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By HANS-ANDREAS LEHMANN and HEINZ JASPER

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1. Introduction

The German North and Baltic Sea Coast being an integral part of the Federal provinces (Länder) Lower Saxony, Bremen, Hamburg, Schleswig-Holstein and Mecklenburg-Vorpommern was shaped by the last ice age. Under the influence of the external forces of the sea it evolved to be a continuously changing boundary line between land and water.

Approximately 2,500 years ago, man began to colonize the coastal zone. Subsidence of the coastal area as well as the melting process of the polar ice led to gradually rising sea levels and, consequently, more frequent flooding of coastal areas. In order to protect themselves against rising water levels the coastal people started building earth mounds (Warften, Wurten) some 2000 years ago. The further rise of the mean sea level necessitated a continuous raising of these mounds. For a more efficient protection of houses and arable lands the construction of dikes started some 1,000 years ago.

While initially low elevation 'summer' dikes were sufficient for protection increasing tidal levels and storm surges required structures with higher crown elevations. Thus, dikes were strengthened and raised in the course of time. In the following centuries, dike design and construction evolved to create the present efficient flood protection system.

Two main tasks have developed from human habitation of the coastal zone:

- Coastal protection – stabilization of the coastline (prevention of loss of land/receding of the coastline)
- **Flood protection** – prevention of flooding of lowlands during storm surges.

Flood protection is generally defined as the sum of all measures for the protection of the population and material goods against flooding. The protection is provided by flood protection structures (Hochwasserschutzanlagen HWS). This does not only include dikes but particularly artificial structures such as protective walls, sluices, pumping stations and **barrages/tidal barriers**.

2. Barrages, their Development and Operation

In Germany, the planning and design of barrages to dam off entire river regimes and estuaries started about 100 years ago. Initially, their main task was to obstruct storm surges and, thereby, prevent the intrusion of large water masses into river regimes and estuaries and the adjacent fertile lowlands. Thus, barrages provided the basis for a full utilization of those areas for agriculture and habitation. In 1936, the first Eider barrage was completed, followed by the Leda Barrier in the Ems estuary in 1950.

The severe storm surges in the Netherlands in 1953 and at the German North Sea coast in February of 1962 were catastrophic events necessitating the strengthening and raising of crown levels of existing dikes as well as the design and construction of tidal barriers. Another storm surge in 1976 affected particularly the Hamburg harbour region. Based on the experience of these events, major efforts have been undertaken to improve coastal and flood protection. This required major financial investments into the improvement and completion of all protective (HWS) structures.

Often, the construction of tidal barriers results in a shortening of the dike defence line. Consequently, the placing of a barrage close to the river mouth seems to be reasonable. Because of their location barrages would also meet important requirements of water management such as drainage of lowlands, maintaining inland water levels during dry periods and/or maintaining or improving the navigability of a main navigation route and/or tributaries by impounding water.

3. Barriers/Barrages in Germany

The following table deals solely with storm surge barriers. Sluices and locks are not included, even though they can function as barriers dependent on their location. Along the German North Sea coast and in the estuaries, we can find 32 barrages which have to ward off storm surges.

While the Eider Barrier with a discharge width of 200 m used to be the largest and most impressive German tidal barrage at the North Sea coast, in the meantime this claim has been taken over by the Ems Barrier with a passage width of more than 400 m.

Table 1: German tidal barriers

lfd. Nr.	Sperrwerke	Inbetriebnahme	Kennzeichnende Größen	Ansprechpartner
1	Leda-Sperrwerk	1954	Durchflussweite: 70 m Öffnungen: 5 × 14 m Verschlüsse: Hubtore	WSA Emden

2	Ems-Sperrwerk	2002	Durchflussweite: 414 m Öffnungen: 7 (60 m, 2 × 50 m, 4 × 63,5 m) Verschlüsse: 1 Drehsegment, 1 Segment, 5 Hubtore (1-fache Sicherheit)	NLWKN Betriebsstelle Aurich
3	Sperrwerk Leysiel	1991	Durchflussweite: 30 m Öffnungen: 3 × 10 m und Seeschleuse Verschlüsse: Hubtore	NLWKN Betriebsstelle Aurich
4	Hunte- Sperrwerk	1979	Durchflussweite: 92 m Öffnungen: 4 (2 × 26 m und 2 × 20 m) Verschlüsse: 2 Stemmtore und 2 Segmenttore	NLWKN Betriebsst. Brake-Olden- burg
5	Ochtum-Sperr- werk	1979	Durchflussweite: 20 m Öffnungen: 2 × 10 m und Schleuse Verschlüsse: Hubtore	NLWKN Betriebsst. Brake-Olden- burg
6	Lesum- Sperrwerk	1979	Durchflussweite: 60 m Öffnungen: 4 × 15 m und Schleuse Verschlüsse: zweiteilige Hub- tore	Bremischer Deichverband a. r. Weserufer/Bremen
7	Geeste Sturm- flutsperrwerk	1961	Durchflussweite: 31 m Öffnungen: 1 × 24 m und Spülöffnung Verschlüsse: Stemmtore und Rollschütze	Bremenports GmbH & Co KG/Bremerhaven
8	Sperrwerk Schleusenpriel	1979 + 2009 n. Umbau	Durchflussweite: 19 m Öffnungen: 1 × 19 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
9	Sperrwerk Alter Fischerei- hafen	2009 (geplant, nach Neubau)	Durchflussweite: 14 m Öffnungen: 1 × 14 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
10	Oste-Sperrwerk	1968	Durchflussweite: 110 m Öffnungen: 5 × 22 m Verschlüsse: 1 × Stemmtore und 4 × Segmenttore	WSA Cuxhaven
11	Freiburg- Sperrwerk	1967	Durchflussweite: 8 m Öffnungen: 1 × 8 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
12	Stör-Sperrwerk	1975	Durchflussweite: 130 m Öffnungen: 4 (2 × 22 m und 2 × 43 m) Verschlüsse: 2 × Stemmtore und 2 × Segmenttore	WSA Hamburg Außenbezirk Glückstadt

13	Sperrwerk Wischhafen	1978	Durchflussweite: 30 m Öffnungen: 3 (1 × 20 m und 2 × 5 m) Verschlüsse: 1 × Stemmtore und 2 × Hubtore	NLWKN Betriebsstelle Stade
14	Sperrwerk Ruthenstrom	1978	Durchflussweite: 14 m Öffnungen: 2 × 7 m Verschlüsse: Stemmtor (vorn) und Hubtor (hinten)	NLWKN Betriebsstelle Stade
15	Sperrwerk Abbenfleth	1971	Durchflussweite: 13,5 m Öffnungen: 1 × 13,5 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
16	Krückau-Sperrwerk	1969	Durchflussweite: 44 m Öffnungen: 3 (1 × 20 m und 2 × 12 m) Verschlüsse: 1 × Stemmtore und 2 × Hubtore	WSA Hamburg
17	Pinnau-Sperrwerk	1969	Durchflussweite: 36 m Öffnungen: 3 (1 × 20 m und 2 × 8 m) Verschlüsse: 1 × Stemmtore und 2 × Hubtore	WSA Hamburg
18	Schwinge-Sperrwerk	1971	Durchflussweite: 16 m Öffnungen: 1 × 16 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
19	Lühe-Sperrwerk	1959	Durchflussweite: 10 m Öffnungen: 1 × 10 m Verschlüsse: Stemmtore	NLWKN Betriebsstelle Stade
20	Sperrwerk Este-mündung	2000	Durchflussweite: 40 m Öffnungen: 1 × 40 m Verschlüsse: Stemmtore	HPA Hamburg
21	Baumwall-sperrwerk	1969	Durchflussweite: 7,30 m Öffnungen: 1 × 7,30 m Verschlüsse: Stemmtor (vorn) und Segmenttor (hinten)	LSBG Hamburg
22	Nikolai-sperrwerk	1969	Durchflussweite: 10 m Öffnungen: 1 × 10 m Verschlüsse: Klapptore	LSBG Hamburg
23	Sperrwerk Billwerder Bucht	1966 + 2002 n. Umbau	Durchflussweite: 128 m Öffnungen: 4 (2 × 34 m und 2 × 30 m) Verschlüsse: Klapptore (oben gelagert)	HPA Hamburg
24	Sperrwerk Veringkanal	1965 + 2003 n. Umbau	Durchflussweite: 12 m Öffnungen: 1 × 12 m Verschlüsse: Stemmtore	HPA Hamburg
25	Sperrwerk Schmidtkanal	1966 + 2002 n. Umbau	Durchflussweite: 12 m Öffnungen: 1 × 12 m Verschlüsse: Stemmtore	HPA Hamburg

26	Sperrwerk Müggenburger Durchfahrt (privater HWS)	1978	Durchflussweite: 41,90 m Öffnungen: 1 × 41,90 m Verschlüsse: Klapptor (1-fache Sicherheit)	HPA Hamburg
27	Sperrwerk Marktkanal (privater HWS)	1978	Durchflussweite: 18,70 m Öffnungen: 1 × 18,70 m Verschlüsse: Klapptor (1-fache Sicherheit)	HPA Hamburg
28	Sperrwerk Peutekanal (privater HWS)	1978	Durchflussweite: 41,90 m Öffnungen: 1 × 41,90 m Verschlüsse: Klapptor (1-fache Sicherheit)	HPA Hamburg
29	Sperrwerk Seevesiel	1966	Durchflussweite: 15 m Öffnungen: 3 × 5 m Verschlüsse: Schlagtor (vorn) und Hubtore (hinten)	NLWKN Betriebsstelle Lüneburg
30	Ilmenau-Sperrwerk	1974	Durchflussweite: 36 m Öffnungen: 3 (1 × 16 m und 2 × 10 m) Verschlüsse: 1 × Stemmtore und 2 × Hubtore	NLWKN Betriebsstelle Lüneburg
31	Eider-Sperrwerk	1973	Durchflussweite: 200 m Öffnungen: 5 × 40 m + Schleuse Verschlüsse: 5 Segmentverschlüsse	WSA Tönning
32	Sperrw. Greifswald-Wieck	in Planung	Durchflussweite: 21 m Öffnungen: 1 × 21 m und 2 × 17 m Verschlüsse: 1 Drehsegment (1-fache Si.) und je Uferseite 2 Schiebetore	Staatl. Amt für Umwelt und Natur/Ueckermünde

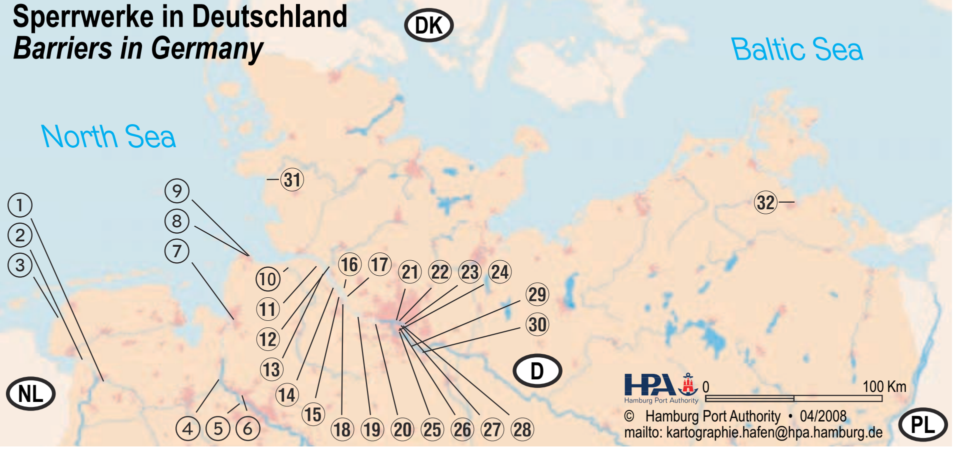

Fig. 1: Location of the German tidal barriers at the North and Baltic Sea coast

4. Layout and Concept of the Barrages

Planning and design of a tidal barrier requires a conception aimed at the particular location and its requirements as well as establishing the compatibility between the manifold operational tasks of the barrier with the various local and boundary conditions. Due to this, safety is of the utmost importance. Along with the standard principle of doubled safety for the gates the redundancy of technical systems plays an important role nowadays. The insertion of spare elements (e.g. two independent power supplies, doubled instruments or modules) serves to increase the reliability of technical systems in case of failures or break-downs and, thereby, guarantees a higher likelihood of uninterrupted operation.

4.1 Gates and Other Closure Devices

Mitring, radial, flap and vertical lift gates are the most common gate types which have evolved for barrages. Main advantages in comparison to other gate types are their economical design, the sturdiness, operational safety and the possibility of closing them even when the drives have failed. Moreover, they are easily maintained and repaired.

However, the choice of a suitable type of gate always depends on the particular case. Technical, operational and economical conditions always influence this decision.

4.2 Drives

While in the past mechanical drives using chains, steering racks and steel cables have been deployed generally hydraulic drives can be found nowadays. Mainly, they stand out because of simple maintenance and can be easily steered and monitored from a control centre.

4.3 Scour Protection

At the bottom of a river in front of and behind a barrier scouring can occur at different degrees. Particularly affected areas are to be protected against erosion. The extent of the scour protection is not only dependent on the local conditions (e.g. external forces, properties and stability of the bottom of the river or estuary). The Eider Barrier was built in a wadden sea environment in contrast to other barrages built in the course of a river or channel. Experience and practical knowledge derived from its operation have clearly indicated that the currents occurring under these particular conditions as well as the operation of the barrage substantially influence the development of scour. Therefore, and under these particularly difficult conditions, the execution of model tests is highly recommended. Because of still remaining imponderables the extent of the scour protection should not be designed too sparingly in order to prevent costly supplementary protection measures afterwards.

4.4 Additional Installations

To guarantee the operational safety of barrages in the cold season at low temperatures **electrical heating and air bubblers** are part of the standard equipment. They are to prevent icing around the seals, the gate stop faces and recesses.

In order to increase operational safety in case of a power failure, many barrages include an **auxiliary power generator**. For this purpose major barrages usually have a permanently installed diesel generator in a special casing or room. Smaller barrages have a mobile power generator or can be easily connected to an auxiliary power network.

For the purpose of inspection, repair and maintenance **auxiliary gates** can be inserted for drainage and dry access to the barrier gates. They are usually stop-logs, needle dams and gate boards. In case of a storm surge and for the replacement of entire gates the single auxiliary gate is not sufficient. Today, for that purpose barrages maintain a so-called double-safety standard, i.e. two gates arranged behind each other. Both are not necessarily of the same type.

An essential element of a functioning disaster control in case of a storm surge is a well maintained and open dike defence road. Thus, all barrages can be crossed on **bridges** which also may be part of major traffic arteries. Often, these are bascule or swing bridges which are only opened for the passage of ships if the barrage is connected with a lock.

4.5 Secondary Installations

If barrages have to be kept closed for a longer period the reservoir capacity between the river dikes may not be sufficient to store the fresh water discharge. This can be compensated for by coastal pumping stations and/or storage polders.

To enable navigation into and out of the rivers or estuaries at all times, the passages for maritime traffic of some barrages are designed as locks.

5. Design and Construction

The main issue of storm surge and flood protection is the safeguard of human lives and material values. However, the task of nature and landscape protection is to also maintain the bases of all animal and plant life. According to the present legislation the construction or improvement of a barrage represents an encroachment on nature and landscape. Thus, each and every case has to be examined and evaluated meticulously to arrive at a decision – even though the protection of human lives has priority. Aspects of nature and landscape protection have to be considered in the design of the planned structure in the sense of an encroachment minimization. Should, however, the project prove to be an encroachment on nature and landscape, compensatory measures have to be taken.

5.1 Legal Principles

Coastal and flood protection are the responsibility of the federal provinces (Länder) within the legal framework of the federal Water Management Act (Wasserhaushaltsgesetz).

Additionally, the European Community Law (EU) supersedes the national legislation. The single citizen, however, has no legal claim to flood protection and/or a certain type of protection measures. Coastal and flood protection structures or installations (HWS-Anlagen) require a project approval procedure (Planfeststellungsverfahren). The so-called dike regulations (Deichordnung) include restrictive bans on the utilization of such installations.

5.2 Owner Functions and Control

Coastal and flood protection installations, if not in private hands, are generally federal or provincial property unless a dike association (Deichverband) owns it. The supervisory authority – usually called water authority (Wasserbehörde) – has to control the status of the installation and carries out inspections on a regular basis. This does not apply to private installations, unless they are subjected to legal regulations such as the polder regulation in Hamburg. Areas in the harbour of Hamburg which are not protected by the public main dike due to their location are secured by polders. This private initiative was established after the storm surge of 1976.

6. Operation and Maintenance

The operation and maintenance of barrages are the responsibility of the owner. Independent of the mentioned mandatory control regulations, the owner checks and monitors his installation on a regular basis, thereby ensuring its operational safety and readiness. In addition to the daily visual check a regular preventive maintenance provides the essential basis for a safe and reliable operation.

Based on the present equipment of barrages with hydraulic drives and modern control technology, the operation of barrages could not be spared the current reduction of personnel. In modern barrages all functional and operational processes are automated. Within the framework of dike strengthening and crown elevation measures of the last few years the electrical control of older barrages has been adapted to modern standards. Steering, control and visualization on electronic monitors, alarms and recordings of all states of operation and messages are carried out by programmable-storage modules (SPS = Speicher programmierbare Steuerung) for the support of operating staff in the control centre.

7. Future Prospects

Coastal and flood protection is an everlasting task of generations. Predictions of future development prove to be difficult since the extent and evolution of climatic changes with their consequences for the German coastal zone are difficult to determine. In the foreseeable future, increasing design levels can be still counterbalanced with strengthening structures and raising their top levels. Moreover, these measures can be accompanied by a flood risk management. Decisions for further investment, however, need a reliable database. Should, therefore, the global sea level rise take on greater dimensions one would have to consider the design and construction of new and even larger barrages. Scenarios resulting in a sea level rise of several meters let us only guess the effects on the German North and Baltic Sea coast – a withdrawal of the inhabitants from the coastal regions could be the final consequence.

8. Description of Selected Barrages

8.1 Ems Barrier in Lower Saxony

With an overall width of 476 m the Ems Barrier is the largest and most modern barrage in Germany. After a construction period of four years, the barrage went into operation in September 2002. This was a delay of one year since construction had been brought to a halt by a court order in November 1998, just 2 months after the first pile had been driven. Quarrelling in court concerning the legality of the barrage had accompanied the project for several years. In a court settlement, the province of Lower Saxony committed itself to a payment of altogether 9 Million € for compensation measures along the river and estuary of the Ems.

Main functions of the barrage are on the one hand the improvement of the storm surge protection along the Ems and its tributaries. On the other hand the weir function would increase water levels to NN + 2.70 m and ensure navigability between Papenburg and Emden. Moreover, the safe transfer of larger vessels with a draught of up to 8.5 m was made possible.

The barrage has been planned for a design water level of NN + 6.4 m with a single safety. The second safety level is being provided by the existing dikes along the Ems (crown elevation NN + 8.0 m).

Technical data:

- Size of the barrage approx. 476 × 56 m
- 7 passage gates, with 1 main navigation opening (HSÖ) B = 60 m, 1 navigation opening for barges (BSÖ) B = 50 m, 5 secondary openings (NÖ): 1 × 50 m and 4 × 63.5 m wide
- Entire flow passage width: 414 m
- Water level during closure: NN + 3.5 m
- Clearance of the BSÖ = 5.25 m above MHW. Barges with a draught of up to 4.5 m can pass the opening
- Elevation of the threshold of HSÖ: NN – 9.0 m, BSÖ: NN – 7.0 m, NÖ: NN – 7.0 m and NN – 5.0 m
- Flood gate safety: single
- Type of gates: revolving sector gate (HSÖ), radial gate (BSÖ), lift gates in all NÖ
- Drives: hydraulic with two lifting cylinders at each gate
- In addition to the operations and information building the structure includes service bridges and tunnels (accessible sills in three northernmost openings) as well as a service pier
- Closing of all gates of the barrage takes approx. 30 minutes
- Overall costs of the project were more than 215 Million €

Fig. 2: Aerial photograph of the Ems Barrier/© NLWKN Aurich

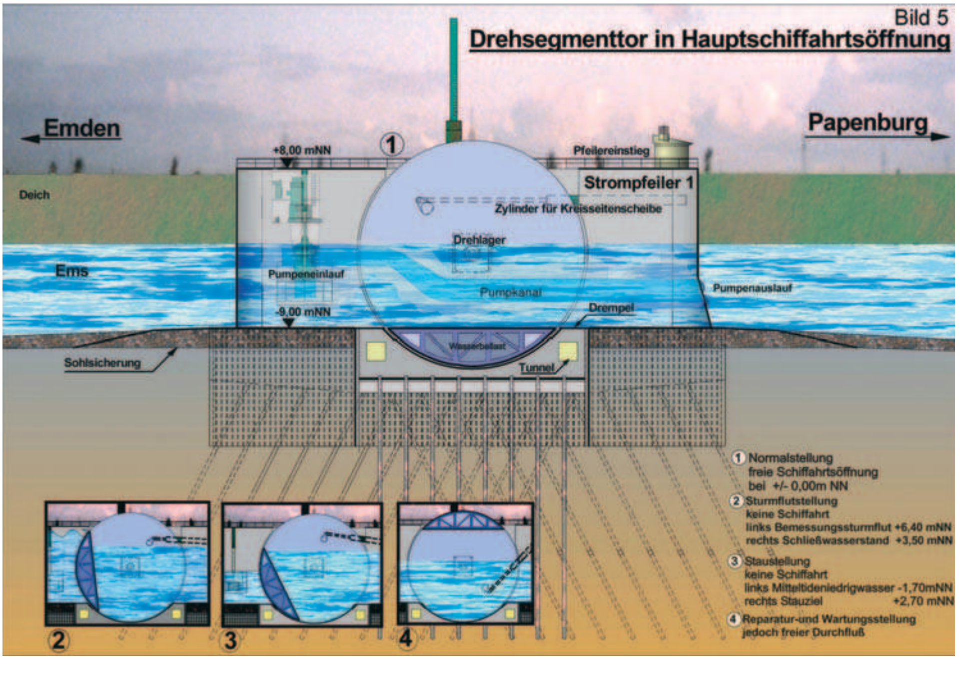

Fig. 3: Cross-section of pier No. 2/© NLWKN Aurich

Construction procedure:

The structure was built in a trench. Construction began with dredging works to move the main navigational channel. Securing the river bed with bush mattresses covered with armour stones was carried out before starting work on the bridge piers and sills. For the construction of the bridge piers sheet pile boxes were installed whose piles had to be driven through the river bed fortification. After driving the foundation piles, the sheet pile boxes were sealed on the bottom by underwater concrete. Thereby, bridge piers could be erected in dry building pits. After finishing the piers, the emplacement of the pre-fabricated sills with a single weight of up to 1,000 t were carried out. Only the sill of the HSÖ was cast in site-mixed-concrete in a dry building pit. Afterwards, service bridges and vertical lift gates as well as the sector gate and the service bridge of the BSÖ were installed. The revolving sector gate of the HSÖ was lowered onto its hinges. In March 2002, the HSÖ was opened for navigation – the outer geometry of the barrage was finished. The completion of the service building followed, and transformers and the electrical, hydraulic and machinery equipment were installed.

8.2 Lesum Barrier in Bremen

To achieve a comprehensive solution of coastal protection problems on the Lower Weser, the provincial government of Lower Saxony and the Senate of the Free and Hanseatic City of Bremen decided on the erection of three tidal barrages in the river mouths of Hunte, Lesum and Ochtum, tributaries to the Weser. At that time, this solution seemed to be the most economical way to guarantee storm surge protection within a short time span. Because of their influence on the tidal water levels downstream these three barrages could only start to operate conjointly and after the completion of all other flood protection installations along the Lower Weser. This condition was finally met in 1979, even though the construction of the Lesum Barrier had been completed in 1974.

Based on the results of hydraulic model tests carried out by the Franzius Institute of the University of Hannover the barrage was built with four flood gates. The bridge spanning the barrage serves as the connection between the district of Grohn (Bremen-Vegesack) and Werderland (Lesumbrock) in Bremen-Burglesum.

Technical data:

- Size of the barrage approx. 118 × 35 m
- 4 passage gates with 15 m width each (60 m passage width overall)
- 1 lock, clear dimensions: B × L = 14 × 30 m
- Backwater level: NN + 2.50 m
- Bridge: solid road bridge across the passages and a balanced bascule bridge across the lock. Overall length: 120 m
- Clearance at bridge closed: NN + 7.0 m (lower edge of bridge)
- Sill elevation of passages and lock: NN – 3.3 m
- Gate safety: doubled safety
- Type and drive of the gates: Split lift gates with mechanical drives with pivoted chains for the flow passages and hydraulically driven mitring gates in the lock
- Secondary installation: pumping station with three pumps, capacity: 3 × 15 m^3/s

Fig. 4: View from downstream/© Bremischer Deichverband am rechten Weserufer, Bremen

Construction procedure:
The Lesum Barrier was erected between 1971 and 1974 in three stages in a trench. Because of favourable subsoil conditions, a low-cost spread-foundation could be chosen. Phase I: lock with two adjacent passage openings and river training measures on the right Lesum embankment. Phase II: passage openings 3 and 4 . Phase III: pumping station and shore connection to the left Lesum embankment.

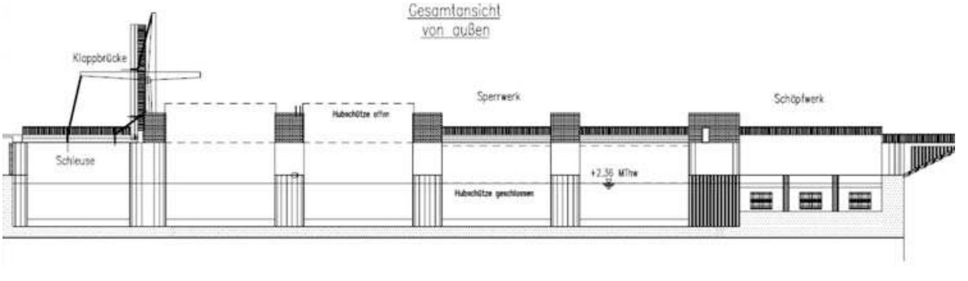

Fig. 5: Cross-section of the barrage/© Bremischer Deichverband am rechten Weserufer, Bremen

8.3 Eider Barrier in Schleswig-Holstein

The Eider Barrier was completed in 1973 and is part of the dike defence line of the North Friesian coast. For almost 30 years, the Eider Barrier could claim to be the largest coastal protection structure in Germany. Only in 2002, this 'title' had to be handed over to the Ems Barrier. Planning for the construction of an Eider barrage already started in 1957. First suggestions for its location and alignment and hydraulic model investigations at the Federal Waterways Engineering and Research Institute (Bundesanstalt für Wasserbau – BAW) followed. Construction started on March 29, 1967.

The Eider barrage is composed of several structures: the tidal gates, the bottom foundation plate, the lock and the 5 km Eider causeway. The tidal gate structure has an overall flow passage width of 200 m. The openings are framed by piers and bridged by pre-tensioned concrete girders. These so-called weir trusses (Wehrträger) have a length of almost 43 m and an elliptical cross-section. The hollow interior serves as an auto tunnel for the coastal road connecting the regions of Dithmarschen and Eiderstedt. Radial type steel gates are used for closure. They are pivoted on the weir trusses. The bottom foundation of the passage openings is a reinforced concrete slab of 0.8 m thickness which connects on both sides to the 150 m long rigid bed protection. The navigation lock is equipped with 5 pairs of steel mitring gates. The two pairs of gates in the outer sluice head represent the two-fold safety. The lock is bridged by a balanced bascule bridge.

Technical data:

- Size of structure approx. 240 × 65 m (without lock)
- 5 sluice gates with 40 m passage width each
- Sluice sill elevation: NN – 4.6 m
- Weir trusses above the flow passages
- Bottom edge of weir trusses: NN + 2.0 m; top edge: NN + 10.35 m
- Sector gates, 2 for each flow passage, pivoted at the weir truss; weight 250 t each, drives: 2 oil-hydraulic cylinder-plunger-aggregates for each segment

Fig. 6: Aerial photograph of the Eider Barrier, © Raabe, Friedrichstadt

Fig. 7: Lock chamber with bascule bridge/© WSA Tönning

Fig. 8: View of the Eider Barrier/© WSA Tönning

- Lock: (effective chamber dimensions: L = 75 m, B = 13.5 m) with 5 pairs of mitring gates; drives: oil-hydraulic lift cylinders; auxiliary gates: needle weirs with floatable supports (needle beams)
- Sluice sill elevation: NN – 5.6 m
- Gate safety: two-fold
- Road connection (two lanes) goes through the weir truss (236 m tunnel roadway)
- Balanced bascule bridge (width between supports: 18.6 m) spanning the lock with a width of 12.15 m
- Operation: tidal and storm surge barrier

Construction procedure:

The sluice structure, lock and building harbour were constructed within a protective ring dike erected by way of the build-up of an embankment on a sandbank in the wadden area. Material transport was carried out over a 1 km long, one-lane auxiliary bridge connecting to shore. After the construction of the lock on a pile foundation and of the sluice structure, the longer Eider causeway of approx. 4 km length was built towards the North. After removal of the construction island and start of the operation of the sluice and the lock the improvement of the navigational channel and the build-up of the southern Eider causeway was carried out. The construction of the elliptical weir truss represented a special feature of the project. Because of the exterior shape and the interior design as a road tunnel the pre-tensioned concrete modules were fabricated in several phases in a pulsing procedure. This required sophisticated and expensive tooling and formwork.

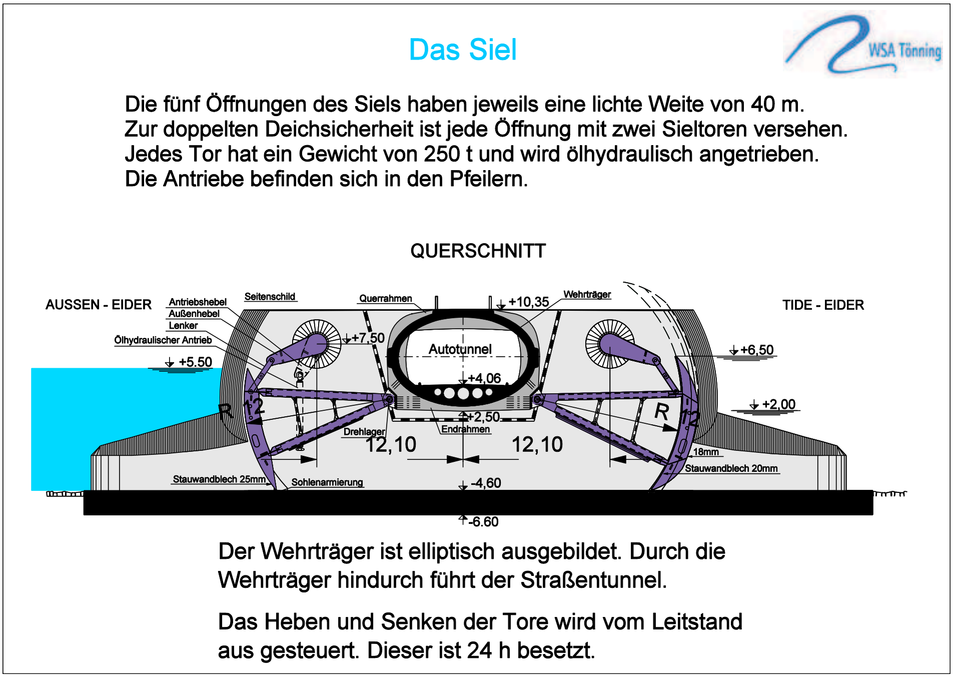

Fig. 9: Cross-section of the barrage/© WSA Tönning

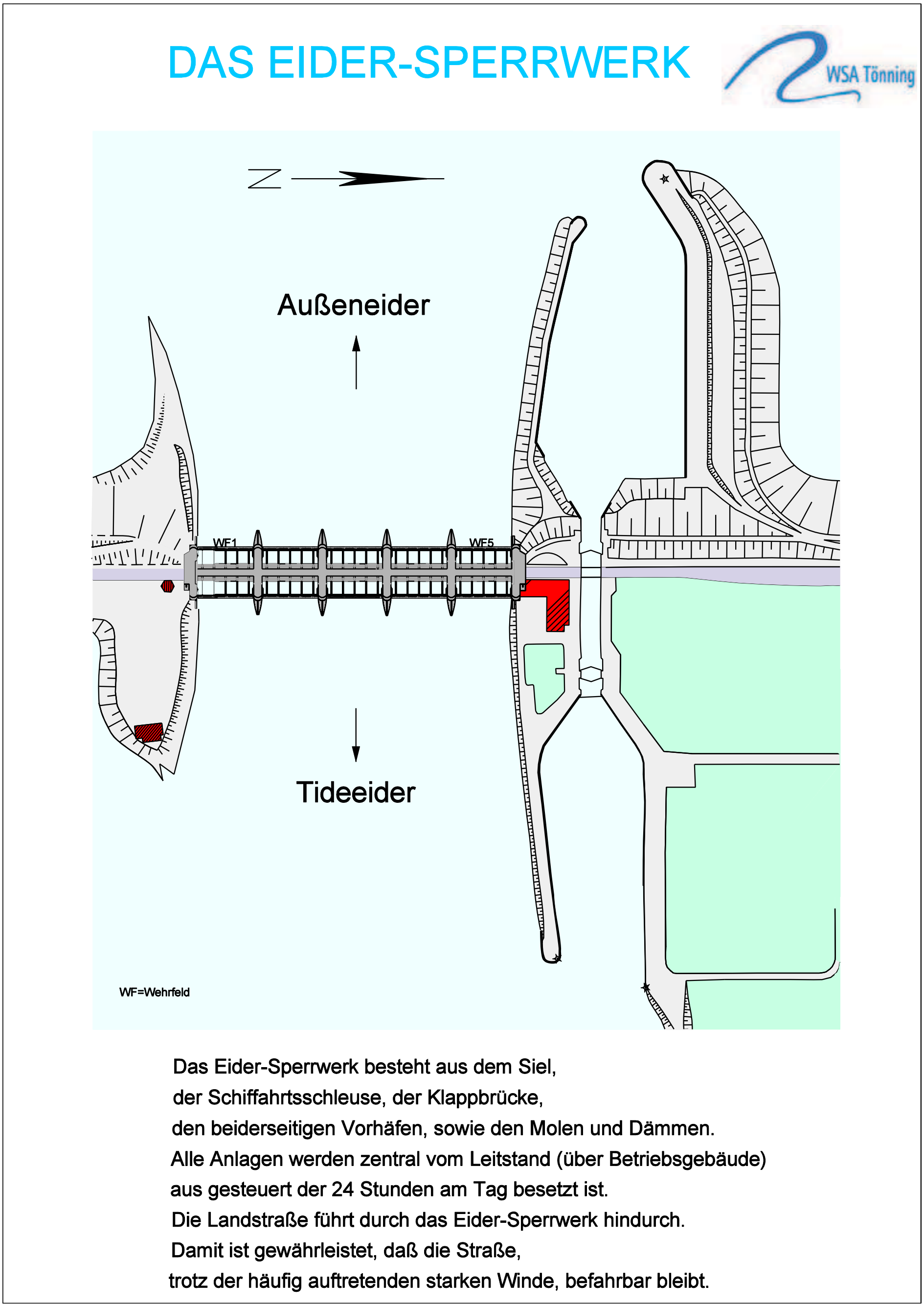

Fig. 10: Layout plan of the barrage/© WSA Tönning

The sector gates were transported to the construction site on waterways and were assembled and paint-coated on site.

8.4 Barrage Billwerder Bucht in Hamburg

The barrage Billwerder Bucht is the third-largest barrage in Germany. It was erected for the protection of the region of Billwerder Bucht and its adjacent industrial canals between 1964 and 1966. Thereby, it became part of the main dike defence line of the City of Hamburg, which was drawn up after the storm surge of 1962. Between 1999 and 2002 the barrage was rebuilt within the framework of the Hamburg Construction Programme for the adaptation of all storm and flood protection structures to the new design water level. The reconstruction was tantamount to a new construction since the barrage was not only raised by 1.2 m to a new crown level of NN + 8.2 m, it also added a second defence line of equal elevation behind the first one.

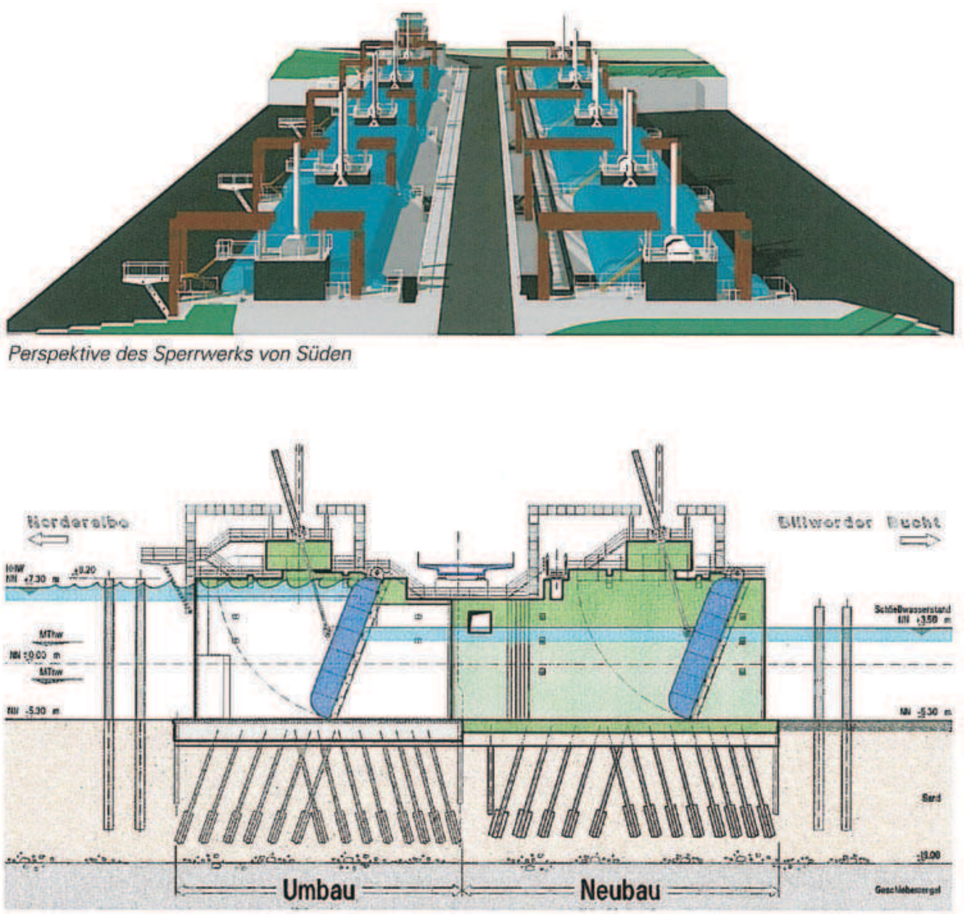

Fig. 11: Cross-section of the Billwerder Bucht Barrier/© HPA Hamburg

Technical data:

- Size of structure approx. 150 × 55 m
- 4 flood passages, of which two are navigable with a width of 34.5 m each, and 2 secondary passages with 30 m width each
- Overall passage width: 128 m
- Backwater level: NN + 3.5 m
- Passage clearance for navigation: NN + 8.05 m (bottom edge of the bridge/flap gate)
- Top of sluice sill: NN – 5.3 m (navigable passages) and NN – 4.2 m (secondary passages)
- Gate safety: two-fold
- Type of gates: steel flap gates (on upper mountings) built as girder grids with a steel-plate cover
- Drives: hydraulic, with two hydraulic jacks per flap gate
- Road bridge: 1 steel box girder as a 4-field continuous system with an orthotropic two-lane carriageway plate and a cantilevered sidewalk; overall width approx. 9.0 m
- Control building and machine house; housing for the diesel-operated auxiliary hydraulic power aggregate
- Architecture: 8 welded brackets per pier (powder-coated aluminium caskets with float glass at the front); upper edge of the bracket: NN + 15.5 m

Fig. 12: Aerial photograph of the Billwerder Bucht Barrier/© HPA Hamburg

Construction procedure:

1966: step-by-step construction of the first barrage in a trench in sheet-pile boxes

1999 – 2002: new construction of the eastern defence line with subsequent reconstruction of the previous line (dismantling of the old flap gates, demolition of the 5 machine houses, heightening of the existing piers, lifting of the road bridge by approx. 1 m and shifting towards the East by 3.15 m); new construction of the control building.

The construction sequence was carried out under the following boundary conditions:

- Guarantee of full flood protection at all times
- Maintenance of navigation operations
- Maintenance of road traffic to a large extent
- Avoidance of reduction of the flow passage

The construction of the piers was carried out in sheet-piling pits; the sluice sills were exclusively poured in underwater concrete. The gate bed-stop rail was designed as a 1 m wide pre-fabricated concrete slab commensurate with the passage width.

8.5 Barrage Greifswald-Wieck in Mecklenburg-Vorpommern

The danger of flooding the downtown region of the Hanseatic City of Greifswald and townships in the lower Ryck (Ryckeniederung) area is met by this barrage and the adjacent dikes. The province of Mecklenburg-Vorpommern will invest approx. 25 Mio. € into the project 'Storm Surge Protection Greifswald' and, thereby, reduce the flood defence line by 3.5 km. The barrage is located in a cross-section of the Ryck close to its mouth at the 'Dänische Wiek', Baltic Sea.

Within the planning framework, special attention was paid to the design and integration into the urban development around the harbour of Wieck. Thus, a structure evolved which – because of its low constructional height – blends into the coastline very well. The 21 m wide navigation passage with a revolving sector gate element is the core of the installation and the most modern type that water engineering has to offer presently. On each side of the main passage a 17 m wide secondary opening in the dike is arranged as an aperture for the shoreline promenade. Both sliding gates designed for the secondary passages have been invisibly arranged inside the adjacent dikes. The secondary passages in the coffer dams have been dimensioned for taking the discharge of the Ryck should the main passage have to be closed for a longer period due to severe icing or ice drift.

Start of construction: planned for 2010

Beginning of operation: planned for 2012

Technical data:

- Size of structure: width of barrage incl. piers: 30 m; incl. coffer dams: 53 m, length of piers: 32 m
- 1 navigation passage (SÖ) with a width of 21 m; 2 secondary passages as dike openings with a width of 17 m each
- Overall passage width: 21 m
- Backwater level: NN + 3.0 m (= design high water level)
- Top of bottom sill: NN – 4.0 m
- Type of gates: revolving sector gate in the SÖ, sliding gates in the secondary passages
- Gate safety: single safety for the SÖ and in the secondary passages in the dikes
- Drives: 2 hydraulic cylinders for the SÖ

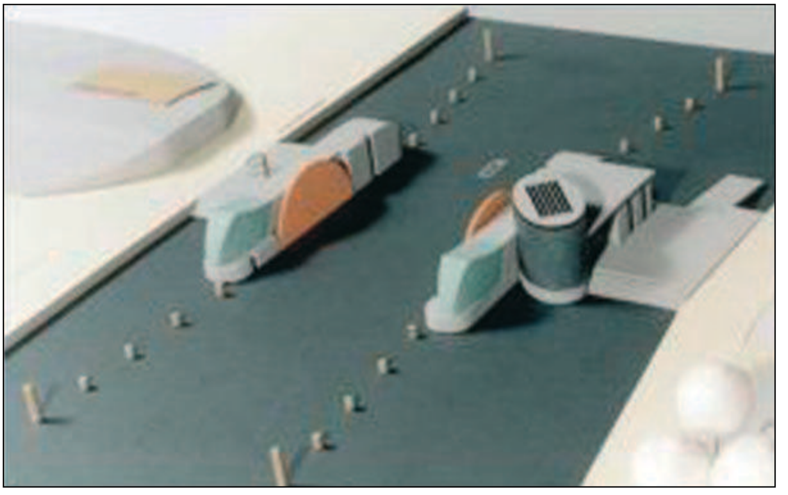

Fig. 13: Model of the barrage Greifswald-Wieck/© Staatl. Amt für Umwelt und Natur/Ueckermünde

Fig. 14: Mouth of the Ryck in Greifswald-Wieck (planned location)/© Staatl. Amt für Umwelt und Natur/Ueckermünde

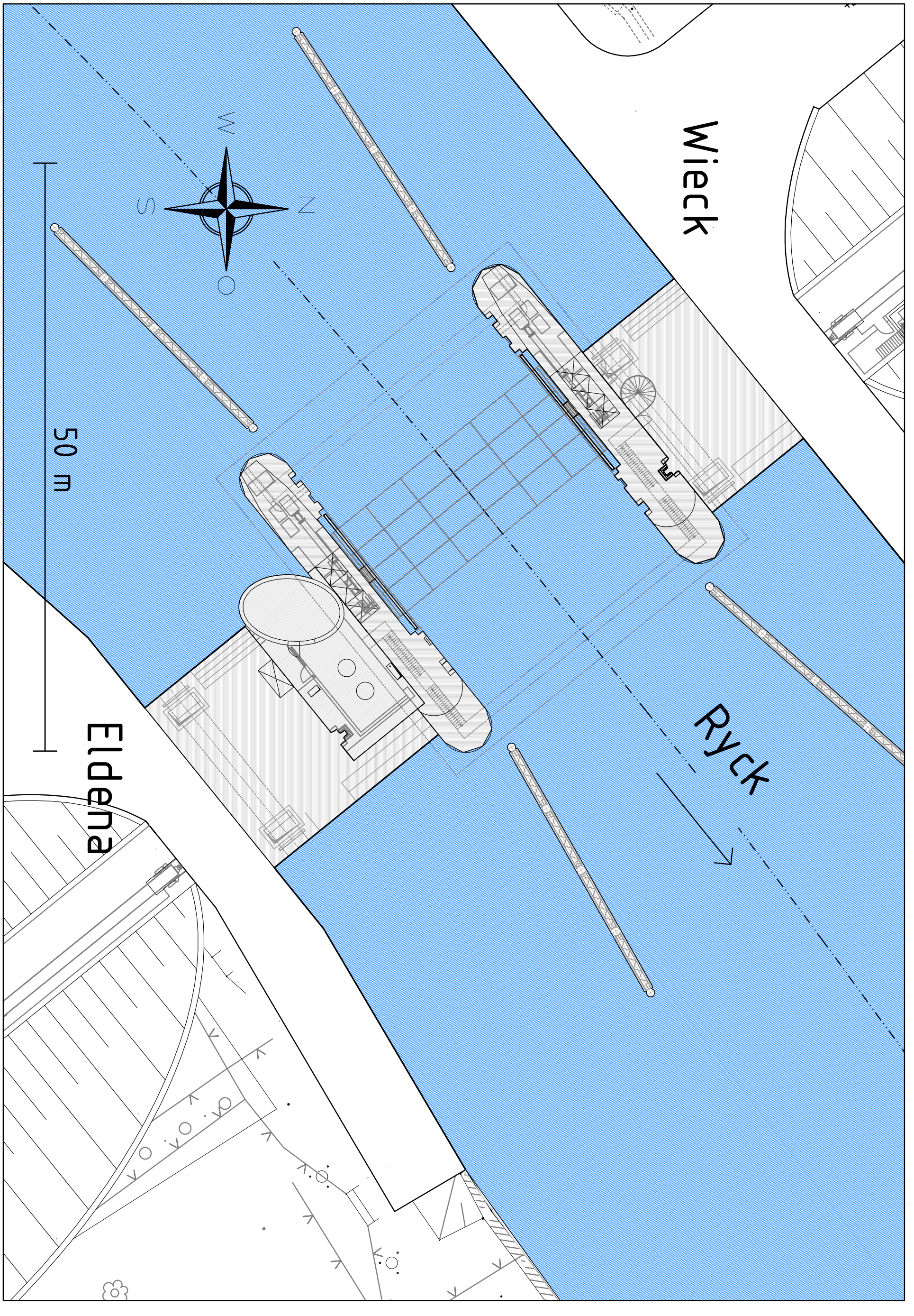

Fig. 15: Layout plan of the barrage Greifswald-Wieck/© Staatl. Amt für Umwelt und Natur/Ueckermünde

- In addition to the control building, the barrage is equipped with inspection hatches for the main passage, as well as two independent drive aggregates with auxiliary power supply
- Control by programmable-storage modules (SPS) from the control room

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