

A: Interventions in rivers and deltas – some examples

Typical interventions in each part of the river, delta and/or estuary are treated in the lectures. The following document will discuss more examples of interventions along the river Rhine.

The Rhine River originates in the south eastern region of the Swiss Alps in the canton of Grisons and flows through Germany and France with a total length of 1320 km until it discharges into the North Sea in the Netherlands. An overview of the Rhine is shown in Figure A-1.

The course of the river can be divided as follows:

- The **upper course** of the Rhine is divided in the Alpine Rhine, the High Rhine and the Upper Rhine. The Alpine Rhine lies in the Swiss Alps, where it flows into Lake Constance. The High Rhine flows from Lake Constance at an altitude of approximately 400 metre (m) above Mean Sea Level (MSL), to Basel at a level of 250 m above MSL. Some stretches in this region form the border between Germany and Switzerland. From Basel the Upper Rhine flows to Bingen at a level of 77 m above MSL, where the river changes its course from west to north.
- The **middle course of the Rhine** flows from Bingen to Bonn at a level of 50 m above Mean Sea Level.
- **The lower course of the Rhine** flows from Bonn to the Delta in the Netherlands.
- **Rhine-Meuse-Scheldt delta:** After passing the German – Dutch border, at Lobith, the river Rhine divides into several branches. At Lobith the average discharge of the Rhine is 2,250 m³/s. The three distributaries are the IJssel (average discharge of 250 m³/s), the Waal (average discharge of 1,500 m³/s) and the NederRijn (average discharge of 500 m³/s).

Table A-I gives an overview of important types of river and delta/estuary interventions, their function and typical locations along the river. Examples of these interventions in the Rhine are provided.

Table A I Types of interventions (the X's mark which functions are satisfied by each intervention)

Intervention	Typical location	Hydro power	Water supply	Navigation	Flood safety	Ecology	Example
Hydropower dam	River: Upper course	✓	✓			-	Eglisau-Grattfelden Hydropower plant, Switzerland
Groynes	River: Middle course			✓			All along the river Rhine, example in Trechtingshausen/Wessel
Sediment nourishment	River: Upper course					✓	German Niederrhein
Ports	River / Delta & estuary Middle / lower course			✓			2 nd Maasvlakte
Weirs	River: Middle course		✓	✓	✓	✓	Driel, Netherlands
Sluices /	River / Delta & estuary			✓	✓		Lock Gambsheim, France

locks	Middle / lower course			
River dikes	River: Middle / lower course		✓	✓
Room for the river	River: Middle / lower course		✓	✓
Dams	Delta & estuary	✓	✓	✓
Storm surge barriers	Delta & estuary / Coastal		✓	
Dredging	Delta & estuary / Coastal	✓		-
				Rivierenland, Netherlands
				Project Noordwaard in the Netherlands
				The Afsluitdijk and/or the Brouwersdam
				Maeslant barrier / Eastern Scheldt barrier
				Dredging of Nieuwe Waterweg

A.2 Interventions in the upper course of the Rhine

As was previously explained, the particular topographic relief in the upper courses gives high potential for electricity generation with hydropower (figure A-1). The drop in height at the High Rhine of about 150 m in an extent of 165 km results in high discharges, typically 450 m³/s, which are exploited by hydroelectricity plants. There are a total of twelve plants in the High Rhine.

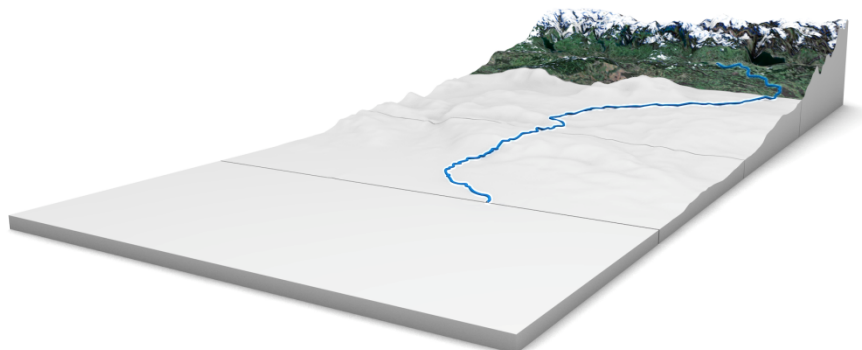


Figure A- 1 Upper course of the Rhine River

Eglisau-Glattfelden hydropower plant

The Eglisau-Glattfelden hydropower plant, located in the municipality of Glattfelden Switzerland, is an example of a low-head hydropower plant. The hydraulic head difference used for electricity generation in this type of power plants is only of a few meters, in this particular case the maximum head difference is 11 meters and its design flow rate is 500 m³/s. The capacity of the dam is 47 MW which provides an average generation of 318 GWh per year. This is sufficient to provide energy for 120,000 households yearly.



Figure A- 2Eglisau-Glattfelden hydropower plant, Switzerland [Source: Gemeinde Glattfelden].

A.3 Interventions in the Middle and Lower Rhine

The Rhine becomes navigable from the city of Basel in Switzerland. The relative steep slope of the High Rhine gradually becomes less steep in the Upper and Middle Rhine, resulting in milder flow velocities (Figure A-3). Originally, this area was characterized by diverse patterns of islands and bends. During the 19th century the river was normalised (a narrow uniform width was created) by means of groynes, channel closures and bend cut-offs to increase the safe discharge of ice, water and sediment. By reducing the width of the river the flow in the main channel was increased which increased bed erosion.

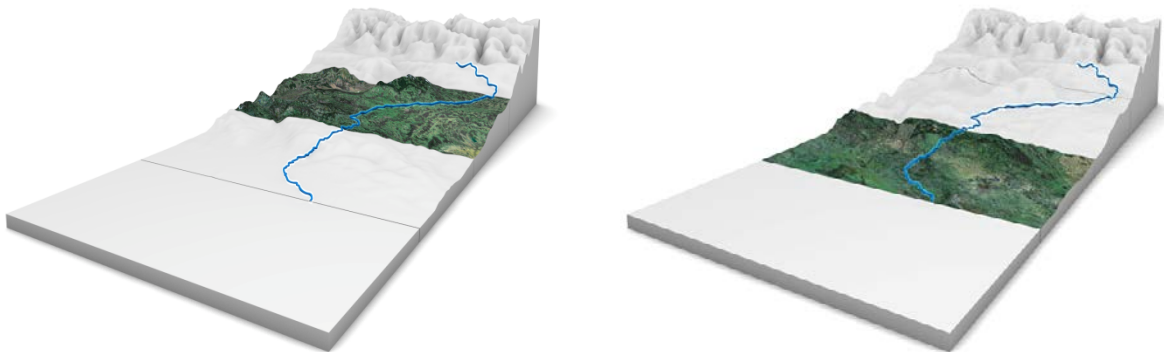


Figure A- 3 Middle and lower course of the Rhine

These interventions initially had a positive effect on agriculture and navigation, but on the long term caused up to 10 meter of river bed erosion which exposed the underlying bedrock, see figure A-4. Keeping the Rhine navigable necessitated the construction of the parallel Grand Canal d'Alsace. The flow through this canal is regulated by means of 10 dams with adjacent hydropower plants and locks that allow the accessibility of shipping traffic. Additionally, several weirs and small dams also regulate the flow in the old Rhine river bed.



Figure A- 4 On the left the level difference is visible between the original river banks (where the cars are parked) and the current river bank. On the right the exposed rock on the river bed is shown in the upper Rhine at the border between Germany (left) and France (Right) [Source: E. Mosselman]

Due to ongoing erosion of the river bed the rocky subsoil is exposed, which changed the ecological system. The negative effect on morphological dynamics in the river can be reduced with large scale nourishments with sediment and/or by removing groyne fields. This can result in further incision of the river and lower river beds, which may result in problems for existing retention polders. Due to renewed morphological dynamics and deeper river beds the retention areas may lay too high, compared to the river, to remain useful to level off flood peaks.

Despite the negative long term effects groynes are still found along the middle and lower course of the river. Figure A-4 shows both submerged and emerged groyne fields. The former are typically present in upstream regions, while emerged groyne systems will become more common further downstream and all the way into the lower course and deltaic region.



Figure A- 5 Groyne fields in Germany. Left: Submerged groynes in Trechtingshausen, Middle Rhine. Right: Emerged groynes near Wessel, Lower Rhine [Source: Google Earth].

Lock Gamsheim for river ships

Alongside the hydropower station in Gamsheim, France, a lock is situated which operates daily for an average pass of 90 vessels, of which 90% are self-propelled ships with a deadweight around 3000 tons. It consists of two chambers of 270m long and 24m wide. When the ships are inside, these chambers are emptied or filled to adjust for an average water level difference of 10m between the upper and the lower part of the river. Approximately 70,000 m³ of water is required for these manoeuvres which are completed in about 7 minutes.

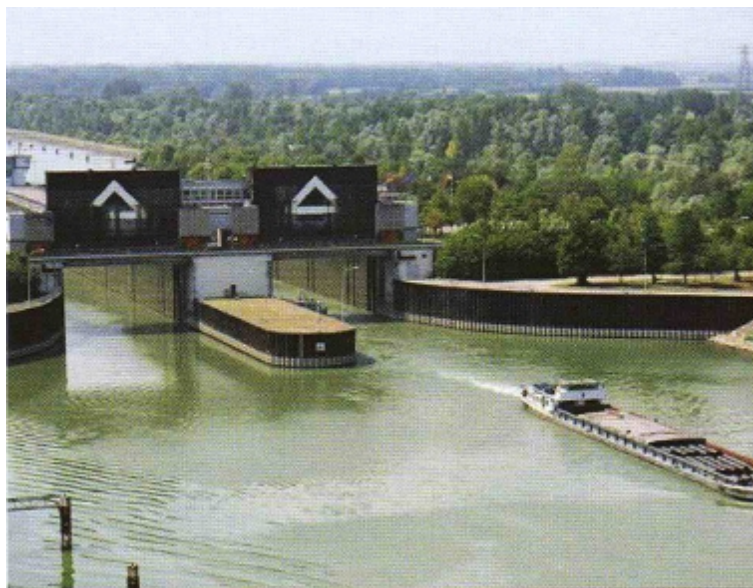


Figure A- 4 Lock Gamsheim, France [Source: ANPEI].

A.4 Delta and Estuarine Interventions

The Rhine enters the Netherlands near Lobith and branches off into the three main distributaries: the Waal River, Nederrijn and IJssel. Along these smaller rivers a diversity of interventions is found. In these regions the surface level of the land is often relatively low compared to average mean sea level and river water levels, high river discharges could potentially lead to flooding of these areas.

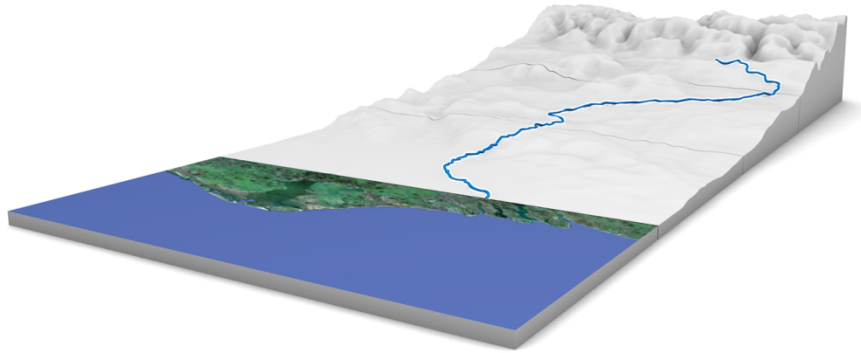


Figure A- 5 Delta and estuary region of the Rhine

Movable weir at Driel

This structure is the first of three weir dam complexes in the Nederrijn and Lek rivers. Each complex consists of a sluice weir, a weir, a control building and a fish ladder. The weir ensemble regulates the distribution of water between the Waal, the Nederrijn and the IJssel. Operation of the weirs ensures the maintenance of navigable waters, and makes sure that the IJssel Lake is provided with an adequate amount of fresh water. If all the three dams are closed, which is the case for most part of the year, the Nederrijn acts as a channel and navigation is only possible with the use of the locks. In case of floods or high discharge, ships can pass under the open weir arches.



Figure A- 6 Movable Weir at Driel, The Netherlands [Source: www.driel.info]

Room for the rivers: the Noordwaard

Dikes and flood defences are found along all the main rivers to protect the flood prone areas from flood waves. The Room for the River programme, which will be completed in 2015, consists of about 35 local projects aiming to increase discharge conveyance during river floods thus reducing high water levels. This will be achieved by carrying out various risk reducing measures apart from the traditional dike reinforcement, resulting in increased safety for the Dutch population but also an improvement in the economic and environmental quality in the river region.

In this project, the rivers in the Netherlands will be given more space to flow through and avoid the high water levels by increasing its discharge capacity. Some of the measures that will be carried out in order to achieve this extra space include the relocation of existing flood protection further inland, deepening the bed and removing obstructions on the river's banks and bed. With more space additional canals can be integrated that will also enhance the discharge capacity. Furthermore, storage areas will be used in order to retain high water volumes in case of extreme flows.

The Noordwaard is one of the 35 locations in the Netherlands where, as a part of the room for the river programme, the discharge capacity of the Nieuwe Merwede River will be increased. By partially excavating the dikes on the river side a "flow-through" retention area will be created. It will be flooded several times a year and will be able to accommodate the volumes of high water events occurring once every 1,000 years. The project will reduce the water levels in the river locally by 30 centimetres.



Figure A- 6 Room for the River: Noordwaard [Source: West8]

Afsluitdijk

The Afsluitdijk dam was constructed between 1927 and 1933 as a part the Zuiderzee works. With the construction of this dam the Zuiderzee, a former 5,000 km² inlet, was closed off and the fresh-water IJssel Lake was created. With the realization of this dam, the reclamation of new land was possible. The province of Flevoland was created by reclamation of three polders. The 32 km dam connects the provinces of Friesland and North Holland, it includes two complexes of shipping locks to allow navigation between the Wadden Sea and the Lake IJssel. Since the river IJssel continuously feeds the lake, discharge sluices are also included to discharge fresh water to the sea. In the future the dam will need to be adapted to rising sea levels.



Figure A- 7 Left: The Afsluitdijk from above. Right: Lake IJssel, with the Afsluitdijk indicated in yellow [Source: Rijkwaterstaat, Google Earth].

Eastern Scheldt storm surge barrier

The Delta works, in the provinces of Zeeland and South Holland protect the Delta from storm surges and high sea levels. One of the largest projects of the Delta Works was the construction of the Eastern Scheldt Barrier. It was constructed to protect the flood-prone area around the Eastern Scheldt of large storm surges on the North Sea. Even though it was initially planned to be a closure dam, it was later decided to construct it as a barrier that is only closed under heavy storms and high water levels. In this way the estuarine salt water environment in the Eastern Scheldt is maintained. The 9 km barrier is composed of 62 gates of 40 m width for a maximum retaining level of 5 m above MSL and it is designed for a life span of 200 years.



Figure A- 8 The Easter Scheldt storm surge barrier, The Netherlands [Source: Rijkswaterstaat].

Maeslant barrier

The storm surge barrier of Maeslant was the final piece of the Delta Works, it was finished in 1997. Together with the Hartel barrier it protects the greater Rotterdam area against storm surges on the North Sea. The gates have a length of 240 m each and are stored in docks in the banks of the Nieuwe Waterweg under normal circumstances to allow access to the port of Rotterdam. The barrier is closed fully automatically at a water level of 3 metre above Mean Sea Level to prevent the surge from entering the port of Rotterdam.

During a surge event the docks are flooded and the hollow doors begin to float. After being manoeuvred and brought to the middle of the river by means of a small train, the doors are filled with water and sink into the bed by their own weight. The force against the barrier during a storm is about 350 Mega Newton. This structure is the only storm surge barrier in the world with movable parts of such dimensions.



Figure A- 9 The Maeslant barrier, final piece of the Delta Works [Source: Van Wijngaarden Marine Services B.V.].

Maasvlakte 2

The largest port of Europe, the Port of Rotterdam, stretches out about over 40 kilometers from the city of Rotterdam to the North Sea and dates back to the 14th century. The accessibility and safety of the port is guaranteed by interventions such as barriers, navigation locks and dredging operations.

As a result of its increasing activity the city of Rotterdam has developed into a major port city. Port facilities have expanded along the Nieuwe Waterweg in direction of the North Sea. The 2nd Maasvlakte is the latest extension of this complex and it is expected to double the maximum transfer capacity of the existing port. The expansion consists of a total surface area of 2,000 ha constructed to a height of 5 m above MSL to be protected against flooding. In addition, for the protection against extreme surge and waves, the 11 km stretch of coast will be protected by means of a sea wall raised to a height of 14 m above MSL.



Figure A- 10 Latest expansion of the port of Rotterdam, The 2nd Maasvlakte [Source: Port of Rotterdam, Project Organization Maasvlakte 2].

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