. In the same period, an agreement was made between the Rhine River riparian states: Germany, Switzerland, France and The Netherlands, to cease the contamination of the Rhine River, and to allow only clean water to drain into the river.

As a consequence, municipalities and industries in this region have built hundreds of water-purification plants. Since then, the water quality has been improved remarkably. An international commission now continuously monitors the water quality at nine measuring stations, by making chemical analyses and by bio-monitoring. In case of a calamity, for instance a ship collision, by which a harmful chemical product could enter into the water, an alarm is given to all authorities involved. It must be realized that the eco-system of a river is very fragile and that the equilibrium can easily be destroyed by an uncontrolled use for the above mentioned purposes. Especially, waste water disposal can have disastrous consequences for nature. It is in the technology of *dredging* that many technical solutions are found for realizing the above mentioned objectives, without destroying the environment and its ecological systems.

2. Control of a River

According to recent investigations, a change in climate is likely to occur due to the warming up of the atmosphere. Glaciers are melting and a further decrease of the extent of the polar ice fields can cause a general *rise of the sea level* of all the oceans.

For lowland countries, situated on river estuaries, this situation is a threat. It is a challenge to take appropriate measures against the gradual rising of the water level, for instance by building stronger and higher dikes. But the behavior of some rivers is also changing. In many countries a strong deforestation has taken place in the upper catchment areas of the rivers and in the mountain areas.

During heavy rainfalls, much black earth and humus soil is taken away by the water currents. Rainwater cannot penetrate into the soil, but flows directly into a brook or river. By this phenomenon the discharge of a river accelerates. The high water levels of the river will continue to rise, and many lowland areas along the river banks and in estuaries can be flooded. River dikes have to be constructed to keep the river within its bounds, and to protect settlements and cultivated lands against the flood waters. A combination of storm floods from the sea, and high water from the river, can cause a dangerous situation for settlements behind the dikes. In most countries, water authorities have undertaken studies concerning this problem, and had to update the design criteria regarding dike-crest levels.

River navigation upstream of the river has to face the difficulties of *low water* during the dry periods of the year. Therefore, some rivers are canalized upstream, by building barrages to maintain water depth. In these areas, vessels have to pass one or more ship locks at each barrage to enter into the upstream reach of the river. The water depth is also maintained for navigation at as near a constant level as possible. In some rivers a parallel canal is constructed alongside, to maintain a water level independent of that of the river.

Within the framework of this chapter, only the item *The Use Of Rivers For Navigation*, will be dealt with as related to *Dredging*. Each river has its own characteristics; no two rivers and no two seaports in the world are the same. To illustrate these differences some data are given in Table 1 below.

Name of River	**Catchme nt Area (km^2)**	**Length (km)**	**Annual Discharge million cub.m.**	**Maximum Discharge cub.m./sec.**	**Minimum Discharge cub.m./sec.**
Amazon	7 000 000	6500	3000	200 000	-
Yangtze Kiang	1 900 000	6400	700	84 000	5270
Mississippi/ Missouri	3 200 000	6400	600	75 000	3500
Danube	820 000	2900	200	16 600	-
Rhine	160 000	1290	70	13 000	6303

Table 1: Data on Some Principal Rivers of the World

3. Navigation on a River

Of course, one cannot discuss all rivers in this context, but one can take a further look at the River Rhine, which has the busiest river navigation in the world. The catchment area of the River Rhine is shown in Figure 1. The River Rhine arises from glaciers of the Saint Gotthard mountain in Switzerland and flows into Lake Constance (Bodensee). This lake acts as a natural buffer storage and during the year delivers always a fairly constant discharge via the Schaffhausen waterfall (25 meters in height) to the Upper Rhine. The Swiss town of Basel has a busy river port already. From there a ship can travel in three days down stream to Rotterdam and from there in four days up stream back to Basel.

Further downstream, a great number of riverside ports in Germany, France and The Netherlands have direct connections to the Rhine. In The Netherlands the river has many branches and it forms a great estuary, together with the mouths of the rivers Meuse and Scheldt. The main seaport of Rotterdam is situated on one main branch of the Rhine Estuary. The older ports are situated in and close to the city. More modern ports have been constructed along the 34 kilometer new artificial waterway to the sea. These are the Pernis ports, with extensive oil refineries and oil terminals; the Botlek port and the Europoort, accessible for heavy draft vessels. The newest extensions for heavy draft vessels, called “Maasvlakte”, have been reclaimed from the North Sea by *dredging* and *hydraulic sandfill*.

The access channel has been dredged to a depth of 23 meters below low water level, in order that the largest ocean-going vessels can enter the port. In this area, among others, there is a great container terminal, and another terminal for iron-ore and pit-coal as shown in Figure 2.

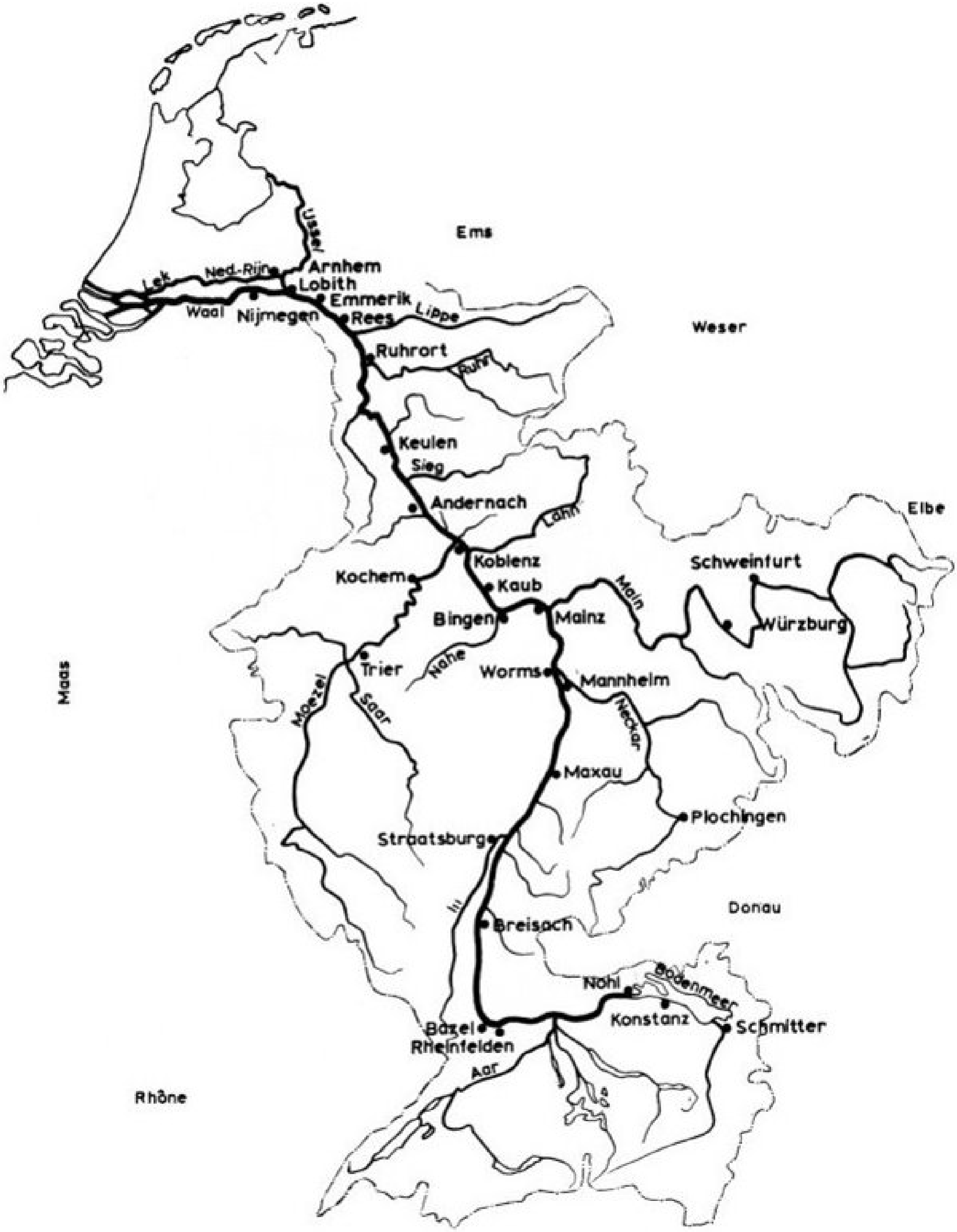

Figure 1: Catchment area of the River Rhine

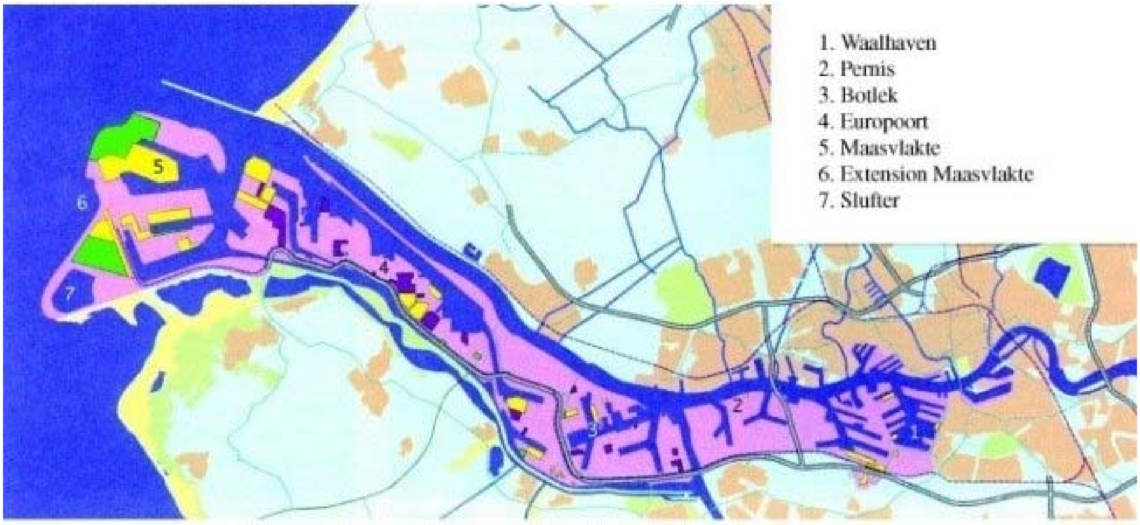

Figure 2: Plan of the Port of Rotterdam

3.1. Push-Barge Transportation for Bulk Cargo

The *sea-going vessels* are moored in a tidal harbor basin; the *river-going barges* in a separate basin with direct connection to the river via a canal. The bulk commodities are trans-shipped to the river barges from the sea-going ships (mostly after having been stored at the wharf). The river barges are standardized and have dimensions 76.5m in length, 11.4m in width and a loading capacity of 2700 tons.

The barges are coupled for further transport to the German steelworks on the Rhine (Ruhrgebiet) in units of four or six barges. The units are pushed by powerful push-tugs with a capacity of approximately 5400 hp or more. On arrival at the port of destination, the tugs do not have to wait for the unloading of the barges, but they immediately go back with another set of empty barges.

This method of river transportation is very efficient, because the tugs can operate continuously, day and night, with shift crews. The barges themselves do not need a crew, because they form a unit with the tug.

3.2. Container Push-barge Transportation

The same system is also practised for *container transportation*, with suitably adapted barges. Many inland ports also have container terminals. The containers are trans-shipped at the seaports for further transport over inland sea or open ocean. From the container terminals, *road trucks* deliver the containers further inland to local destinations.

3.3. Ro-Ro Transportation (Roll On, Roll Off)

Door-to-door *road transportation* by truck-trailer with an *over-water link* is developing strongly between British ports and inland ports on the Rhine. The truck-driver can rest during the time of over-water travel, or else another driver takes care of delivery of the cargo at the port of destination. On arrival at the seaport, the truck is trans-shipped on an inland river barge convoy that is pushed by a tug, or on a special river vessel. At arrival in the inland *Ro-Ro* port of destination, the truck proceeds by road on the last part of its travel to the client.

3.4. LASH Transport (Lighter Aboard Ship)

Another transport system between Rotterdam and the American East Coast ports, New Orleans and Charleston, is by *LASH* carrier. These sea-going vessels can carry some 83 *lighters* with dimensions 18.7 by 19.5 by 4.4 meters and a loading capacity of 378 tons each. Within the seaport the *carrier-ship* can, with its own lifting devices, discharge the lighters and let them down in the water. After that, the ship can take a new loading of lighters out of the water and sail back to another overseas destination. In the harbor the lighters are combined into units. In this way a push-convoy is formed for further transportation by a push-tug on the inland waterways. In this manner commodities can be transferred from door to door from any inland port in America to any port on the European waterway system.

Another smaller, self-propelled submersible, LASH carrier vessel is operating between Rotterdam, Felixstowe (UK) and the Weser River. Because the contents of the LASH-barges do not need to be trans-shipped, less damage occurs to the cargo.

3.5. Inland Waterway Motor Vessels

The major part of river transportation is done by *self-propelled inland waterway motor vessels*, such as vessels adapted for parcel commodities, for handling solid bulk, for handling liquid bulk (tankers), for shipping containers and for Ro-Ro (Roll On, Roll Off) transportation. Annually, approximately 130 000 inland waterway ships are calling at the port of Rotterdam.

3.6. Special Transport

Heavy cargo and oversize dimensioned cargo can generally be transported in a safer and more convenient manner on a navigable river, as compared to other means of transport**.**

-
-
-

Bibliography

The Annual Reports from the *Hafenbautechnische Gesellschaft*, Hamburg, were a good source of information. [Harbor Construction Technical Association’s Reports].

The Directions of the Federal Water Management in Hamburg and Bremerhaven, were very helpful in giving information. [Reports from the Federal Society of German Inland Navigation, Duisburg**].**

The publications of the International Association of Dredging Companies gave interesting facts.

Useful information was found in publications of the Ministry of Public Works and Water Management, The Hague (The Netherlands) and the Federal Ministry of Traffic in Germany. [Annual Reports and publications of the ports of Antwerp, Hamburg, Le Havre, and Rotterdam].

Biographical Sketch

Rudolf van den Bosch, Engineer, was born in Amsterdam in 1932. He has thirty-seven years of experience in dredging and civil engineering. After having completed his studies in civil engineering, he worked in The Netherlands, for the State Direction on the Zuider Sea Works and was engaged there in dredging and dike construction.

After that, he became Manager of a contracting enterprise in The Netherlands and realized many dredging- and civil-engineering projects throughout the country. He later became General Manager of the German subsidiary, and was responsible for the execution of its contracts, such as for river regulation works and dredging on the rivers Rhine, Main, Moselle, Ems, Weser and Elbe. In addition, he was also responsible for the construction of harbors, quay-walls, industrial areas and pipeline-crossings under rivers and canals.

In 1975 he changed over to another employer and became Area Manager for an internationally operating dredging company, based in Rotterdam. Since then he became Project Manager for dredging projects in Walvis Bay, Namibia and in Wales, Great Britain. Later on, as Area Manager, he was responsible for contracting projects in France, Germany, Spain, Scandinavia and Eastern Europe, and for their proper execution. Next, he became Area Manager for the Far East, stayed in Jakarta and was responsible for projects in Indonesia, Malaysia, Bangladesh and India.

In 1982 he returned to Europe and was appointed General Manager of his employer's office in Bremen, Germany. He was the promoter of the new method of water injection dredging, which has now been applied world-wide. After retirement, he now resides in France.