the delta project

THE NETHERLANDS
DELTAPROJECT
IN A NUTSHELL

p.v.koppen

the delta project

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Introduction

Geographically Holland belongs to the alluvial coastal region of the North Sea. The country lying above average sea level can roughly be said to consist of two parts, viz. a row of dunes with many gaps in it, running along the coast in the west and north, and moderately high grounds in the east and south, the highest point rising to 300 metres (1 000 ft). Low clay and fen lands lie between these two areas, the deepest point – about 6.5 m (22 ft) below Dutch Ordnance Level – being located within the triangle formed by lines joining Rotterdam, Gouda and The Hague. Dykes keep the water out of these low-lying areas. All the water that gets in through locks and by seepage or precipitation has to be pumped out and discharged into watercourses communicating with the sea. The country has developed in such a manner economically and socially speaking that 60 % of the population live and work in this constantly threatened part of the country, which constitutes 50 % of the area of the Netherlands.

These low-lying tracts consist of a series of large and small areas that are kept dry by both natural and artificial means. They are called polders, and possess a considerable degree of technical and administrative independence. The line of dunes running along the North Sea , which stretches from Cap Gris Nez to Jutland, and the low-lying land inside it, are traversed by several large rivers.

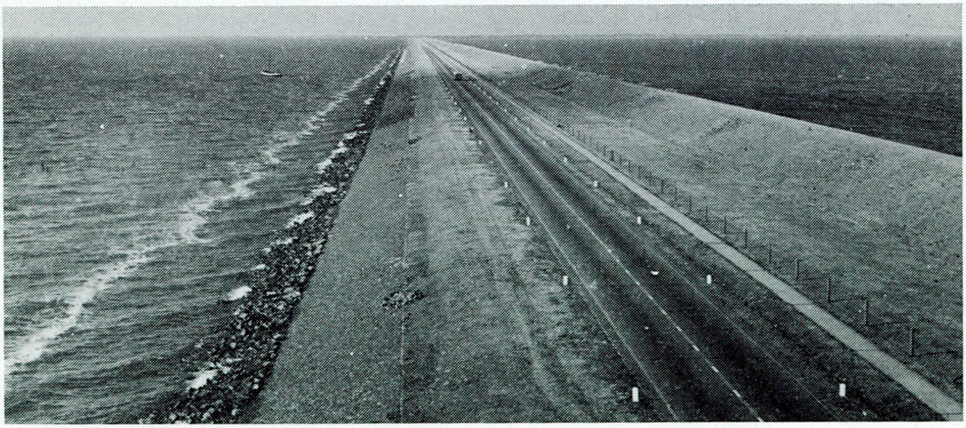
The Ems, the Rhine, the Meuse and Scheldt all run into the sea on Netherlands territory. The estuarial region of the latter three rivers is known as the Delta area and it is there that the Delta Section of the Royal Netherlands Government Water Control Department ("Rijkswaterstaat") is carrying out the Delta Project.

Land Reclamation

The reclamation of land in Holland by turning it into polders goes back to ancient times. In the 16th century even small inland seas were encircled with dykes and were pumped dry later when windmills with rotatable heads were invented. The Schermer, Beemster, Purmer and Wormer are examples of such old polders. The introduction of steam-driven pumps made it possible to undertake the reclamation of larger areas such as the Haarlemmermeer polder and Y polder.

Land reclamation down the ages

Zuyder Zee Barrier Dam



Zuyder Zee

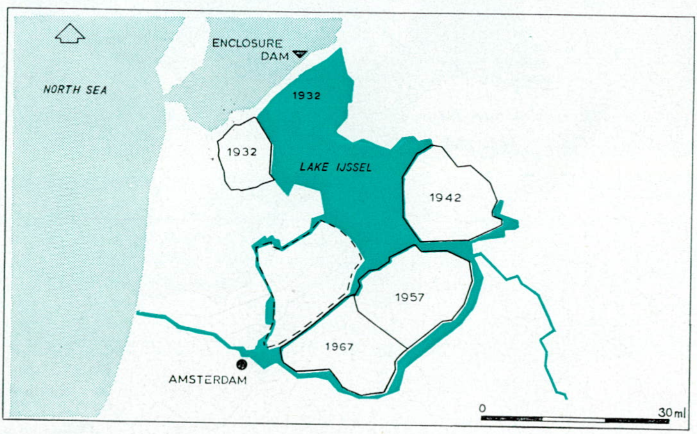
Not until the nineteen-twenties did work start on a very extensive scale with a view to damming off the largest inland sea. This necessitated overcoming the difficulties caused by heavy ebb and flood currents.
The dyke, known as the Barrier Dam, that turned the Zuyder Zee into a lake – called Lake Yssel – was constructed between 1926 and 1932. This was made possible by the discovery of considerable quantities of boulder clay in the vicinity and by the improved machinery the contractors had at their disposal then.

Delta Project

The need to strengthen the defences in the South-West against storm floods had long been apparent to the Government Water Control Department and associated institutions. The floods of 1st February 1953 made the work urgent.
A commission was set up three weeks after the disaster to study the problem; it was called the Delta Commission. The Delta Section was inaugurated by the Minister of Transport, Water Control and Public Works on May 1st 1956. It is a special branch of the Government Water Control Department.
The Delta Commission had to choose between two solutions, viz.

a) adequate raising of the existing sea dykes;
b) damming off the sea arms of the delta altogether.

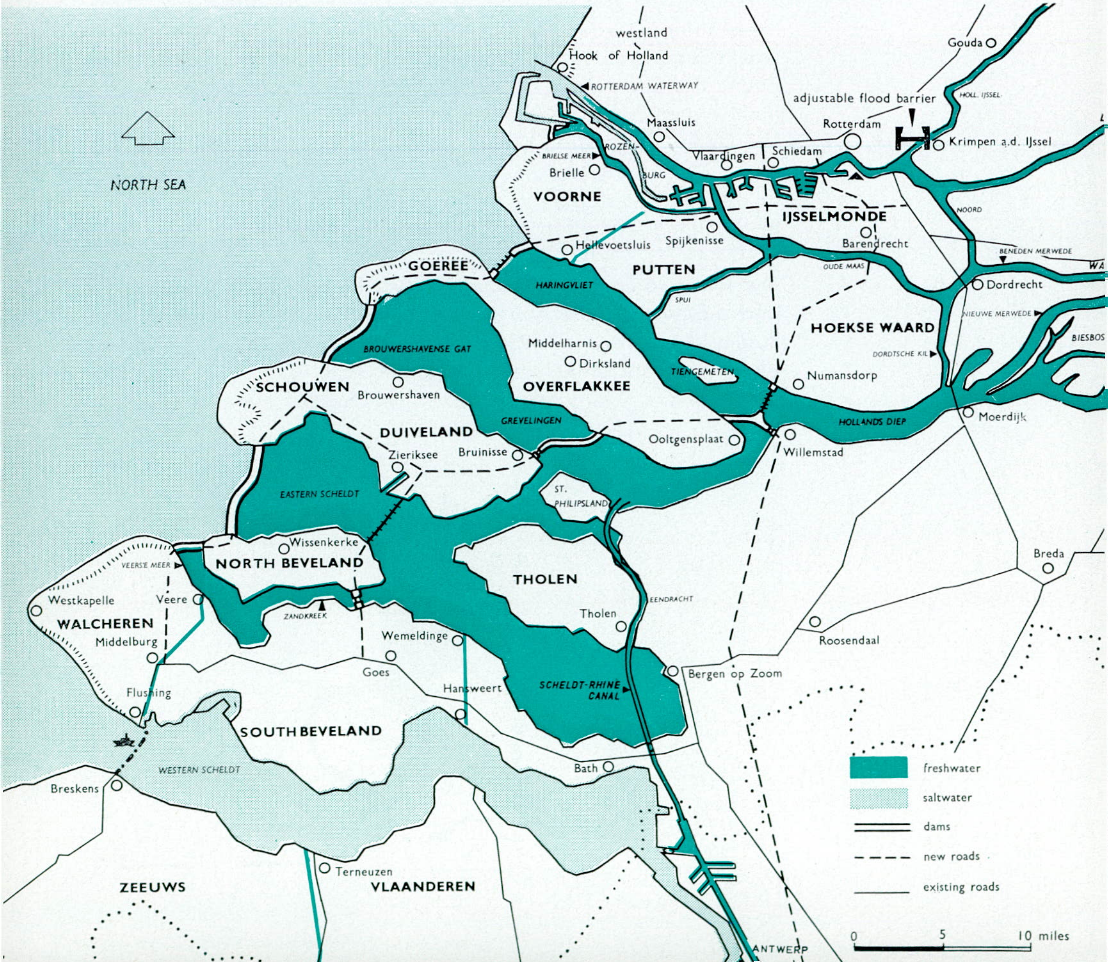
The latter solution was recommended by the Delta Commission and adopted by the Minister of Transport, Water Control and Public Works. In June 1958 Parliament, too, approved the undertaking and sanctioned it by passing the Delta Act.



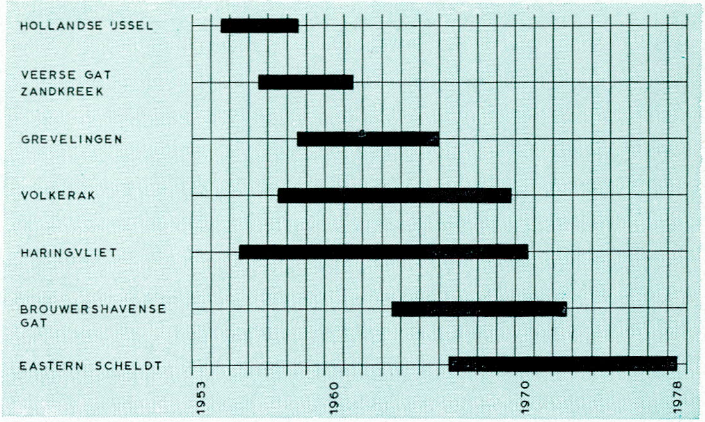
Map showing Zuyder Zee Project

Areas flooded in 1953

Map of Delta region



Delta Project time-table for the execution of the works



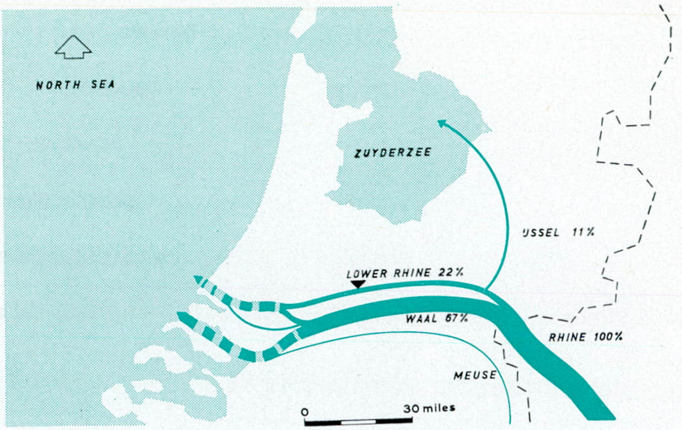
General

The object of the Delta Project is
1) by closing off the sea arms, to considerably shorten and strengthen the total length of coast and dykes washed by the sea;
2) to combat the salination of the Dutch reaches of the rivers and adjoining channels and so increase agricultural production. Land reclamation is not the purpose of the project; very little, if any, will be gained.
Ancillary objects are
3) to free islands from their isolation by building roads on the dykes;
4) to develop new opportunities for recreation and new openings for the tourist industry.
5) to establish a new shipping route between the port of Antwerp and the Rhine within the Delta area.

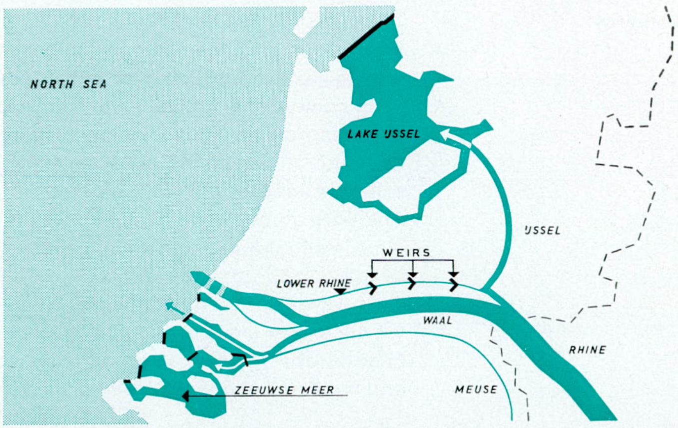
To achieve those objects all the sea arms affected by the tides will be dammed off.
The New Waterway, which is the approach to the Port of Rotterdam, and the Western Scheldt, which is the seaway leading to Antwerp, will remain untouched. The dykes along those tidal rivers will be raised and strengthened.
One of the disadvantages is the disappearance of sea fisheries and the oyster and mussel beds in Zeeland.

The Works

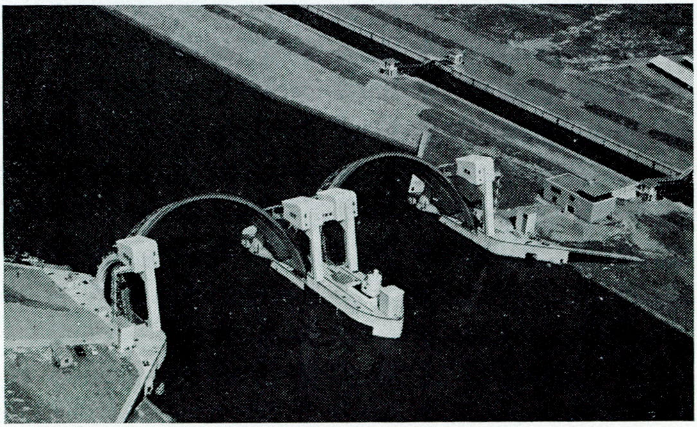
The Brielse Maas and the Veerse Gat have already been dammed off.
The dams across the Haringvliet, the Brouwershavense Gat and the Eastern Scheldt are under construction.



How fresh water reaches the sea



Future distribution of fresh water



Movable weir in the Lower Rhine near Hagestein

The final closure, that of the Eastern Scheldt, marking the completion of the Delta Project, will take place in 1978.

One of the most important links in the chain of closures is the storm tide defence at Capelle aan de Yssel. It consists of a huge steel gate which is open under normal circumstances, leaving the Hollandse Yssel behind it in uninterrupted communication with the tidal waters of the Nieuwe Maas and the New Waterway but which in an emergency can be lowered to isolate the Hollandse Yssel.

Mention should also be made of the Braakman dam, which was completed in 1952. The Braakman was a branch of the tidal river known as Western Scheldt.

Three secondary dams are included in the general plan, viz. those in the Volkerak, the Grevelingen and the Zandkreek.

The accompanying diagram shows the timetable according to which the main closures are being accomplished. It is the outcome of a great many factors.

The total length of the sea defences will have been reduced by about 700 km (440 miles) when all the dams have been completed; the dams themselves add up to 30 km (18.5 miles). The existing dykes will be reduced to secondary defences and will lie along non-tidal water. Greater safety and lower maintenance costs will result. Even if one of the big dams should be breached – which is almost inconceivable in view of the way they are constructed – the second-line dykes would never again be exposed to the intensity of attack that could be anticipated in an open sea arm. Main barrier dams and secondary dykes are also useful for joining the hitherto isolated islands with the mainland by means of an interconnecting system of roads.

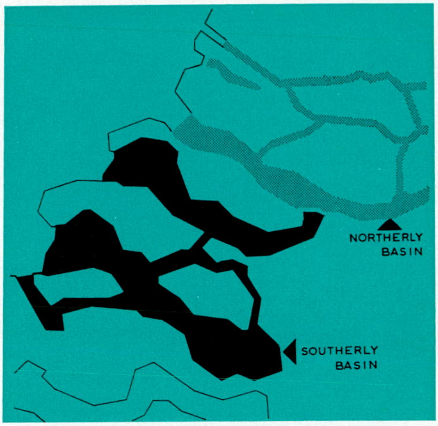
Water Management

The estuarial region will be split up by the Volkerak into two hydraulically different areas, a south basin and a north basin.

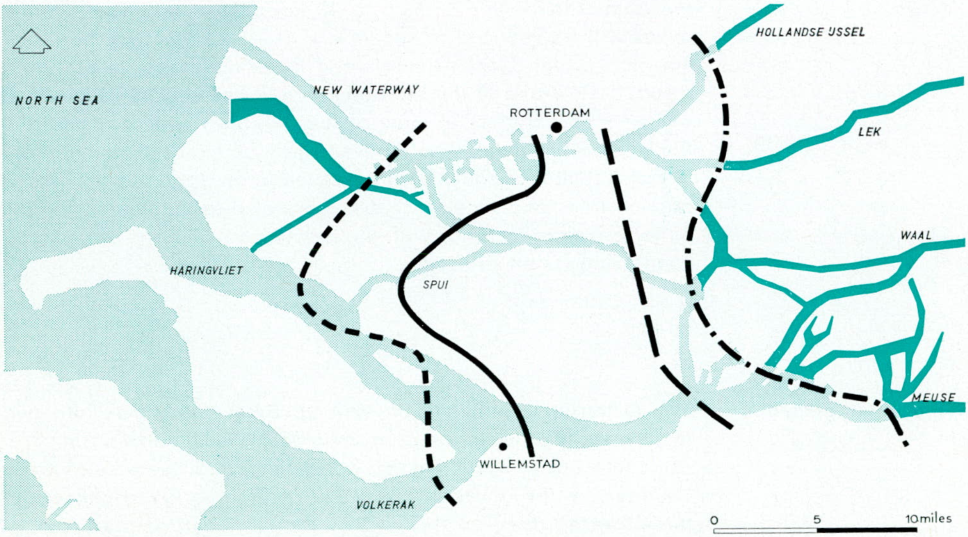
The south basin, which will probably be called Zeeuwse Meer, is bounded on the north by the island of Goeree Overflakkee and the Volkerak dam, on the east by the mainland of the province of North Brabant, on the south by the islands of South and North Beveland with the Zandkreek dam and on the west by the dams in the Eastern Scheldt and the Brouwershavense Gat. The lake, which will gradually turn into a fresh water reservoir, will be tideless. Fresh water will enter chiefly through the sluices in the Volkerak dam and will come from the northerly basin. Discharge is possible through the outlet sluice in the Eastern Scheldt dam and the canal of South Beveland when the Western Scheldt is low and if necessary by means of pumping stations built on the dams.

The northerly basin will still be influenced by the tides, because

The two fresh water basins



The 300-milligrammes-of-chloride-per-litre limits, under various circumstances



- - - - The 300 mg Cl per litre limits at low tide and average Rhine discharge of 2200 cubic metres per sec.

—— The 300 mg Cl per litre limits at high tide and average Rhine discharge of 2200 cubic metres per sec.

— — The 300 mg Cl per litre limits at low tide and low Rhine discharge of 620 cubic metres per sec.

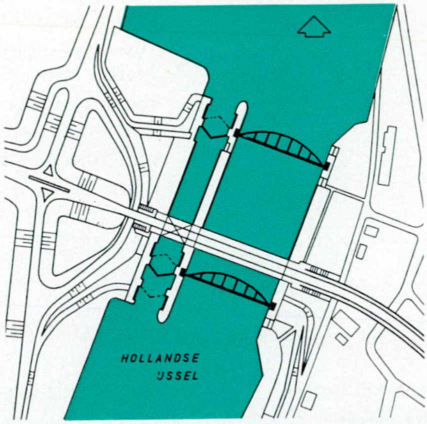
—·—· The 300 mg Cl per litre limits at high tide and low Rhine discharge of 620 cubic metres per sec.

of the link with the sea at Hook of Holland, but less than formerly. This area is bounded on the north by the northern dykes of the New Waterway, the Nieuwe Maas and the Lek, up to the end of the backwater curve.
The boundaries on the Lek, Waal and Meuse are a theoretical indication of the easterly limits, while in the south the basin is bounded by the northern coast of Brabant, the Volkerak dam and the island of Goeree Overflakkee. In the west the boundary passes along the Haringvliet sluices and the Brielse Maas barrier dam.

Anti-salination measures

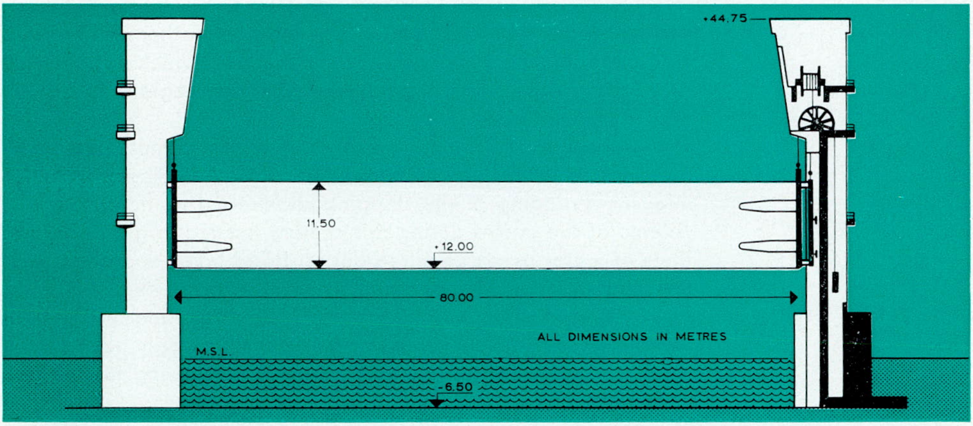
Under existing circumstances sea water flows in through the estuaries twice every twenty-four hours when the tide comes in. It is true that the ebb current, swollen by the discharge of the big rivers, will carry most of the salt water out to sea again, but much salt will remain behind, owing to mixing and other phenomena. Consequently, there is a well-defined salt line, which has crept up alarmingly, especially in the New Waterway region, as can be seen in the accompanying graph.
This movement upstream is mainly due to the tremendous development and extension of Rotterdam's harbour basins and also to intensive dredging of the shipping channels. The increase in the volume of the basins during this century has led to greater quantities of water being admitted during flood tides, and deepening the shipping channels has made it easier for the heaver salt water from the sea to flow inland. Especially the Westland district with its hothouses and Rotterdam's domestic water supply have suffered badly as a result of this salt water line creeping further and further inland.
This salt line, which only reached Maassluis when the New Waterway was opened, is now almost up to the mouth of the Hollandse Yssel, so that brackish water has to be admitted to the Delfland polder area between The Hague, Rotterdam and Hook of Holland. The salt water in the Haringvliet, Grevelingen, Brouwershavense Gat and Eastern Scheldt sea arms also has a harmful effect on agriculture on the islands in the Delta area and in the adjoining coastal regions of the mainland.
Large engineering projects are in hand or have already been completed to prevent this salination. Fresh water flows into the country largely via the Rhine and the Meuse; 67 % of the water of the Rhine is carried by the main channel known by the names Waal and Merwede, 22 % flows through the Lek, the continuation of the Lower Rhine, in which 3 'Visor' flood-gates have been built, and the remaining 11 % pusses through the Gelderse Yssel to Lake Yssel. If one considers the position of these watercourses, it is not difficult to realize that most of the fresh water runs away

Siting of storm barrier in the Hollandse IJssel



1 Elevation of storm barrier

2 Cross-section of typical polder country



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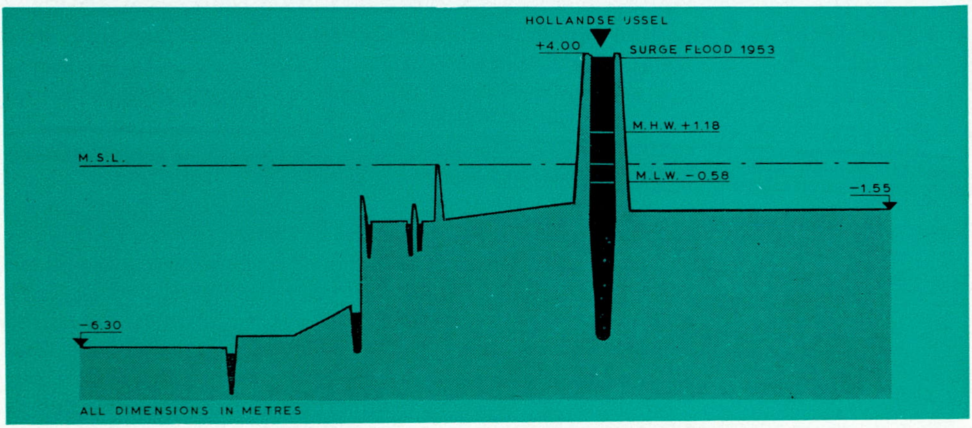

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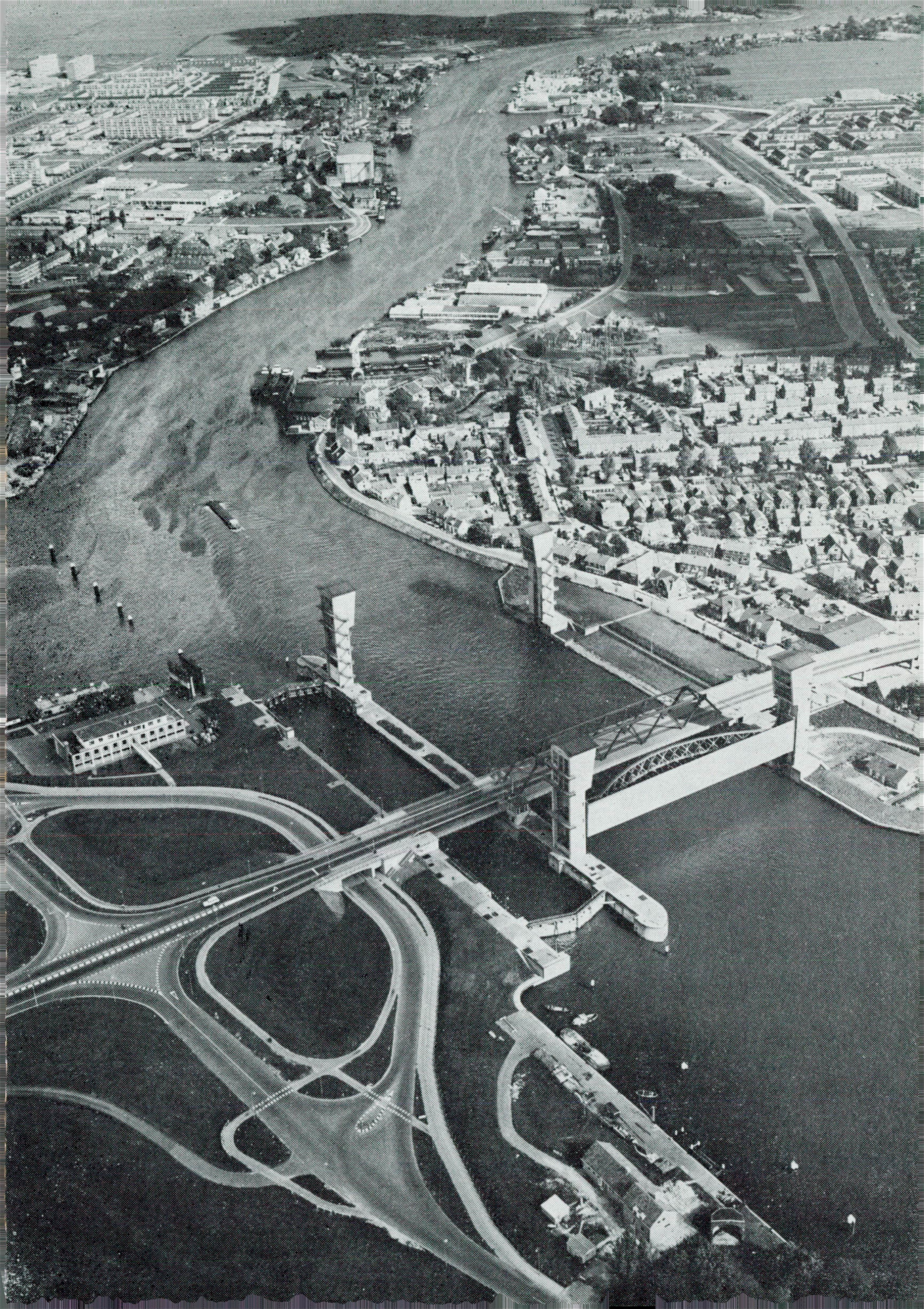
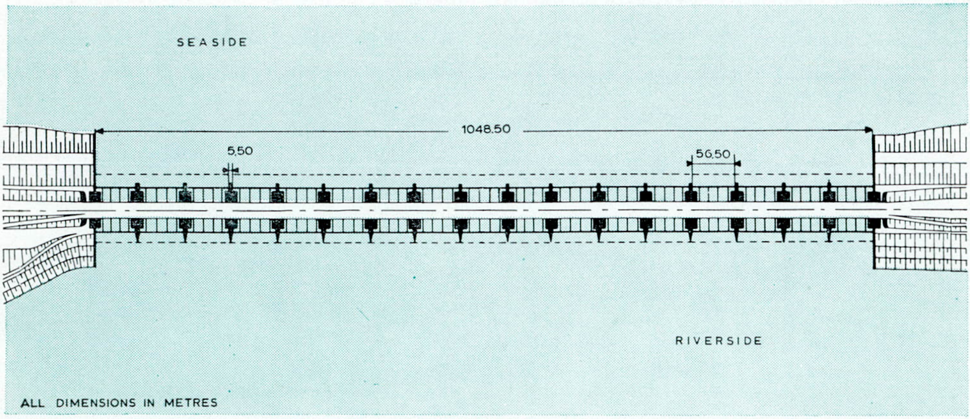


Siting of dam across the Haringvliet

1 Plan of sluices

2 Cross-section of sluices



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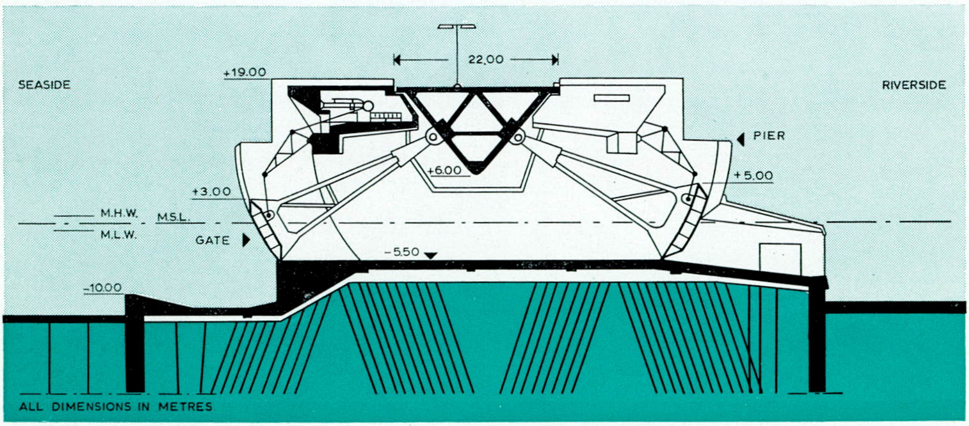

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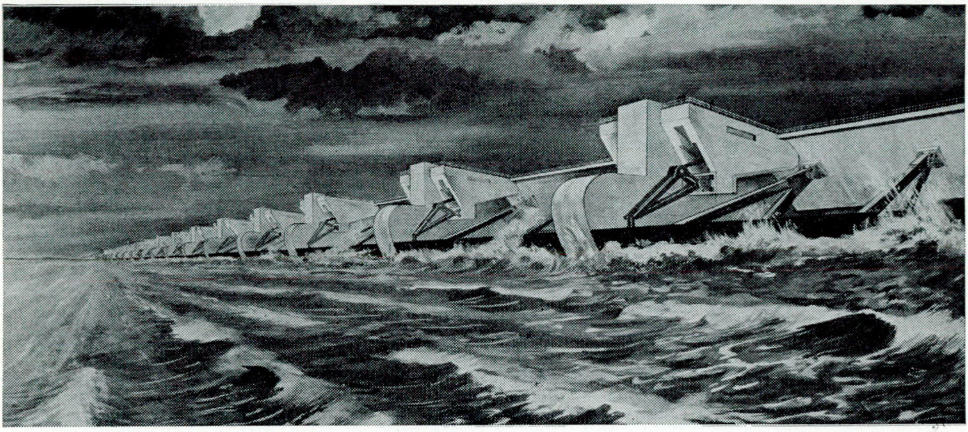
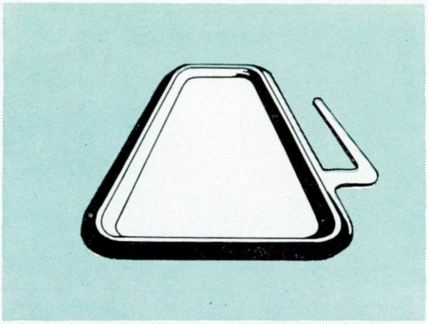


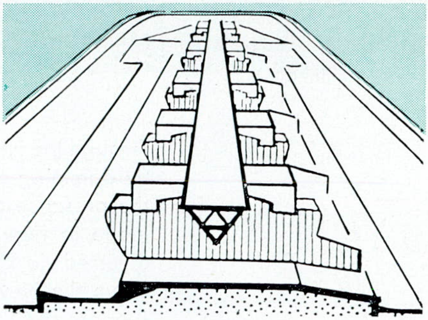
An artist's impression of the finished sluices

through the Haringvliet and is lost. This wastage will be prevented by damming off the Haringvliet from the sea in the west and by the presence of the Volkerak dam. The fresh water will then be made to flow through the Noord to the Nieuwe Maas and be diverted via Rotterdam, thus effectively pushing the salt line back down the New Waterway. The fresh water will also help to desalinate the Oude Maas, the Brielse Meer, the Spui and the Haringvliet. It will also be possible to discharge surplus fresh water through a future sluice in the Volkerak dam into the southerly basin (the Zeeuwse Meer) and store it there.
The fresh water will be used for the regular desalination of the water in the canals and ditches on the islands in the Delta area and to counteract the desiccation of the arable land in the province of North Brabant and on the island of Goeree Overflakkee. However, when the volume of water is too great for it all to flow through the narrow Noord and the Nieuwe Maas when the rivers are in spate a spillway will take care of the excess. The battery of discharge sluices in the Haringvliet dam was designed for the purpose. So these sluices will as a rule remain closed to collect the fresh water and keep the salt sea water out. In the latter capacity they will have to be capable of withstanding the heaviest waves that can reasonably by expected.
The sluice gates will only be opened to allow excess fresh water or ice to flow away.
It is also possible that salt water will be admitted at high tide in winter to prevent the formation of solid masses of ice.
So it will be possible to control the water economy of the Delta area completely by operating the Haringvliet and Volkerak sluices correctly, the latter solely to allow fresh water to reach the southerly basin. This will greatly benefit agriculture in the surrounding islands and the adjoining coastal areas.

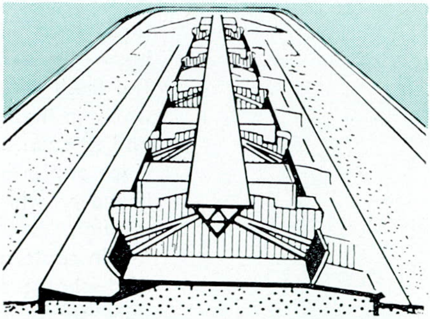
How an artificial island is made



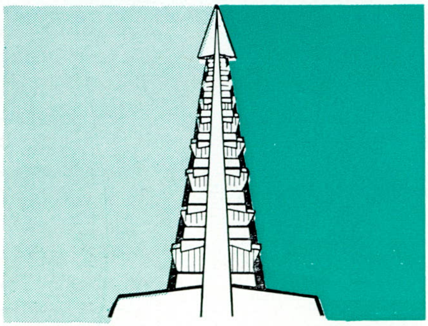
Building the piers and spans on the sluice bed

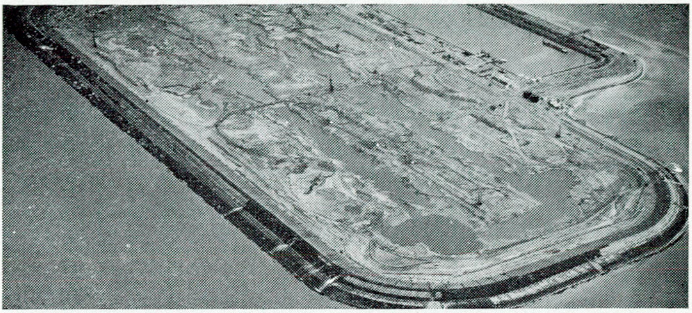


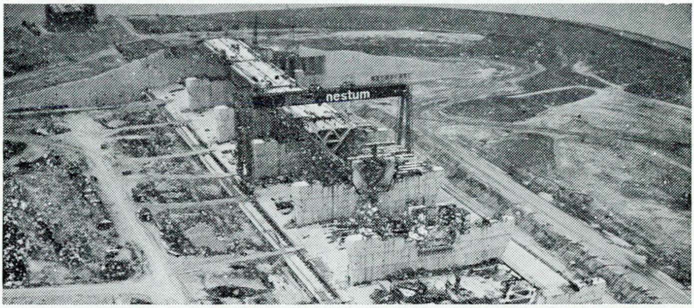
Fitting the steel gates



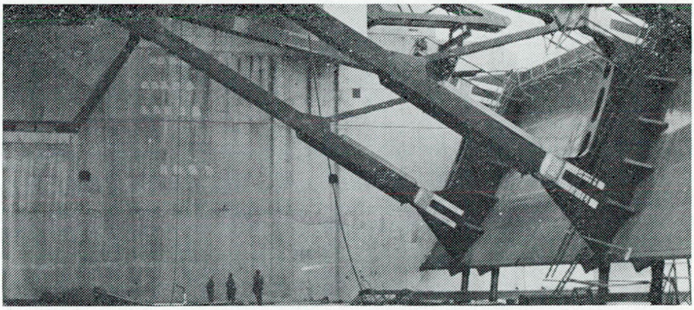
When the sluices are completed the encircling dyke will be dredged away and dams built on either side

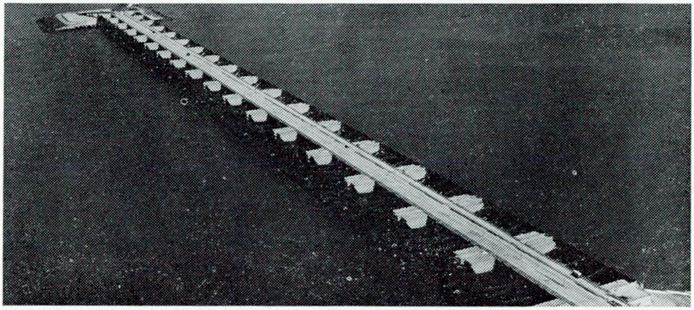


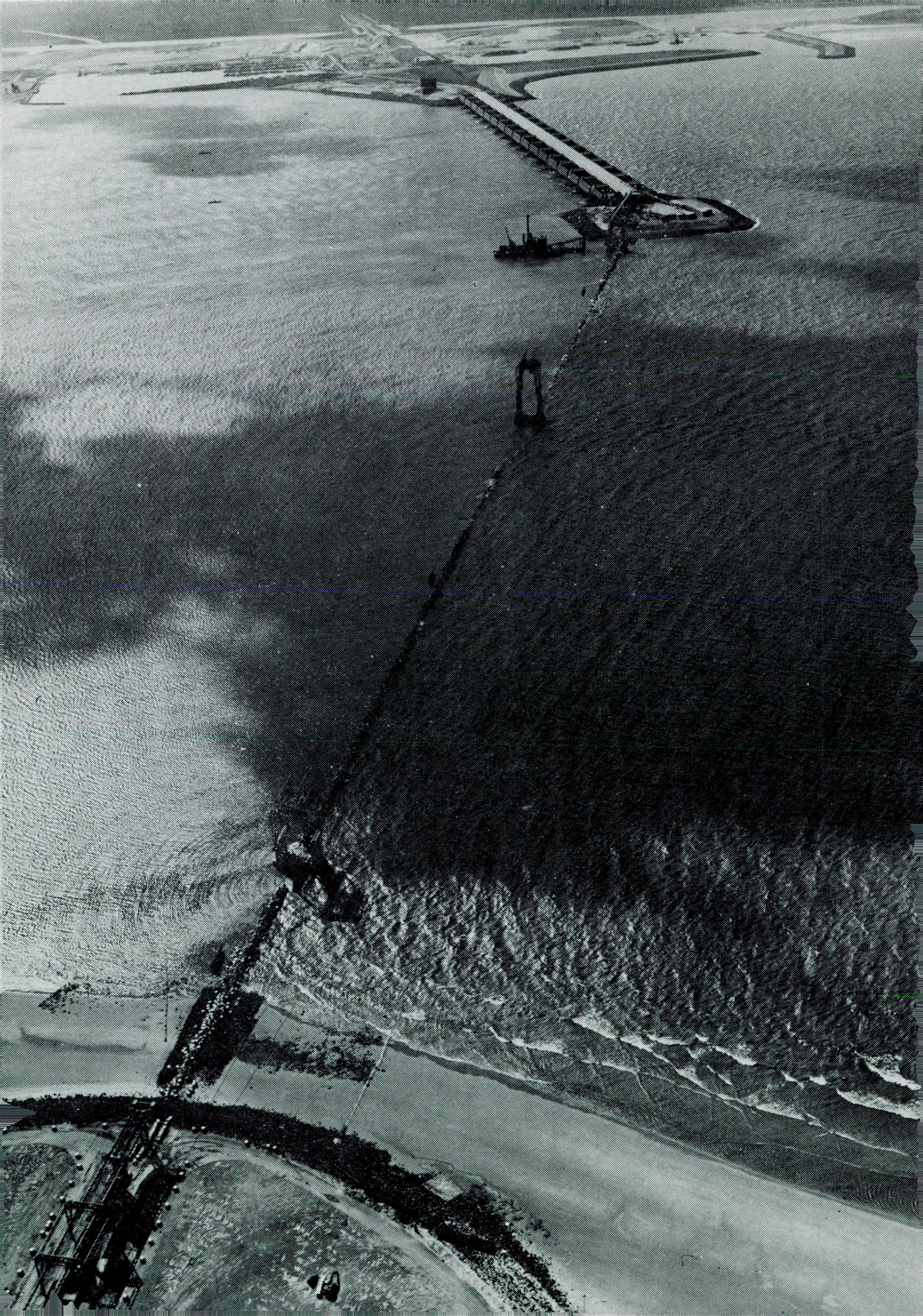

View of building site



The sluices under construction


Fitting the steel gates


The completed sluices

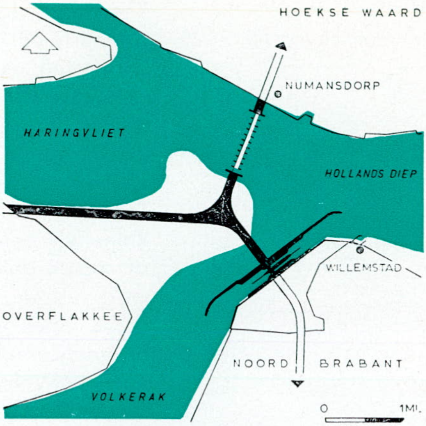


The Haringvliet sluices are now completed. The water level in the southerly basin, which will be non-tidal after the dams have been completed, will not vary more than 1 metre (3'–6") in the course of a year; it will fluctuate between 0.5 metre above and 0.5 metre below Dutch Ordnance Level. Once that basin has been desalinated it will be relatively simple to desalinate adjacent Zeeland islands.
The very vital shipping routes between Antwerp and the Upper Rhine will benefit by the elimination of currents and the creation of comparatively calm water. Fresh water will no doubt freeze more readily, but in that respect it will not differ from the water in the upper reaches of the rivers, and in any case icebreakers will be freely used. When all the sea arms have been dammed off, the gates at Wemeldinge will be opened and Scheldt and Rhine shipping will only have two sets of locks to negotiate, viz. the ones at Hansweert and those in the Volkerak dam.
The latter will be very large indeed and have been designed to accommodate pusher-tug shipping.

However, as the result of a treaty recently concluded between the Belgian and Dutch Governments a ship canal of considerable dimensions is to be constructed in the near future. The new canal will enable Rhine barges to travel almost directly from the Antwerp Port Area to the Volkerak Basin in non-tidal waters. The project includes one set of locks to be negotiated besides the Volkerak dam locks mentioned above. The level of the northerly basin is, however, dependent on tidal movements and water brought down by the rivers, as also by corrective measures taken by the outlet and inlet sluices in the Haringvliet dam and the Volkerak dam. As a result it is less easy to control salinity in this basin than it is in the southerly basin.
Since it will no longer be possible for high tides to enter the Haringvliet, the places along this sea arm and to a lesser extent those on the Merwede and the Noord will benefit by a marked drop in storm tide levels.
It is clear therefore that the main purpose of the Volkerak dam is to separate the northerly and southerly basins. The Grevelingen and Zandkreek dams will also act as secondary defences, each with a lock for letting water into the Grevelingen basin and Veerse Meer respectively. They are located at spots where originally the tidal currents occurring on either side of the island met. Consequently, the horizontal movement of the water, i.e. the currents, was comparatively slight, so it was fairly easy to build dams there. These dams prevent excessive current velocities when the main dams are being built. That is why the construction of these secondary dams precedes that of the primary ones.
These secondary dams have yet another secondary function, viz. that of carrying motor roads.

Aerial view of work in the Haringvliet

Sketch of dam across the Volkerak



Aerial view of work in the Volkerak

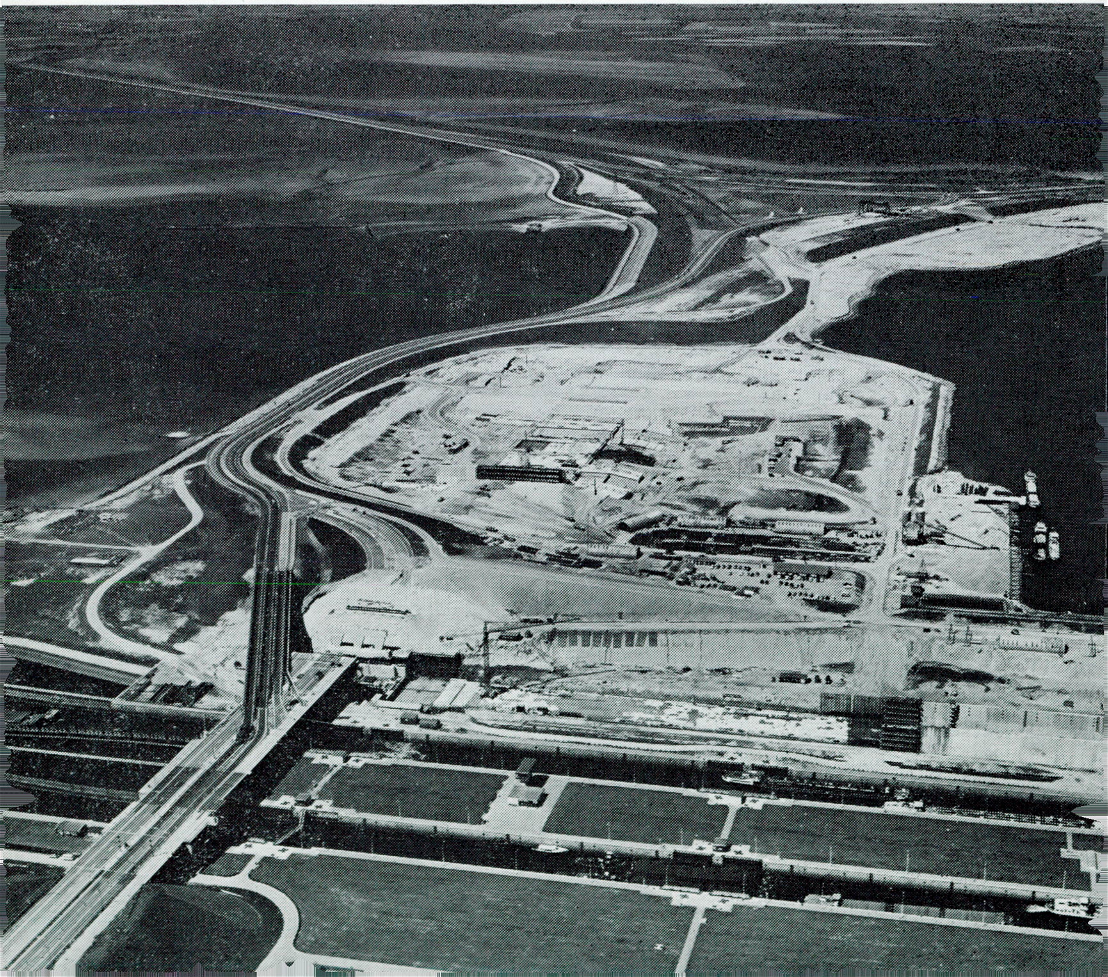
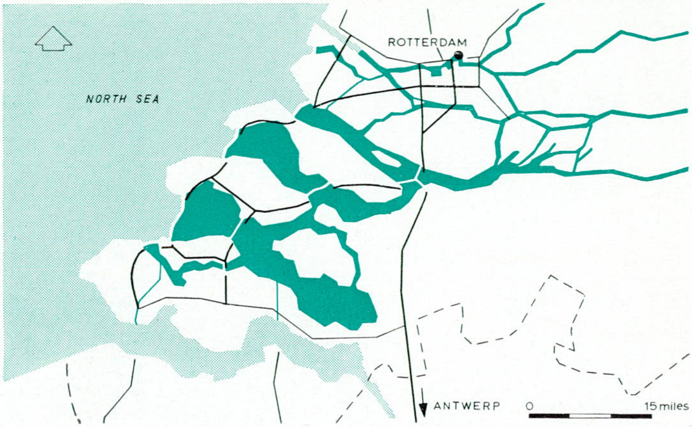


Diagram showing the new roads



Communications

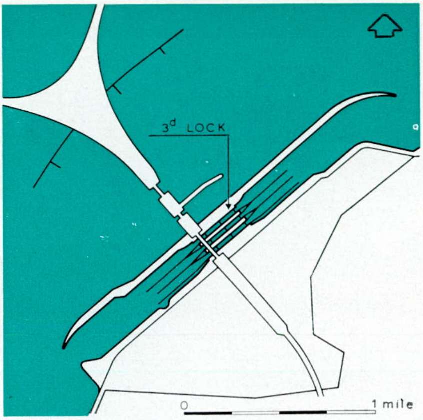
The projected Benelux motorway starts at Vlaardingen, goes through tunnels under the Nieuwe and Oude Maas and bridges the Haringvliet at Numansdorp. The main road will fork left over the Volkerak dam to the mainland and Antwerp, whereas a secondary road will fork right and run across the Grevelingen dam and so connect the islands of Schouwen Duiveland and Goeree Overflakkee with the economically important Western Netherlands.

A bridge in prestressed concrete, which was completed in 1965, spans the Eastern Scheldt between Duiveland and North Beveland and completes the direct motorway linking Rotterdam and Middelburg.

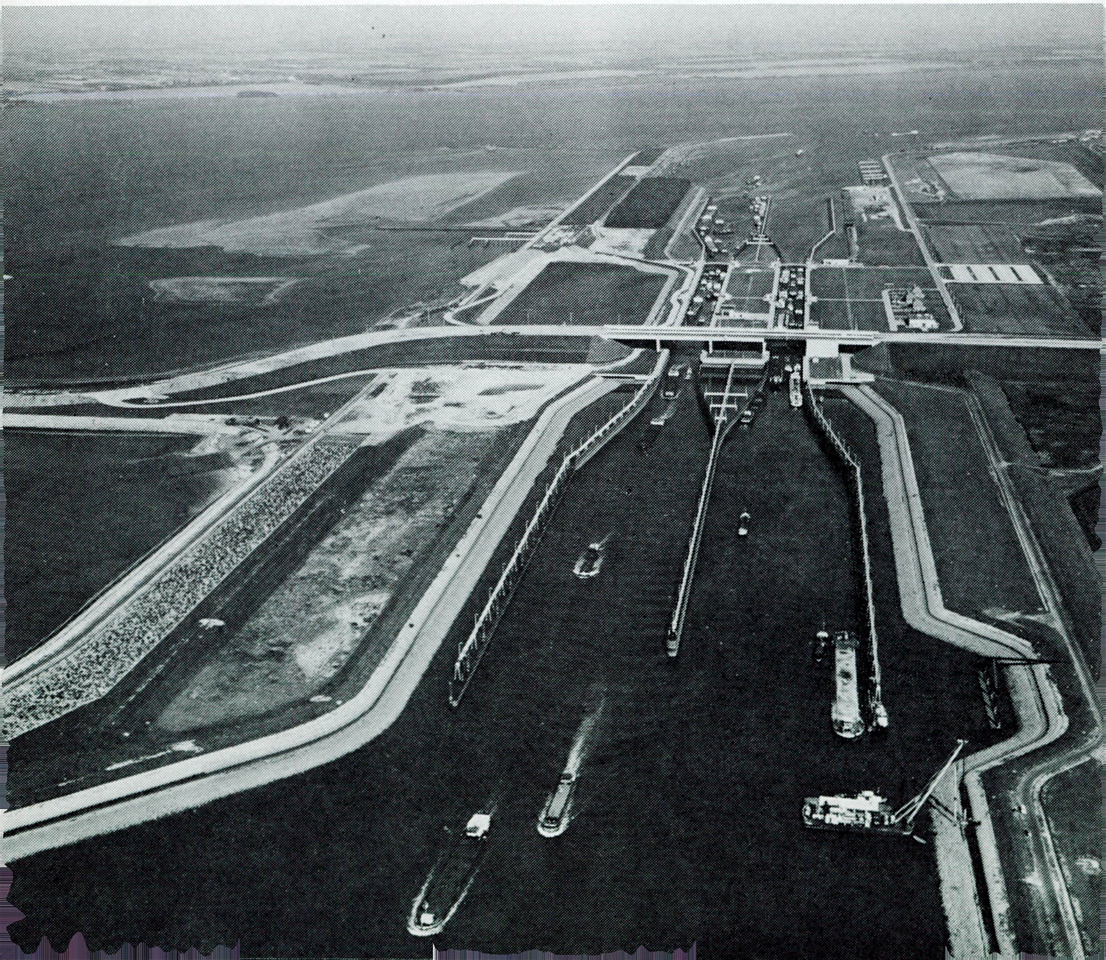
Safety

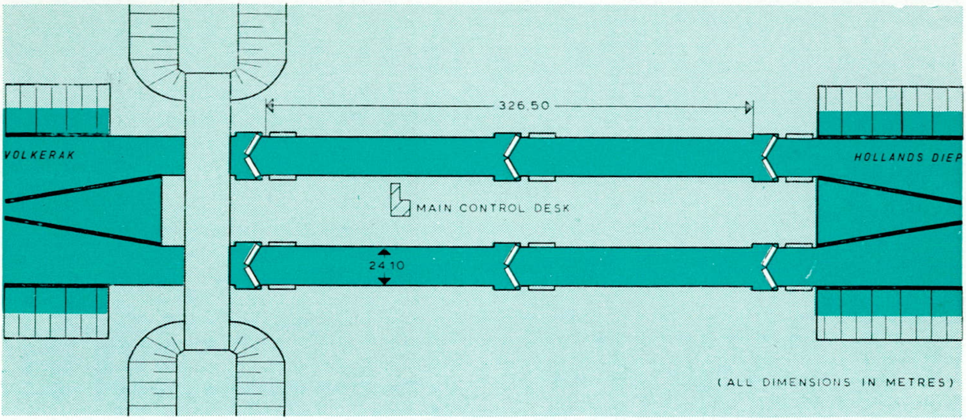
Before the general project could be worked out a basic or project level of anticipated maximum water levels had to be fixed. Calculations used to be based on the level of the highest storm tide recorded; the present project, however, is based on a level consonant with a probability of occurrence acceptable to the authorities. During the 1953 floods the storm flood level at Hook of Holland reached 3.85 metres above Dutch Ordnance Level. Though that was the highest level ever recorded, it was not deemed safe enough as a project level because it was not certain how often the same high levels would recur. Statistics showed that it would be about every 300 years. After further extrapolation of the statistical data it was decided to fix the project level at 5 metres (16′–6″) above Dutch Ordnance Level. This level is not likely to be exceeded more than once in every 10,000 years.

Sketch of locks in the Volkerak



Aerial view of locks





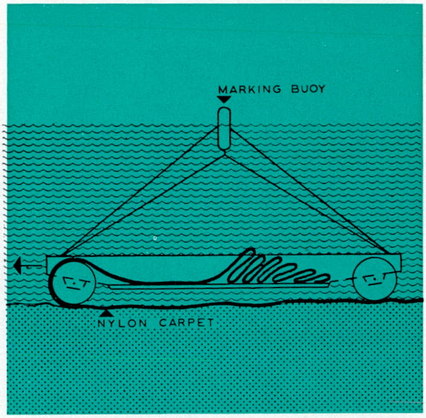
Plan of locks

The next step after fixing project level was to calculate other levels and values. A hydraulic model of the Delta area – scale 1 : 64 – and an electronic model working by analogy were used to speed up the many calculations that had to be made.
When the anticipated maximum level has been established for a given spot the height of the top of the dyke is decided on and the extent to which it will have to be strengthened, the property and interests to be protected by the dyke being decisive factors.
The higher a dyke is the more it will cost but the safer will be the land protected by it. It will be clear that as soon as the dyke is strengthened less capital will have to be set aside to meet the cost of any future disasters.

New working methods

Working methods that were still satisfactory when the barrier dam closing off the Zuyder Zee was built can no longer be used for projects of this magnitude. There is neither sufficient labour nor sufficient building material available. There are not enough stone-layers and men for fixing the osier mattresses and there would be a great shortage of osier and boulder clay.
The modern method of building a dyke is to make an embankment of sand by means of suction-dredgers, which can do the work quickly. The embankment is then at once covered with a watertight layer of asphalt.
The layer usually covers the outer slope from the low water level upwards; the top of the dyke and part of the inner slope are also

Roller trolley used for laying nylon cloth



2 Mechanical stone distributor

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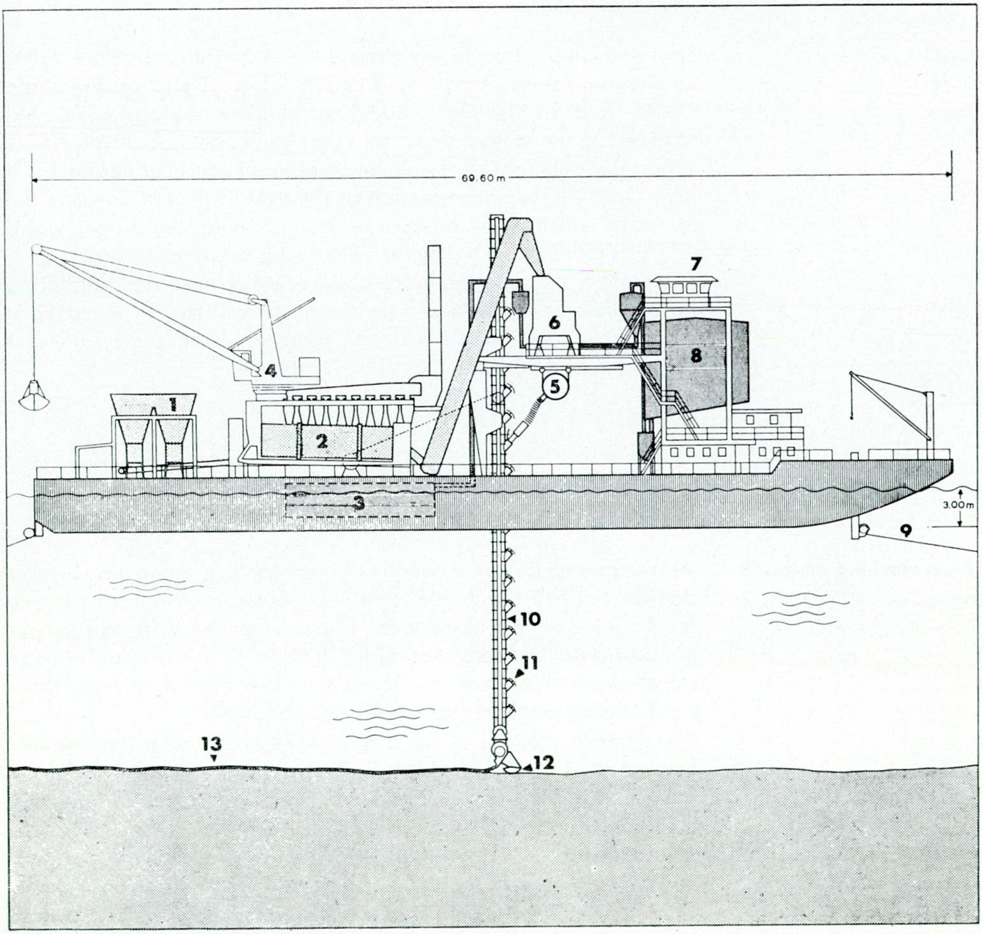

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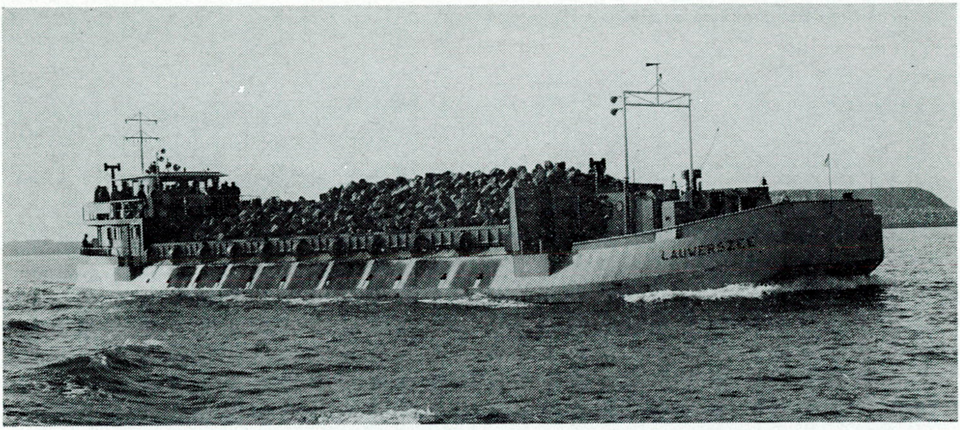
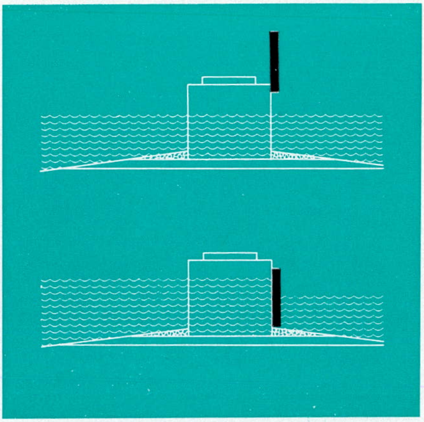


1 Diagram of asphalt-laying device

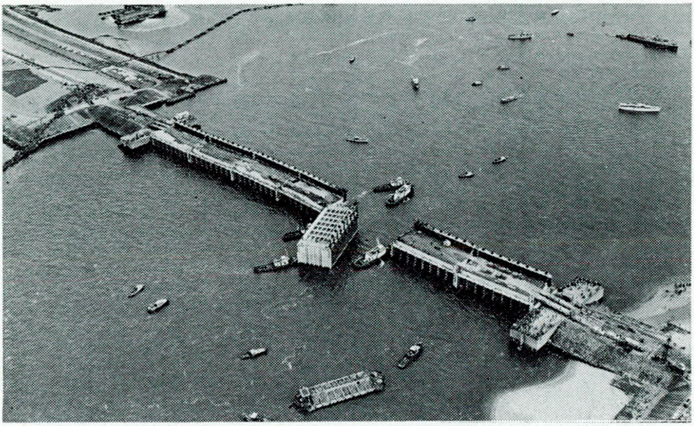
1 sand
2 sand drier
3 bitumen tank
4 crane
5 stirring drum
6 charge mixer
7 operator's cabin
8 aggregate bin
9 anchor cable
10 feed pipe
11 filter orifices
12 feeler
13 asphalt bottom protection

covered. Below the low water level the foot of the dyke is protected by retaining osier mattresses or by an artifical beach.
The danger inherent in this construction is, however, that when the water level outside the dyke is low and the phreatic level in the sandy embankment is high the asphalt layer may be pushed off. This may happen as the result of a quick withdrawal of the tide.
The orthodox technique of employing osier mattresses ballasted with stones is now being replaced by the technique of applying asphalt layers or nylon carpeting.
The asphalt layers can be applied under water at a depth up to 20 m (66 ft.) by a vessel equipped with asphalt making machinery. The nylon carpeting is unrolled from a trolley towed along the sea bottom. The carpeting has pockets at regular intervals filled with sand for ballasting. The ballasting of these underwater protective layers is also done mechanically.
The greatest problem encountered when constructing a dam in a tidal channel is how to close the final gap, because the velocity of the current will of course increase as the gap is narrowed.

Diagram showing principle of sluice caisson



The completed dam in the Veerse Gat



Floating the last caisson into position in the Veerse Gat

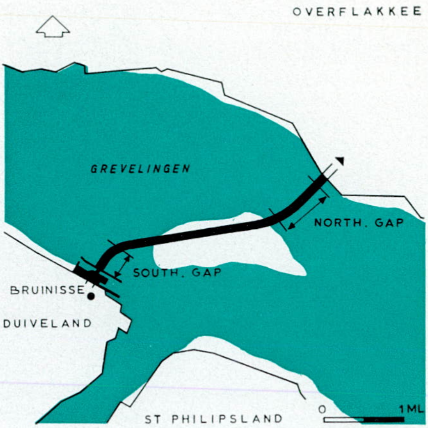
Caissons

In the Zuyder Zee Project closure was still effected by using extra transport and machinery to speed up the delivery of boulder clay to the gap and fill the latter with the least possible delay.
In the Delta Project, where great differences in tidal levels and high current velocities are often encountered, concrete caissons are now being used for closing the gaps. This method is based on the experience gained in and after World War II. The caissons are floated into position and then sunk.
Originally, at Walcheren, closed – standard – caissons were used, and also for the Brielse Maas, the Zandkreek and the southern gap in the Grevelingen dam. Sluice caissons were used for the first time when the Veerse Gat was closed.
The sluice gates were left open for some time after the caissons had been sunk so that the tidal currents were free to move in and out. When all the caissons had been sunk and an unbroken line had been formed all the sluice gates were closed simultaneously, thus separating the estuary from the sea for ever.
However, caissons are not the answer to all damming problems. For instance, the structural balance of the sand on which the dam rests may be upset if caissons are used. So other methods are also being tried.

Overhead Cableway

One of them is to fill up the gap gradually with stones transported in pouches of chain netting suspended from gondolas running to and fro along a cable at an appropriate height above the site of the projected dam. The stones are dumped at the required spot by releasing two of the four suspension cables.
This method was tested on the northern section of the Grevelingen dam, which was closed off by means of a cableway in 1964.

Sketch of barrier across the Grevelingen



1 View of telpher

2 The completed dam across the Grevelingen

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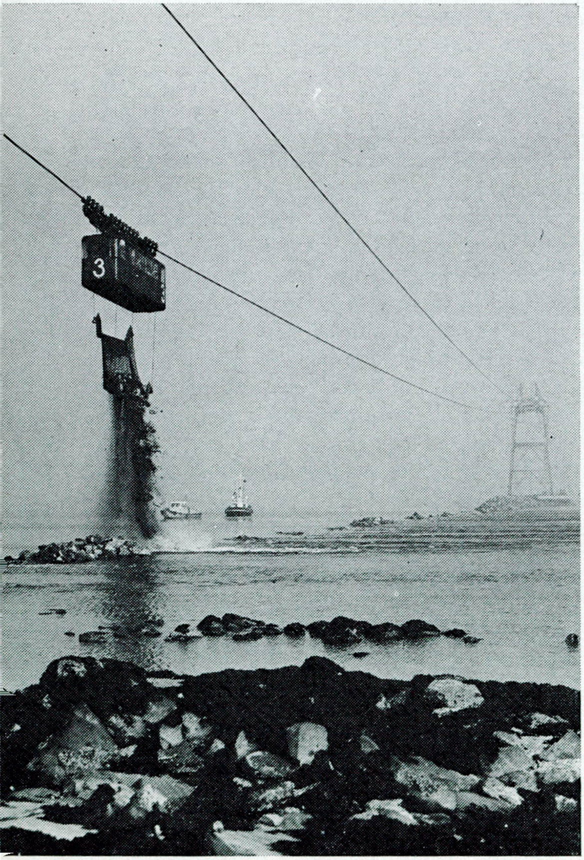

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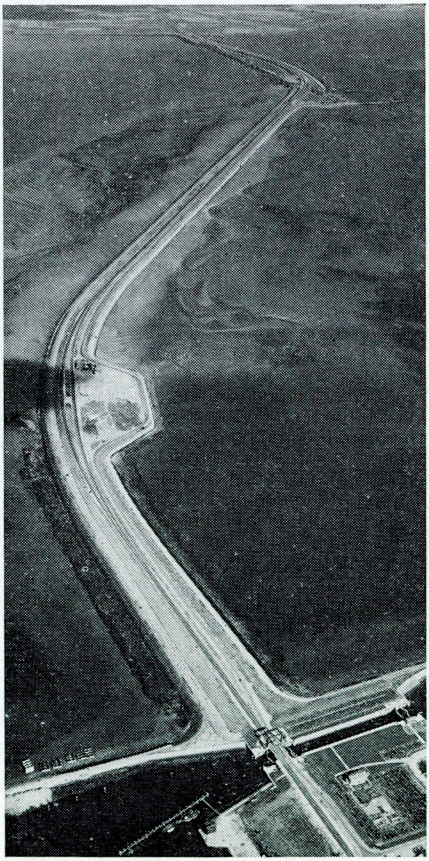


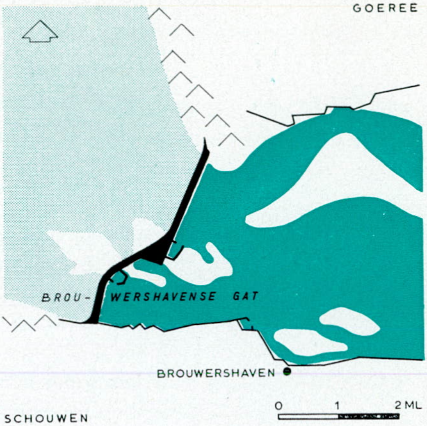
Both these methods, the sinking of caissons and the dumping of stones from a cableway, have, in certain circumstances, proved satisfactory; they have therefore been used or are currently being used for the other closures in the Delta area. For instance, after the closure of the Veerse Gat, the Volkerak was also closed with caissons incorporating sluice gates, and caissons of a similar type are now being constructed for the closure of the northern gap in the Brouwershavense Gat. However, whereas the caissons for the Veerse Gat and the Volkerak were 45 m (148 ft) long, those for the Brouwershavense Gat measure no less than 68 m (224 ft). Thanks to this extra length, made possible by a special base construction, the towing and sinking operations will be reduced by a third.

The same cableway that was used for closing the northern gap in the Grevelingen dam will be put into service once again to help close the 1,200-metre-wide gap in the Haringvliet dam. A new cableway will be needed for closing the southern gap in the Brouwershavense Gat as, when that work starts, the other cableway will still be engaged on the Haringvliet dam. The latter cableway incorporated a 20-ton diesel-driven gondola carrying a 10-ton load. The new one will achieve a much better carrier-load ratio, with its 15-ton hoisting frame and 15-ton capacity.

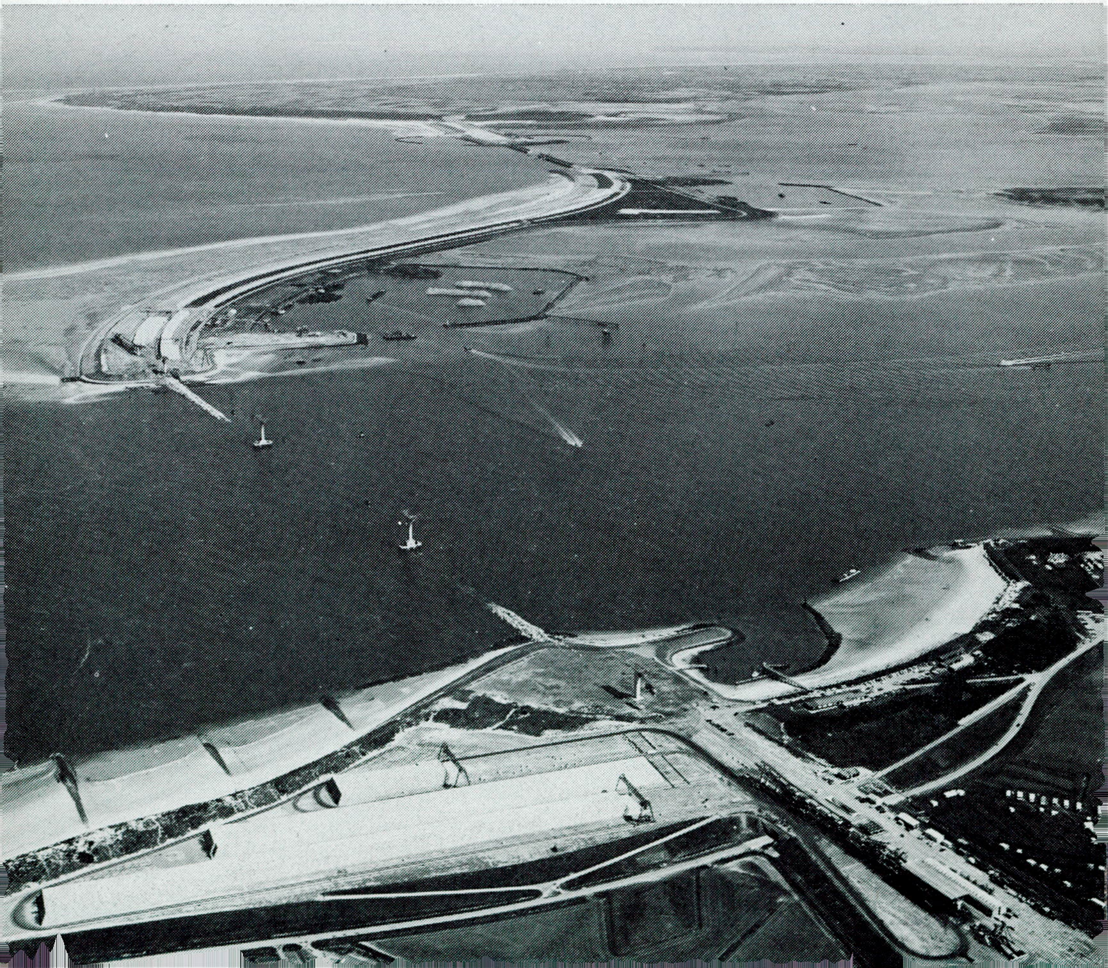
The tremendous amounts of rubble that would be needed for this job would have had to be brought in from abroad, involving a considerable drain on foreign currency reserves and long, vulnerable supply lines, which could be blocked by accidents or strike action. By using local material and producing concrete units on the site, it is possible to get round these difficulties almost entirely. As sand, gravel and cement are available practically everywhere within the area of the Delta Project, it was decided to make use of concrete blocks, first in closing the Haringvliet and then in closing the Brouwershavense Gat. A concrete block of one cubic metre weighs about 2,500 kg, but if heavier blocks should be needed their manufacture would present no problems and, in fact, the price would, relatively speaking, be lower. It can be seen from the above that, whereas a gondola at the Haringvliet could take four blocks of one cu. m. at a time, the hoisting frame used at the Brouwershavense Gat can take six blocks.

Whether closure is effected rapidly, with caissons, or gradually, by means of a cableway, the one objective is to cut off the flow of the tide back and forth through the gap and thus remove the impediment to the process of pumping up sand. When the sluice gates of the caissons are lowered or the stone dam has been raised to above high-water level, the tidal flow is eliminated and the part of the dam where the final gap had been can be reinforced with pumped-up sand and finished off unhindered by currents.

Sketch of barrier across the Brouwershavense Gat



Aerial view of work in the Brouwershavense Gat



Sketch of barrier across the Eastern Scheldt

Progress report

At the end of 1970 it will be possible to give the following progress report on the Delta Project:

Zandkreek: closed with standard caissons on 4 May 1960 – work completed.

Veerse Gat: closed with sluice caissons on 27 April 1961 – work completed.

Grevelingen: southern gap closed with standard caissons on 12 May 1962, northern gap closed with stone dumped from cableway in January 1965 – work completed.

Volkerak: the dam, closed with sluice caissons on 28 April 1969, practically completed; locks in use since 3 November 1967; inlet sluice to be built around 1978.

Haringvliet: locks and outlet sluice completed; last gap (1,200 m) closed with concrete blocks in April 1970.

Brouwershavense Gat: part of dam (3.5 km) in middle of water completed; sluice caissons being built for northern gap, cableway being set up for southern gap.

Eastern Scheldt: the first of the three service islands completed (also excavation of site outlet sluice) and the second under construction; methods for constructing the dam and closing the three gaps still under consideration.

The cost of the Delta Project is estimated at 3,000 million guilders, to be spread over about 20 years. This works out at 150 million guilders or 2 % of the National Budget. If a balance sheet is drawn up of all the direct advantages and disadvantages accruing from the project, benefits equivalent in value to about half the expenditure figure will appear on the credit side. The other half, i.e. 1 % of the National Budget, is being spent in order to safeguard the country against the type of flooding that might occur once in 10,000 years.