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The storm surge barrier in the Eastern Scheldt

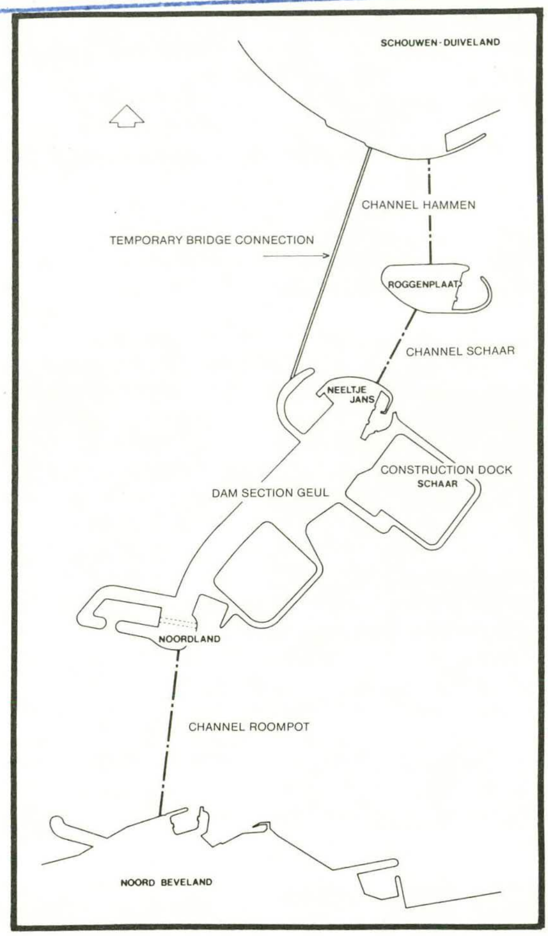
Delta project

Since 1954 work has been going on on several major civil engineering projects along the entire Dutch coast. The Delta Project, as the whole scheme is known, aims to protect the low-lying polders against flooding from the rivers and the sea and to enable fresh water and salt water to be separated and controlled.

The Delta Project includes four large dams across the inlets between the Western Scheldt and the New Waterway, three of which, the Veerse Gat dam, the Brouwershavense Gat dam and the Haringvliet dam have already been completed, while the fourth, that in the Eastern Scheldt, is due to be completed in 1985.

Work Harbours

The project in the Eastern Scheldt was started in 1967 with the building of two harbours, with quays, jetties and yards: Schelphoek (1967) on the Schouwen coast and Sophia (1968) on the North-Beveland coast. The harbours are used to store and transfer construction materials such as mine-stone, quarrystone, concrete blocks and wood, which are delivered by road and sea from near and far. In bad weather suction dredgers, bucket dredgers, floating cranes, pontoons and small boats can shelter in the harbours. The mattresses used to protect the shifting bed of the Eastern Scheldt from the scouring action of the water are made there. The Schelphoek yards are being used to develop and test new methods and materials. In fact Schelphoek has also become the „dump" for the Delta Project; equipment used earlier such as the pylons and cabins for cableways, is parked there until such time as it is needed elsewhere.



Construction islands and abutments

The actual construction of the 9 km dam started in 1968. Three construction islands, Roggenplaat (1969), Neeltje Jans (1970) and Noordland (1971), the Geul dam section (1972) and the Noord-Beveland (1972) and Schouwen (1973) abutments were built successively on the shallower parts of the river bed. Five km of dam had been completed by the end of 1973, about 2 km of which was at the final height of 11.5 m above Amsterdam Ordnance Datum, AOD, (average sealevel) According to the plans, the remaining three channels, Hammen, Schaar and Roompot, should have been „plugged" with quarrystone and slag, followed by concrete blocks, gravel and sand between 1974 and 1980. The intention was to dump

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the slag and the stone from barges, the concrete blocks from cableways, the gravel by means of trailer dredgers and the sand by means of suction and trailer dredgers. Earlier (in 1971) helicopters had been considered to dump the concrete blocks.
After trials had been carried out in late 1971 and early 1972 with a helicopter from the American Seventh Army, based in Germany and using concrete blocks left over from the Brouwershavense Gat, it was decided not to investigate this method any further.

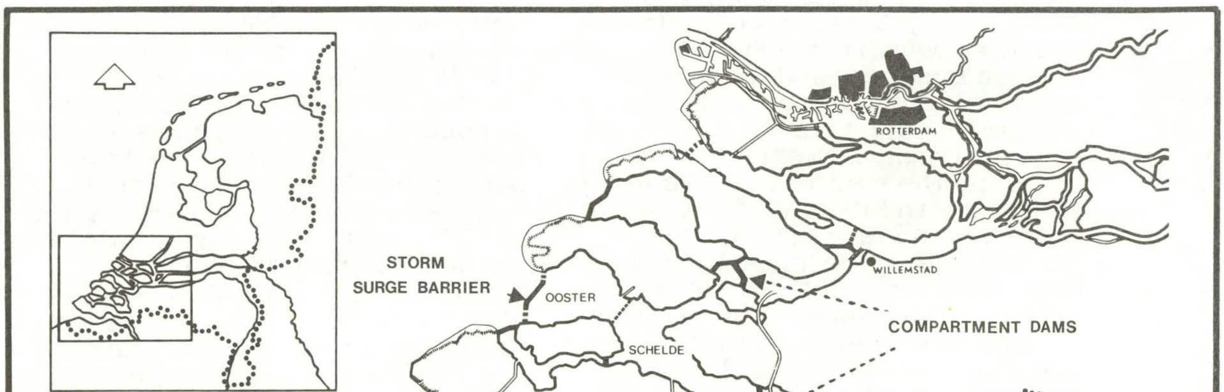
Work harbours were built on the construction islands and abutments are used as stone depots and provides bases for the vessels carrying out the work in the channels. The islands and abutments were built large enough to accommodate the end of the cableways, and storage facilities for storing the concrete blocks. The Roggenplaat construction island was made very large because the initial plan had been to build a sluice there for the desalination of the Eastern Scheldt and later for regulating the quality and level of the water. Later it was thought better to build the sluice on the Noordland work island, and a construction pit was excavated there in 1973.

The original plan

In 1973 when the idea was still to close off the Eastern Scheldt completely, a start was made with laying the protective mats in the three remaining channels. The mats were needed during the construction of the dam to prevent scouring of the seabed and to keep the erosion expected on each side of the concrete block dam far enough away from the dam itself.
At first the protective matting consisted of filtercloth and wood, with rubble as ballast. Later mattresses with fixed ballast were used: in the Hammen and the Schaar van Roggenplaat mattresses of stone asphalt made on a floating asphalt ship, the „Jan Heymans", and in the Roompot concrete block mattresses made in the factory at the Sophia work harbour.
The 13 towers for the cableways which were to be used for dumping the concrete blocks were installed in the three channels in 1973 and 1974 by means of a lifting platform.

Safety versus the environment

In the meantime, by the early seventies, the plans to close the Eastern Scheldt had become the subject of heated discussions.
A number of groups opposed to complete closure began to state their views more and more vigorously. They argued that the area could be sufficiently protected by raising existing dykes, and that the Eastern Scheldt should be kept open in order to preserve te existing tidal environment with its shellfish beds. Supporters of complete closure pointed out that this was the only way to guarantee the complete safety of the land in the area.



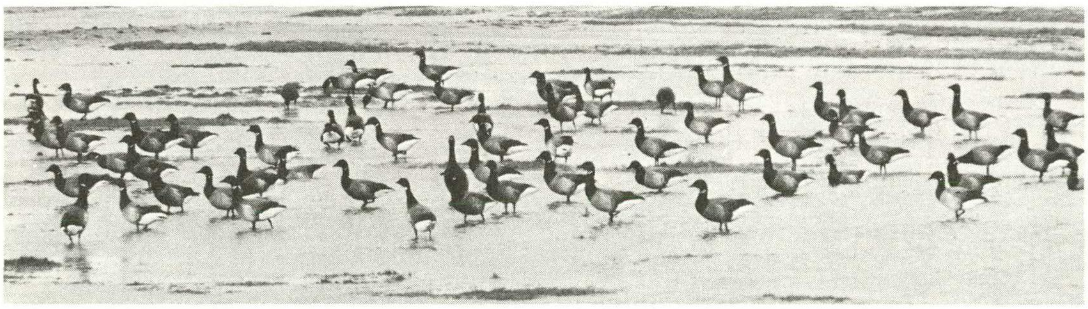
The discussions led the Minister of Transport and Public Works to appoint a committee whose terms of reference were to report on all aspects of safety and the environment connected with the Eastern Scheldt project.

The committee was to advise the Minister on whether the Delta Project could or should be modified, and if so to what extent, and whether the Delta Act would have to be amended accordingly.

Report on the storm surge barrier

The committee issued its report on 1 March 1974. The conclusion was that in the interests of safety and of the environment, it would be best to build a storm surge barrier across the Eastern Scheldt which could be closed when necessary. According to this plan, open concrete blocks would first be placed in the Hammen, Schaar van Roggenplaat and Roompot channels. These would have to be impervious enough to lower the storm surge level at the head of the estuary by about 70 cm and porous enough to allow an average tide of about 1.80 metres at the Yerseke mussel banks.
The concrete blocks would be brought into position using the cableways already being built, except for the largest concrete blocks of 40 tons or so, which would be transported by the ships which had been used in a similar way when the piers at the Hook of Holland were being built.

The concrete block dams could be completed by about the same time (1978) as those envisaged in the original plans. This would be a first and temporary arrangement to be followed by a second stage in which a storm surge barrier would be built in a coffer dam on the work island between the Roompot and the Schaar van Roggenplaat, between the islands of Noordland and Neeltje Jans and the Geul dyke. The storm surge barrier was envisaged as a complex of closable tunnels situated below low water level. After the completion of the storm surge barrier the third stage would be the final closing of the concrete block dam. It was estimated that the entire scheme, including two compartment dams in the eastern part of the Eastern Scheldt, could be completed by about 1990.



Other methods

Following the publication of this report, the DOS consortium and the Public Works Department put forward other technical proposals for the design of the storm surge barrier, taking into account three conditions laid down by the government:

a) it must be technically feasible
b) it must be completed by 1985
c) the cost must be within certain limits.

Designs were made for a triple storm surge barrier in the remaining channels, Hammen, Schaar van Roggenplaat and Roompot. They all had one thing in common: the barrier was to be prefabricated because construction docks could not be built in the channels, since they would have temporarily closed the estuary to the detriment of the environment.

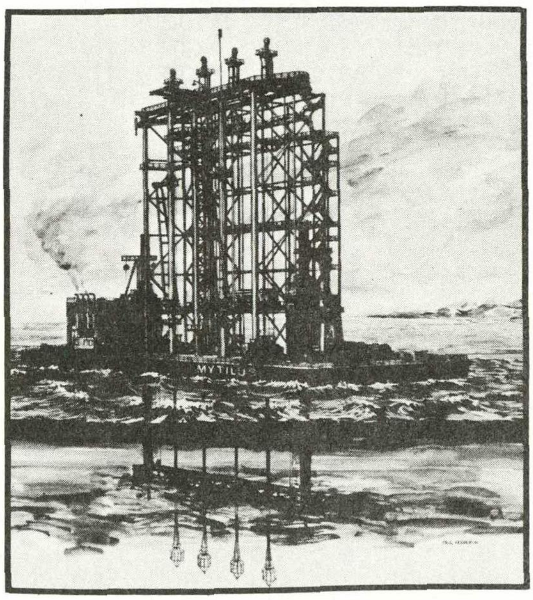
Designs were produced successively for storm surge barriers consisting of closable caissons on a threshold, caissons on a driven foundation and piers on a driven foundation.

The chosen design

The design finally chosen was for a storm surge barrier consisting of monolithic piers, the seabed between

them being raised by a sill construction of quarry stone and threshold beams. The piers, the sill and the beams together form the frame within which steel sliding gates can be raised and lowered. During normal weather conditions the gates will be kept raised so the water can pass freely through the barrier and thus preserve the tidal environment. During gales the gates will be lowered. In this way the shortened coastline referred to in the Delta Act as a way of protecting the land from flooding is achieved. Work was also begun on heightening the dykes along the shores of the Eastern Scheldt, to give the surrounding Zeeland countryside the necessary extra protection before the target date of 1985.
The size of the total opening through which the water is to flow is determined partly by the requirement that the tidal range remain as large as possible, and partly by the requirement laid down by the government that the cost of the barrier be kept within financial limits.

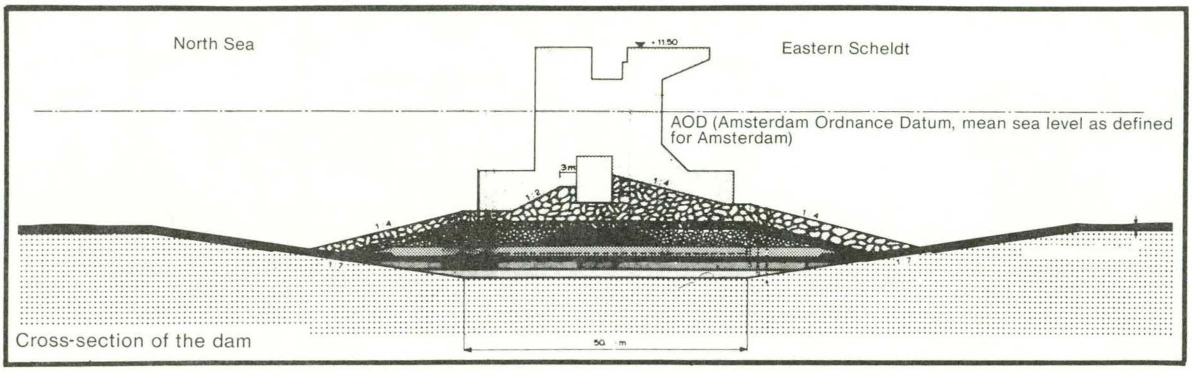
The size of the opening is designed to allow an average tidal range at Yerseke of 2.70 m, (77% of the existing range). An effective opening of 14,000 m^2 is needed to achieve this. The storm surge barrier will be over 2,800 m long, with 63 closable openings and a total of 66 reinforced concrete piers: 16 in the Hammen, 17 in the Schaar van Roggenplaat, and 33 in the Roompot. The piers have baseplates of 25 x 50 m, their heights vary between 35 m and 45 m and they have a miximum weight of 18,000 tons. The distance between the piers, centre to centre, is 45 m.



Compacting Barge

Before the piers can be sunk into position the soft sand on the seabed has to be compacted. This is being done by a specially designed compacting barge, equipped with four vibrators of 40 metres which can consolidate the seabed to a depth of 15 metres.
When inserted into the seabed, the vibrating needles cause the sand particles to pack together more closely, forming a firmer base with a greater bearing capacity.
The compacting barge Mytilus (Mussel) is 68 metres long and has a beam of 33 metres. It consists of one main and four side pontoons; the 55 metre high portal construction of the main pontoon controls the four long vibrators.

The raising of the seabed by means of sills and threshold beams in the 63 openings will allow for the required wet cross-section below Amsterdam Ordnance Datum (AOD). The sills will be built in the form of filters with layers of stony material such as sea gravel, phosphorus slag and quarry stone. Heavier materials will be used in each successive layer to help withstand the passing currents. The existing scour protection matting will be extended on each side of the sills to 650 m from the barrier in the Hammen and the Roompot and to 550 m in the Schaar van Roggenplaat.
The protection adjacent to the sills will be reinforced with asphalt and quarry stone. To close the storm surge barrier the gates, normally in a raised position, will be lowered between the piers on to the threshold beam and against the upper beam. During gales the water will be retained by the gates and upper beams; from the threshold beam to 1.20 m above AOD by the gates, and from 1.20 m to 5.80 m above AOD by the upper beams. The threshold and upper beams will be made of pre-stressed concrete and the gates of steel.
All the gates are over 42 m wide and 5.50 m thick; their heights vary from 5.90 m to 11.90 m, since the level of the sills between the piers also varies, and they weigh between 300 and 500 tons. The sliding gates will probably be hydraulically operated, two hydraulic cylinders being required



Cross-section of the dam

for each gate. 126 cylinders will therefore be required to close the 63 openings – an operation that will take about one hour – when a gale warning is received.
The current required, about 5,000 to 6,000 KWA. will be generated by a special diesel power station.
A motorway will be built over the storm surge barrier. The bridge sections over the piers will be constructed from pre-stressed concrete box girders, which will house the machinery for operating the gates.
A lock with harbours, which is needed for the passage of floating construction equipment during the construction period and will measure 100 x 16 x 7 m, will be built on the work island of Noordland, and is due to be completed by the summer of 1982. It will subsequently be open to normal shipping.

Construction dock

The construction of the piers in the Schaar construction dock, the most northerly of the two docks sited on the work island of Neeltje Jans, began in April 1979.
Construction of the docks was begun in 1976, when the intention was to use them for building the caissons but this method was subsequently rejected. The Schaar construction dock is in fact a polder, which is kept dry by a deep well pumping system consisting of 320 underwater pumps: 296 to a depth of about 30 m (capacity 25 to 35 m^3/hr) and 24 to a depth of 60 m (capacity of 50 m^3/hr). The requisite power is drawn from an electric power station on the work island of Neeltje Jans.
The construction dock, which covers an area of 800 x 1200 m^2, has been excavated to a depth of 15 m below AOD. The sand won from the excavations has been used to construct the dykes which divide the dock into four compartments. When a compartment is completely filled with piers, it will be flooded and the ring dykes surrounding it will be dredged open. The piers will be transported to the channels one by one by a lifting barge. The lifting barge is U-shaped so that it can manoeuvre around the pier in the construction dock; it will lift the pier three metres from the seabed, using two portal cranes with hoisting tackle and heavy claws. While in transit with the lifting barge the pier will have a draught of 12 metres.

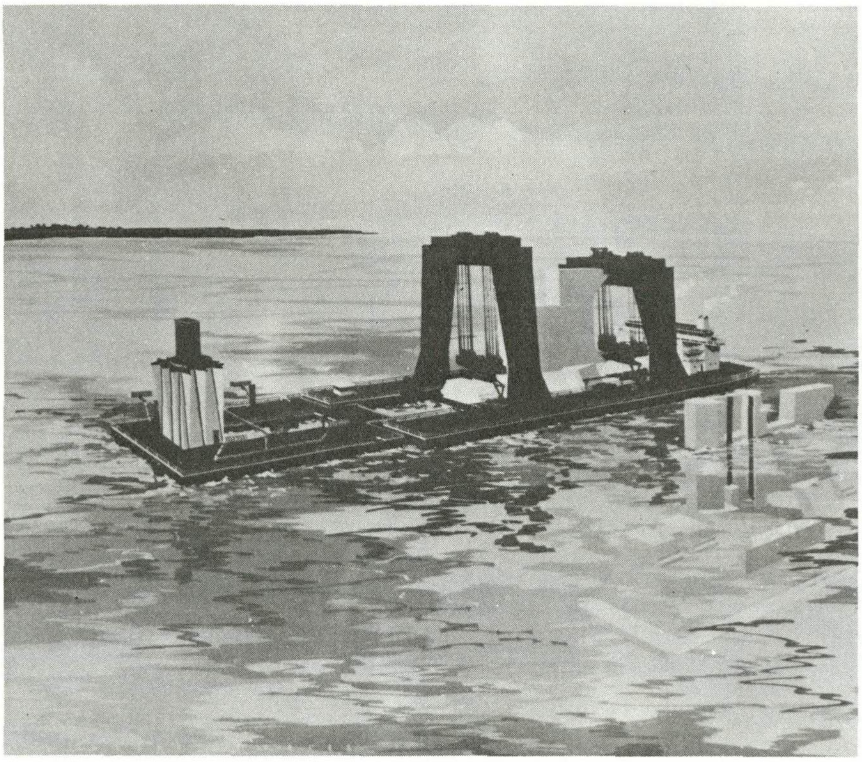
Using its own power, aided by tugs and taking advantage of ebb and flood currents, the lifting barge Ostrea (Oyster) will then move to its destination in one of the three channels, where the pier will be sunk on to the prepared foundation.

The lifting barge will be 87 metres long, have a beam of 47 metres and portal arches of 36 metres. It will cost 72 million guilders to build.

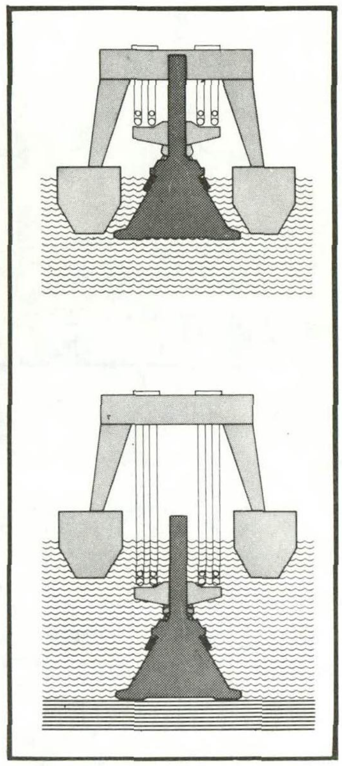
The first piers will be sunk into position in 1982.

Construction of the piers

The Schaar construction dock has been divided into four compartments for the construction of the piers. 19,27 and 20 piers will be built in docks I, II and III respectively. Dock IV will be used for the construction of the 63 threshold beams.
An estimated 290 working-days will be needed for the construction of the first pier; with experience the construction period for one pier will



The lifting barge



gradually be cut down to 242 working-days.
A new pier has been started every 8 working-days since construction began. At the peak of production, when 28 piers will be simultaneously under construction, a similar number of tower cranes will be required, each with a lifting capacity of 6 tonnes at 30 metres distance.

For the first pier to be sunk into position on time in early March 1982, dock I will have to be dredged open at the end of 1981. This will allow work to go ahead with sinking the first group of piers, while production of the following piers is still in full swing in docks II and III. The last pier should be completed by early 1983 making a total construction period of four years. Construction of all the piers in one compartment in a period of two years would have involved roughly twice the amount of equipment and double the labour force.

Production of the other concrete elements – box girders for the motorway, the threshold beams and upper beams – is to start at the beginning of 1982, when some of the labour force can be transferred from pier construction, which by then will have passed its peak.

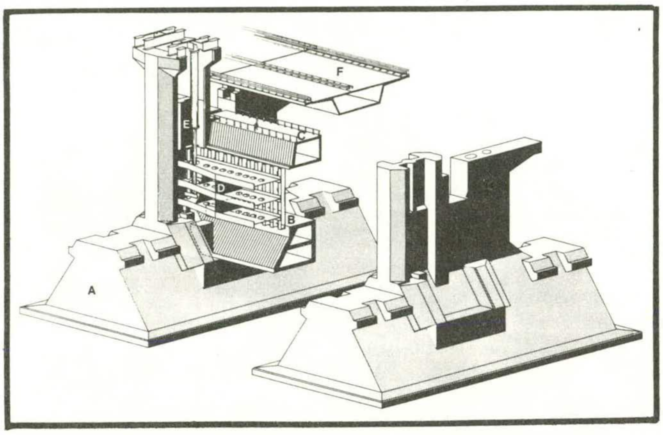
Concrete mixing plant and work sites

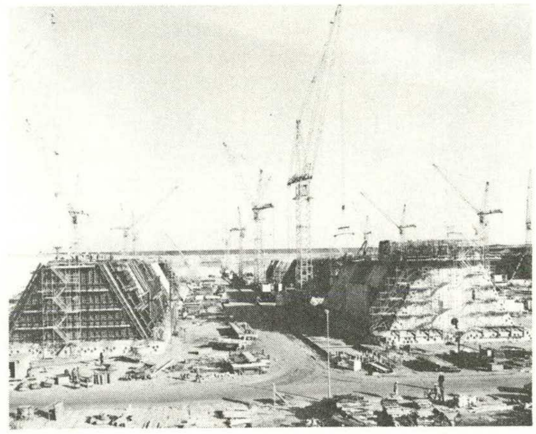
A mixing plant and transit jetty are required for the concrete mixing site. The mixing plant for the 66 piers at the Schaar site has a capacity of 160 m^3/hr, (not including reserve capacity for repairs). Two mixers have been installed, each with a capacity of 120 m^3/hr. A total of 600,000 m^3 of concrete will be required which will be transported from the plant to the building site in mixer trucks.

The large quantities of sand, gravel and cement arrive by ship and are unloaded at a transit jetty equipped with two mobile cranes, which has been built adjacent to the plant. The workshop for producing the prefabricated shuttering, steel reinforcement and pre-stressed elements are also adjacent to the plant.

Power station

The power station has an output of 12,000 KWA, a capacity sufficient to supply a town of 30,000 inhabitants. 4,800 KWA of its output is used for the deep well pumping system and 7,200 KWA for concrete and asphalt production equipment, workshops, tower cranes, lighting installations etc.





The construction dock.
foto B. Hofmeester

The 12,000 KWA is produced by 15 units, each of 800 KWA. The 15 power units are divided between 2 power stations: one, with 6 units, for the deep well system and the other, with 9 units, for the installations in the dock. They run on diesel fuel which is delivered by tanker. When work on the storm surge barrier is completed in 1985, the power station will be provided with a central control room and its output used to open and close the 63 sliding gates.

Construction methods

The sills will be built on site, using floating equipment. The scour protection mattresses will be made in the plant at the Sophia harbour and rolled into place on the seabed by a special pontoon. The asphalt will be sunk into position by the floating asphalt plant, the Jan Heymans. When the piers are in place and the sills completed, the box girders to carry the road, the gates, the threshold beams and the upper beams will be installed in that order. These elements of the storm surge barrier will be brought to the site by ship, and installed by means of floating cranes and other floating equipment.

Temporary bridge

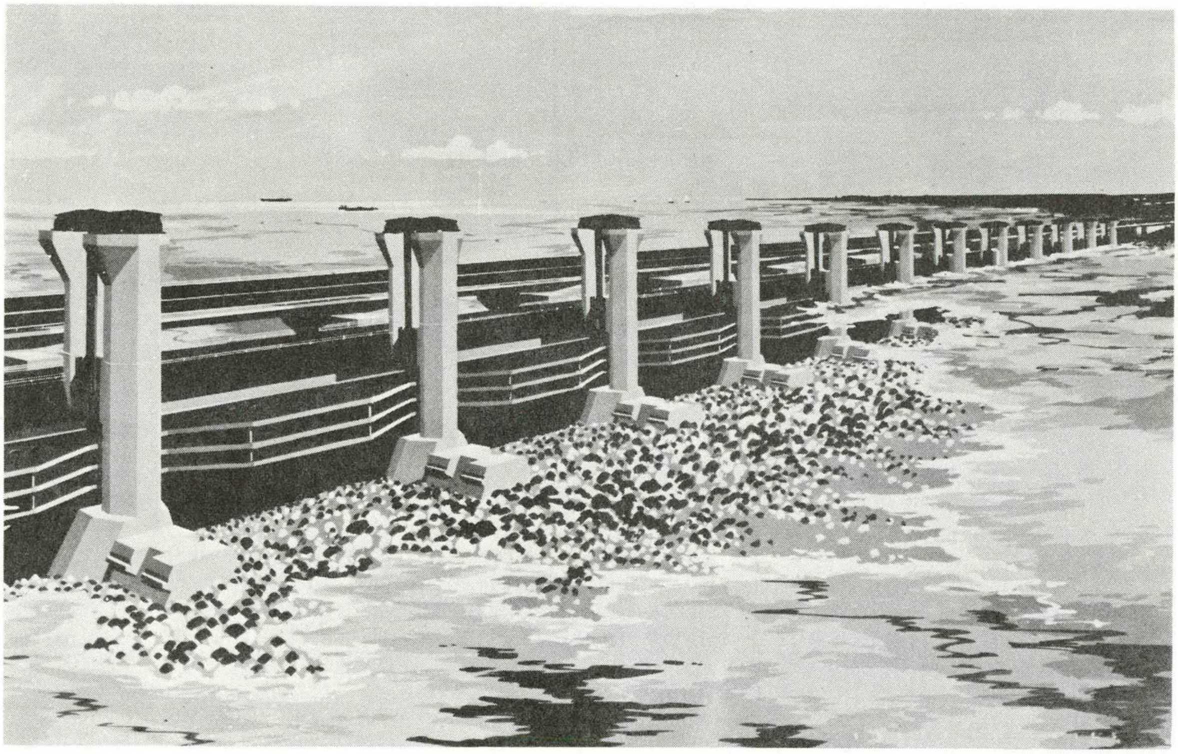
A large labour force will be needed for the construction of the storm surge barrier: approximately 1,100 people will be employed on the Neeltje Jans work island between mid-1980 and mid-1982.
To facilitate the transport of men and materials to and from the construction island a bridge between Westerschouwen and the work island was built in 1978.
A steel construction with 20 spans of 145 metres, the bridge is 3 kilometres long and has an effective width of 7 metres. It is 13 metres above AOD. Some of the 19 piers which support it were constructed with the help of the steel casing piles from the cableway towers which had been erected in 1973 and dismantled in the winter of 1976/1977. The bridge will probably be of service again later when the Philips dam and Oester dam are being closed off.

The estimated cost of the storm surge barrier in the Eastern Scheldt at mid-1979 price levels is 3.42 billion guilders (not including the costs of preliminary studies).

Compartment dams

The Eastern Scheldt project includes two more dams: the Philips dam, between the existing Grevelingen dam and St. Philipsland, and the Oester dam, between Tholen en South Beveland in the eastern part of the estuary. Both are now under construction, and should be completed at about the same time as the storm surge barrier. These compartment dams are required to delimit the Eastern Scheldt, so that the tidal range in the entire basin will remain at an adequate level even with the restricted flow allowed by the storm surge barrier. There is also an agreement with Belgium to guarantee a fixed water-level in the Scheldt-Rhine canal, and the Philips dam and Oester dam have the additional purpose of closing off the area through which the canal runs.

Both dams will also be used to control salinity levels, helping to prevent the intrusion in the salt water of the Eastern Scheldt estuary of too much fresh water from the main rivers



of the Delta area. The water behind the
Philips dam and the Oester dam
will become a fresh-water lake.

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