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“The Delta of the Rhine and the Meuse in the Netherlands.”

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THE kingdom of the Netherlands consists of the eleven provinces of Friesland, Groningen, Drenthe, Overijssel, Gelderland, Utrecht, North and South Holland, Zeeland, North Brabant, and Limburg. It is bounded on the north and west by the North Sea, on the east by Germany, and on the south by Belgium. The soil consists of, 1st, the western continuation of the German glacial diluvium; 2nd, a belt of sand dunes on the sea coast; and 3rd, between these, alluvium: mixed sand, clay, silt, and peat, from the rivers Rhine, Upper Meuse, and Scheldt, forming the delta of these rivers. In Limburg the carboniferous formation is met with. The most productive and important parts of the country are the low lying alluvial districts, which are in most places below the level of the sea and river floods. They are guarded against encroachments of the ocean and rivers by high and massive embankments and dykes. A comparatively unimportant area is drained naturally into the rivers and estuaries; the remainder,—reclaimed fens and morasses, lakes and old river-beds, now forming deep and fertile polders (some of them 5 to 6 mètres below mean sea-level),—is kept dry by pumping. These rich lands owe their prosperity to silt deposited by the rivers, which are also the roads that bring commerce and traffic to the towns. Danger from the sea through high tides¹ may be obviated, but the rivers carry an element of destruction with them that no foresight or care can avoid. When, after severe frost, the ice breaks up, and in floating down meets with an obstruction, such as a shoal, a sharp bend, or an old wreck, the following shards press up, run aground, and, accumulating rapidly, form a dam across the river, choking its bed. The water then rises above the ice-dam till it overtops the dykes, and inundates the low country. The rivers, therefore, are a subject of constant attention; and the repairs and maintenance

¹ A table of the tides for some places on the North Sea coast, and the estuaries of the Rhine, is given in the “Pocket Book” of the Royal Engineers of the Netherlands.

of the dykes and the drainage arrangements are entrusted to the riverside owners and inhabitants and their local boards, under supervision of the Government department of public works called the Waterstaat. This corps is also directly in charge of the river beds between the dykes, and the navigation works, hydrography, and pilotage, and in times of danger and urgency is invested with unlimited power in matters pertaining to the department.

In the Roman period the country was covered with dense forest; and the inhabitants lived on the higher parts, or on artificial mounds, of which many still remain. The oldest village churches are often built on these mounds, having taken the place of the ancient temples of Thor or Freya.

As the population increased, the higher lands were embanked. There is evidence of the existence of dykes even in the second century, but in the eighth and ninth centuries large tracts had in this way been poldered. Sea dykes in the more exposed situations were in those early times defended on the outward slopes with reeds, rushes, and straw, and later on with seaweed,¹ gathered in the estuaries and salt-water meres. In the tenth and eleventh centuries the dykes had attained great importance and considerable dimensions, and were under the special care of the reigning princes. Vast improvements in the construction of machines for raising water led to poldering lower land than before. Seaweed was not considered suitable in many cases, and from 1466 the principal dykes were strengthened on the outside by rows of piling. About this time attention was turned to the reclaiming of the deeper basins, old meres and pools, and such fens as had been excavated for peat, the staple fuel of the country; and since then many polders and so-called *droogmakerijen*, or reclamations, have been made, and the whole country may now be said to consist of polders, each a little republic in itself. In most cases these polders are combined in groups having common interests into a *waterschap*, to bear jointly the expenses of dykes and drainage.

The dykes along the rivers are called *bandykes*, and are so constructed as not to be overflowed by the highest spates. These *bandykes*, which are of great importance to the well-being of the country, are often high and massive, and costly in construction, maintenance, and repair, and are guarded against destruction as long as possible. If at any spot the river reaches the top of the

¹ *Zostera marina*.

dyke, another dyke is laid on this again, called a *kisting*, and is made of anything at hand, hay, straw, dung, and even furniture, bedding, and buildings. When the river rises above a certain height, or as soon as the ice begins to appear about 1 to $1\frac{1}{2}$ mètre ($3\frac{1}{4}$ to 5 feet) under the so-called *noodpeil* or top of the dyke, the "dijkleger," or dyke army, is called out, and all the able-bodied male population is ready to rush to the places of danger; the whole extent of the dyke is constantly and vigilantly watched, and information immediately given of any suspicious occurrence. Besides the dangers from ice, the dyke may fail through an unsafe subsoil; the river forcing a passage through a sand stratum under the dyke, and bursting up inside the polder, forms what is called a *kwel*, which, if left alone, would soon undermine the bank. The dyke may also fail from bad workmanship, by having been often raised gradually and with unsuitable materials, no other being obtainable; and after continual wet weather it may at last give way and sink into the almost liquid subsoil, or *staal*. Another cause of danger, which exists all the year round, is that of the river attacking the dyke under water, when the deep-water channel approaching the bank at last undermines it. An occurrence of this kind, named a *schaardijk*, is provided against by *sinkstukken* or *bleslagen*, that is by osier beds or fascine mattresses; or the current is kept away by groynes, also of fascine work. When all these precautions are of no avail, a new dyke is laid farther back, called an *inlaagdijk*. This was, however, prohibited in old times, and the Count Floris V. of Holland ordained, in 1266, that if the old dyke could not be maintained another should always be laid in front, and not behind it. In less important cases, where no great depths are found, and for strengthening landings and river quays, the fagots are built up like a wall, and then called *pakwerk*. Where the slope has to be defended from an overflow—a weir for instance, or from surf—the brushwood is spread over it, kept down by low osier wattle work, called *tuinen*, and covered by brick, ballast, gravel, or quarry refuse; this is called *beslagwerk*. Similar constructions are also used for improvements in the river bed. Mr. T. C. Watson, M. Inst. C.E., has, in an interesting Paper, given a full description of fascine works in Holland.¹

The foreshores are also defended from occasional spates by low dykes, *summerkade*, which are covered during the higher floods, and allow the stream to extend over such foreshores or *waarden*. The handykes are usually from $4\frac{1}{2}$ to $5\frac{1}{2}$ mètres wide at the top,

¹ Vide Minutes of Proceedings Inst. C.E., vol. xli., p. 158.

with slopes of $2\frac{1}{2}$ or 2 to 1 and 2 or $1\frac{1}{2}$ to 1 outside and inside respectively. Except in very few cases the dykes on the rivers are faced with fascine works; the sea dykes, however, are more and more being overlaid with heavy stone pitching, since in 1730 the *teredo navalis* was noticed in the seaweed, fagots, and timber.

Notwithstanding the care taken of these dykes, inundations have always been frequent; they became more destructive as the dykes increased in height, and as the area left for the spates diminished by polders encroaching on the rivers. Where a breach occurs a deep hole is usually made in the ground by the water. Pools, or *wiels*, are everywhere numerous along the river dykes, and show the great frequency of these calamities.

Before taking a rapid glance at what has been done to obtain, as far as possible, immunity from danger and to improve the rivers, the boon and the bane of the Netherlands, a short description is necessary of their course and of their characteristic features. In the following statement all heights refer to the datum of the Amsterdam Peil, or the former mean high water at Amsterdam, about equal to mean sea level in the North Sea and Zuiderzee.

The bandykes are shown in thick black lines on the accompanying maps (Plates 10, 11, and 12).

GENERAL DESCRIPTION.

The Rhine receives a great number of tributaries, of which the Aar, the Neckar, the Main, the Moselle, the Ruhr, and the Lippe are the principal. Below Emmerick, in Rhenish Prussia, the river reaches the delta with an average discharge of 2,500 cubic mètres per second in the summer, and 10,000 cubic mètres per second in the winter and spring.¹ Its surface width is 480 mètres in summer, and 2,550 mètres in winter, and the river drains an area of about 4,000 geographical square miles.

Above Emmerick this river has flowed almost exclusively between high banks and in a natural channel, for ages, without important changes. In the lower reaches, however, the stream in many branches meanders to the sea through alluvial plains, and must be confined to a constant bed, mainly by dykes and embankments. About 19 kilomètres below Emmerick the river divides near the village of Pannerden into two branches: 1st, the Waal, taking two-thirds of the total volume, bending south and afterwards west,

¹ February 8th, 1862, surface at Emmerick at 17·38 mètres + A.P., 10,403 cubic mètres per second. Waal at Hulhuizen 6,936 cubic mètres.

with a discharge of 1,600 cubic mètres per second in summer and 7,000 cubic mètres per second during flood; and 2nd, the Lower Rhine, flowing north and west, receiving the remainder. This proportion, of two-thirds and one-third to the Waal and Lower Rhine respectively, is maintained as far as possible by a groyne or jetty pointing up-stream from the island between the two branches, cleaving the river as it were, and by bridling and profile works on the banks.

The Waal after two bends passes the ancient city of Nijmegen, situated on a spur from the Cleve hills, on the left bank, and Tiel on the right, and near St. Andries approaches the Meuse. Here, between the villages of Dreumel and Rossum, a narrow neck of land, about 1 kilomètre wide and 6 kilomètres long, separates the two rivers, which being left undyked allows the Waal water during high floods to flow over into the Meuse. A short canal with locks establishes communication for shipping. Three channels which formerly existed have been closed one after the other, the last in 1856. Flowing on past the city of Bommel on the left hand, the Waal receives the Meuse near Woudrichem, also on the left bank, with a volume of 200 cubic mètres per second in summer, and 4,000 cubic mètres per second in winter, and is thence called the Merwede. Passing Gorinchem, on the right bank, the Old Merwede continues its course to Dordrecht, but the greatest volume of water passes through the newly-formed channel in a southerly direction to the Hollandsch Diep estuary. The mouth of this new branch near Deeneplaat is 600 mètres wide in the summer bed, with 200 mètres foreshore on each side. The distance from Emmerick to the Deeneplaat is 124·8 kilomètres; the fall in that distance is about 12 mètres, or about 1 in 10,000, in summer, and 17·5 mètres, or 1 in 7,000, during floods. Except at Nijmegen and near St. Andries the river is embanked on both sides, and the tide runs up to Bommel.

The Lower Rhine, about 6 kilomètres below its separation from the Waal, receives, near Kandia, the discharge from an old side branch, which during floods takes water from the Upper Rhine over a weir near Lobith on the north bank, and 4 kilomètres below Kandia, near Westervoort, gives a third of its total volume to the Geldersche Yssel, on the right bank. The Lower Rhine passes Arnhem, on the right bank on high ground, and along the foot of the Veluwe hills to Wageningen, where the dyke recommences and is carried as far as Grebbe, and about 7 kilomètres lower down. Thence past Rhenen to Amerongen the stream is bounded on the right bank by high ground. At Amerongen the Lower Rhine is called the Leck, and

passes the ancient city of Wijk bij Duurstede on the right, Culenburg and Vianen on the left, and Schoonhoven on the right again, to Krimpen, where it receives the Hollandsche Yssel, an old side branch. Here the Leck unites with the Noord, which communicates with the Old Merwede at Dordrecht, taking the name of New Meuse, passes the towns of Rotterdam, Schiedam, Vlaardingén (where it communicates with the Old Meuse through the Botlek to the south), and Maassluis, and through the new channel of the Hook of Holland, to the North Sea. The total distance from this spot to the separation from the Waal near Pannerden is 166 kilomètres; the fall in summer is about 10 mètres, or 1 in 16,600; and during freshets about 15 mètres, or 1 in 11,000. Except near Arnhem and Rhenen the river is banked on both sides; on the north, the ancient and important Grebbe dyke and the North Leck dykes defend the richest parts of the country, and many deep polders in South Holland. The island between the Waal and Lower Rhine branches is divided into five principal "waterschappen," or confederations of polders: the Upper and Lower Betuwe, the Tielerwaard, the Alblasserwaard, and Vijfheerenlanden; of these the two last lie very low, viz.: from 1·20 mètre to 2 mètres below A.P. in some parts. This island is partly drained by the Linge brook, which runs nearly east and west through it, and discharges into the Merwede at Gorinchem, and through a deviating canal, made in 1819, thence to Steenenhoek, 8 kilomètres further west. From near Culenburg on the Leck to Gorinchem, cross embankments, known as the Dief dyke and the North Linge dyke, partly defend the Vijfheerenlanden and Alblasserwaard from inundation and from breaches in the Veluwe dykes above it, and lead the flood water to the Merwede, through locks and over weirs in the river dykes near Dalem between Gorinchem and Vuren.

The Hollandsche Yssel was in old times a side channel of the Leck, and flowed out of it below Vreeswijk opposite Vianen; now the only communication is through a culvert and sluice. It bends from thence to the north, past the town of Gouda, and is locked above that place. Lower down the river is tidal; at Krimpen it joins the New Meuse, enclosing, with the Leck, the waterschappen of the Lopickerwaard and Krimpenerwaard, and receives the drainage of a large tract of South Holland. The waterschap of Rhineland discharges partly into it at Gouda, with a pumping engine below the lock, of 250 HP.

The Geldersche Yssel branches off from the Lower Rhine with a long curve at Westervoort, flows with many bends in a northerly direction, successively past the towns of Doesborgh, where it receives

the Old Yssel, Zutphen, where the Berkel brook falls into it, and Deventer, all on the right bank, and past Hattem and Kampen on the left bank. Opposite Hattem, near Katerveer, a canal communicates with the town moats of the city of Zwolle, and the creek of the Zwarte water, which runs past Genemuiden, and between jetties nearly 6 kilomètres long, into the Zuiderzee at Kraggenburg. Below Kampen the Yssel flows through two mouths, the Ganzendiep to the right, and the Keteldiep, which has been much improved of late, into the Zuiderzee. The total distance along the fairway from its separation from the Lower Rhine to the Ketelmouth is 127·8 kilomètres; its fall in that distance is 9·15 mètres when the river is in ordinary condition or 1 in 14,000, and 13·90 mètres during floods or 1 in 9,000, in round numbers.

The dykes of the Geldersche Yssel are not continuous, the river being partly confined between high banks. At the upper end the east bandyke of the Lijmers district constitutes its right bank as far as Doesborgh. Between Lathum and Bingerden a lowered dyke-length allows inundation water coming from breaches in the North Rhine banks, to discharge at this spot into the Yssel. The Old Yssel, besides draining the high ground to the east, also intercepts this flood water, bringing it past Doesborgh on the main river. From Bingerden to beyond Deventer, high ground renders a bandyke unnecessary, thence downward bandykes reach to Kampen. The left bank is dyked all the way from above Zutphen to the sea, except for a short length above Hattem, skirting the high ground of the Veluwe.

The Meuse has its source in the Vosges, and, flowing in a northerly direction, passes the towns of Commercy, Verdun, Sedan, Dinant, Namur, Liège, Maastricht, and Venlo, and leaves the higher moorlands near the village of Mook, above Grave, to enter the delta, with an estimated volume of 170 cubic mètres per second in summer, and of 3,800 cubic mètres per second in winter, being the drainage of 860 square geographical miles. Passing Ravenstein to St. Andries, where it receives the flood water from the Waal over the undyked Heerewaarden lands, and communicating with that river through a short canal and double lock, it reaches Crève-cœur, where the Dieze brook discharges into it through a lock; then past Heusden, it joins the Waal near Woudrichem, opposite and above Gorinchem. The direct distance from Grave to Woudrichem is about 50 kilomètres, the length of the fairway 95 kilomètres, and the fall in that length about 4 mètres, or 1 in 23,750. The river is dyked on both sides, except on the left bank

in two places—between Cuijk and Grave, near St. Andries, and near Bokhoven—where, in winter, flood water is allowed to overflow the low-lying polders of North Brabant, to discharge past Bois-le-Duc, and across the weir at Baardwijck, the Little Meuse, and the Amer, to the Hollandsch Diep.

The estuaries are numerous, and intersected by cross channels forming numerous islands and shoals.

The Hollandsch Diep, after passing under the railway bridge at Moerdijk,¹ divides near Willemstad, about 18 kilomètres west of the Deeneplaat, into two wide arms communicating directly with the sea—one bending south and then west, with the names consecutively of Krammer, Volkerak, and Grevelingen, reaches the North Sea beyond Brouwershaven on the south shore, on the island of Schouwen; the other arm, continuing in a north-westerly direction, joins the sea past the harbour of Hellevoet, under the names of Haringvliet and Noorderdiep. The two arms enclose the islands of Goerée and Overflakkee. From the Merwede at Dordrecht to the Hollandsch Diep, near Moerdijk, the Dordtschekill, though narrow, affords a good navigable channel for large ships to Brouwershaven, with a minimum depth of 4 mètres at low tide. The Old Meuse runs westerly, forming with the Haringvliet the islands of Beijerland, Putten en Voorne, and with the New Meuse and Noord the island of Ysselmonde. Receiving some of the water from the New Meuse through the Botlek, forming with it Rozenburg island, and widening out, it reaches the sea beyond Brielle. The coast bends south-west and north-east. Before high water the current sets from the south-west, returning in that direction with the fall of the tide. The mouths of the estuaries on the coast all bend to the south-west, opening against the rising tide, and discharging parallel to the ebb current. The islands are all dyked; their surface is generally above low-water level, and they are mostly drained by gravitation. Only on their western edges, nearest the sea, do sand-downs exist, forming a continuation of those on the other parts of the eastern coast of the North Sea. A canal through the island of Voorne, from Hellevoet to the Old Meuse, at Nieuwesluis, enables vessels of 5 mètres draught to reach Rotterdam from the sea by the Goerée channel through the Botlek and the Old Meuse. The rise and fall of the tides, and direction and velocity of the currents in these estuaries, are very irregular, particularly so in the cross channels.

¹ Of fourteen spans of 100 mètres and two of 16 mètres, or about 1 mile in length.

Such is a general outline of the present course of the Rhine and Meuse in the Netherlands. They were naturally subject to many changes in bygone ages. It is supposed that the coast line advanced much farther west into the German Ocean before the Cimbric flood in 110 B.C., when the sea forced a passage through the present Straits of Dover, and its mean level was permanently raised, swamping large tracts of land, which still exist as sandbanks in the North Sea.

The earliest geographical information about the delta of the Rhine is obtained from the Romans, and must be inferred from their description of battles and campaigns in those parts. It is probable that in those days a branch left the Rhine just below the Elten hills, near Emmerick, and flowed northwards through marshes and fens. The Roman commander, Drusus Germanicus, first made this branch navigable, and embanked parts of it. The principal channel of the Rhine flowed to Wijk bij Duurstede, and thence to the north, with many branches, one past Leyden, another through the Zuiderzee, which was only an inland mere, and, through a mouth called Flevum, past the Helder. Below Wageningen some water was also discharged to the north, and the Roman Domitius Corbulus cut a passage from below Wijk to the westward, which is the present Leek. This joined a wide gulf, the *os immensus* of Tacitus, now divided into several estuaries. No islands were mentioned as existing in it. The Waal and Meuse had a common outfall into this gulf. The towns of Nijmegen (Oppidum Batavorum), Wijk (Dorestad), and Utrecht (Nifterlake) were commercial towns at that time, and continued to be so till the reign of Charlemagne. By the sixth and seventh centuries many embankments had been formed, and tracts of land poldered, as the population increased. In the thirteenth century a large part of the country had been so reclaimed, as shown by several laws and charters of those days. The Grebbe dyke was already an important work; and in 1233 and 1234 the Count of Holland caused the North Leek dyke, from Amerongen to Schoonhoven, to be laid down. A law was made against digging for peat in places dangerous to existing dykes. No important changes seem to have occurred till the great flood of 1421, which swamped the whole country, and destroyed the South Hollandsche Waard between Dordrecht and Gorinchem. After this calamity the Waal and Meuse, which had before followed the bed of the present Merwede, pursued a shorter road to the sea across the submerged land; and the Waal, obtaining a better fall than that of the Lower Rhine, soon became the principal mouth, drawing more water than the others.

Nothing was done to counteract the altered condition, or to make the best of it, owing to civil wars and disturbances. Consequently, when the new Waal mouth began to shoal, and islands were warping up in it, the polders near Gorinchem, the Tielerwaard, and Alblasserwaard, were endangered by the raised river surface, which was, however, favourable to the shipping interest; and quarrels arose about this, as also about the Lower Rhine and Leck, so that nothing was done. At last a great inundation, on the 11th of January, 1624, swamped about 170,000 hectares of land, principally in South Holland, and brought the inhabitants to their senses.

The States-General took the matter in hand; but it was not till 1696 that the engineer Passavant reported to them on the Lower Rhine and Yssel branches. He found the Yssel in its upper reaches nowhere navigable; and the Lower Rhine and Leck, as far down as below Schoonhoven, fordable in many places, an invading French army having easily crossed the Rhine without boats near Lobith in 1672. The Waal took at that time nearly the whole volume of water from the Upper Rhine, leaving only a twenty-fourth to the other branches in summer; while in winter the undefended river banks and irregular and curving channels permitted any excess of water to flow down the Rhine. He proposed to discharge the Upper Rhine, over a weir in the north bank, near Zevenaer, into the Geldersche Yssel, to relieve the other branches. This plan, though often considered, was never executed. In 1701 a channel was begun for straightening the upper part of the Lower Rhine near Pannerden. It was finished in 1706, and gave much satisfaction, till, in 1740, a breach in the north bank below Emmerick threw a large volume of water into an old abandoned Rhine bed, and so into the Lower Rhine, again discharging into that river too large a proportion of water. Some works executed to improve these reaches were of no avail; at last the engineer Brunings, in 1770, was empowered to bring this vexed question to a conclusion. On his proposition a number of works were carried out between 1771 to 1776, which have remained almost unaltered. The bandykes on both sides were raised and strengthened, the old bed of the Rhine near Lobith was shut off by a dam, and a new channel was cut through two bends in the Upper Rhine below Emmerick, called the Bijlandsche canal. A groyne was also run out, pointing up stream, from the separation point of the Lower Rhine and Waal, so as to ensure to the Lower Rhine a permanent share of one-third of the total volume of the Upper Rhine, the rest of the water going to the Waal. The same system was put into practice at the division

between the Lower Rhine and Yssel, which last river received a new intake a little above the old one, and one-third of the total volume of water of the Pannerdsche canal. All these works were protected with "bleeslagen" and groynes. The weir near Lobith was the weak point in the system, but it had to be made on account of the polders above. It was decided at that time that the top was to be raised no higher than + 11 mètres A.P., but it has been since raised to + 13.91 mètres A.P. To counteract partly the bad effect of this side discharge, a portion of the bandyke of the Lijmers, near Oud Levenaar, was, in 1809, lowered to allow some of the water to escape across these lands to the Yssel at Bingerden. It has been of use twice only—once in 1820, and once in 1855—and was after this latter date raised again to its full height.

A bend on the Waal was also cut through at Bimmen, above Nijmegen, in 1654, and two bends were similarly dealt with at Waardenburg, near Bommel, in 1655 and 1680, by which that stream was straightened.

On the Lower Rhine about that time some improvements to deepen the fairway were also carried out at Malburgen, and in several places on the Leck after 1770.

The overflow from the Meuse, near Cuijk and Grave, existing since the fourteenth century, when the bandykes lower down had been united and continued, was regulated in 1766; and the weir at Baardwijk was lengthened in 1795, and again in 1812, when it was improved and strengthened.

So far the amended water division at the head of the delta had given good results, and the condition of the river beds was better than in the seventeenth century; but, on the whole, the want of system in carrying out the different works, and the numerous conflicting interests and local influences, led to slow progress being made. In 1800 the engineer Brunings proposed a number of improvements, but the disturbed times did not allow of much being done till 1815. The inundation of 1820, which flooded nearly the whole of the low grounds and polders, forcibly directed public attention to the subject.

A Royal Commission was appointed in 1821, which presented to the King a voluminous report on the state of the rivers, and advised many and very costly works, besides critically considering other propositions.

The commissioners were of opinion that during the preceding centuries the river beds had been much raised; that floods, too, were of late years more frequent, and rose higher, than before,

owing to a change of climate, cultivation, and improvements of the upper rivers. A proposition to dredge the river beds to the necessary depths was found impracticable, as it was calculated that to gain 1 mètre in depth about 200,000,000 tons of material would have to be removed, at an estimated cost exceeding 100,000,000 florins.

The German hydrographer Wiebeking advised that the bandykes should be raised and strengthened, and the fairway straightened. This was not considered feasible, as in many places the subsoil was unable to carry a heavier embankment, and it was next to impossible to clear away all the villages and dwellings on and near the dykes to make room for structures of increased dimensions.

Mr. Luitjes urged that the bandykes should be lowered so as to allow the swollen rivers to overflow, and thought that in this way the silt would, like that of the Nile, enrich the land, and in course of time raise the surface. He, however, excepted from this system such low polders as had no natural drainage, and would, therefore, remain flooded all the year round unless powerful artificial draining could be resorted to. Against this idea it was averred that the fructifying properties would be uncertain, as the silt is not precipitated equally over a large surface, and the river often carries sand and gravel instead, and would be continually varying its course, which could be hardly prevented, and would often not be discovered till too late.

The Government engineer Goudriaan suggested that a great number of overflows or weirs should be made in the dykes at convenient places, so as to allow flood water to leave the river, and to lead this water between dams across the land, through so-called "green rivers," to spots where it could be got rid of. However, large tracts of land would have been almost permanently under water, and this scheme was open to the same objections as that of Mr. Luitjes.

General Kraayenhoff proposed to form new rivers by excavation, through the lowest districts, and in as direct a line as possible to the sea. In outline his idea was to lead the Rhine through a new channel from near Lobith to Doesborgh, thence to straighten the Yssel to Deventer, and from thence to give it a single and capacious outfall into the Zuiderzee; to canalise the Lower Rhine and Leck from Pannerden to Krimpen, dividing this branch into eight levels by means of locks; to close all communication between the Waal and the Meuse, and to give this last river a separate outfall, by reopening the ancient mouth passing by Geertruidenberg; and to close the creeks and channels of the Biesbosch, so as to lead all

the water of the Waal through the Merwede to Dordrecht. These gigantic schemes were open to the objection of their great costliness (60,000,000 florins), and that though the low polders on both sides of the Leck would in future be free from inundations, the whole of Holland would in dry summers be without fresh water. The danger of icedams on the Waal, and of floods and inundations in the Alblässerwaard and other low polders, would not be obviated, and it was thought North Brabant would not be sufficiently relieved from periodical floods.

The Royal Commission, after taking evidence, suggested a series of improvements, adopting some of the propositions mentioned. They favoured :

1st. An overflow between leading dams from Lobith, through the Old Rhine bed and past Zevenaar, to Lathum above Doesborgh, cutting through a number of sharp bends in the Yssel, clearing the foreshores on both sides of obstructions, and giving it a new and roomy outfall past Kampen to the Zuiderzee.

2nd. A side discharge, or "green river," from Weurt, below Nijmegen on the Waal, to Appeltern on the Meuse, and across this river and the North Brabant polders to Baardwijk.

3rd. A discharge from the Leck by means of sluices in the Grebbedyke below Wageningen, and past Amersfoort to the Zuiderzee.

4th. The strengthening of the North Leck dykes from Amerongen to Schoonhoven, raising them higher than those opposite the river, and to allow floods to flow across the Betuwe, above the Dief dyke, and across the Linge dykes into the Merwede, at Dalem, near Gorinchem.

5th. A similar arrangement for discharging flood water during dangerous spates from the Merwede across the Altena polders to the Hollandsch Diep, near Geertruidenberg.

6th. The formation of a new channel across the Biesbosch.

The Commission also recommended that the law of 1806, for the better superintendence and maintenance of the rivers, should be strictly enforced; and they estimated the total cost of their propositions at 18,250,000 florins.

Against the views expressed by this Royal Commission it was contended that, according to observations, the bed of the rivers had not been raised during the last eighty years, and that floods did not rise higher than before. The proposed green rivers, and the lowering of the Betuwe dykes, were much deprecated, and the sum to be expended was thought excessive. Nothing was done, and a second Royal Commission was appointed in 1828. Wars and troubles

intervened, and the report was not published before 1849. Except as to the overflow of Weurt and of Altena, which were thought unnecessary, the second commission seconded the propositions of their predecessors, but reduced their estimate to 12,000,000 florins.

In the mean time some improvements had been carried out; the Beersche Meuse, or overflow from Grave to Baardwijck, had been cleared, so that flood water was got rid of in a shorter time than previously, and the North Leck dykes had been brought into a better state. At last, in 1850, a valuable report was made on the subject by two eminent Government engineers, the late Messrs. Ferrand and Van der Kun, containing numerous suggestions; which have all been followed, and that able advice still directs the system of improvements. They proposed that the rivers should be brought everywhere as far as possible to a regular channel and definite widths, that narrow places should be widened, and wide side-bays filled up, and the stream led into a regular channel by groynes and parallel dams.

They also recommended :

1st. The making of a new mouth for the Waal and Merwede across the Biesbosch and Bergsche Veld, and the improvement of the Merwede to Dordrecht by dredging and groyning.

2nd. To regulate the overflow and channel near St. Andries.

3rd. To regulate the Leck below Culenborg by groynes.

4th. To strengthen some weak parts in the Leck dykes, and to cut off a sharp bend in the Leck above Wijck, the so-called Roodvoet.

5th. To raise refuge mounds in districts liable to inundation, particularly the Betuwe above the Dief dyke, which it might in some cases be necessary to flood in order to save the low-lying polders north of the Leck; and

6th. To improve the Yssel.

They were of opinion that with a yearly expenditure of 200,000 florins these works might be brought to a close within a reasonable time. On their advice also, the staff of the Netherlands' Waterstaat was much strengthened; and it is mainly to the able and untiring efforts of this eminent corps of Government engineers, and to the soundness of the views expressed by Ferrand and Van der Kun, as proved by the experience of the last twenty-eight years, that the country owes its immunity from dangers and calamities like those of the previous period.

It may be of interest to notice the river work in the Netherlands during the last quarter of a century, and the results obtained, without going into minute details.

THE MERWEDE.

The key of the situation was the Bergsche Veld, or Bieschbosch. How to make a roomy waterway through this group of islands, at a moderate cost, was the first problem to be solved.

Anterior to 1421 the Bergsche Veld formed part of an island called the Great South Holland Waard, between the different branches and estuaries of the Waal and Meuse, covering an area of about 44,000 hectares. Its boundaries were, on the north the Merwede, on the west the inlets of the North Sea called the Meeren, on the south the high moorlands of Brabant, and on the east the Meuse. Before 870 another branch of the Meuse flowed through the island, but had silted up, and had then been dammed off and poldered. The soil consisted partly of clay and river deposit, and partly (this principally on the south side) of low peat bogs. The surface cannot have been lower than low-water mark, or about A.P., as the whole island being enclosed in one ring dyke depended for drainage on the ebb. In 1421 no mechanical means were known for raising water; only sluices existed, and there is evidence of many locks having been built in Holland before 1315.

The peat fens, however, were probably a good deal lower, having been dug for turf, as proved by documents of 1313, 1403, and 1409, in which the Counts of Holland granted licenses thereto; and of 1382 and 1404, by which it was forbidden to excavate too near the dykes, for fear of damage. These dykes certainly existed in 1374, and probably long before, as in that and following years contracts were made between different landowners to assist each other with men, ships, and materials, in case of breaches. These contracts also refer to inundations having previously flooded the whole island, the dykes having been carried away, and much mischief done.

At midnight on the 18th of November, 1421, during a heavy north-west gale and spring tide, the dykes succumbed in two places—one on the north, on the Waal, still called the Oude Wiel; the other in the sea dyke near the Meeren, on the south side, which had been strengthened about ten years before. Thus the sea water was let in, and during that single night the site of a well-cultivated and prosperous island was turned into a lake, drowning more than 100,000 inhabitants, and destroying seventy-two villages, of which thirty-seven were lost for ever.

The Waal and Meuse cut a deep channel through this submerged land to the Meeren and the sea. Attempts to close these breaches,

and to re-drain the flooded land, were made in vain during the following years; but soon after the calamity the eastern and western parts—the land near Heusden and Strijen, being probably the highest, and therefore least submerged—formed into separate polders. In 1620 other tracts were reclaimed, and in that year the island of Dordrecht was partly embanked again. Other portions also again became shoal and dry in patches, forming low, reedy islands; this occurred, however, but slowly, and principally on the north side, near the Merwede bank, near Dordrecht, and north of the island.

This new channel having shortened the course of the Rhine to the sea by one-third, the Waal began to draw more water than the Lower Rhine, and soon became the principal branch, to the great detriment of the mercantile towns on the Lower Rhine and Leck, though part of the Waal water seems still to have flowed through the old bed to Dordrecht, and through the New Meuse past Rotterdam to Brielle.

For about a century and a half the situation remained unaltered. In 1565 the inhabitants of Dordrecht and Rotterdam found the waterways deteriorating; and, as in the mean time more islands had been formed, they wanted to close the creeks between them, to direct a greater volume of water along the Merwede and the New Meuse. This was partly done, with the approval of the Regent, Margaret of Parma; but the inhabitants of Gorinchem and of the Alblasserwaard and Altena polders objected, as the closing of these creeks would have raised the surface of the river, and endangered the dykes. In consequence, they again destroyed what the Dordrecht and Rotterdam people had done, and maintained an armed vessel in the Merwede to prevent anything of this kind being carried out in future. As more land became dry, it was leased, on condition of planting it with willows and reeds, to augment the silting-up; in consequence of which, about 1725, the water only flowed through the Bergsche Veld in numerous narrow creeks, which still drew away so much water that the fairways to the west were incommoded. The merchants of Rotterdam complained that the bar at Brielle was so shoal that where, in 1700, the largest men-of-war could float, there was then only about 4 feet depth of water at low tides. An ineffectual attempt was made in 1726 to dam these creeks on the Bergsche Veld, and another trial failed in 1738. In the former year it had been proposed to shut off all the creeks by a low embankment, so as to allow water to escape over it when the water rose above a certain level; and this had been partially constructed, when it

was destroyed by ice and high water during the following winter.

A similar accident happened to a dam across the Bassekill, made in 1752, and to the other creeks in 1770. In 1805 and 1806 the attempt succeeded, but, not being properly maintained, the embankment had not the expected effect, and was soon ruined.

Ultimately the inspectors of the Waterstaat, Ferrand and Van der Kun, proposed to combine the two interests, improving the fairway to Dordrecht and Rotterdam through the Merwede, and giving a free discharge to the Waal, which below Woudrichem has a maximum volume of 9,600 cubic mètres if the Rhine and Meuse are simultaneously at their highest level, namely, the Waal discharging 7,000 cubic mètres, and the Meuse 2,600 cubic mètres, per second. This was to be effected by clearing the course of the old river of banks and shoals, and by forming a single channel through the Bergsche Veld wide enough to carry the whole of the water of the Waal in case of need, but only about two-thirds of it in summer, the other third to be given to the Merwede and the Leck through the Noord.

This judicious advice was followed, and in 1851 the work was started. The system pursued was, first, to throw out groynes from the up-river bank at the entrance of the creeks, abstracting the water from the Merwede; the groynes, pointing into the old river and down stream, turned the current off the creeks, and led it back to the Merwede. This river, and the Noord, were at the same time regulated by parallel dams and groynes, to obtain a better scour, and some shoals were dredged away. It was decided to form the new channel through the most important creek, called the Westkil, leaving the Merwede at an angle of about 45° in a south-west direction, then curving west, south, and south-west again, and falling into the Hollandsch Diep through the Deeneplaat. It was to be 400 mètres wide, 3.5 mètres deep below A.P. at the upper, and 4.4 mètres below A.P. at the lower end, with a foreshore on each side of 300 mètres, and a length along the centre line of 17.750 kilomètrés. The width was afterwards increased to 500 mètres at the upper end, and 600 mètres at the mouth.

In 1852 low fascine dams, or sills, were laid at the mouth of the creeks along the Merwede, and head dams made at the inflow of the Westkil, leaving the proposed opening for the new channels. At the same time the higher parts of the islands, mostly near the Merwede, and what remained of the old dykes and dams of former works, were lowered to 1 mètre above summer level, and the earth was used for strengthening the dams in the creeks, so as to allow

the Waal to discharge over the whole Bergsche Veld when high, diminishing the current in the creeks and removing the pressure on the dykes of the Alblasserwaard and Altena polders. In 1853 the closing dams were laid down in a number of less important creeks, and those in the Bakkerskil and Steurgat were raised higher, and strengthened with earth from the adjoining islands and from those in the new channel, which were excavated to low-water point. This work went on for some years, as also the strengthening of the adjoining dykes of the Anna Pauwlowna polder, and the island of Dordrecht. The new channel had to be carefully watched, encroachments outside its proper course prevented, and damage repaired in the closing dams. In consequence of the diminished waterway, the mean river level was heightened near Gorinchem. In 1858, at the mouth of the Steenenhoek canal, it was 0·43 mètre higher than in 1848, to some degree diminishing the drainage of an area of 70,000 hectares Linge polders; and a steam-engine of 125 HP., which was finished in 1864, was erected to assist the discharge. In 1859, the whole channel having been completed to low-water mark, a gullet was dug along the centre line on the Deeneplaat and other islands lying in the way at its lower end, and training dams were laid parallel to the centre line 1,000 mètres apart, which much assisted the scour. This increased so much, that in 1862 a steam dredger of 25 HP. was put on, and in 1863 another, but smaller one, of 12 HP.; two more dredgers were added in 1864, and again two in 1866. The mud was carried into the adjoining creeks by ten iron scows and two 20 HP. tugs. As the capacity of the new channel increased, and the fairway in the old rivers improved, dykes were laid along the south bank of the Old Merwede, first only with their formation level at + 1·70 mètre to + 2·40 mètres A.P., and the leading dykes extended to the lower end of the new channel. In these years considerable repairs were needed, particularly by the dams in the Bakkerskil and Steurkil, which, owing to their depth and a sandy or boggy subsoil, were severely damaged at nearly every high flood. The same was the case with the new leading dykes, which were not yet consolidated. In September 1861, of the 1,200 cubic mètres of water per second which passed Gorinchem (the river being at 1 mètre below mean summer level), 370 cubic mètres flowed through the Old Merwede, 640 cubic mètres into the new channel, and 196 cubic mètres through the Steurgat. The dam in this creek was again washed away in January 1862, and had to be relaid; but the new channel had obtained a depth below low-water mark of 2·50 mètres. At last, in 1864, the dams in the

Steurkil and Bakkerskil, and the dykes to the south of the Merwede on that side could be raised to a height of + 4 mètres A.P. In this year, of the whole volume of the undivided Merwede at mean river height, 42 per cent. flowed on to Dordrecht, and 58 per cent. passed down the new channel. In 1800, the old Merwede only carried to Dordrecht 9 per cent., and in 1822 only 18 per cent., the rest being absorbed by the creeks. The creeks having been filled in, closed, or silted up, locks and sluices had to be constructed for the drainage of the adjoining old lands, and for navigation. A lock, 40 mètres between the gate, 7 mètres wide, and the sill at - 1·50 mètre A.P., was built at the Bakengat; also one at the Helsloot, and another at the Kikvorschkil, 43 mètres long between the gates, 7·30 mètres wide, and the sill at - 2 mètres A.P.

In 1869 the minimum depth in the fairway of the new channel was 3 mètres at the upper, and 4 mètres at the lower end, and the channel was widened to 450 mètres at the Merwede inflow, 500 mètres midway near Dordrecht island, and 600 mètres on the Deeneplaat in the Hollandsch Diep. The groynes laid before the creek mouths were cleared away as the closing dams became trustworthy, the Merwede bank was then regulated by parallel works, and the river cleared of several islands and bars by dredging.

In 1871, steamers drawing 3·10 mètres of water could pass up the new channel, and traders from Rotterdam to the Meuse, Waal, and Upper Rhine adopted this new route, preferring it to the old one along the Merwede, which had a depth of only 2·40 mètres.

The mean water-level at Gorinchem had also fallen 0·32 mètre since 1856, indicating the benefit derived by the Waal from its new mouth. Dredging still went on, often under great difficulty from the snags and old trees imbedded at the depth of - 4 mètres A.P., which had been reached by this time. Great attention, too, had to be paid to the new works, and repairs went on incessantly. After 1867 it became possible to contract for the current maintenance, which had been previously impossible. In 1875 the new channel was practically completed, though the cost of repairs is still heavy and constitutes a large portion of the total expenditure.

All the work, except some locks and sluices, was fascine work, earth and boulders, no other material being resorted to. The dams below water were raised by consecutive layers of "sinkstukken," or fascine mattresses. The total quantity of soil dredged between 1862-1875 from the Merwede and the new channel, now called the New Merwede, was a little more than 5,800,000 cubic mètres, at

a total cost of 1,689,586 florins, or at about 0·333 florin per cubic mètre. The amount spent on these works from 1851 to 1875 was—

	florins.
For indemnities and expropriation	637,334
„ repairs and maintenance	1,804,323
And for new works proper.	5,020,841
	<hr/>
Being a total of	<u>7,462,498</u>

WORKS ON THE UPPER RHINE AND WAAL.

After the inundations of the Zuid Hollandsche Waard, in 1421, the Waal gradually became the principal branch of the Rhine, carrying to the sea two-thirds of the total volume of water, and at times even more. On both sides of the river the surface of the polder land is considerably below flood level, except for a short distance on the left bank, at the ancient city of Nijmegen, where the stream cuts into a spur of the Cleve hills, on which the city is built. In preceding centuries many improvements had been effected by straightening and deepening the river, but these works being local, and without reference to a general plan, left much to be done. Ferrand and Van der Kun had indicated the proper course to be pursued, and proposed to regulate the widths of the river in the following manner:—

The summer bed to have a width of 400 mètres for the undivided Upper Rhine to Pannerden; of 360 mètres from the division to Bommel; of 360 mètres from Bommel, widening to 400 mètres at Loevesteijn; of 600 mètres from Loevesteijn for the united Waal and Meuse, called the Merwede, to the mouth of the new channel across the Bergsche Veld, which was to be 500 mètres wide; and the bandykes of the polders on each side, to be 100 mètres apart. Narrow parts were to be widened; wide reaches to be narrowed by groyes and parallel dams, and the current to be confined as much as possible to a single channel.

In 1851, a beginning was made with the new system. The Upper Rhine, between Lobith and Pannerden, had remained in a satisfactory state since the improvements of 1771. Here, in the period from 1851–1875, repairs only were necessary, and the dykes near Spijk were strengthened by fascines and groyes.

Before a definite plan was adopted, it was found advisable to settle the question of the St. Andries channel. Near this place the Waal and Meuse flow parallel to each other for a distance of 6 kilo-mètres, on an average only 600 mètres apart, separated by a low isthmus about + 6 mètres A.P. This isthmus had, in 1599, been

cut through for military purposes, and three channels existed by which much of the Waal was discharged into the Meuse. During floods in winter and spring, when the height of the Waal exceeded + 6.50 mètres A.P., the river flowed across the whole width of 6 kilomètres between Heerewaarden and Rossum. The three channels drawing too much water from the Waal, and this river shoaling, in 1728 two openings—one above Heerewaarden and one near Vuren—were closed; but the lower channel, near the fort of St. Andries, was allowed to remain for navigation. The channel having widened, and in 1830 having shown a tendency to discharge all the water of the Waal into the Meuse, an attempt was made in 1837 and 1838 to prevent it by laying down a groyne at the northern entrance, though without much effect on the fairway of the Waal. It was difficult to improve this reach below the channel, as, when the Meuse was the higher of the two rivers, water flowed into the Waal, and made the problem complex as long as the channel remained open. But it was thought imprudent to close the channel altogether before a better outlet had been given to the Waal across the Bergsche Veld, and in 1851 it was reduced again by another groyne. As the clearing on the Biesbosch proceeded, a commencement was made in 1853, by raising a fascine ring-dam westward of the channel, and laying down in it the concrete foundation for a lock, which was finished in 1855. The dimensions of the lock are: sill on the side of the Waal, 3 mètres below mean river level, or + 0.85 mètre A.P.; on the side of the Meuse, + 0.35 mètre A.P.; extreme width, 8 mètres, and length between the gates, 90.50 mètres; top of the walls, + 9.75 mètres A.P., and of the gates, + 7.75 mètres A.P. There are four pairs of gates, two in each direction, so as to lock either way. When the river rises above + 7 mètres A.P., the lock is closed by "schot-balks," piled in grooves in front of the gates. The lock is amply sufficient for the passage of the largest ships navigating the Meuse. Immediately after opening the lock for traffic, the old channel was closed, in March 1856, by a dam 350 mètres long between the lock and the old fort of St. Andries, advantage having been taken of a propitious moment in respect to the levels of the two rivers, and it was raised to a height of + 8.25 mètres A.P. The total cost of this work, with entrance passages on both sides, and closing the dam in the old channel, was 367,285 florins. The overflow across the grounds of Dreumel and Heerewaarden, between the west dyke of the Dreumel polder and the old St. Andries fort retained a width of about 3,500 mètres, with a minimum elevation of + 6.95 mètres A.P.; and

there is another width of about 1,130 mètres between the new lock and the Rossum dyke, which begins to be covered when the river is at + 6.60 mètres A.P., or about 2.54 mètres above mean level.

About the same time the dyke of the Erlecom polder, on the left bank above Nijmegen, gave much trouble. At this point the Waal impinges on the shore, and scours a pool of more than 10 mètres depth below mean river-level, with its deepest gullet parallel to, and only 20 to 40 mètres away from, the toe of the dyke. Frequent slips occurred; the dyke was breached repeatedly, and the polders behind it flooded. The fairway being so near, no groynes could be projected from the bank, and it was only possible to defend this section by strengthening the dyke, principally below water, by a "bleeslaag." Some work was done in 1851, but the proprietors of the polder not being financially able to go on with the work, the Government, in 1862, put down "sinkstuks" of 3,900 and 600 square mètres over a length of 150 mètres, 200 mètres of "beslag," and 600 tons of basalt ballast, for 13,600 florins; in 1863, 3,600 square mètres of "sinkstuks" were sunk on a length of 120 mètres, with 600 tons of basalt, for 9,800 florins; in 1864, 125 mètres by 30 mètres of "sinkstuk," with 600 tons of stone, for 9,488 florins; and 195 mètres by 30 mètres of "sinkstuk," with 600 tons of stone, for 10,500 florins, in 1865. The next year 340 mètres by 20 mètres of "sinkstuk" were deposited, with 800 tons of stone, and 340 tons of brick ballast, for 13,885 florins; in 1867, 230 mètres by 30 mètres of "sinkstuk," 600 tons of stone, and 230 tons of brick, for 9,946 florins. In 1868, further to defend this work, two perpendicular groynes were laid down from the fore-shore of the Keckerdom polder, 142 mètres and 168 mètres in length, at distances of 920 mètres and 670 mètres above the upper end, at a cost of 13,900 florins. In 1869, 7,777 florins were spent in repairs, and a third groyne, 272 mètres long, was laid 220 mètres below the lower groyne of 1868, with a "sinkstuk" in continuation on the river bottom 75 mètres by 15 mètres wide, with 800 tons of basalt and 300 tons of brick, to prevent excessive scour along the head; this cost 12,786 florins. In 1870, a fourth groyne, 310 mètres long, was put down, 220 mètres below the groyne of 1869, and 50 mètres by 15 mètres of "sinkstuk" in continuation, with 750 tons of basalt, and 150 tons of brick, for 18,852 florins. In 1871, two groynes, 250 mètres and 500 mètres below the groyne of 1870, and 182 mètres and 100 mètres long respectively, and 1,200 square mètres of "sinkstuk," with 600 tons of ballast stone, and 400 tons of bricks, were deposited for 27,580 florins. All these groynes, with their ends 0.14 mètré above mean river-level,

rise 1 in 200 to their junction with the shore, and are 3 mètres wide on the top. In 1875 a further length of 100 mètres was protected with 600 square mètres and 1,000 square mètres of "sinkstuk," a "pakwerk" of 223 mètres, with 500 tons of stone, and 370 tons of brick ballast, for 7,900 florins. Up to 1875, 33,095 square mètres of "sinkstuk," 6,450 tons of stone ballast, and 1,790 tons of brick waste, had been used, forming a fascine defence 1,680 mètres long, for 148,407 florins, including five groynes of from 100 to 310 mètres long.

Below Erlecom, on the right bank, between that place and the city of Nijmegen, in the bend at Groenendaal, a cape projected into the river, forming a narrow. More than two centuries ago the river curved much further to the north than at present, but in 1654 the bend had been cut off by a channel 1,130 mètres long. The old bed had gradually silted up, and, assisted by willow plantations, and landings for a brickfield and kilns, the bank at last encroached on the river at its upper angle. Between the years 1857 and 1868 this obstruction was cleared away by lowering the surface to low-water level, and then intersecting it by ditches to help the scour, after having first closed the old bend with a summer quay, with its top about + 12·80 mètres A.P., or 1·30 mètre above the surrounding ground. Some dredging had to be resorted to for obtaining a depth of 3 mètres below mean water-level, as stiff clay, mixed with brick waste, was met with, resisting the action of the current. This work, including 460 mètres length of summer quay, with a "bleslaag," parallel and 50 mètres in front of it, 500 mètres long, and indemnities to the amount of 23,594 florins for kilns and rather more than 3·80 hectares of ground, cost 73,867 florins.

The Waal between Pannerden and Nijmegen having three tortuous bends, it has been proposed to give it a new direction, either by cutting across the left bank from the Erlecom dyke to above Nijmegen, through the Ooij polder and the lands of Ubbergen, or by a new channel on the right bank to the north of the village of Lent, over the grounds of Elst. But the Ubbergen scheme would be too costly, necessitating a deep cutting through high ground, 4,000 mètres long; the other, though less expensive, would take the river away from the city of Nijmegen; and plans for the improvement of these reaches are for the present in abeyance.

At Nijmegen the river quay for some years showed signs of subsidence, partly caused by a deep pool being scoured in front, and partly by spring water from the higher ground behind. A

“bleslaag” has been sunk in front along the quay wall, with a heavy covering of *pierre perdue* of basalt boulders, and holes have been drilled through the quay wall to drain the springs. Groynes are now being laid down in the bend above the city, to keep the current away from the wall. This work, which is still in progress, has so far been successful.

In addition to embankments for approaches to the railway bridges across the river below Nijmegen, made in 1876, and another similar work above the city of Bommel, made in 1865 and 1866, and the partial clearing away of small islands at Herwijnen, and near Ewijk, the works executed between 1851 and 1875, on the Upper Rhine and Waal, consisted of numerous groynes, parallel works, and dredging operations along the whole length of the river, which have already had a considerable influence on its carrying power and navigation, the minimum depth of water under mean river-level, between Emmerick and Gorinchem, being at present 3·05 mètres. These works are still being proceeded with. In many places the bandykes on both sides have been strengthened and raised, principally at the expense of the riverside owners; and several refuge mounds have been made in the lower districts, at Wamel, Kerkwijck, Brachem, Delwijnen, Heerewaarden, Apeltern, and Dreumel. These have an elevation on the top of about 1 mètre above highest known river-level.

THE MEUSE.

The Meuse is a tributary of the Waal. Its channel is tortuous and unequal; the direct distance between the towns of Grave and Woudrichem being about 56 kilomètres, whilst its length along the fairway exceeds 90 kilomètres, consisting of a great number of deep pools, divided by sills and shoals with a depth of only about 1·70 mètre, which render navigation impossible in dry seasons. The Meuse enters the delta near the village of Cuijk, 12 kilomètres above Grave, with a volume of water in summer of 170 cubic mètres per second. In winter and spring this volume is increased to 3,800 cubic mètres per second at Maastricht, and the river is then in a chronic state of overflowing, losing a large quantity of water over two lowered dyke lengths in the left bank below Cuijk, of 800 and 4,200 mètres in width respectively, with the tops at + 10·19 mètres A.P. This inundation water skirts the high ground of Ravenstein, and flows westwards across the Groenedijk (top at + 6·35 mètres A.P.) between this and the left Meuse dykes. The river near Lith and Alem receives water from the Waal across

the low grounds near Heerwaarden during floods in this branch of the Rhine; also from the accidental inundation water from the Meuse, and Waal, and Nijmegen polders, over the so-called Dreumel overflows, being two low lengths of dyke in the North Meuse bank (tops at + 7.49 mètres and + 6.95 mètres A.P.) at Alphen; which again raise its level, so that at Bokhoven, between Crève-cœur and Hedikhuijzen, it flows over its left dyke through two openings of 600 mètres each (tops at 3.80 and 4.10 mètres). This flood water flows south, joining that from Cuijk, and, turning westward, discharges into the low Lang-straat meadows, over a weir near Baardwijck, then past the town of Geertruidenberg and through the Amer creek into the Hollandsch Diep, thus inundating, nearly every year, a large part of the province of North Brabant. The main river flows on to meet the Waal at Woudrichem, where it discharges comparatively but little water into this branch, which is at such times brimfull. Usually the Waal is at a higher level than the Meuse near Heerwaarden and at St. Andries, particularly during floods, and in spring. Before the St. Andries channel was closed, the Meuse used sometimes to discharge water into the Waal in summer. To close this side discharge from the Waal at Heerwaarden would endanger the dykes of all the polders further down, and it constitutes the great difficulty in improving the Meuse. The fall in this river is much less than that in its neighbour, the mean river-level at Grave being + 4.09 mètres A.P., at Woudrichem + 1.45 mètrè A.P., and at Nijmegen + 8.47 mètres A.P.; the fall from Nijmegen to Woudrichem is 7.02 mètres in about 65 kilomètres, and that from Grave to Woudrichem only 2.64 mètres in 90 kilomètres. The average fall on the Waal is 1 in 9,285, and that on the Meuse 1 in 34,190, or about a third of that in the Waal. Many plans have been suggested to remove the anomaly. In 1827 the ground was cleared of obstructions from Grave to the Dieze; locks were built on the right bank of the river, and the dyke on the left bank was lowered in several places so as to form an overflow to Baardwijck. This last weir was also widened at that time from 622 to 1,022 mètres. But even when covered with water to a depth of 1.15 mètrè, it only discharges about 1,400 cubic mètres per second; whereas about 2,500 cubic mètres are calculated to flow into the Meuse across the overflow at Heerwaarden, with a fall of 0.10 mètrè, and 2 mètres depth, as is not unusual during high water, and when obstructed by ice. The Meuse does not discharge all this excess of water at Woudrichem, where the current is sometimes very slight; and the remainder is temporarily stored

on the low ground near Bois-le-Duc, often flooding the district to a great depth.

Since 1851 much has been done, by groynes, parallel works, and dredging, to improve the summer bed of the river; the closing of the St. Andries channel by a lock has also had a good effect on the reaches below this point. Between 1858–1860 the mouth of the Dieze was also closed with a lock and improved, at a cost of 268,065 florins. This lock serves the double purpose of defending Bois-le-Duc from the Meuse water, and of assisting the navigation of the Dieze in dry seasons.

The only efficacious remedy against floods would be to reopen the old mouth of the Meuse which joined the Hollandsch Diep to the south of the Altena polders near Geertruidenberg, but which has since silted up. There is still a creek in that direction called the Little Meuse. General Kraayenhoff proposed in 1823 to open up the river from near Well, south of the town of Heusden, and to lead it into this creek; to widen the channel so that it should be capable of carrying all the water of the river, including the flood water; to enlarge the reaches to the same dimensions between St. Andries and the new mouth; and to close the present river to Woudrichem by a lock below the entrance to the proposed channel. The overflow at Bokhoven could then be shut off, and the water from the Beersche Meuse would cease to flow across the Dieze. The advantage of this plan was the better fall which it would give to the river. The mean low tide at Woudrichem is at present + 2 mètres A.P., that at Keizersveer, - 0.52 mètre A.P., giving a better fall of 2.52 mètres. High water at Woudrichem reaches + 2.22 mètres A.P., at Keizersveer + 1.32 mètre A.P., giving at high water an increased fall of 0.90 mètre. The new channel would have a length of only 21,000 mètres, whereas the length of the present course of the Meuse past Woudrichem and of the New Merwede to the sea is 45,000 mètres. By abstracting so much water from the Waal over the Heerewaard overflow, the flood level at Gorinchem would be lowered by about 0.40 to 0.50 mètre. At such a time the Meuse at St. Andries, reaching a level of + 8.77 mètres A.P., as on the 12th of February, 1871, and taking mean sea level at Keizersveer at + 0.40 mètre A.P., would give a fall of 1 in 3,570, as compared with 1 in 34,190 at present. This also would undoubtedly have a good influence on the Meuse above St. Andries, the tidal wave would then probably come up the river as far as Lith. The whole river would be so improved that the weirs at Cuijk might be closed. The inspectors of the Waterstaat, Van der Kun, Fijnje and Conrad, again strongly recommended this

scheme, and estimated the total cost at 4,000,000 florins in eight years; but the work has not yet been taken in hand.

LOWER RHINE AND LECK.

The Lower Rhine leaves the Upper Rhine at Pannderden, where it separates from the Waal, and takes, in theory, one-third of the volume of water. In the years immediately following their completion, the works proposed in 1771 seem to have answered very well; but latterly the quantity of water in the Lower Rhine has fallen off slightly, owing to a hard and ever-returning gravel bank in the mouth of the Pannderden canal. At mean river-level the Waal sometimes takes seven-ninths of the total volume instead of its proper share of six-ninths. When, however, the Rhine rises over + 13.50 mètres A.P. at Lobith, or 2.38 mètres above mean river-level, the weir in the north bank in the mouth of the Old Rhine branch begins to be overflowed, and when the river is 3 mètres above mean level, the proper ratio is restored. In very high floods, like that of the 31st of January, 1861, with the river at 16.91 mètres at Lobith, or 5.80 mètres above mean level, the Lower Rhine receives too large a proportion of water. Such floods rarely last long, and the overflow is usually from 0.20 to 0.50 mètre in depth. The Old Rhine began to silt up soon after the opening of the Bijlandsche canal, but at the instance of the Cleve Government it was not embanked; and in 1745 only a weir was laid, 264 mètres long, which in 1771 was lengthened to 339 mètres, and it was decided that the height should not exceed 11.98 mètres. Formerly the water escaped to the Yssel across another weir in the north bank, near Oud Zevenaar, across the Lijmers district. Being of great inconvenience to this polder, the Lijmers weir was raised in 1851 to + 15.91 mètres A.P., and in 1860 still further to + 16.31 mètres A.P., or bandyke height; all the water entering at Lobith now flows back into the Lower Rhine near the village of Candia, below the Pannderdsche canal. Of the total volume the Yssel takes a little less than one-half, instead of one-third, although the works at Westervoort have been kept in good repair since their construction, in 1777. At low water, navigation is difficult for ships drawing more than 1.80 mètre.

In the period from 1851-1875 numerous groynes and parallel dams were laid down on the whole length of the river in order to obtain for it definite breadths. These breadths are 170 mètres from Pannderden to Westervoort; 150 mètres from Westervoort to Wijk bij Duurstede; from thence widening to 170 mètres at Vianen, where

the tide begins to be felt, and again to 200 mètres near Krimpen at the junction of the Lower Rhine with the Noord.

The principal improvements are: 1st, at Malburgen above Arnhem, where the fairway had been crooked and shallow; 2nd, in a bend above Wageningen, where the river was encroaching on the right bank; 3rd, near Jaarsveld, where a low island was united to the right bank, closing the intervening channel by a dam; 4th, the cutting through a troublesome double bend called the Roodvoet, above Wijk bij Duurstede, which was a source of danger to the dykes, by icedams settling in it. At this spot, in 1867, the summer quay enclosing this peninsula was set back on the right bank, and old groynes and other works in the way of the projected channel were removed. In 1868 a summer quay was laid on the left bank parallel with that on the right bank, and a ditch was excavated 30 mètres wide and 1·60 mètre below mean river-level. In the following year this ditch was widened from its central line to 90 mètres for the full length of the cutting, and to a depth of 1·60 mètre below mean river-level, leaving a dam of about 20 mètres wide at the higher end, with a centre cutting 1 mètre deeper. In 1870 the groynes and parallel works above and below the proposed channel were altered and prepared for the new direction of the current; and in the winter of 1870–1871, an ice-dam having formed in the old bend, the strip of ground at the upper end, having been excavated to a width of about 3 mètres, gave way to a head of 1·50 mètre between the river-levels above and below. The new channel was now speedily scoured wider by the current, and the old bend was closed, at first with low parallel dams, which were raised to 2 mètres above mean river-level in the next year. Some dredging was also necessary to clear away a stiff clay stratum above the sandy subsoil, which resisted the scour. In 1874 the left bank was further adjusted, to bring the channel to the normal width of 150 mètres; the groynes above and below the new channel were finished, and the banks on both sides were protected by fascine work. The depth of water in that year was from 4 to 5 mètres below mean river-level. The total cost of this work amounted to 395,761 florins, including 91,077 florins for land and compensation. Although the depth of water in the Nether Rhine has not augmented generally of late, some very shoal places have been improved, and the fairway has become much more regular as regards direction, width, and depth.

Besides these hydraulic works, the dykes, particularly those on the north bank, were raised and strengthened considerably. In the winter of 1855 the south bank was breached by high water and ice

in five places opposite Rhenen—three breaches occurred near Lienden, one at Ingen, and one at Maurik—and a great part of the Lower Betuwe island was flooded; the damage was repaired soon afterwards for 149,617 florins. The Nodijk dyke, between Wageningen and Grebbe, was breached in the same winter; and water ran over the North Leck dykes, at Amerongen, to a depth of 0·60 to 0·50 mètre for a length of 115 mètres; at Veertiggarden, 0·15 mètre deep for a length of 2,100 mètres; at Schalkwijk, 0·30 mètre deep for a length of 1,680 mètres; and near Culenborg, 0·20 mètre deep for 1,125 mètres. The dykes on the Lower Rhine and Leck are interrupted by sandy highlands from Arnhem to Wageningen, and again from Grebbe to near Amerongen; and instead of the usual earthen dykes, brick walls exist at Wijk bij Duurstede, Schoonhoven, and Lekkerkerk. After the calamities of 1855 these dykes were raised, the Nodijk at Wageningen to + 12·65 mètres A.P., and that at Grebbe to + 12 mètres A.P., the width at top being 5 mètres, the slopes outside being 3 to 1, and inside 2 to 1. The dykes from Amerongen to Schoonhoven were carried up to 1·40 mètre above the highest known flood-level, their width at top being 5 mètres, and their slopes 2 to 1; while at some places, where the subsoil was unsound, the slopes were increased to 3 to 1. The dykes of Krimpenerwaard were also raised and strengthened. In places liable to “kwelwater,” or springs, ditches were sunk through the porous stratum down to a harder soil, and then filled with clay puddle. Where this could not conveniently be done, a second dyke was laid behind the existing bandyke, so as to confine the spring to its source, and all ditches and holes on the inside of the dykes, to some distance, were filled in. The sluices and locks in these dykes were also altered, to withstand the higher water. The dykes on the south bank of the island of Betuwe were raised and made level, and facilities given to discharge flood water from the polders towards the south into the Merwede. With this view, instead of the previously existing weirs at Dalem, above Gorinchen, two sluices were constructed in 1858 and 1859, with a united clear width of 36 mètres, and sill 2 mètres below the mean level of the Merwede. At Nieuwpoort the old town walls were raised to + 3 mètres A.P., so as to serve as a refuge in case of inundation; and the Diefdike,¹ a cross dyke defending the Alblasserwaard and Vijfleeerenlanden polders against flood water from the higher ground to the east, was considerably strengthened. In this way the dangers to the low lands near Veenendaal and Amersfoort

¹ Made in the twelfth century.

from a breach in the Grebbe dyke, and to the deep South Holland polders from breaches in the North Leck dykes, have been much diminished. The Lower Rhine and Leck are now in a sound and thoroughly good condition, and events of unprecedented magnitude only are likely to damage the works.

THE GELDERSCHE YSSEL.

The Geldersche Yssel is the smallest of the three mouths of the Rhine, and in theory only carries one-ninth of the total Upper Rhine water to the sea. This should be in summer and winter respectively 278 cubic mètres and 990 cubic mètres per second. At low-water level the quantity received by this river is much less; in 1809 it was only one twenty-fifth of the Upper Rhine, owing to deposits of sand at the junction with the Rhine at Westervoort. During floods a fair share is, however, obtained, and the mean river-level has even gradually risen since 1836, when the needle groyne at Pannerden underwent some repairs and slight alterations, to which this increase has been attributed. It is more probably due to the improvements in the fairway of the river, which are still actively going on. In the year 1865, for instance, sixty-six groynes, from 20 mètres to 56 mètres long, had been laid down in different spots along both banks.

The Yssel has a better fall than the two other branches, the total length along the fairway, from the junction at Westervoort to the mouth in the Zuiderzee being 126 kilomètres, with a fall at mean river-level of from + 8.99 mètres A.P. at Westervoort to + 0.44 mètre A.P. at the Zuiderzee, or 8.55 mètres, being equal to 0.068 mètre per kilomètre. Many plans have been brought forward to relieve the Rhine in this direction during floods and when ice floats down, particularly as the dykes are wide apart and high. In 1809 the north dyke of the Old Rhine, near the village of Oud-Zevenaar, had been lowered so as to give a passage to this river when flooded across the Lijmers district to the Yssel at Bingerden, where a similar lowering of the dyke had been effected. General Kraayenhoff and the two River Commissions had all advocated a cutting in this direction for a new channel. The weir at Oud-Zevenaar was totally breached and carried away by high water and ice in 1820. This ruined the whole Lijmers district. Again in 1850 the weir caused much inconvenience without being of much relief to the Rhine. Consequently it has now been raised to full bandyke height of + 16.31 mètres A.P. The Yssel receives three small rivers—at Doesborgh the Old Yssel, at Zutphen the

Berkel, and at Deventer the Schip Beek—which drain the high grounds to the east, and at Hattem the Grift, draining the Veluwe. None of these streams much increase the volume of the Yssel, except at times the Old Yssel, which intercepts the flood water when it breaches the North Rhine dyke near Emmerick or Rees, and discharges into the Yssel at Doesborgh, as happened on the 28th of February, 1838. After the closing of the Lijmers overflow the weir at Snippeling was raised. This had always been a point of contention. In ancient times the city of Deventer was situated on an island in the middle of the river, but the land to the east, becoming dry, had been poldered about the year 1300, by surrounding landowners, and a bank was laid down in 1358 between the city and the higher ground, as well as dykes to the east, to protect the polders of Zalland and the environs of Zwolle. This of course raised the level of the water during floods, to the inconvenience of the citizens of Deventer. The dyke was again raised in 1609, but was destroyed by the city in 1658; and though repeatedly repaired by the landowners, it was always breached by the drowned-out citizens, in order to obtain relief, during floods. In 1809 the maximum elevation had been fixed at + 6.60 mètres A.P., but in 1857 it was allowed to be raised to + 7.45 A.P., and in 1864 to + 9 mètres A.P., the main channel of the Yssel being considered by that time large enough for its volume of water. This result had been obtained by systematically regulating the width of the summer bed, bringing it to 100 mètres at Westervoort, 120 mètres at Deventer, 150 mètres at Katerveer, and 170 mètres from Kampen, to its mouth through the Keteldiep. The inspectors Ferrand and Van der Kun had also recommended, in 1850, that the five mouths of the Yssel should be reduced to one, with an outfall of sufficient capacity for the whole river. Several plans had been made on this subject, which also included the improvement of the waterway from the city of Zwolle to the sea. This ancient commercial city lies on the Zwarte Water, an old mouth of the Yssel, cut off from communication with the river by the gradual transformation of its north bank. In the fourteenth century a rudimentary canal had been made, to re-establish this navigation, which in 1809 was improved, widened, and deepened to - 1.80 mètre A.P. with two locks, one on the Yssel, with sills laid at 2.32 mètres A.P. on the Yssel, and one with the sill at - 2.05 mètres A.P. in the entrance near Zwolle, and a width of 6.04 mètres. For sea-going vessels this canal was too narrow, and they had to reach the sea by the Zwarte Water, between two jetties about 6,000 mètres long, ending in only 1.80 mètre depth of

water. Dredging and the construction of groynes had been going on for some time in this channel, but without much effect. In 1866 it was decided to deepen the canal of 1809 (the Willemsvaart) to $-2\cdot10$ mètres A.P., or by $0\cdot40$ mètre; to build a larger lock on the Yssel side; to deepen the Yssel to $-2\cdot75$ mètres A.P. from this point to near Katerveer; to replace the old bridge, erected in 1448, by a new bridge at Kampen, with an increased waterway; to close the Regter and Noorderdieps; and to lengthen the jetties at the mouth of the Keteldiep, from 2,950 to 3,750 mètres, so as to reach a depth of $2\cdot50$ mètres at their termination in the sea. All these works were commenced simultaneously in 1868, and successfully accomplished in 1873, by which a depth of more than 3 mètres of water has now been obtained from Zwolle to the sea, at mean low-water level. An overflow across the Dronthen polders, from above the city of Kampen to the west, still remains as a relief for high water and ice, and as a safeguard to the city.

The Ketelmouth had been chosen for its shortness—the Ganzendiep being about half as long again, and having two bends—and for its proximity to deep water and sheltered position, the island of Schokland, which lies to the north and north-west, breaking the force of the sea. Since 1873 the distance between the Ketel jetties has been increased from 70 to 100 mètres by relaying the northern dam 30 mètres farther outward. The lower reaches of the river and the fairway between the jetties need some dredging every year. The Ganzendiep remains as a shorter communication for small craft from Kampen to the polders lying to the north, and to the harbours on the Zuiderzee in the province of Friesland. By the lengthening of the Ketel jetties, and the quicker discharge of water down the improved bed of the Yssel, the mean summer level of the water at Kampen has risen since 1812, at high tide, from $+0\cdot29$ mètre A.P. to $+0\cdot43$ mètre A.P., and at low tide from $+0\cdot21$ mètre A.P. to $+0\cdot24$ mètre A.P.

THE ESTUARIES.

Between the main land of the province of South Holland on the north, and the coast of Flanders on the south, the Leek, the Waal, the Meuse, and the Scheldt reach the sea through a maze of channels and creeks forming a large number of islands and shoals. The direction of the currents in these channels depends on the flow and ebb of the tide, and in a smaller degree on the volume of water discharged by the rivers, and is therefore very irregular. The sea coast, which trends south-west and north-east, has the same character as all that part of the North Sea shore, and is a continua-

tion of the chain of sand dunes that borders it, only broken by wide gaps where the estuaries run inland. In the Roman period these dunes extended much farther to the west, it is said, forming a band from 40 to 60 kilomètres in width; but they have been scoured away by the currents of the coast, and deposited farther inland, shoaling what was formerly deep water, and enlarging existing islands. These islands were embanked to some extent in the ninth century; and regulations respecting them prove that the dykes must have been of great importance in the thirteenth century, as is also shown by a law of Zeeland passed in the year 1256. The channels have been subject to great changes for the last three hundred years; creeks and lagoons have become dry which were formerly navigable, thus destroying the shipping of many towns which were flourishing in the eighteenth century.

The changes caused by the inundation of 1421 on the upper rivers also had their effect on the lower reaches, particularly on those of the Leck and New Meuse.

The tide flows from the south, and the ebb returns to the south; high water occurs sixteen minutes later at the Hook of Holland than near Brouwershaven, and at Kimpen two hours and five minutes later than at Willemstad on the Hollandsch Diep, and the ebb two hours and eighteen minutes later. This has had a disturbing influence on the currents in the Noord, the Killen, and the Old Meuse, and has injured the navigation of the New Meuse.

Where King William III. entered the Meuse, at Brielle, in 1691, with his whole fleet, there were in 1732 only two narrow channels, with 3 mètres depth of water; and in 1748 fishing boats could with difficulty cross the bar. Two ferry dams near Dordrecht had done much harm, and rapid deterioration had been aided by reclaiming large tracts of foreshore, so that the surface covered by the water in the New Meuse, which had been 4,387 hectares in 1732, was only 2,959 hectares in 1850. Ships drawing more than 3 mètres could not enter at Brielle even at high water, and had to come up by way of Hellevoetsluis and Dordrecht, and ships drawing more than 5 mètres had to make for Brouwershaven, and thence through the Volkerak to Dordrecht. Both passages, with their uncertain currents and intricate fairways, were inconvenient. To benefit the towns on the Meuse, a canal was made in 1829 through the island of Voorne from Hellevoetsluis to the Meuse, 10,544 mètres long and 5·10 mètres deep, and locks of a width of 14 mètres were constructed. Other plans had been proposed, as, for instance, to construct a canal through the island of Goerée to the Brouwershavensche Gat. In the mean time improvements were effected in

all the above-mentioned branches and creeks. The Hollandsche Yssel was also canalised and deepened, and locks established above Gouda. The Noord and the Kielen were dredged, but were with difficulty kept at a depth of 4 mètres under low water.

In 1862 it was resolved to give a new mouth to the Meuse on the plans proposed by Mr. P. Caland, Inspector of the Waterstaat. The works were to consist of training the banks of the New Meuse from Krimpen to the width of 225 mètres, widening to 450 mètres at Vlaardingén, and of excavating the new mouth through the sand dunes to a width of 900 mètres between fascine jetties slightly bending southward, and ending in the sea at a depth of 7·50 mètres. Subsequent to 1858 some steps were taken in this direction between Rotterdam and the Scheur. In 1863 a small harbour of refuge was constructed on the sea coast near the proposed mouth, and the shore ends of the jetties were laid down. The next year the south dam was lengthened to 800 mètres. In 1865 an island near Delfshaven was united to the north bank, as had been another near Schiedam in 1856. The south jetty was lengthened to 1,000 mètres, that on the north to 500 mètres; and a gullet was excavated down to the bottom level along the centre line, 10 mètres wide at the bottom of the cutting. In 1866 a length of 200 mètres was added to the south, and of 300 mètres to the north jetty, and the gullet was excavated farther; the jetties in this and the following year were also strengthened by extra piling through the body of the fascine work and heavy stone pitching. In 1868 the north jetty was lengthened to 1,000 mètres, the canal further excavated and the tide admitted. In 1869 the old fairway through the Scheur was curtailed by groynes from both banks, and some dredging was done in the new channel; this deepened gradually by the scour to 1·90 mètré below low water in 1871, and the Scheur was closed by a dam about 0·40 mètré above low water. In the same year the north jetty was lengthened to 1,100 mètres. In 1872 the north jetty was lengthened to 1,460 mètres, the dam in the Scheur was raised to + 1·50 mètré A.P., or 0·60 mètré above high water, the depth in the new channel was increased to 3 mètres for a width of 500 mètres, and steamers drawing 3·20 mètres followed the new route. In 1873 the north jetty was lengthened to 1,800 mètres, and the dredging went on in the cutting. It was calculated that the new channel discharged 38,752,740 cubic mètres of water during ebb, and admitted 30,697,248 cubic mètres during the flow of the tide; the channel was also buoyed and lighted. In 1874 the north jetty was lengthened to 2,000 mètres, the south to 1,400 mètres; and in 1875

the latter was extended to 1,850 mètres ; and again to 2,300 mètres in 1877. The channel reached a depth of 3·95 mètres below low water, and ships drawing 5·70 mètres passed through it without difficulty. Dredging and widening went on in the mean time, and ships drawing 5·70 mètres now come up to Rotterdam without breaking cargo, as, for instance, the transatlantic steamer "P. Caland," of 4,000 tons. At present a commission is considering the advisability of further improving this waterway.

The docks at Rotterdam have been of late years much enlarged, and many important and interesting works have been constructed at that city.

The estuaries are still being improved, and every year some good result is obtained. The navigable channels admit ships of 6 mètres draught up to Rotterdam ; thence past Dordrecht to Gorinchem, through the Kil and the New Merwede, of 4 mètres. The fairway from Dordrecht to Brouwershaven is 5 to 6 mètres deep, the Old Meuse 4 mètres, and the Old Merwede 3 mètres. These are also the minimum depths along the Waal and Upper Rhine to Emmerick. In the Lower Rhine, Leek, and Yssel not more than 2 mètres depth of water can be calculated upon, except during floods.

The greatest danger to the island polders in the estuaries are rapid changes in the channels, and the currents scouring deep holes. When the bank is weakened in this way by a great depth of water approaching the dyke, it needs constant watching and heavy works, "sinkstukken" and stone pitching, to keep it from being undermined and washed out, taking the dyke with it, and thus opening the polder to the high tide. These so-called falls are frequent, and a source of considerable apprehension. The dykes are always carefully observed, and the submerged foreshores repeatedly sounded. The sea dykes on the islands are raised mostly to a height of + 4 mètres A.P., and in exposed situations are covered by heavy stone pitching in courses. The next great work to be taken in hand at the new mouth of the Meuse will be the better outfall of the Brabant Meuse.

The absence of calamities enjoyed by the country of late years is due in some measure to mild winters ; but the improvements of the defence works warrant the hope that great devastations will in future be avoided, although the inhabitants of this low-lying and boggy land will never be quite safe from dangerous inroads from the North Sea and the Rhine.

The Paper is accompanied by fifteen maps and sections, from which Plates 10, 11, and 12 have been prepared.

APPENDIX I.

NEW MERWEDE.

EXPENDITURE, 1851-1875.

Years.	Land and Compensation.	Repairs and Maintenance.	New Works.	Total.
	Florins.	Florins.	Florins.	Florins.
1855	..	49,364	69,955	119,319
1856	16,553	83,726	40,983	141,262
1857	..	56,824	63,800	120,624
1858	30,000	..	92,819	122,819
1859	12,759	8,789	162,663	184,211
1860	26,000	7,450	107,492	140,942
1861	17,993	30,849	147,787	196,629
1862	40,325	91,958	251,033	383,316
1863	8,857	45,478	181,455	235,790
1864	40,770	33,331	291,321	365,422
1865	22,664	69,811	289,034	381,509
1866	1,696	27,068	266,441	295,205
1867	67,264	141,573	208,837	417,674
1868	117,767	158,783	170,457	447,012
1869	64,988	123,562	425,976	614,526
1870	114,611	145,936	299,600	560,147
1871	30,556	198,771	344,053	573,380
1872	19,156	124,769	199,551	343,476
1873	..	122,189	518,449	640,638
1874	2,525	140,016	565,695	708,236
1875	4,850	144,071	323,450	472,371
	639,334	1,804,323	5,020,851	7,464,508

APPENDIX II.

NEW MERWEDE.

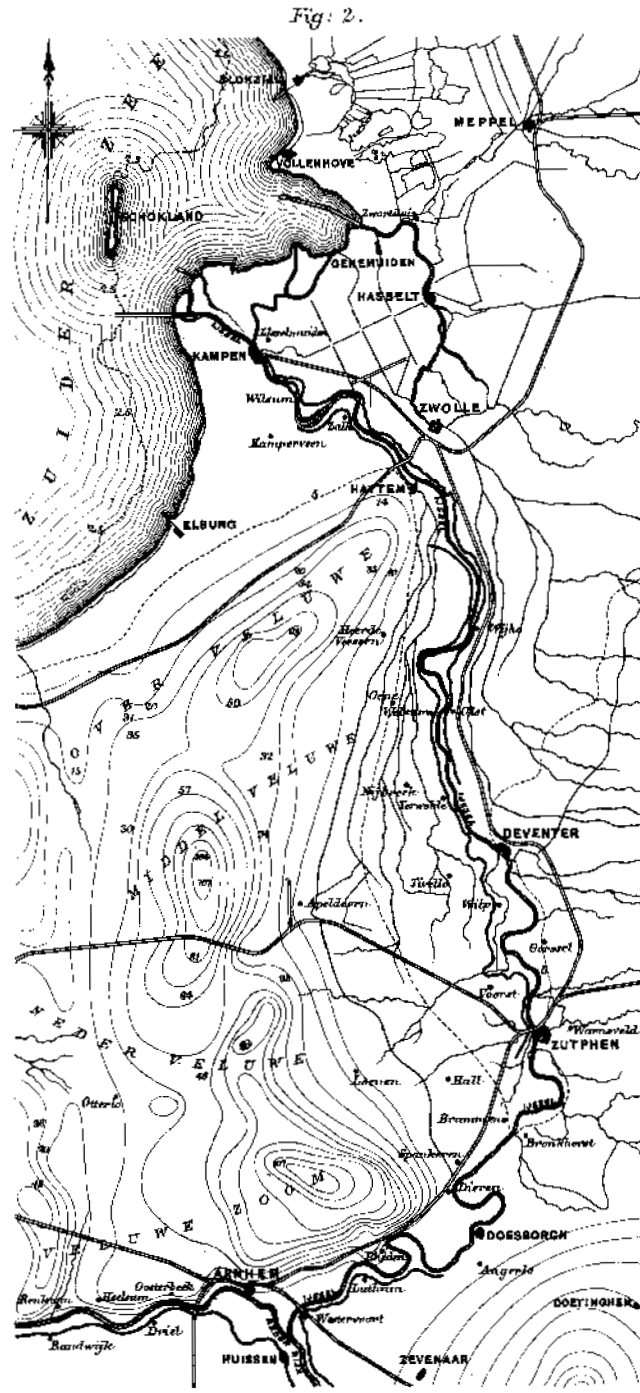
QUANTITIES DREDGED BY STEAM DREDGERS, and COST OF DREDGING.

Years.	Quantities.	Cost.	Other Expenses.	Total.	Remarks.
		Florins.	Florins.	Florins.	
1861	..	..	73,500 ¹	73,500	{ ¹ 25-HP. steam dredger and 3 scows iron.
1862	71,189	28,176	13,585 ²	41,761		^{2} 11,780 for 20-HP. tug.
1863	95,505	28,945	16,795 ³	45,740	³ 12-HP. steam dredger.
1864	303,643	105,387	36,585 ⁴	141,972	{ ⁴ 2 × 12-HP. steam dredger.
1865	340,000	112,815	59,565 ⁵	172,380		^{5} 2 × 12-HP. steam dredger. and 6 scows.
1866	585,315	181,227	12,944 ⁶	194,171	⁶ 20-HP. tug.
1867	400,000	116,000	..	116,000	
1868	250,848	96,000	4,400 ⁷	100,400	⁷ Improvements to dredgers.
1869	413,135	128,294	6,600 ⁸	134,894	⁸ Ditto.
1870	450,000	116,562	3,370 ⁹	119,932	⁹ Repairs to dredgers.
1871	508,712	131,680	1,620 ¹⁰	133,300	¹⁰ Ditto.
1872	541,407	126,399	8,537 ¹¹	134,936	¹¹ Ditto.
1873	550,000	148,250	7,387 ¹²	155,637	¹² Ditto.
1874	600,000	189,966	..	189,966	
1875	656,769	179,885	..	179,885	
	5,806,523	1,689,586	244,888	1,934,474	{ Or 0.333 florin per cubic metre; or, 4.62 <i>d.</i> per cubic yard.

APPENDIX III.

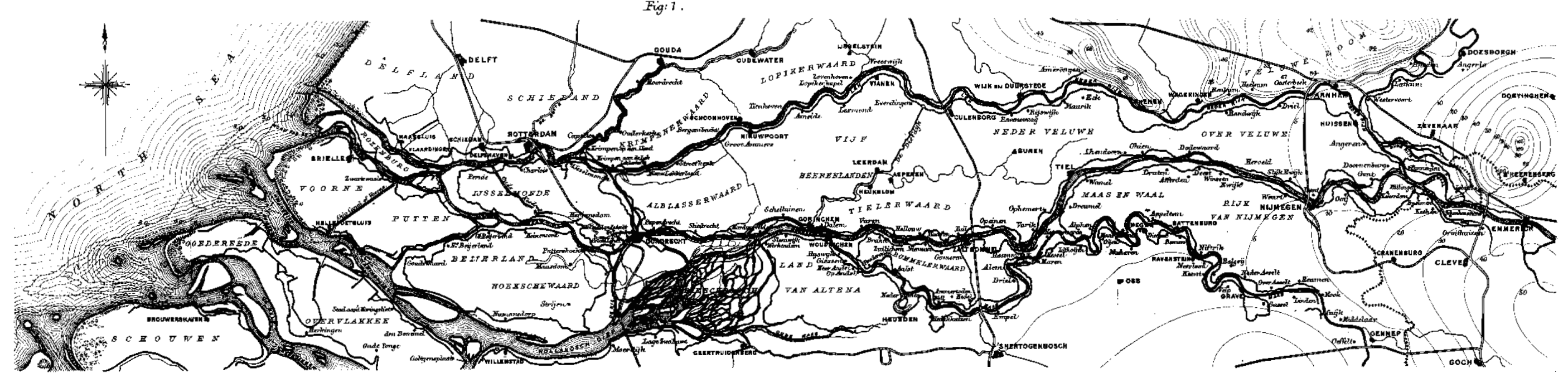
COMPARATIVE VOLUMES of WATER PASSING DOWN the BRANCHES of the RHINE, the VOLUME of the UNDIVIDED UPPER RHINE STREAM BEING TAKEN EQUAL to 9 UNITS, at THREE DIFFERENT RIVER LEVELS.

Theoretical Volume.	At Mean River Level.			At 1 Mètre + Mean River.			At 1 Mètre - Mean River.		
	Waal. 6	N. Rhine. 2	Yssel. 1	Waal. 6	N. Rhine. 2	Yssel. 1	Waal. 6	N. Rhine. 2	Yssel. 1
Years.									
1841	6.50	1.73	0.77	6.40	1.80	0.80	..	..	..
1846	6.26	1.82	0.92	6.23	1.91	0.86	6.88	1.64	0.48
1851	6.11	2.01	0.88	6.03	2.04	0.93	6.44	1.92	0.64
1856	6.22	1.88	0.90	6.07	1.99	0.94	6.81	1.55	0.64
1861	6.36	1.80	0.84	..	..	..	6.63	1.70	0.67
1866	6.29	1.82	0.89	6.26	1.83	0.91	6.63	1.71	0.66
1871	6.30	1.74	0.96	6.20	1.84	0.96	6.50	1.74	0.76
							In 1871, 2 mètres + mean river.		
							6.09	1.85	1.06



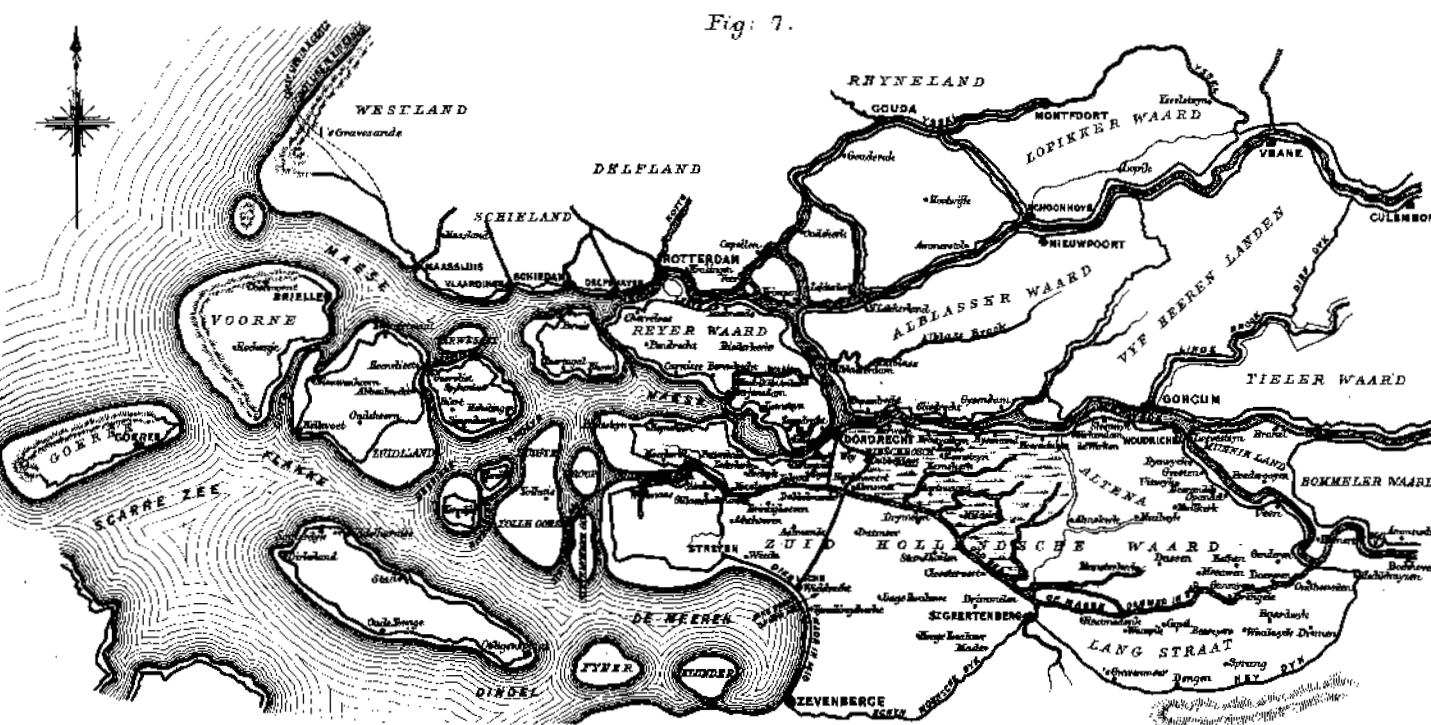
THE VESSEL MOUTH OF THE RHINE.

H. SICCAMI, DELT. Scale: 1:500,000.



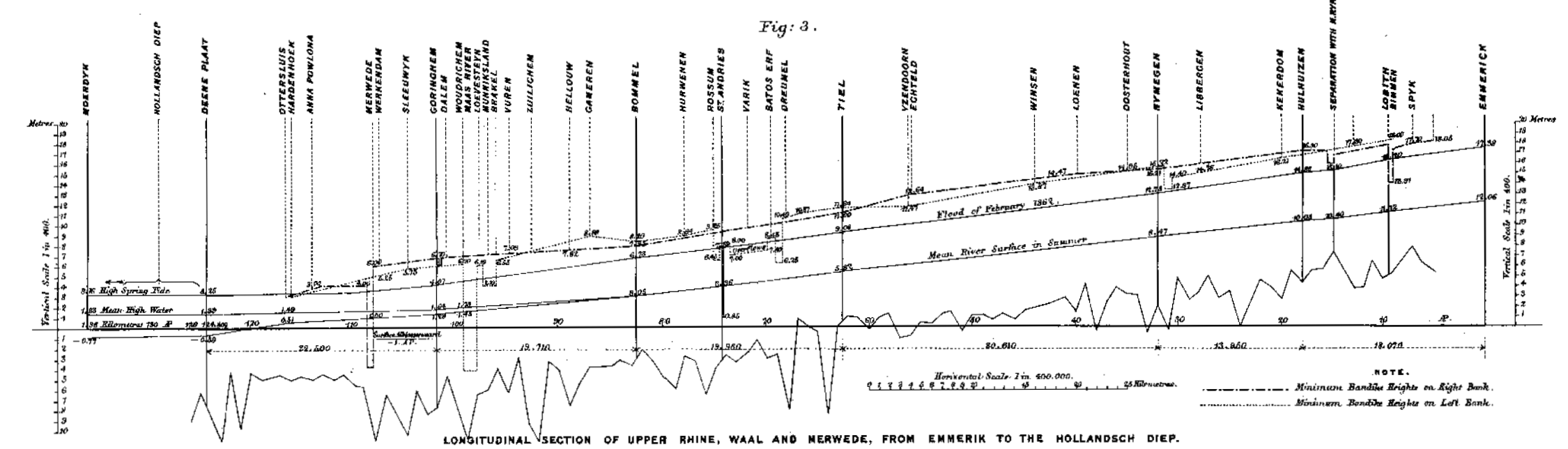
THE DELTA OF THE RHINE AND THE MEUSE, THE LECK AND THE WAAL MOUTHS.

Scale: 1:500,000.



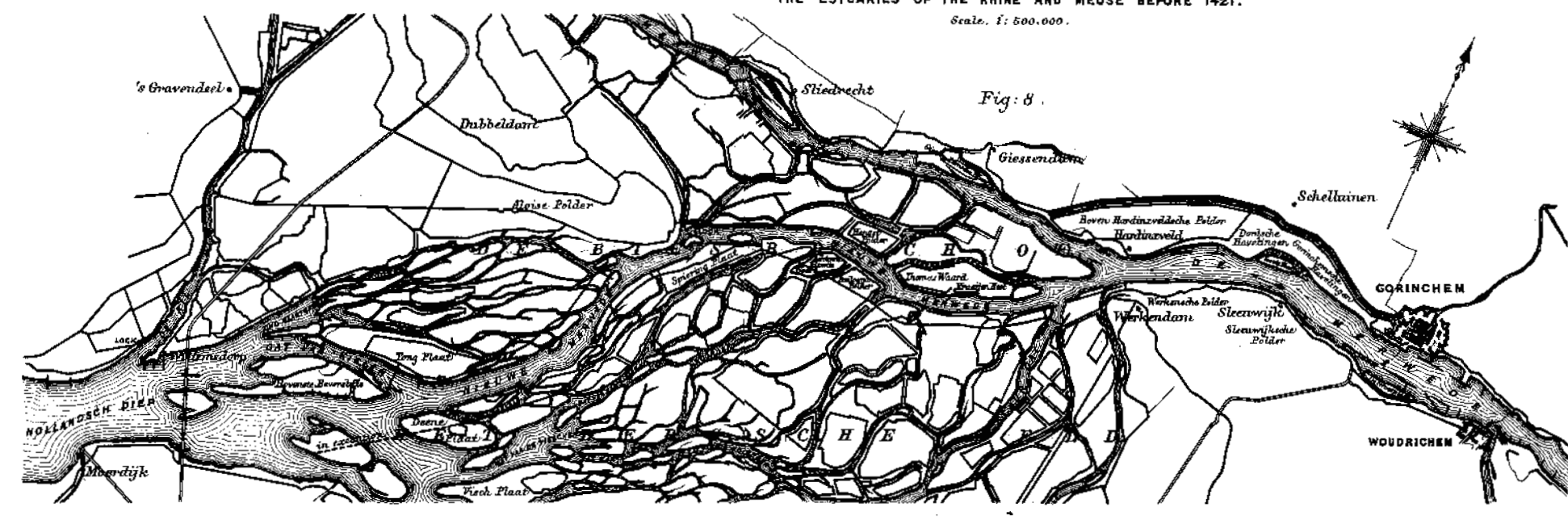
THE ESTUARIES OF THE RHINE AND MEUSE BEFORE 1421.

Scale: 1:500,000.



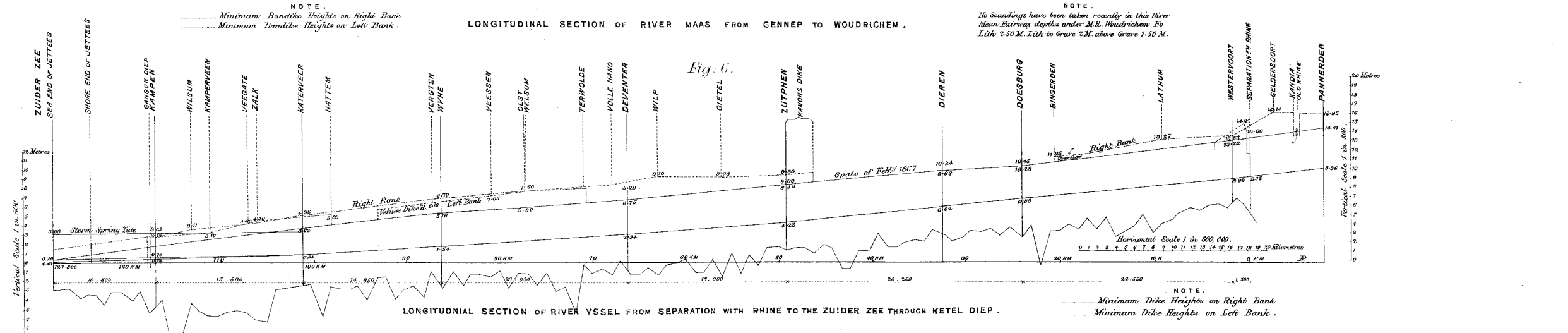
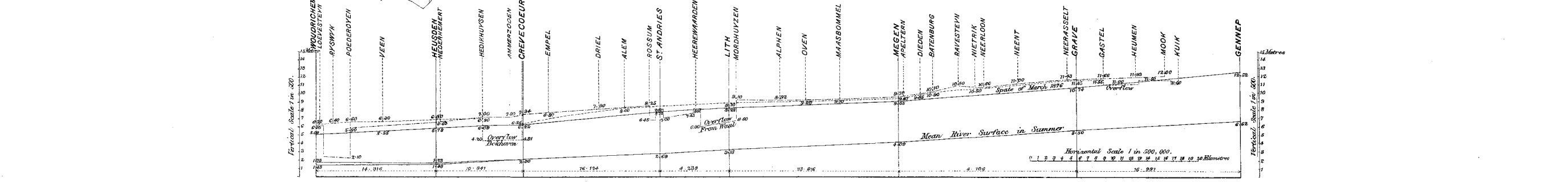
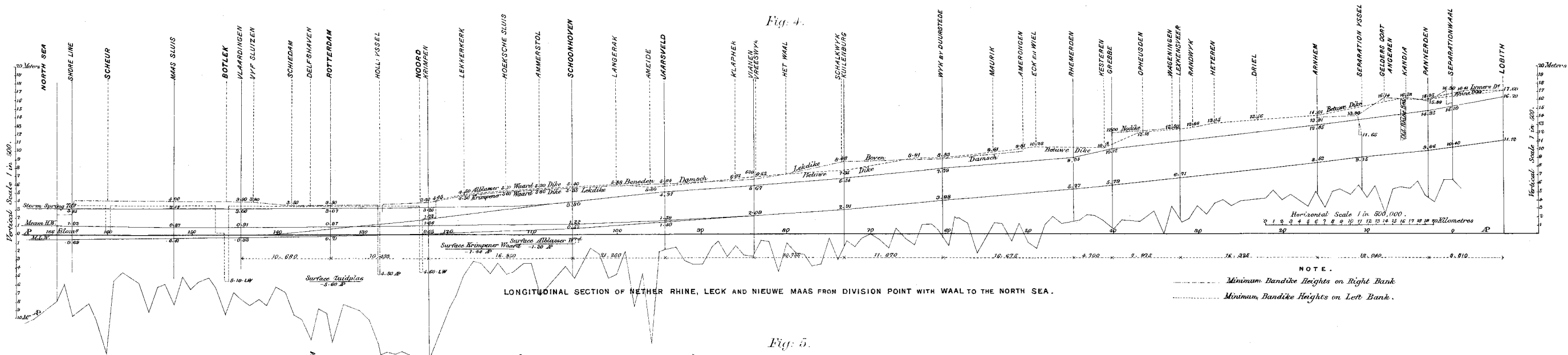
LONGITUDINAL SECTION OF UPPER RHINE, WAAL AND MERWEDE, FROM EMMERIK TO THE HOLLANDSCH DIEP.

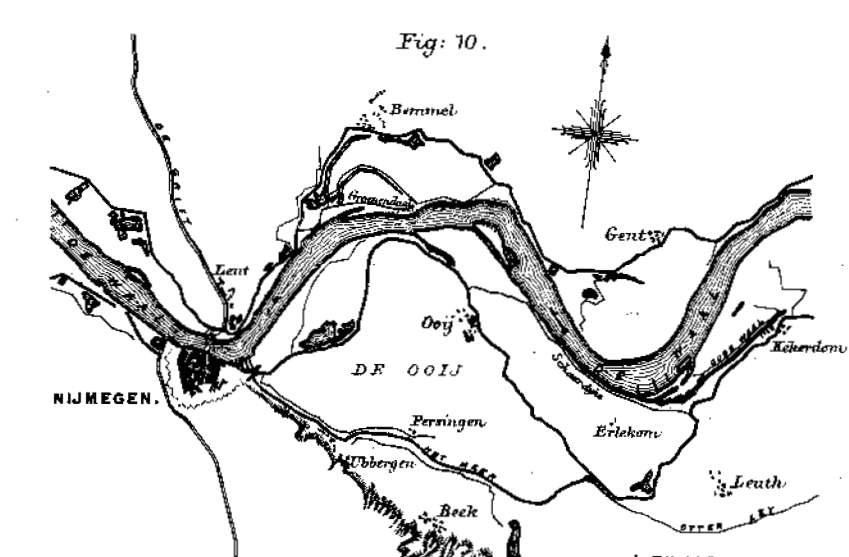
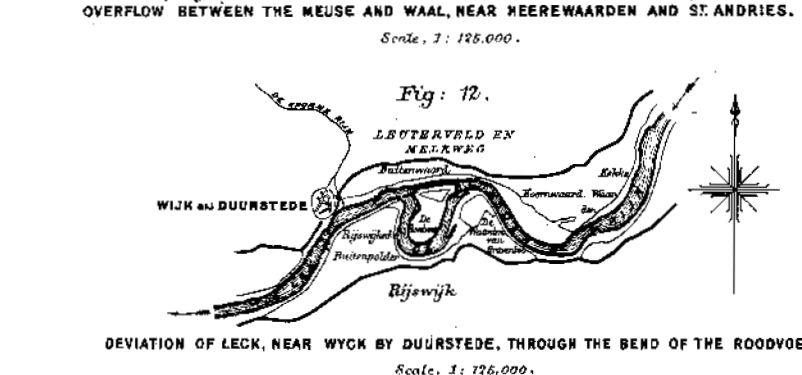
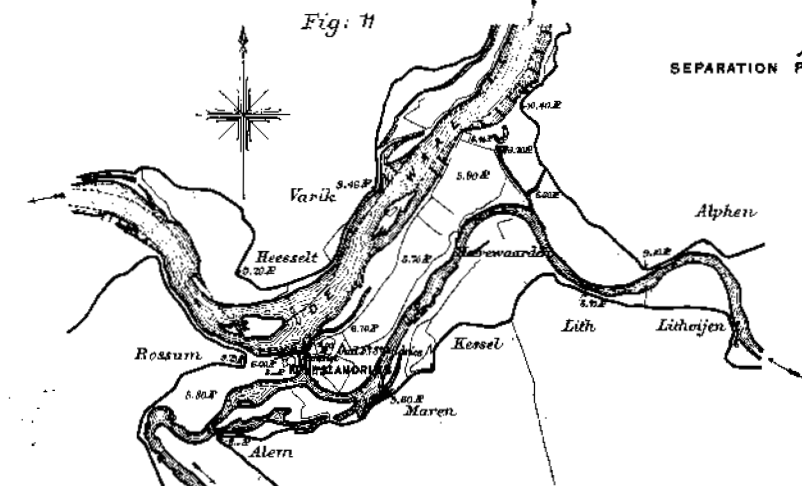
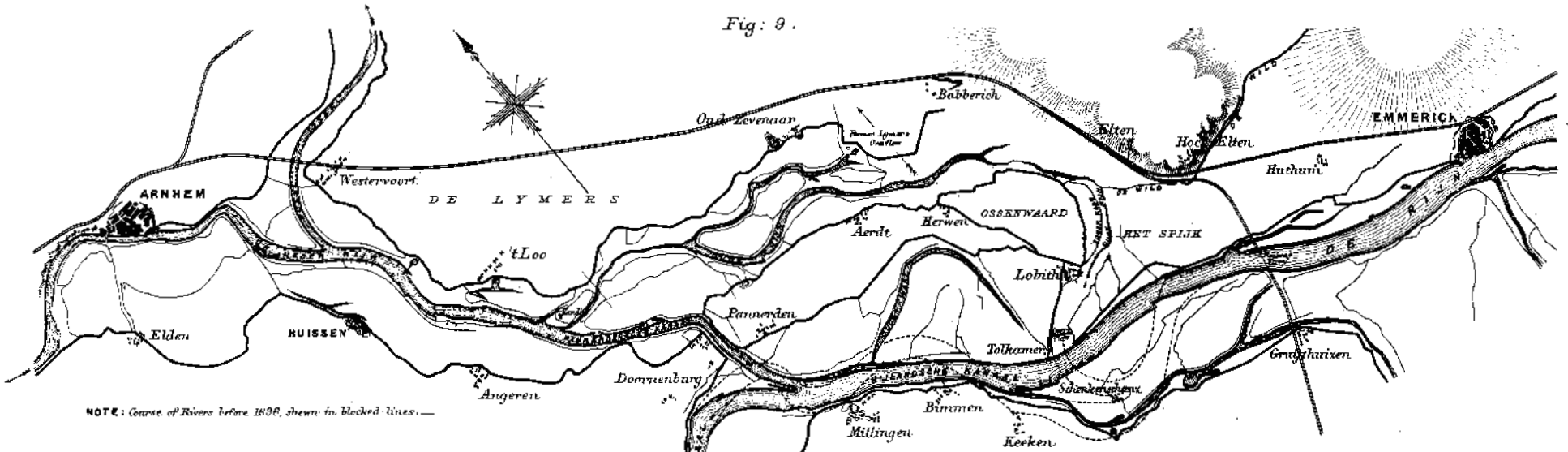
NOTE.
 - - - - - Minimum Bankside Heights on Right Bank.
 - - - - - Minimum Bankside Heights on Left Bank.



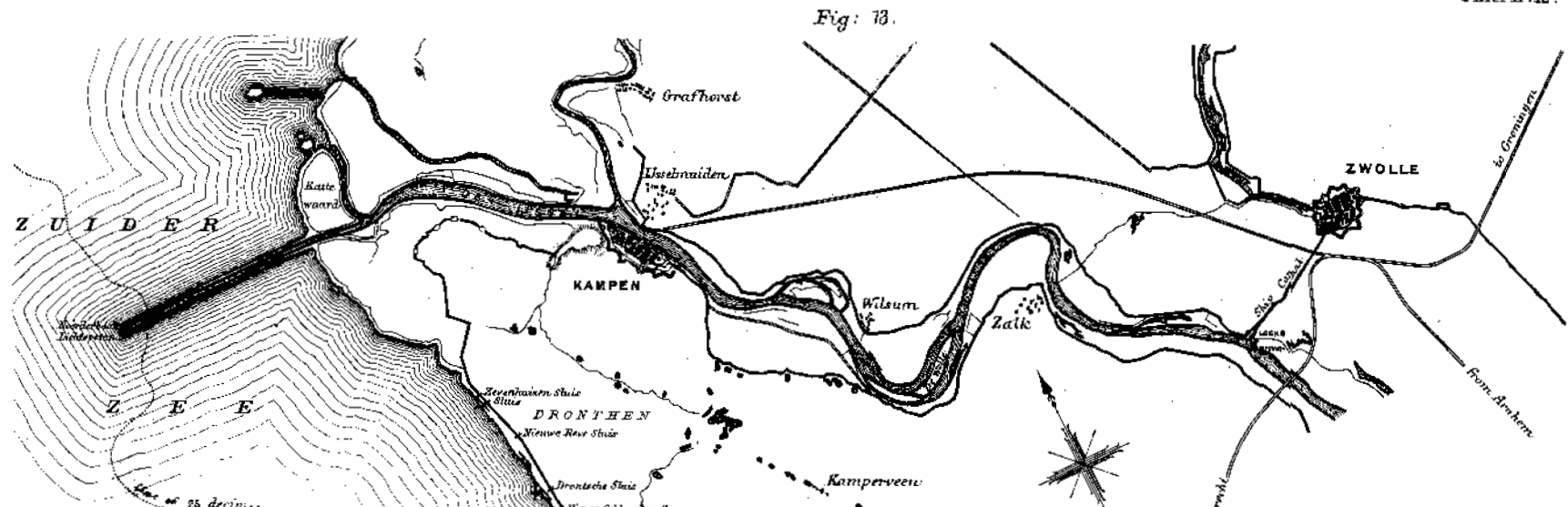
NEW CHANNEL OF THE MERWEDE, FROM GORINCHEM TO THE HOLLANDSCH DIEP.

Scale: 1:125,000.

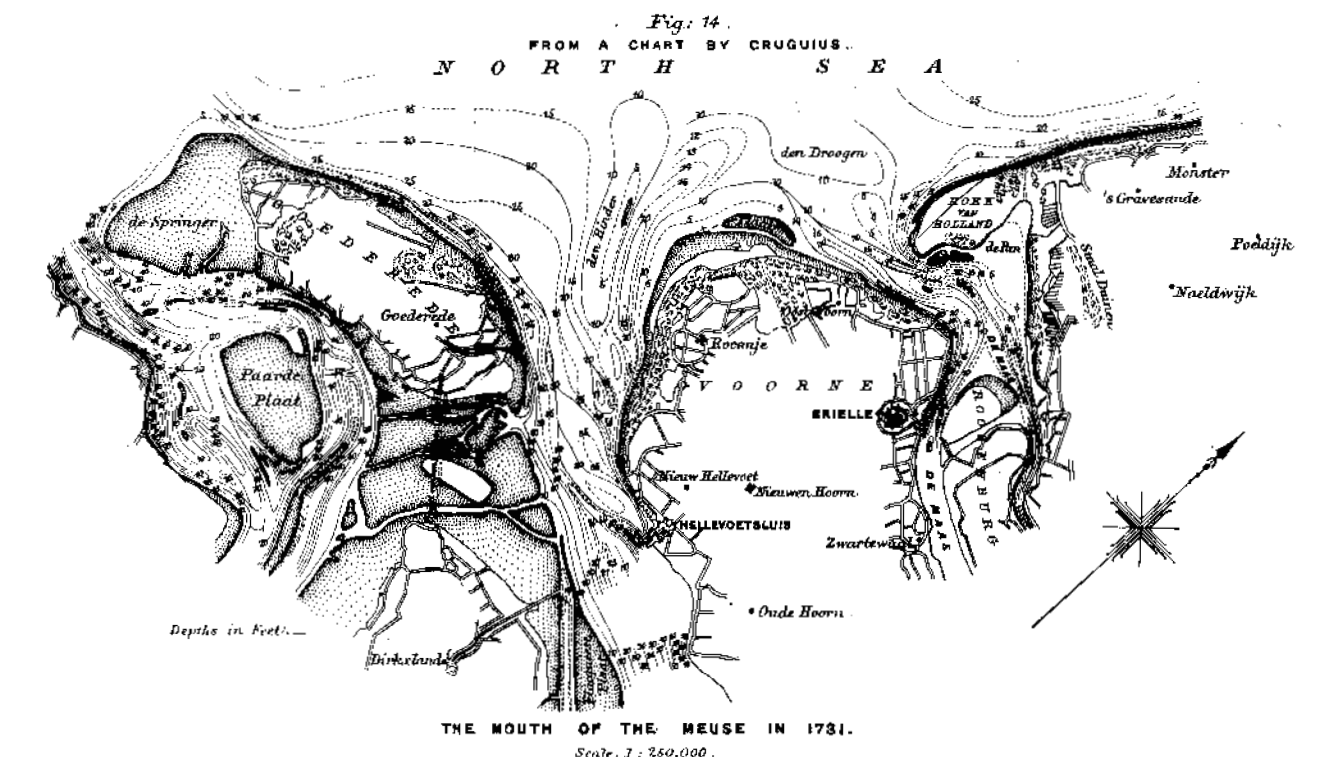




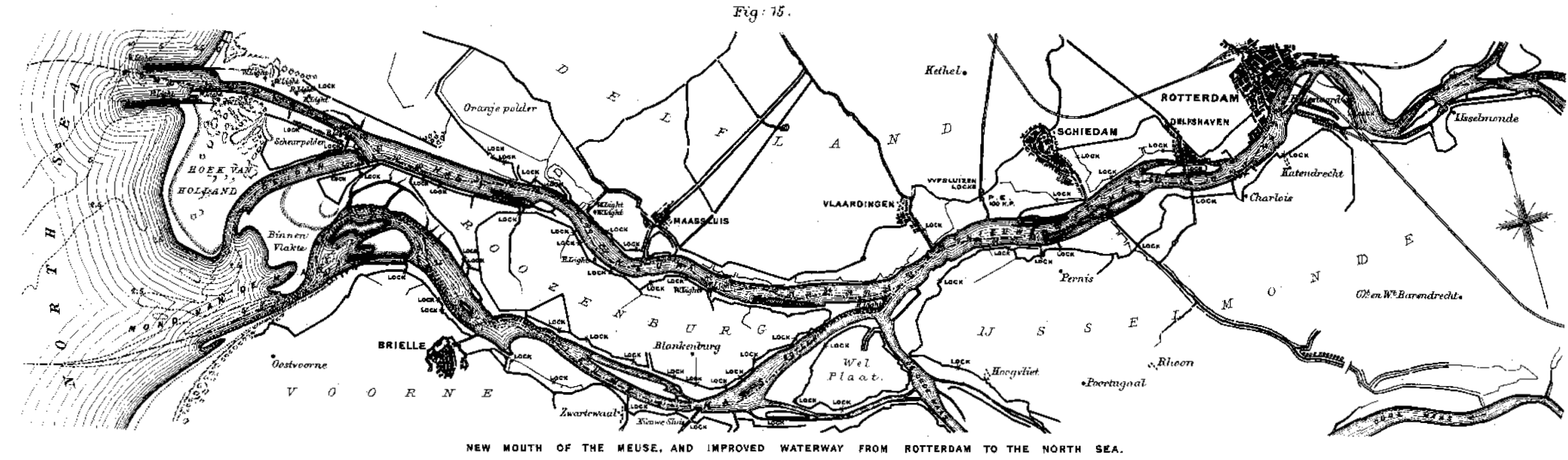
THE WAAL NEAR NIJMEGEN, PROTECTED SCHAARDYKE NEAR ERLEKOM, AND WORKS NEAR GROENENDAAL. Scale, 1:125,000.



THE YSSEL MOUTH OF THE RHINE, AND WATERWAY FROM ZWOLLE TO ZUIDER ZEE. Scale, 1:125,000.



THE MOUTH OF THE MEUSE IN 1731. Scale, 1:250,000.



NEW MOUTH OF THE MEUSE, AND IMPROVED WATERWAY FROM ROTTERDAM TO THE NORTH SEA. Scale, 1:125,000.