Introduction

The largest "sediment trap" and, therefore, potential concentration of contamination, can be found at the end of rivers, where an enormous amount of sediment is trapped yearly in estuaries and coastal zones, e.g. in ports and harbours. The already existing situation for these port areas to pay – in addition to the high capital costs for the maintenance of navigation channels – the expenses for the shortcomings in the emission control within their catchment areas can be aggravated further in an even less predictible manner (extreme flood events, climate change). In the scope of this project future risks for the Port of Rotterdam will be assessed that may arise from resuspension of historical sediment contamination upstream following natural events (e.g. floods) or anthropogenic activities (e.g. dredging activities).

Likely sites for the accumulation and potential exposure of contaminated sediments are:

- river reservoirs and barrages where sediment is accumulated and which can release the contaminants during floods events
- inland harbours with wide openings to the river Rhine
- dead arms which have been cut off due to straightening of the river during the 20th century, as they are potentially contaminated and exposed to high floods.
- tributaries and bypass channels which historically were industrially used but which have not been maintained by continuous dredging
- industrial areas which are located within the potentially flooded area and which contain waste deposits. The risk of these has been demonstrated during the Elbe flood in 2002, when flooding of the Bitterfeld area and the industrial site "Spolana" raised a lot of concern.
- the vicinity of larger cities (and emissions from municipal wastewater plants)

Contaminated material can also be introduced to river systems from contaminated soil during surface run-off or erosion events. As this report focuses on historic sediment contamination, terrestrial sites will only be dealt with to a minor extent.

To our knowledge there is no comparable approach to predict the effects of both extreme flood events and dredging activities on the transfer of historical contaminated sediment to a port area at the lower reaches of such a large catchment area. In fact, there are many uncertainties in this prognosis, arising from the complexity of influencing factors, but also from gaps in process knowledge and deficiencies at problem-specific databases:

- In Chapter 1 the **key processes** controlling hydraulic and chemical mobilization as well as transfer of contaminants to organisms are described. On the other side, there are stabilizing processes such as ageing, which can be used for developing cost-effective remediation techniques for in situ and dredged sediments.

- Chapter 2 presents an overview on the **requirements on sediment data quality**, including strategies for water and sediment assessment as well as quality control of field and laboratory data. In section 2.5 the quality requirements and uncertainties of hydraulic data, forming the key issue in the present study, are discussed.

The present project is an extension of the Rhine Research Project II (1999-2001) "Dredged Material in the Port of Rotterdam – Interface between Rhine Catchment Area and North Sea", which dealt with three major issues: (i) point and diffuse sources in the Rhine catchment and identification of their past, present and future inputs and how they determine sediment quality; (ii) the current and future policies and regulatory frameworks that are relevant for sediment/dredged material as well as their proposals for "new priority chemicals", and (iii) the issue of hazard assessment of contaminated sediments/dredged material through new methodologies and their relation to risk assessment at the disposal site. Since the publication of the report (February 2001) substantial progress has been made in the field of sustainable sediment management (SSM):

- Chapter 3 summarizes recent developments in **sediment management at the Rhine Catchment**. Legal aspects on a European and national level were covered in a review by the Dutch-German Exchange on Dredged Material program, Part 1 (DGE-1, 2003) and management practice, i.e. treatment and confined disposal, in both countries is reviewed by the same program, Part 2 (DGE-2, 2002). Another important new source of information is SedNet, a European sediment research network on environmentally and economically viable sediment management (EC FP5, contract No. EVKI-CT-2001-20002); a final version of the SedNet Strategy Paper has been published in June 2004 and in section 3.3 of the present study an overview is given on "biological effects-based sediment quality in ecological risk assessment for Dutch and German waters" summarizing the SedNet Working Group publication of Den Besten et al. (2003). In section 3.4 information on chemical and biological sediment data from chapter 2 is embedded in the forthcoming strategies for quality control in the analysis and monitoring of EU Water Framework Directive priority substances. Section 3.5 presents short articles on three themes closely related to the catchment scale sediment perspective: "Risk Management", "Sources and Measures", and "Future Research on Soil-Sediment Contaminants".

In the Rhine Research Project II report calculations were made of current emissions and immissions into the Rhine and its tributaries in order to analyze (or forecast) the quality of sediments and dredged material in the Port of Rotterdam. Emphasis lay on the development of acute diffuse and point sources over time. The report showed that total emissions of heavy metals, PCBs and PAHs had decreased since the beginning of the 80s with a strong decline of contribution by industrial emissions. In the present report, the scope of assessing the risk for the Port of Rotterdam is extended to sites and impact of historic contamination in sediments. "Historic" contamination with a potential to be re-introduced into the sediment-suspended matter cycle may gain in importance with further reduction of diffuse pollution. Due to the scarce and inhomogenous data base on "old" sediment contamination,

our conclusions on impact of historical contamination on the sediment in the Eastern part of the Port of Rotterdam had to be mainly deductive and comprised the following steps:

- Chapter 4 lists the substances that are of concern for this report and explains, why we focused on a limited amount of compounds: Only those substances are chosen for further evaluation, that are of concern for the management of the Port of Rotterdam as they frequently exceed or reach the new Dutch "Chemistry –Toxicity Tests (CTT)-levels" which decide about relocation at sea (clean sediment) and Slufter disposal facillity (contaminated sediment). These **substances of concern** ("s.o.c.") are then assigned to different hazard classes (HC_C) due to their behaviour in the environment and the potential danger that they present for organisms (chapter 4.1.). In a second step, we used existing sediment analysis data from the last 10 years to identify those areas in the Rhine and its tributeries, which show increased concentrations of these substances of concern above CTT level and therewith potentially provide a danger of increasing concentration levels at the Port of Rotterdam. These **areas of concern** ("a.o.c.") are classified with regard to the quantity of contamination and available data to give an overview over the distribution of persisting hazards in sediments along the river Rhine. A survey on information about historic emissions follows in order to a) clarify the sources of the sediment contamination; b) validate the possibility of persisting contamination at these sites; c) gather information on management options due to the potential persistence of sources and the distribution of contamination.
- Chapter 5 is dedicated to the **quantification of risk for the Port of Rotterdam** through the contaminated sediments located in the respective areas of concern. Historic contamination can lead to a concentration gradient in a constrained area if it is continuously exposed like e.g. in mining areas or where waste disposal sites leak into groundwater or directly into rivers. More often, however, leagacies of the past in rivers have been covered up by freshly deposited sediment and may be resuspended during flood events or in the process of management or construction activities. This chapter evaluates the possibility that these hazards lead to exposure of sediments downstream to elevated contaminant concentration levels. Information on the hydrodynamic in the Rhine, on erosion thresholds and events and their effect on contaminant transport, theoretical concentrations and calculated loads are discussed in order to conclude, which areas of concern may provide a risk under different discharge scenarios for the Port of Rotterdam. Where management options are planned or have already been implemented for these "areas of risk" these are described in 5.5.

The summary and conclusions (chapter 6) will focus on the results of this report, identifying those areas of concern, which are regarded as presenting a risk for the Port of Rotterdam with regard to potential exceedances of the CTT value(s).

The Rhine catchment area and its tributaries

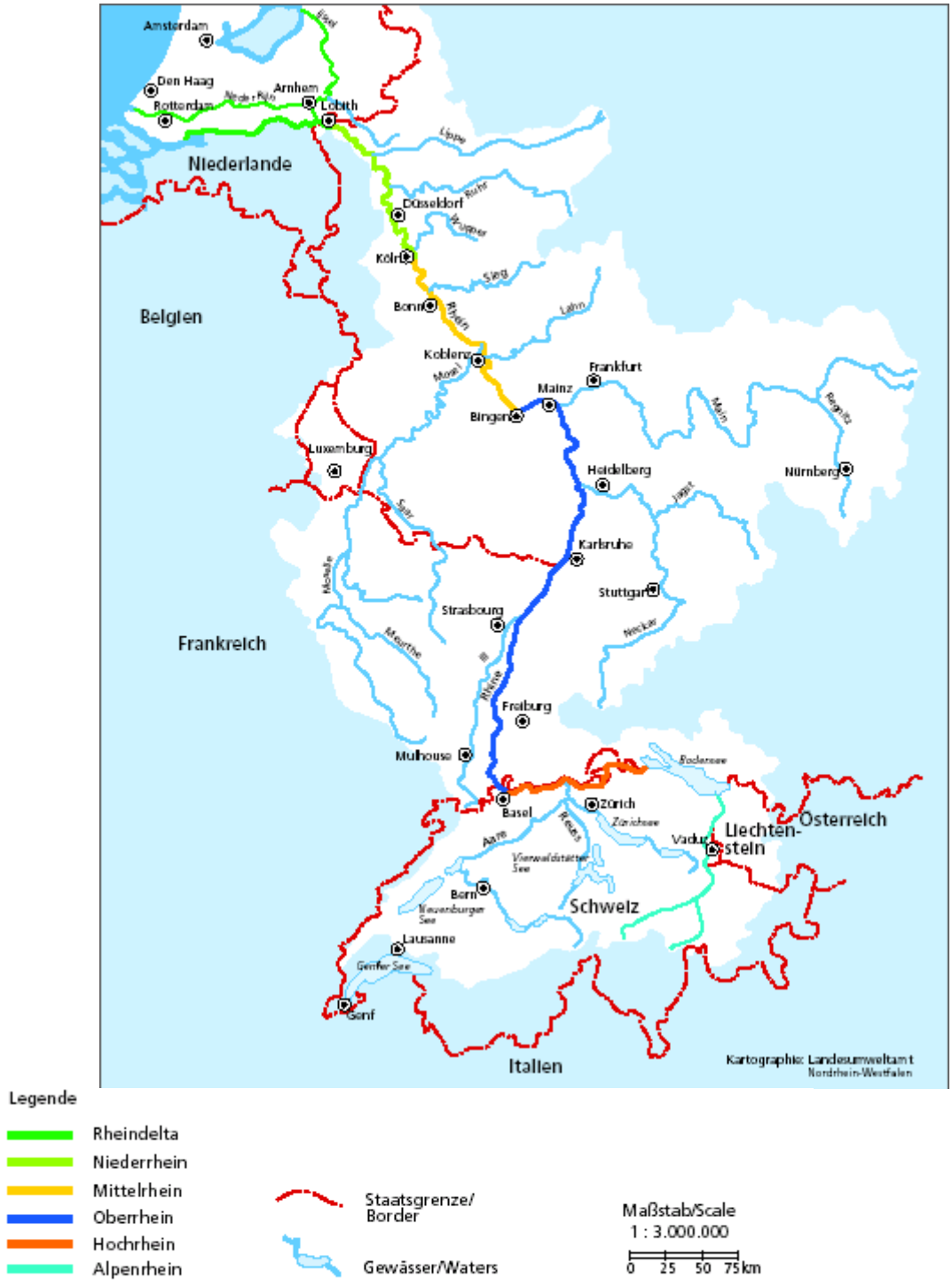

Figure I.1 Catchment area of the Rhine (indicating the area of the Delta Rhine ("Rheindelta"), the Lower Rhine ("Niederrhein"), the Middle Rhine ("Mittelrhein"), the Upper Rhine ("Oberrhein"), the High Rhine ("Hochrhein"), and the Alpine Rhine ("Alpenrhein").