

CHAPTER 19

THE RECONSTRUCTION OF THE NETHERLAND DIKES AFTER THE STORM OF FEBRUARY 1953

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INTRODUCTION

The reconstruction of the damage to the dikes by the flood of February 1953 presented an enormous task. From the hydraulic engineer's point of view the most interesting part was the closing of the major or tidal breaches, that is to say, the places where a dike for a certain length was totally destroyed and where, therefore, the tides had free entrance to the inundated interior, scouring out deep gullies. This called into action the resources of tidal hydraulics, theoretical considerations, and model experiments.

Throughout the region where the gaps occurred, the soil consists of a fairly resistant layer of clay of a few meters thickness at the surface, below which there is a fine sand of a very erodible nature with occasional lenses of clay or peat. Once the upper layer of clay has been cut through, the breaches as a rule deepen and widen rapidly by scouring of the fine sand. As the breaches become wider, the tidal movement in the flooded areas increases. The height of the land in the flooded areas is nearly everywhere below mean sea-level and often at or even below low water (say $1\frac{1}{2}$ to 2 m below mean sea-level). The areas are intersected by roads, usually somewhat higher than the land, and by ditches and canals. Villages and small towns are mostly situated on somewhat higher ground.

During most of the tidal cycle the land is covered with water and the tide propagates all over the area. Naturally the tidal flow tends to concentrate in the lower sections and in particular in ditches and canals which happen to have a suitable direction. These accordingly are scoured out and in some cases they have become powerful tidal creeks, starting from the breaches and gradually lengthening by regressive erosion. At several of the largest gaps, therefore, a system of radially diverging gullies had developed after some time.

In some of the breaches the upper layer of fairly resistant clay was cut through immediately by the inflowing water when the dike was breached. In many other cases, however, the gap remained relatively shallow at first and it took some time for the erosive action of the currents to remove the clayey sill. It was especially in these cases, as will be readily understood, that speed in undertaking and executing the closing was essential. It was, as a matter of fact, possible in a number of places to prevent the breaches from becoming really dangerous by a speedy attack and improvised methods. The principal material used in these activities has been the common sandbag. Especially during the first period after the catastrophe this was an article in great demand. Altogether 15 million sandbags

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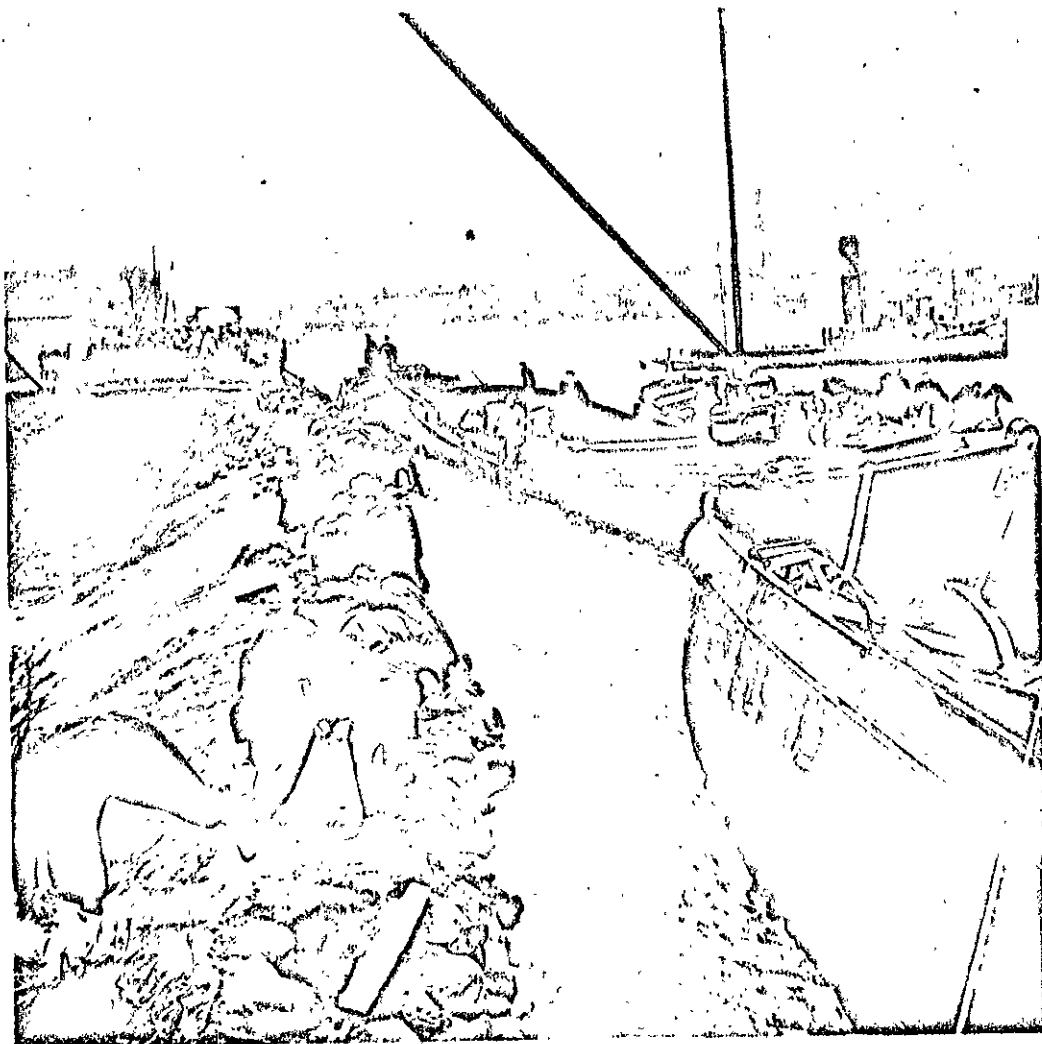


Fig. 1. Placing sandbags.

were used. They were transported by land, by water and by air to the danger spots. Not only sandbags were used, but also the stones from the revetment of neighboring dikes, the paving from the streets and many other improvised materials. Fig. 1 serves to give an impression of this activity.

In this way many smaller breaches were - at least provisionally - filled before they had a chance of developing into tidal channels. Not in all places, however, was this possible; not everywhere was sufficient labor available, or means of transport of material. Some breaches were inaccessible. Moreover during the first days and even weeks in several regions there was no time for any activity but saving as many lives as possible.

Also, of course, quite a number of breaches were so wide or so deep from the start as to render entirely futile any attempt at closing or even controlling them with improvised methods.

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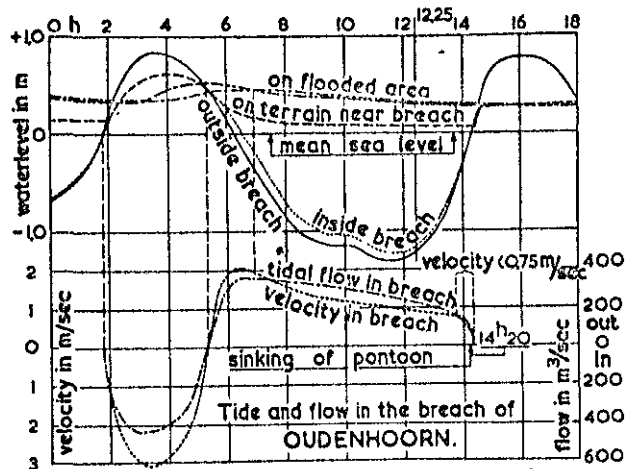


Fig. 2. Tidal curves at breach of Oudenhorn.

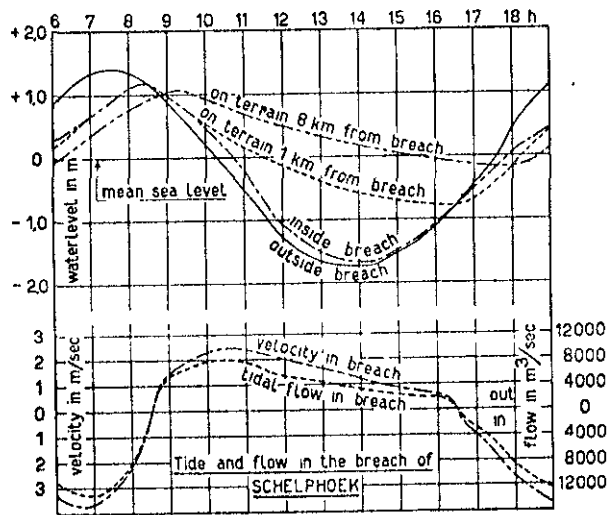


Fig. 3. Tidal curves at breach of Schelphoek.

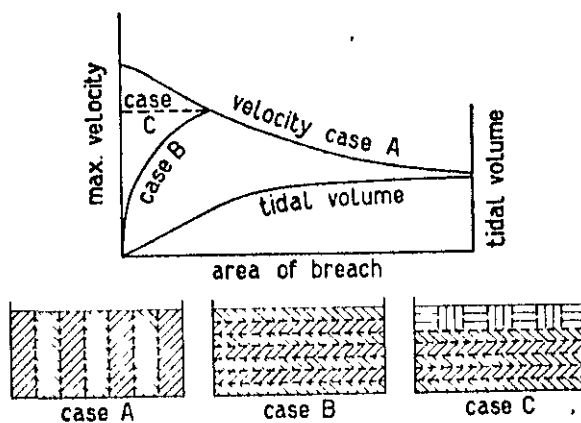


Fig. 4. Tidal volume and flow velocity as function of breach area.

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After this first stage, say at the end of February, 67 tidal breaches existed, the largest of which was about 400 m wide, with a maximum depth of about 35 m, giving access to a storage area of 900 sq. km., and having a tidal volume varying between 100 and 150 million m^3 , according to the variations of the tidal amplitude. This, as an illustration, is equal to the volume entering and leaving the mouth of the Rotterdam waterway in every tidal cycle.

TIDAL MOTION

The first task everywhere was to prevent the breaches from further scouring by protecting the bottom and the sides with fascine mattresses and stone, the traditional Dutch practice, which has been followed for centuries without essential changes. At the same time an extensive reconnaissance by sounding, current measuring and observation of the tides in the flooded areas was carried out. By means of model experiments and tidal calculations these data (subject to continual and sometimes even fairly rapid changes) were correlated in order to obtain a comprehensive picture of the hydrographic and hydraulic situation, which could be used as a base for planning the strategy and tactics of the closing operations. This planning should be understood to be rather like the planning of a chess player who has to be ready to revise his strategy and tactics according to the moves of his opponent, and not the drawing up of a definite plan to be followed in detail to the very end.

In this stage it may be useful to make a few remarks of a general nature on the procedure of closing off a tidal storage area. Given a gap of a certain cross-sectional area feeding a certain area of storage lying at a certain level with regard to the mean water level outside, with a certain amplitude of the tide and a certain value of the resistance in the breach, in the gullies and on the terrain, a definite picture can be made of the tidal movement in the storage area and the associated flood and ebb flow through the gap. Figs. 2 and 3 show this condition for two of the breaches. If the gap is gradually narrowed the amplitude of the tides on the terrain will diminish and also the total flow will diminish, but the flow velocity in the gap will increase. This is presented for a hypothetical case in Fig. 4 (case A). When the gap is nearly closed, the rise and fall inside will be practically nil, but the velocity in the gap will be at its maximum. Given sufficient data at the start, it is possible to predict by calculation or model experiment to a sufficient degree of accuracy the trend of the changes and the values to be expected in every stage of the closing. For the sake of simplicity certain complicating factors are left out of consideration for the moment, such as the fluctuation of spring and neap tides, abnormal high tides by wind action and the opportunity that presents itself in some cases of eliminating a part of the storage area. These factors will find their place later, when a few cases are discussed.

GENERAL PROCEDURE OF CLOSING

With the tidal ranges encountered in the Southwestern estuaries of the Netherlands (3 to 5 m) it is found that the flow velocities at the end will be too high for any of the available materials (sand, clay) except heavy stones. A dam of stones, however, besides being expensive, takes a long time to build, especially as the slack water periods at the transition

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between flood and ebb flow, and vice versa, become progressively short. Moreover, the continuous transport of large quantities of stone presents difficulties. It should be remembered that stone has to be imported from other countries (Belgium or Germany) and that also much stone is needed for ballasting the brush-wood mattresses.

In most cases, therefore, another method has been followed. This consists in narrowing the gap to a certain width, wide enough for the velocities to remain below a critical value. This value is not a constant, but depends on the local conditions, the nature of the soil, etc. In general it should not be over 3 to 3.5 m/sec. at an average tide. The gap thus left is then closed in a single operation. In this way the last stage of the closing, the stage in which the flow velocities grow to dangerous values, is, as it were, cut off. Our ancestors have followed a similar method. They used a ship for the final operation. This has also been done now in some cases, but mostly use is made of concrete pontoons.

There was one case, however, in which this pontoon method could not solve the problem. This was the largest breach of all. Here, in order to keep the flow velocities below the critical value, a final gap of something like 3000 m² would have had to be closed in one operation. This would have meant the use of, for instance, a pontoon 200 m long reaching to 15 m below mean sea level, which was out of the question.

Here it was necessary to follow a different method, a method which would avoid increasing the flow velocities to excessive values. This can be done if the gap is narrowed by building up uniformly from the bottom. In this case, when the crest reaches a certain level a state of maximum overflow prevails. Then the downstream water level has no influence on the velocity of the flow any more, and further restriction of the gap does not lead to higher velocities (Fig. 4, cases B and C).

The crux of this method is to have sufficient width so that the velocity at the stage where the maximum overflow occurs is below or equal to the critical velocity which can be accepted under the prevailing conditions. The need for the instantaneous closing of the remaining gap is thus eliminated. This might be termed the high crest closing method. A sufficient width for this purpose is usually not to be found in the breach itself. Moreover, the actual breach is as a rule not suitable for building up a dam with a fairly high crest, among other reasons, because of its great initial depth. When applying this method of closing, one is therefore led to leave the breach alone and to construct a new embankment some distance inland, encircling the breach and thereby sacrificing temporarily a certain area of land. The base of this embankment is then on the level of the terrain, so that a crest of sufficient height for insuring maximum overflow is more easily obtained. As will be shown later, in the case of Schelphoek, our largest breach, a retreat of about 1 km was made and an embankment of 4 km length was constructed instead of directly closing the 500 m wide gap. It will also be shown that as the situation developed, it was not a high crest closing procedure in the full sense, as had originally been planned,

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but a case of the chess player on the other side of the board obstructing the well thought-out moves.

After this discussion on general procedure, three breaches have been selected for a more detailed treatment, first one of the smaller ones that could be finished relatively early, the largest one, and the one that unexpectedly got out of control and consequently was the last gap of all to be closed.

THE BREACH OF OUDENHOORN

A week after the gale, the breach of Oudenhorn had a width of about 70 m and a depth of $5\frac{1}{2}$ m below mean sea level (Fig. 5). At that depth a layer of fairly resistant clay was encountered which for the time being prevented further erosion. At first the area flooded by this breach was 37 sq. km, but by repairing some inland embankments it was soon possible to reduce the area to 26 sq. km. The terrain was on the average situated slightly above mean sea-level. The tidal volume was about 10 million m^3 , which caused maximum velocities in the gap of about 3 m/sec. Fig. 2 shows a few typical tidal curves and the velocity curve in the gap. These curves represent a neap tide. At spring tide the tidal differences and the velocities are higher.

For closing the breach two concrete ships were at hand, which had been used as floating tanks. They had a length of 25 m each and by combining the two by means of steel girders and sheets, a unit could be obtained of 51 m length, 5.8 m in width and 5.6 m in height. At both ends a steel scaffolding was erected supporting steel sheet piles which could be dropped by removing a ratchet. This construction was christened, "guillotine".

In the time needed to lash together the two hulls and to equip this unit with the guillotine and other necessities, the bottom of the gap was raised by brush mattresses and stone to 4.4 m below mean sea-level. The top of the pontoon (5.6 m high) therefore reached to 1.2 m above mean sea-level; that is, the top was slightly above mean high water. The ends of the dike at both sides of the gap were more or less trimmed by stone.

The closing operation had to be carried out at slack tide, either at high water or at low water (Fig. 2). For two reasons the low slack tide, that is, at the end of the ebb flow was indicated. In the first place, the period of moderate velocities during which the unit has to be maneuvered into position and sunk was somewhat longer. In fact, for about fifteen minutes the flow was below $3/4$ m/sec. In the second place, less time would be needed for sinking, because of the lower initial level. As the draft of the pontoon was 2.2 m and the expected level at the slack time would be about mean sea-level, the pontoon had to sink over $4.4 - 2.2$ or 2.2 m. For sinking the pontoon, the sides of the hulls were pierced and the holes were closed by means of flaps which could be opened by removing a ratchet.

Everything was ready for the closing operation on February 28.

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Experiments had been carried out in the hydraulic laboratory from which the method shown in Fig. 6 was chosen. The pontoon was moored beforehand at one end by means of cables 1, 4, and 5. The actual maneuvering into position was effected mainly by cable 3, controlled by a winch of a floating crane at anchor. Cables 2 and 6, as well as 1, served only for emergency purposes.

As soon as the ebb flow had slackened sufficiently, the operation was started. There was a slight delay because the pontoon touched bottom on a protruding edge of a fascine mattress which had not sunk properly. As the tide was rising during the operation, the pontoon floated free just in time. It was maneuvered exactly into position and sunk within a few minutes (Fig. 7).

This however was by no means the end of the operation. The pontoon with its equipment had a weight of about 700 tons. As can be seen from the tidal curve, the water was rising rather rapidly at the moment of closing and very soon at high water the pontoon would have to withstand a head of say $3/4$ m, that is to say a horizontal pressure of some 200 tons. Moreover the outward pressure at low water would be nearly twice as much. As from previous experience and from special experiments it was established that the friction coefficient of a concrete pontoon on a bed of dumped stone is about 1 : 3, the total weight had to be brought within a few hours to at least 1200 tons. This was done by pumping sand onto the hulls, for which purpose a pipeline was laid on the pontoon, ready to be connected to a pipeline along the dike immediately after sinking. At the same time stones were dumped between the ends of the pontoon and the dike ends, and both in front of and behind the pontoon, to be followed later by clay in order to seal off the leaks left by the imperfect fitting of the concrete pontoon on the rough bed.

Upon completion of the above operation, a full dike of sand covered by clay and stone revetment was built around and on top of the pontoon and this breach was completely closed.

THE BREACH OF SCHELPHOEK

The largest and most difficult breach was that of Schelphoek on the island of Schouwen (Fig. 9). At the time of the first survey it was 300 m wide and the greatest depth was 30 m (Fig. 8). Later it grew to a width of more than 500 m with a maximum depth of 35 m. Gullies, developing into large tidal creeks, were eating their way inland at a rate of 300 to 400 m per week (compare Figs. 10 and 11). The tidal volume was, after some time, between 120 and 150 million cubic meters, with a maximum flow of some 14,000 cubic meters per sec, which is more than the maximum discharge of the Rhine. A picture of the tidal motion is shown in Fig. 3.

It was quite out of the question to deal with this grandfather of all breaches in the same way as at Oudenhorn. Therefore, it was decided

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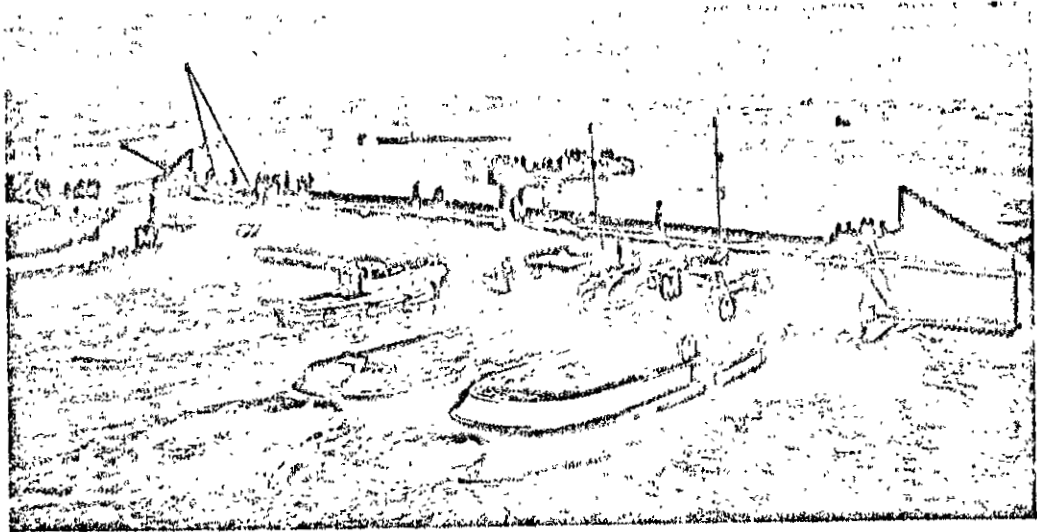


Fig. 7. Pontoon under way.

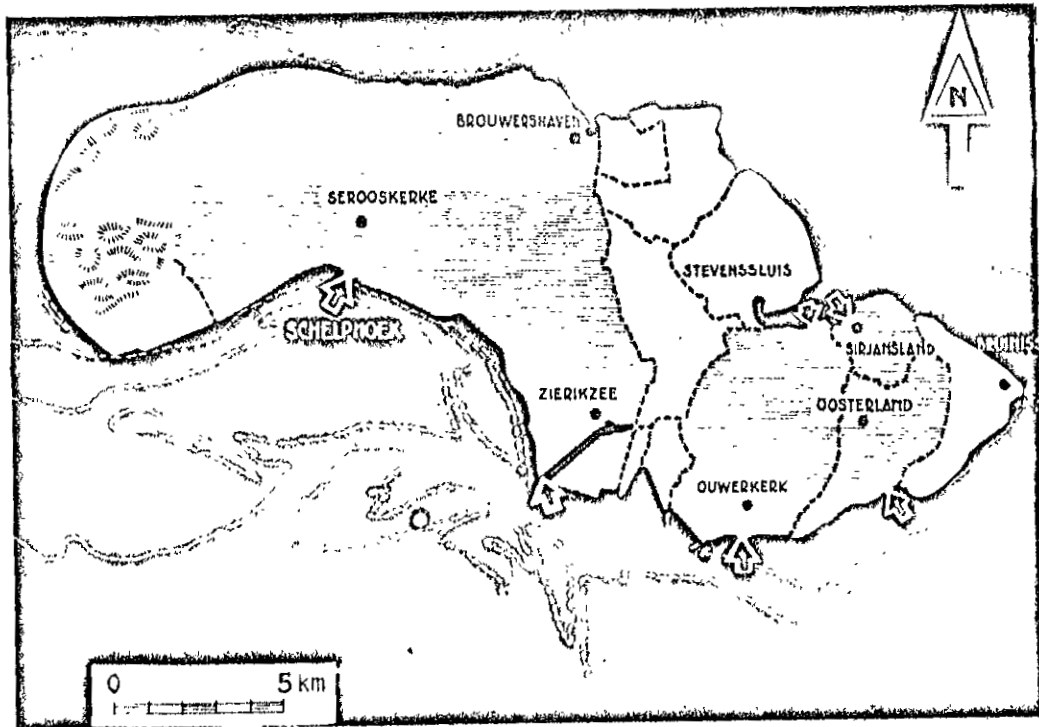


Fig. 8. Island Schouwen-Duiveland.

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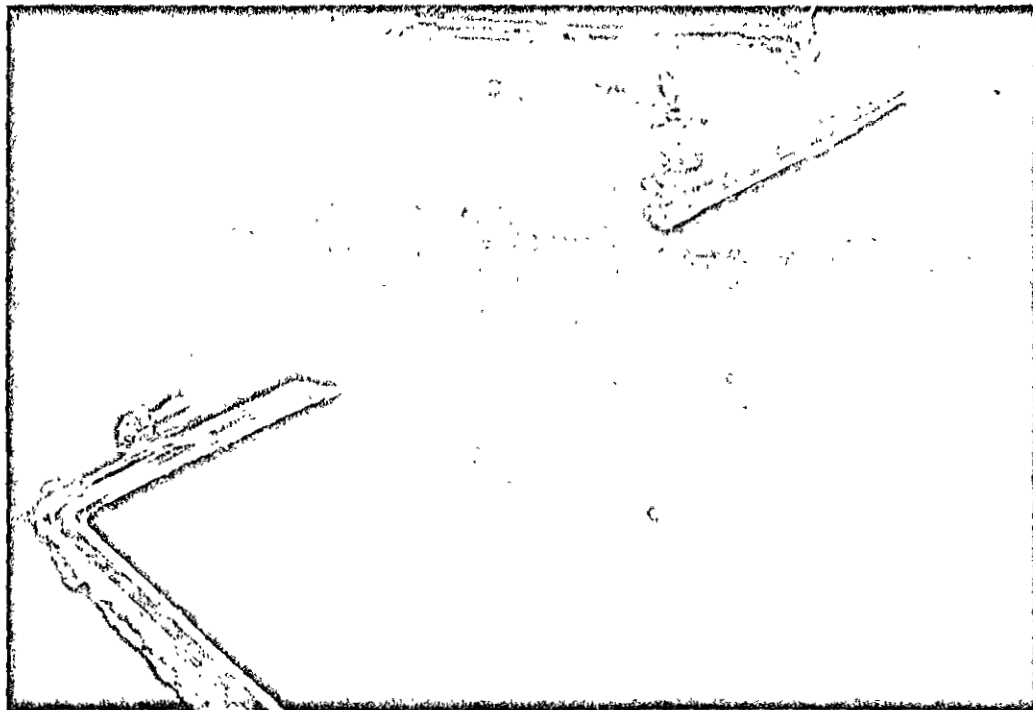


Fig. 9. Breach Schelphoek at high water.

to encircle the breach by a high crest overflow dam. Calculation showed that its length should have to be about 3 km. In the center, just opposite the breach, was the village of Serooskerke, at a distance of nearly $1\frac{1}{2}$ km. This was situated slightly higher than the general level of the terrain, which varied between 1 and $1\frac{1}{2}$ m below mean sea level. As the higher ground around the village did not contribute materially to the flow to and from the breach, and in order to keep the village inland of the embankment, this was fixed at a short distance in front of the village at about 1 km from the gap. From there an alignment was projected, curving gradually to the dike at both sides of the breach (Fig. 12). The embankment was to join the dikes at locations which for practical reasons offered suitable positions for floating pumping stations delivering sand for the embankment by means of pipelines. On the higher ground in front of Serooskerke the embankment was built immediately to above the high-tide level by hydraulic fill, using a suction dredger with floating pipeline, pumping sand between clay mounds built with clay from the site by clam shell dredges. The same was done for a short distance from the dikes at both sides of the breach in order to create starting

FIG. 11. Aerial view August 1, 1963.

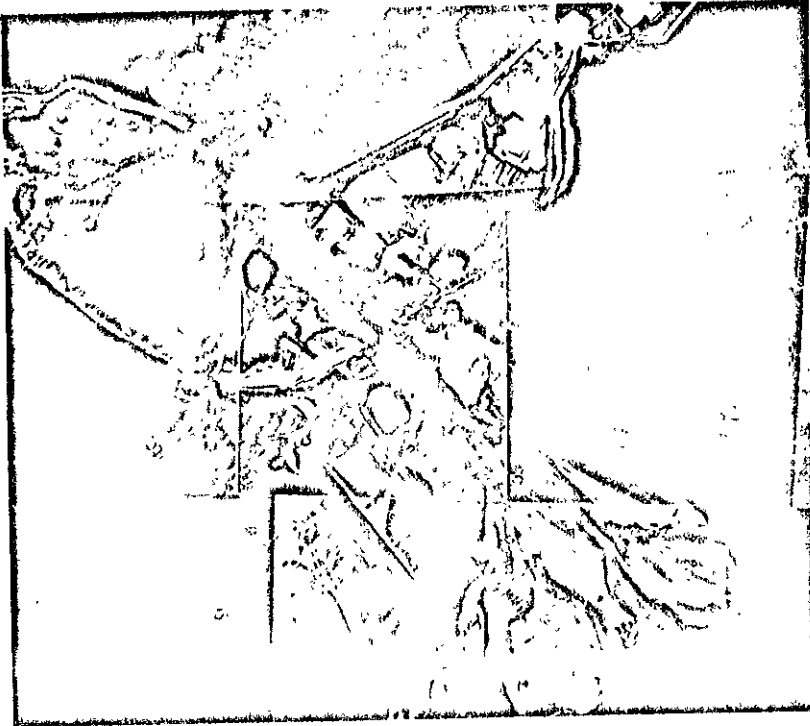
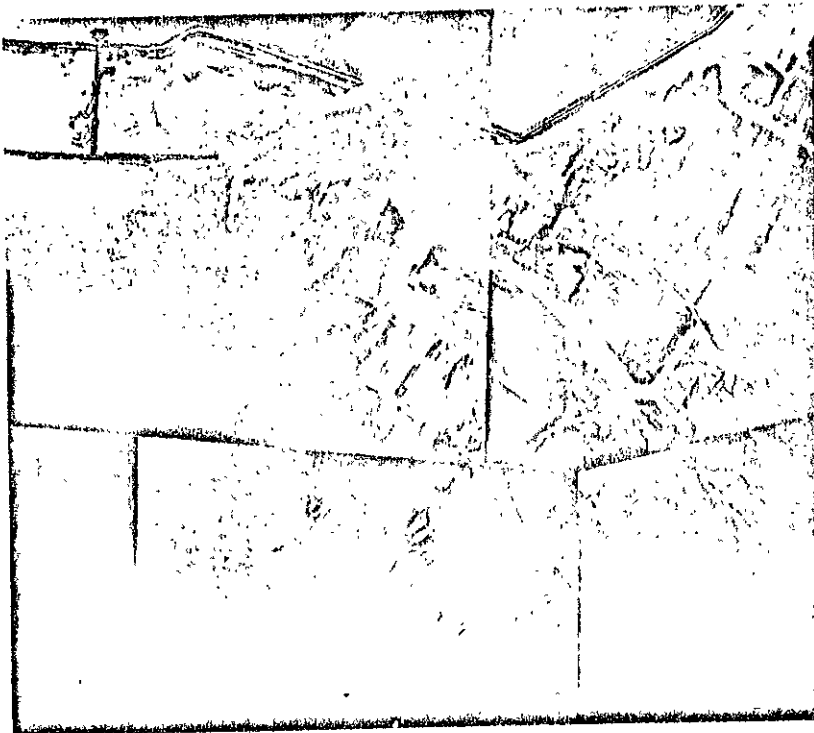


FIG. 10. Aerial view May 1, 1963.



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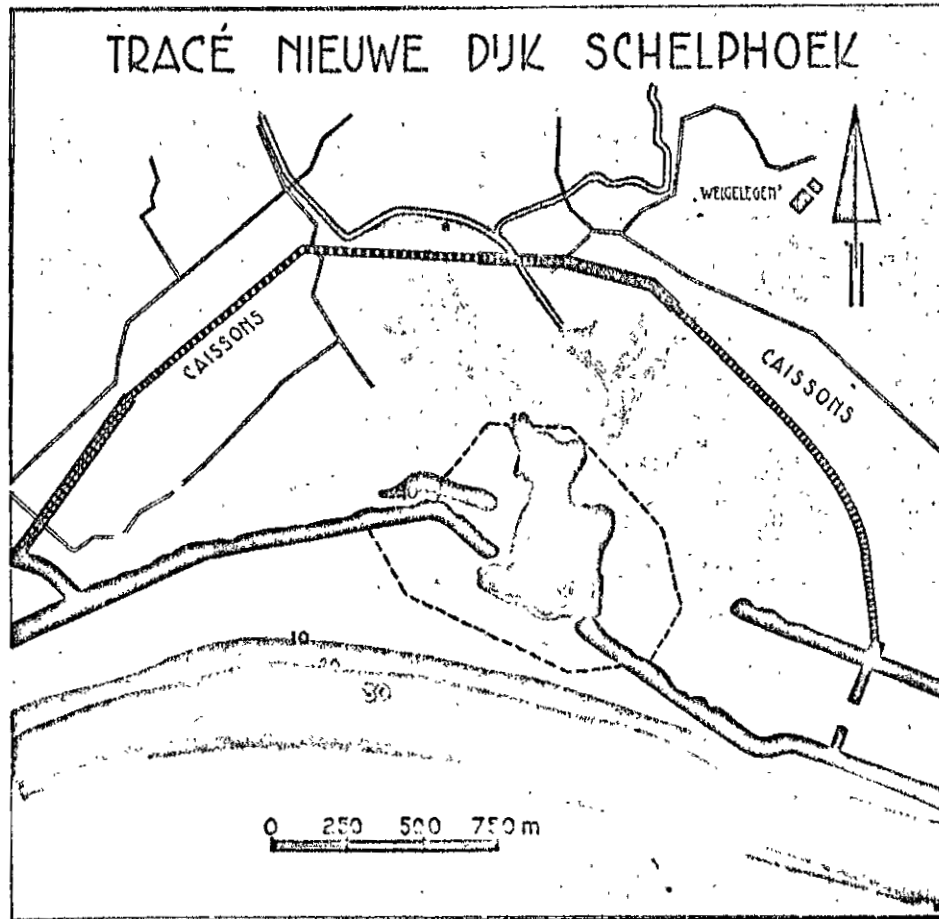


Fig. 12. Alignment of embankment at Schelphoek.

points for the construction of the final embankment. Both east and west of the village in this way there remained some 1500 m, making 3000 m altogether for the overflow crest, and the total length of the embankment was to be 4 km.

According to the plans a 40 m wide strip of brushwood mattress had to be laid and loaded with stone over the entire length of 3 km. This would form a crest, varying in level from mean sea level to 1/2 m below it, sufficient to create maximum overflow conditions everywhere (Fig. 13). On this foundation concrete pontoons 11 m long, 7.5 m wide and 2 to 3 m high were finally placed so as to reach everywhere to at least 2 m above mean sea level (slightly above spring high water). When sunk and filled with water, these pontoons were calculated to be able to withstand the pressure of the tidal differences. They were to form the nucleus of the final embankment.

The project however could not be carried out unchanged. While the construction of the embankment at the center and at the flanks, and at the same time the sinking and loading of the brushwood strip was

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progressing, two of the gullies eroded their way inland beyond the projected alignment of the dam. One of them eroded at such a rate in the northwesterly direction that a shifting of the alignment of the dam in order to keep ahead of it was out of the question. Therefore, the project had to be revised in the following way. The embankment was to cross the gullies in a suitable place. The bottom and sides of the gullies were to be covered by fascine mattresses in order to prevent further deepening and widening at the sites of the crossings. Before starting to place pontoons on the brushwood strip the gullies were to be closed by means of concrete pontoons.

As this revision of the project entailed an increase in the amount of fascine work and therefore prolonged the time needed for this part of the project, it was decided meanwhile to extend the embankment at full height at the two extreme ends of the alignment. This was made possible from a hydraulic point of view because the cross-sections of the gullies were added to the total cross-section area available for the flow. Accordingly the length of the high crest dam could be safely diminished to 900 m at the west side and 1100 m at the east side of Serooskerke.

It took some time to get the work under way. There was no harbor or shelter within easy distance to serve as a base and as a refuge in case of bad weather for the fleet of dredges, cranes, barges, tugs, survey-vessels and other floating equipment needed for a job of this scale. There was no accommodation for the laborers, no suitable site for workshops, office huts, no so called "zate" for constructing the brushwood mattresses. A "zate" is a beach or other fairly even surface, dry at low water and just submerged at high water to allow for floating the finished mattresses. All this had to be created first. Two harbors, one to the west and one to the east of the breach, were dredged out in bights sheltered by protecting ends of abandoned dikes from flood disasters in the past (in this region history records repeated retreats from the assaults of the sea). The spoils from the dredging were used for raising areas for huts, workshops, etc. Because of these necessary preparations it was near the end of May when the activities were in full swing. By that time there were in action around the island of Schouwen-Duiveland alone, 5 bucket-dredges, 33 suction dredges, 126 tugs, 266 barges of different description, 17 floating cranes, 105 draglines and numerous smaller units. The greater part of this equipment was employed at the Schelphoek breach.

In the operation 15,000 tons of stone, 30,000 m³ of clay and 300,000 m³ of sand were delivered and used per week. Also 15 to 20,000 m² of brushwood mattresses were constructed weekly, sunk and loaded with stone. Near mid-August the 2 km brushwood sill was put in place, the two gullies were provided with a protection against further erosion of the bottom and the sides, and the embankments in the center of the two ends of the alignment were in suitable condition. The velocities in the gullies had increased by then to 3½ to 4 m per sec. It was time to start the closing operations of the gullies.

The biggest type of concrete pontoon available was the Phoenix Ax from Mulberry Equipment, a small number of which had been left in England from the war. They were 62 m long, 18 m broad and 18 m high, when floating they had a displacement of 7000 metric tons. They were brought over from England for use in closing the largest breaches.

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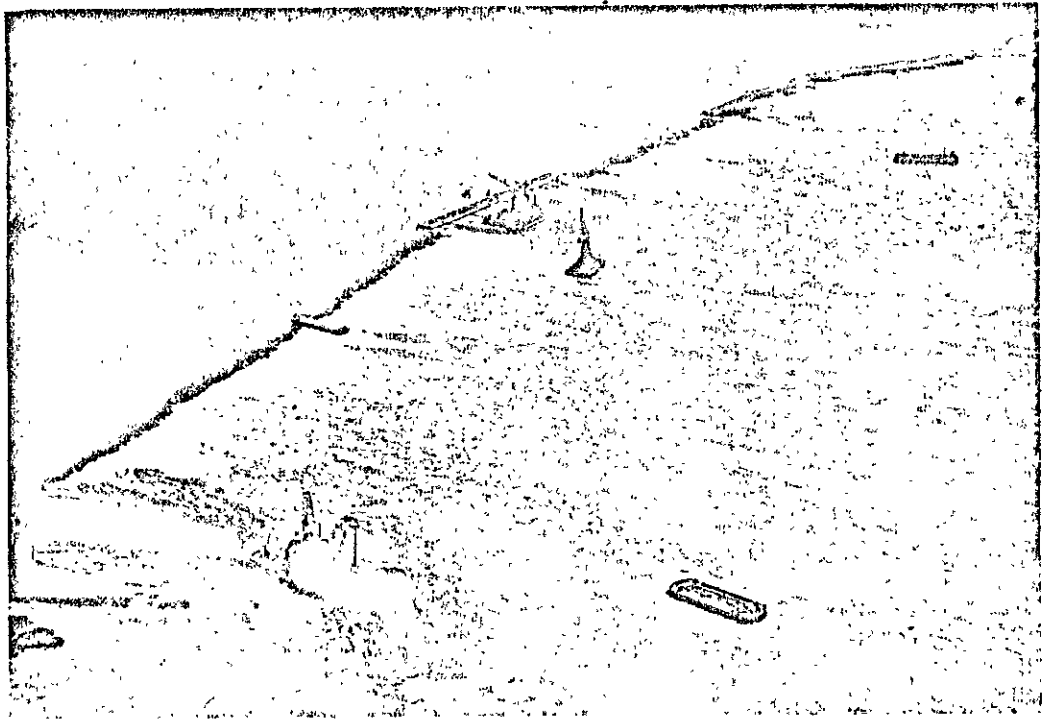


Fig. 13. Overflow crest.

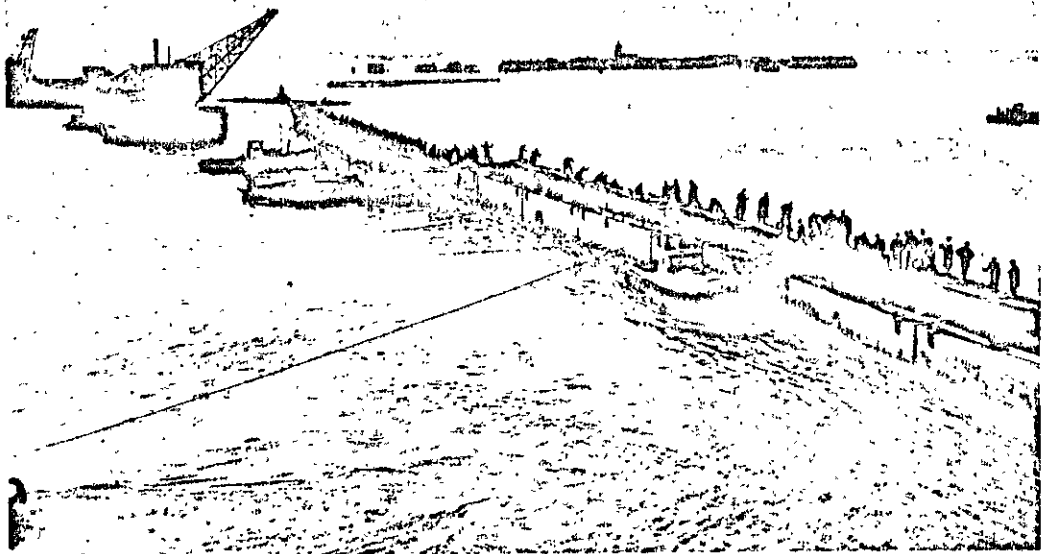


Fig. 14. Closing east gap.

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The gully west of Serooskerke was 100 m wide, and the base of dumped stone on the brushwood mattresses which was to receive the pontoon was at 10 m below mean sea level. Before placing the pontoons, the gap had to be trimmed to the length of the pontoon. This was done by placing smaller pontoons which had been constructed since February. It was realized immediately after the flood that concrete pontoons in great quantities would be needed for the closing of the numerous breaches and accordingly orders were placed with a group of several large contracting companies for the construction of standardized units which could be combined into pontoons of different sizes, according to the needs. The dimensions chosen for the units were 11 m long and 7.5 m wide. The assembled pontoons accordingly could have lengths of either $n \times 7.5$ or $n \times 11$ m and heights of 2, 4, 6 etc. up to 14 m. It was also possible by slight modifications to have intermediate heights.

By means of combining suitably chosen pontoons from this stock and dumped stone, the width of the west gully was restricted to 60 m. This immediately resulted in a local increase of the flow velocities and in increased erosion along the edges of the protective layer of the brushwood mattresses. The most dangerous factors were the vortex trails starting from the edges of the outer pontoons. The protection, originally practically flush with the bed of the gully, formed a sill with undesirably steep slopes. In the extremely fine sand slides began to occur, which resulted in subsidence of some of the concrete pontoons restricting the width. At that moment an important decision had to be made. Either the big pontoon for closing off the gully would have to be put into place immediately or this would have to be delayed until the solidity of the base layer could be improved by extending and reinforcing the protective layer and dumping more stone.

If the first course was to be followed, further erosion could be stopped but the danger of the entire construction sliding down into one of the deep excavations of 30 m at both sides of the sill was a possibility. Moreover, the closing of the west gully would have to be followed with a minimum of delay by the closing of the east gully, because the increased flow would increase erosion in that place.

On the other hand, it was by no means certain that it would be possible by continued sinking of mattresses and dumping stones to gain the upper hand of the rapidly progressing erosion. Moreover, the end of August was nearing, which would bring high spring tides and the possibility of an early autumn gale - they have been known to occur in the first days of September

It was a matter of weighing chances, none of which could be assessed quantitatively. Yet it was felt by everyone concerned that the bold course had to be taken; accordingly, on the 18th of August the big pontoon was maneuvered into place and sunk, as usual at the end of the ebb tide. Again the maneuver had been carefully rehearsed in the hydraulic laboratory and the operation went exactly according to schedule.

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Two days later a pontoon was placed in the east gully. Although this was a smaller pontoon, the operation was difficult because it had to be carried out at the slack tide near high water as the depth at low water was insufficient. The time available was very short, and on this occasion the pontoon had to be held by cables and eased-off with the decreasing flood current instead of pulled against the last ebb flow. However, once again all went well and the most dangerous part of the closing of the Schelphoek breach was past.

Then followed a time of feverish activity in consolidating the position of the two pontoons and sealing the gaps, left below and at the sides, with stone, clay and ultimately sand. At the same time the two stretches of the alignment on the terrain were closed by means of a large number of smaller pontoons (2 to 3 m high) mostly operated in strings of 4 to 6 (Fig. 14). By the end of September the entire ring was closed, although it still took much labor and care to seal all leaks and to convert the slender line of rather flimsy concrete boxes into an embankment capable of withstanding the winter gales. By that time the hope of also closing the breach itself before winter had been given up. It had been planned to use for that purpose 4 or 5 of the big Phoenix pontoons, but as it turned out they were needed at another place. This was the breach at Ouwkerk, the last one to be closed and the last one we will discuss.

THE BREACHES AT OUWERKERK

Ouwkerk is a small village in the eastern half of the twin island Schouwen-Duiveland (Fig. 8). This half is divided by two inland embankments into three polders, all of which were flooded. The sea entered through five tidal breaches, two of which were situated near to each other just south of Ouwkerk. The three other breaches all could be closed without too great difficulties. Also the two embankments separating the polders had been repaired by the beginning of August. This had been a much more troublesome affair because of the difficult transport and the impossibility of putting big equipment to work.

In front of the dike at Ouwkerk there was a shallow shelf or foreland several hundred meters wide. As the dike between and adjoining the gaps was badly damaged also, it was decided to construct a new dike in front of the old one over a length of 2.2 km (Fig. 15). Starting from the breaches in the dike, gullies had been scoured out both in the polder and through the foreland. It was decided to build the parts of the dike on the higher stretches of the foreland first and to leave the gullies for the final closing. Of course the bottom and sides of the gullies were protected first with brushwood mattresses.

The area served by the two gaps was 27 m² with a tidal volume of about 40 million m³. It was calculated that a total area of the two final gaps of 1200 m², 800 m² east and 400 m² west, would be sufficient to keep the maximum velocities below the limit of 3½ m/sec. Both gaps were to be closed by means of concrete pontoons assembled from standard units on two successive days in a week of neap tides.

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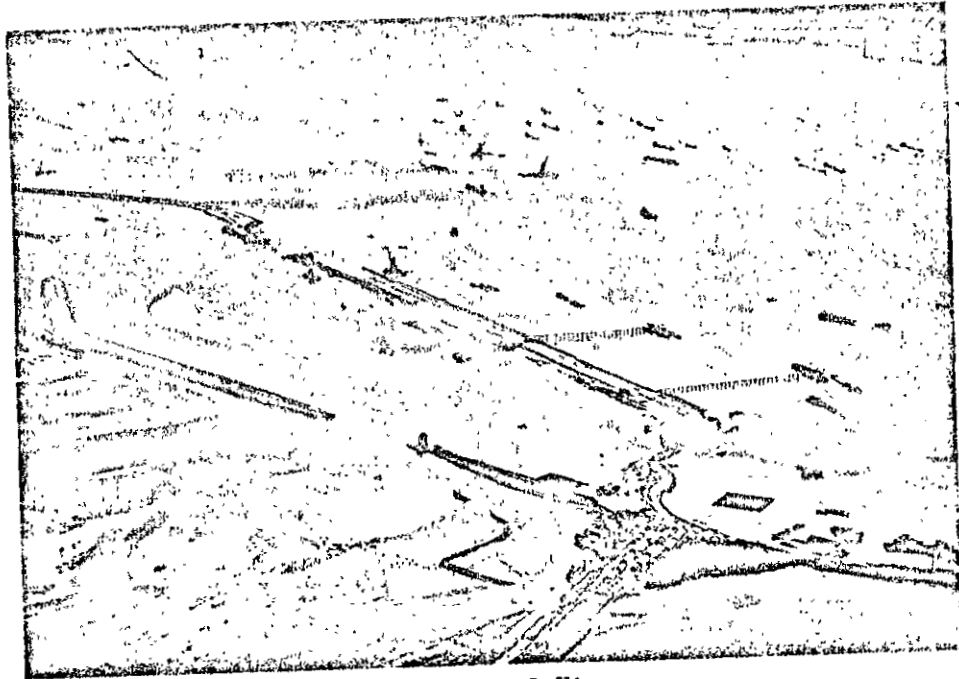


Fig. 16. General View.

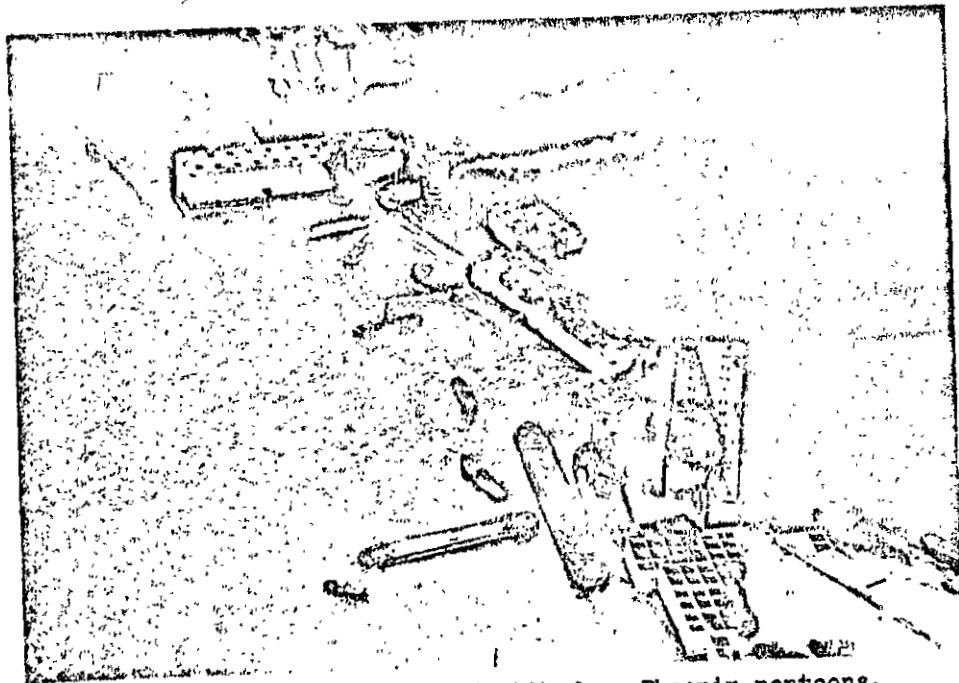


Fig. 17. East gap closed with four Phoenix pontoons.

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STROOMGATEN OUWERKERK

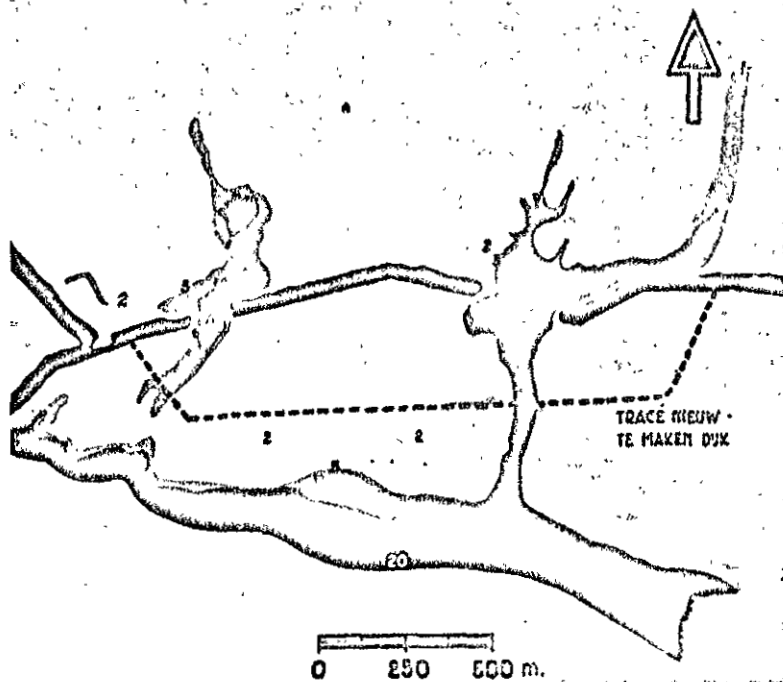


Fig. 15. Scheme for closing breaches at Ouwerkerk.

Compared with Schelphoek it seemed to be a simple and straightforward affair, which proceeded exactly to schedule nearly to the very end. With the approach of the closing operations which had been planned for the week of 20-25 August, difficulties began to arise. Here again pontoons were placed by way of abutments, in order to trim the gap down to the proper size for the closing pontoons. Almost immediately afterwards, the sill formed by dumping stone on mattresses in the west gap on which the pontoon was to rest began to settle at the edges. It became dangerously narrow and the dumping of additional stone did not yield material results. It seemed as if sand flowed from under the mattresses into the deep excavations at both sides of the sill. On the 22nd of August the abutment pontoons one after the other began to settle and to tilt.

As at Schelphoek, it was another case of now or much later, and as it was felt that with the available facilities for constructing mattresses and handling stone (it should be remembered that this coincided with the crucial period at Schelphoek) did not insure gaining advantage over the erosion - especially with the spring tide approaching - it was again decided to venture on the bold course.

On Sunday 23 August 1953 two strings of five standard units each, 6 m high, were let down into the west gap at slack tide between flood and

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ebb. It was a delicate operation because the time for maneuvering was short and the narrow sill made it imperative to place both strings at a slight angle to each other with an accuracy of less than one meter. In the utmost tension the operation was carried out. After the pontoons had been sunk, it soon became evident that in the center three units were slightly outward of their true position. They slid obliquely down, but then were held in a position with the top at about low water level.

In these circumstances it was not possible to close the east gap on the next day, as had been planned. This would have meant an important increase in the pressure on the pontoons in the west gap, because the level within the polder then would have remained practically constant somewhat above mean sea level, and it was practically a certainty that at low water outside the entire pontoon barrier would have been swept away.

In that case there would have been left a 400 m³ gap with maximum velocities of $5\frac{1}{2}$ or 6 m/sec. There was no other possibility but to try to consolidate the barrier in the west gap first. This was eventually done by means of additional pontoons, stone, clay and finally sand. But meanwhile the flow through the east gap increased to 5 m/sec and in a few days the bed protection together with the abutment pontoons became a shambles. Every thought of using this gap as a site for a closing operation by pontoons had to be abandoned. Fig. 16 shows a general view of the situation at this stage.

After careful survey of the new state of affairs by sounding, gauge-reading and flow measuring, an entirely new scheme was eventually developed. This consisted in preparing a new site for placing a pontoon barrier just outside the breach in the old dike. Four Phoenix AX pontoons were to be sunk on a bed of brushwood mattresses and stone at 10 to 15 m depth. As the enclosure dam at Schelphoek by this time was fairly well consolidated, it was possible to concentrate a larger portion of the equipment and manpower on Ouwerkerk. Favored by the exceptionally fair autumn weather, the work proceeded practically without incident so that in the night of 6 to 7 November the last pontoon could be placed according to schedule (Fig. 17).

The old motto of the Province Zealand: "Luctor et Emergo", once more had been made good.