

THE WINNING OF COASTAL LANDS IN HOLLAND.

PLATE 2.
WINNING COASTAL LANDS IN HOLLAND.

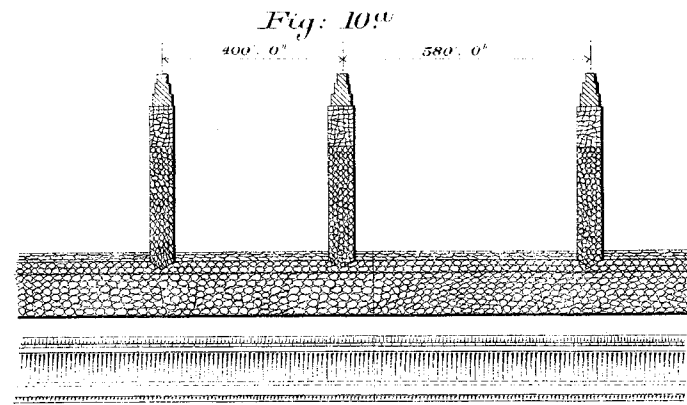


Fig: 10.

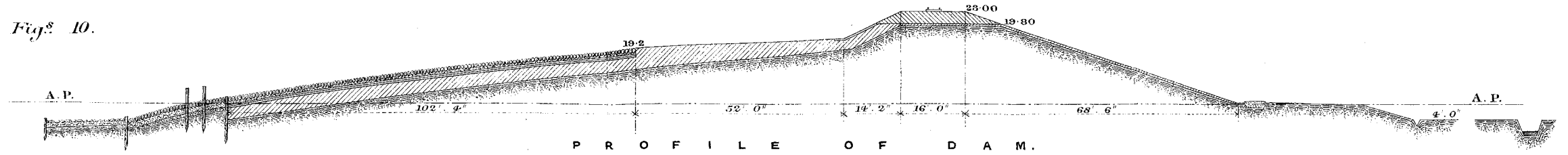


Fig: 10^b

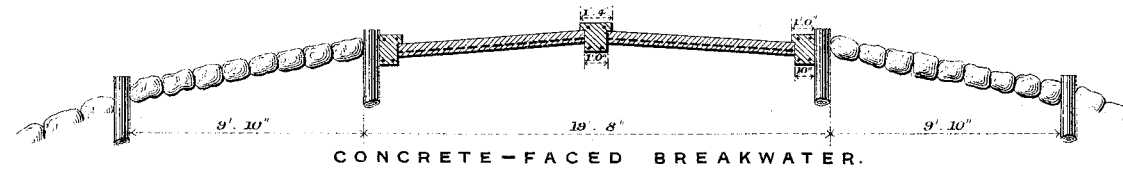


Fig: 12.

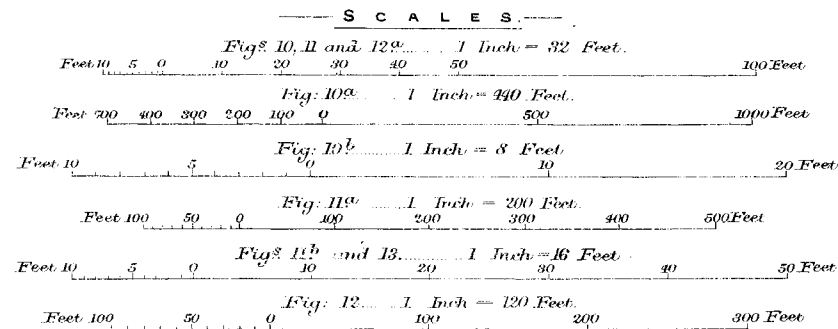
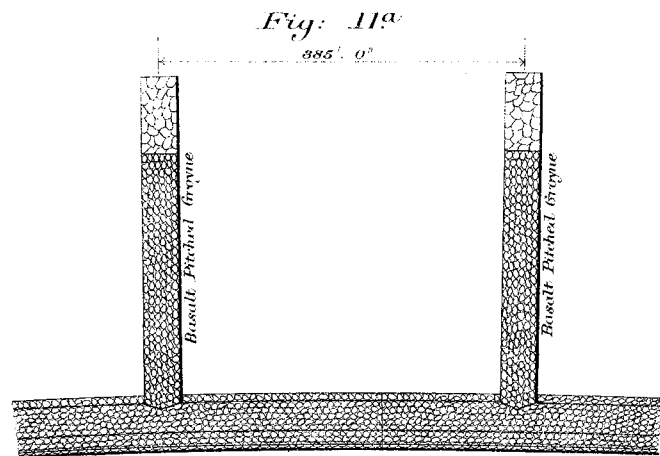
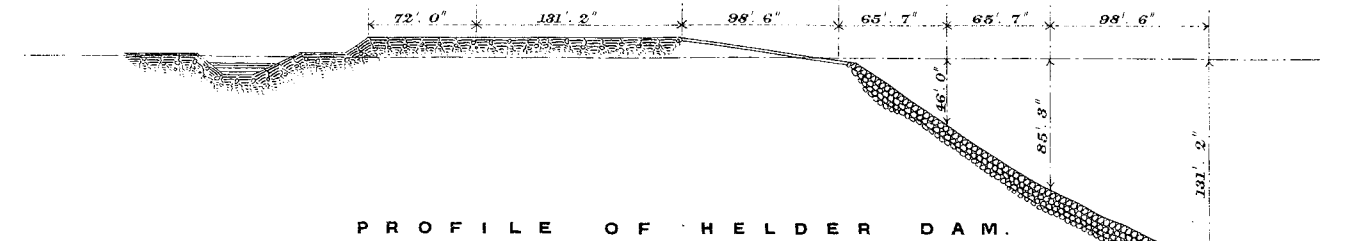


Fig: 11.

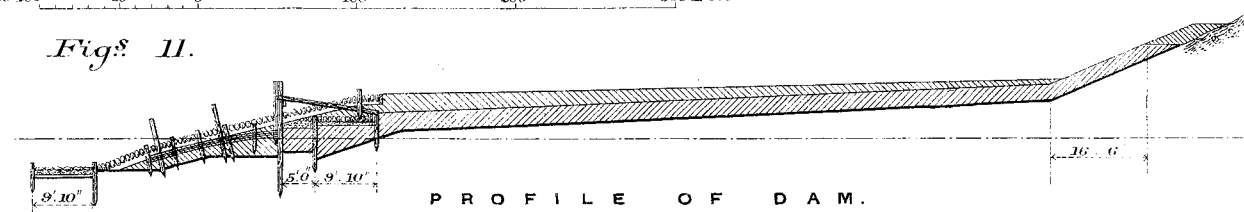


Fig: 11^b



Fig: 12^a

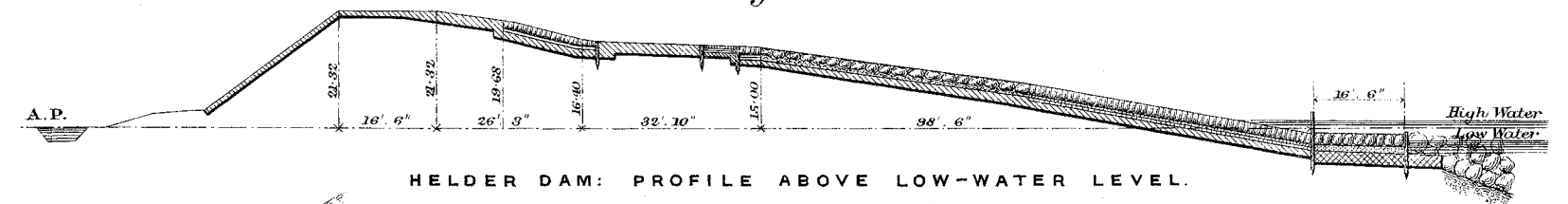
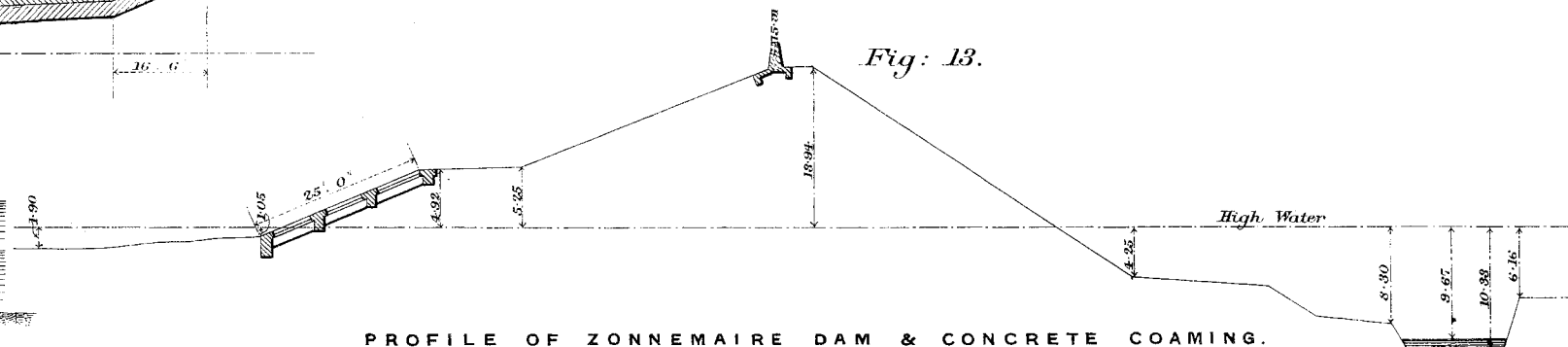


Fig: 13.



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(*Paper No. 3885.*)

“The Winning of Coastal Lands in Holland.”

By ALFRED EDWARD CAREY, M. Inst. C.E.

THE foreshore-defence works on the Dutch coast have received but scanty notice in the Proceedings of The Institution, and indeed little technical literature dealing with such work exists in the English language. In this Paper the Author presents a summary of the observations made by him during a recent inspection of the Dutch coast-line from Flushing to as far north as Texel, when he had the advantage of access to official sources of information. Some comparison of British and Dutch practice is also attempted. The Dutch engineers were the pioneers of land-reclamation in England, their work in the fens commencing about 1652.

The motto of the province of Zeeland, *Luctor et emergo*, is an apt summary of the struggle of the Dutch people. The country being primarily agricultural, the great works which have remodelled the map of Holland are necessarily based upon economical engineering methods and devices, which are the result of slow evolution.

HISTORICAL.

No description of the Dutch coastal regime would be complete without some reference to its historical growth. Napoleon described Holland as the “alluvion of French rivers.” When the Roman forces penetrated to the North Sea, Tacitus and Pliny, in noting the precarious tenure of the half-submerged lands which now constitute the kingdom of Holland, recorded their wonder at the

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diurnal tides, a phenomenon novel to dwellers on the shores of the Mediterranean. Roman travellers were, they said, in doubt if the country were land or water. Eumenæus spoke of lands which trembled under the tread of the pedestrian, and seemed to consist of a shell of land floating over water. The latest geological view of the conformation of the overlying strata of Holland presents a singular analogy to this remark. The late Mr. Harrison Hayter, Past-President Inst. C.E., stated¹ that on a site originally intended for one of the protective dams for the Amsterdam ship-canal works, two men with a hand-auger bored to a depth of 50 feet in 20 minutes.

Travellers in Holland cannot fail to notice the isolated mounds, about 30 to 40 feet high, which occur in many parts of the country, but are most frequent in the province of Groningen. The Dutch call them *terpen*, or *wierden*. The early habitations of settlers were on these artificial mounds; and the Emperor Vitellius (A.D. 69) is reputed to have taken refuge on one. The soil of which they are composed is now often used as a top dressing for the adjoining lands, and when the mounds are levelled, they frequently prove to be museums of antiquities going back to the Stone Age.

One-third only of the area of Holland to-day (i.e., the south-east part of the country) is more than 1 metre above the level of average high water; the remainder of the country is practically below that level. As early as the twelfth century, the Dutch were renowned for their skill in coastal defence; thus, in 1179, after great inundations, Dutch workmen were called in to construct protective works for Bruges, the groyne then built consisting of fascines and earthworks. A century later, the practice was to hold down the fascines with piling or heavy beams of timber; but the destruction of such timber by the *paulworm* or teredo—said to have reached northern Europe in ships engaged in the eastern trade—resulted in the gradual introduction of masonry. The earliest efforts of the scattered settlers were directed to the maintenance of existing lands; but reclamation work was soon commenced. The embankment of the rivers, and the winning of clay lands formed by the deposition of ooze, has gone on thus for centuries. Areas of alluvion so created are termed *polders* in Flanders and in the provinces of North and South Holland and Zeeland, and *kwelders* in the provinces of Friesland and Groningen. In Essex such areas are called “levels”; and it may be noted incidentally as a curious fact that in Essex the word “dike” means a ditch or artificial open drain, and in Holland

¹ Minutes of Proceedings Inst. C.E., vol. lxii, p. 8.

the same word *dijk* indicates a dam or embankment, thus corresponding with the French *digue*.

The sequence of the national embanking operations may be summarized thus:—

In 1277 the country near the mouth of the Ems was inundated, and for more than 200 years the flooded land remained a swamp. The struggle to reclaim these lands, which has been going on from the middle of the sixteenth century to the present day, has resulted in the recovery from the sea of more than 12,500 acres on the coast of Friesland, and of about 57,000 acres on the coast of the province of Groningen. The winning of lands in this district is still proceeding steadily. In the centre of Friesland, an inland sea having an area of 25,000 acres formerly existed, and in Roman times the river Ijssel flowed through this lake to the sea. Between the thirteenth and sixteenth centuries enormous embankments were constructed; but in the seventeenth century these embankments were found to be too low, as they were often breached, in spite of the fact that the coast-line is protected on the north-west by a chain of islands.

In November, 1750, a violent tempest from the north-west destroyed the dams in several places and flooded the country as far as the city of Groningen, causing the death of 20,000 persons. Much of this flooded land has since been reclaimed, but probably the area of the Zuider Zee was considerably enlarged by that historic inundation.

In prehistoric times the Rhine must have followed many channels in debouching on the North Sea, and the gaps which occur in the line of sand-dunes along the coast to-day are doubtless due to the varying outlets of the river. Where sand-dunes exist, they form a natural barrier of defence, and one important branch of the art of the Waterstaat engineers in Holland, who deal with these matters, is the maintenance of the dunes. The measures adopted with this object will be described later.

Before the seventeenth century the country round Alkmaar and Haarlem was inundated when excessively high tides occurred, but between 1540 and 1648 about 63,000 acres in this district were reclaimed. The lake of Haarlem was originally a vast swamp intersected by small rivers, its area of about 45,000 acres being continually increased by the flooding of fresh lands. In 1840, however, further drainage-operations were decided on, and a sum of about £670,000 was voted by the State. The estimate for the drainage of this area was about £17 per acre; the actual cost of the work amounted to only about £14 per acre.

In 1421 the dam near Werkendam, between Dordrecht and Geertruidenberg, was broken down, and 20,000 people perished. The whole of this area to-day is under cultivation, with the exception of the Biesbosch district, which consists of a marshy archipelago, forming one of the best fowling-districts in Holland. The island of Overflakkee consisted, in the fifteenth century, of three islands which were joined by embankments, and in 1751 they were united with the island of Goeree. These four islands originally had an area of 10,000 acres; to-day it is 60,000 acres. The island of Walcheren, again, consisted originally of dozens of small marshy islands. These were united, by the construction of dams, at the end of the fourteenth century, and on that island to-day is the famous dam of Westkapelle, close alongside of which runs a deep channel for ocean-going steamers. The reclamations effected at the mouths of the Maas and Scheldt since the twelfth century have increased the area of Holland by about 250,000 acres of agricultural land.

POLDERS.

Before describing in detail the foreshore-defences of the Dutch coast, it may be desirable to state the general conditions regulating this class of work.

In Holland the flocks pasture on alluvial lands and follow the tide as it recedes. By slow degrees soil accretes, and the growth of vegetation fixes the ooze, film on film, as it washes across the flats. When such land is judged to have reached maturity, it is enclosed by dams, and another polder comes into existence. With the object of draining such a tract of land, it is first entirely isolated by embankments, and a ditch or canal is dug around it, inside these banks. An accumulating-reservoir is necessary to enable discharge to take place at low tide; and, depending on the range of tide, the level at which water stands in these reservoirs is a measure of their maximum efficiency in discharge. In passing from the south to the north of Holland the range of tide decreases, and the size of the accumulating-reservoirs also diminishes, which appears paradoxical. It is explained, however, by the use made of the navigation-canals as channels of discharge, and by the existence of natural reservoirs under and at the base of the sand-dunes. This point is examined in some detail later in the Paper (p. 6). Where navigation-canals exist, the interior water is pumped into them, either wind or steam power being employed for driving the pumps. When a tract of land is thus roughly cleared of water, swamps result, and ditches

are laid out intersecting the area like the lines on a chess-board. The purpose of these ditches is twofold: they provide superficial drainage, and the fertile soil removed in cutting them is spread over the surface of the land to be reclaimed.

Ultimately sluices are constructed: by means of these and wind-mill pumps the level of the flood-water is regulated, and the polder becomes fit for agricultural purposes. Such an operation as that just described obviously requires considerable time, but is usually practicable at small expense. When once the windmill pumps and the sluices are installed, the cost of maintaining the desired water-level is trifling.

POLDER-BOARDS.

As is the case in the low-lying districts of England, the regulation and control of the sea-defences are in the hands of bodies of commissioners. In England such commissioners are nominated by the Crown. They have to be owners of real estate of a given rateable value in the county concerned, but are not necessarily locally interested in the particular area affected. These bodies of commissioners, whose authority in several cases dates from the Tudor period, have statutory rights for the levying of a scot or charge per acre on a defined area of land subject to flooding. The commissioners hold periodical courts, at which the engineer in charge of the levels makes his recommendations for the ensuing season. The court issues orders to landowners to carry out the work considered necessary; and any landowner failing to comply is subject to penalties. One or more resident marsh-bailiffs are in charge of a given level. On some levels the commissioners themselves carry out the orders of the court, charging each landowner affected his proportion of the cost of the work.

The Dutch system differs materially from this. The area known as a *polder* is under the control of a Polder-Board, ten or more representative members being elected by the landowners. These elected members, who form the general committee, elect a committee of five, which is termed the *daijli* committee of the polder, and the engineer for the district is responsible to the latter. These committees often have control over large funds, as some of the areas affected are extensive.

One dominant factor in the Dutch system as compared with the English is the fact that new polders are constantly being embanked and won. Numerous instances could be cited of Acts of Parliament passed in the reign of Queen Elizabeth, whereby various local bodies

in England were empowered to carry out the winning of waste lands overflowed by tidal waters. The depreciation in the value of land in England, more especially of the clay lands of Essex, has checked any attempt at enclosing fresh swampy tracts. In localities such as New England, where the sea-defences are broken down, no attempt is made to recover land so lost.

In Holland there is a constant attempt to extend the agricultural area of the State. In some places, such as parts of Walcheren, the cost of maintaining the sea-walls is greater than the locality can bear. In cases of this kind, which are called *calamiteuses polders*, the State and the Province bear either part of or all of the cost of the sea-defences. Where agriculture flourishes, the landowners defray the cost under scot or levy.

As showing how considerable must be the total expenditure in the kingdom of Holland under this head, it may be mentioned that the polder of Schouwen, the area of which is about 50,000 acres, has a budget, in respect of coastal defence, which is a minimum of about £17,000 per annum, and occasionally reaches £25,000. Protecting the administrative area of 22,500 acres there are about 18 miles of sea-walls and about $2\frac{1}{2}$ miles of sand-dunes. On the Dutch coast the total length of the sea-dikes is about 1,600 miles.

WATER-LEVELS.

A few words as to standard levels in Holland are necessary. The datum is known as *Amsterdamsch Peil*, marked "A.P." on Dutch maps. This represents mean-tide level at Ymuiden, and as a datum corresponds with the Ordnance datum of English maps, but is about $11\frac{3}{4}$ inches (0.30 metre) above it. The variation in tidal range on the Dutch coast is shown in Fig. 1, Plate 1, and will be seen to be considerable. All canal and inland waters are by law maintained artificially at -0.5 metre (-1.64 foot) A.P.

The object of the maintenance of an artificial water-level throughout the country by pumping is to provide what is in fact an immense drainage-reservoir for flood-water in case of inundation. Windmills are largely being superseded by steam-pumps, wind-power being capricious. It is stated that wind-power permits of continuous pumping during only 130 days in the year.

In view of the point already mentioned (p. 4) as to the size of the compensating reservoirs by which the outflow drainage from the polders is equalized, a very interesting collateral investigation has been made by Mr. J. M. K. Pennink,

The water-supply of the city of Amsterdam has, for a long period, been pumped from the sand-dunes. The questions whether this supply is likely to be permanent, and what are the physical causes which produce it, have been much debated. Mr. Pennink held the opinion that the reservoir of water existing in the base of the dunes was due to rain and condensation alone. This opinion, however, was not shared by German engineers, who believed that the supply was augmented by subterranean land-drainage.

The water-level in the dunes rises under capillary attraction and from external sea-pressure. The Dutch and Belgian engineers were at one in attributing the existence of the water-supply primarily to rainfall. Of the rainfall 64 per cent. is absorbed by the dunes, and the remaining 36 per cent. is lost by evaporation, absorption due to vegetation, etc. Mr. Pennink's theory is that a part of the 36 per cent. filters downwards, and escapes laterally. It would appear that only a small portion of the water finds its way directly into the sea.

The rainfall is greater on the dune areas than on any other portion of the country. Borings made by Mr. Hertzberg in the island of Norderney showed brackish water at a depth of 200 feet; above this level the water was fresh, and it was concluded that a substratum of salt water probably exists under Holland, thus bearing out, in an extraordinary manner, the remark of the Roman writer quoted in the early part of this Paper.

In 1902-3, when an additional source of water-supply for Amsterdam was urgently needed, the inadvisability of going too deep for the water was a paramount consideration, as the risk of drawing the underlying salt water into the upper natural reservoir, and rendering the whole supply brackish, was urged, the balance of pressures between the fresh, brackish and salt zones being very unstable. With a view to increase the supply, a proposal was made to divert part of the outflow from the irrigation-canals, causing some discharge from these into the dunes, but the quality of the canal-water was not good, and this would have converted the dunes into filter-beds which, in time, would have become inoperative.

By further comparison of the levels of the water in the substrata of the dunes, and of the fluctuations of these levels under pumping, it has been demonstrated that there exists a transition zone between the fresh-water and salt-water levels, and in this zone the water is brackish. Its depth below the intake in the dune is 33 to 66 feet.

A lowering of the fresh-water level under Amsterdam would, it is asserted, cause a corresponding and much greater drop in the

water-level of the dunes, owing to the balance of pressure now existing between the two. Such lowering, it is believed, would possibly break the fresh-water seal which the dunes naturally cause.

SAND-DUNES.

The geological conformation of the Netherlands affords a key to its hydrographical economy, the western and northern areas being alluvial, and the eastern and southern diluvial, the surface of the country here having been previously subjected to glacial denudation. Near the German frontier, geological formations older than the tertiaries crop out.¹ Here and there in the more recent deposits of Zeeland, North Friesland, and Groningen, the alluvium or sea-clay rises to a level of + 2 metres (6·6 feet) A.P. This alluvial deposit, however, is generally 1 to 2 metres, and in reclaimed lakes even 5 metres (16·4 feet), below sea-level. The chief feature of the alluvial base on which the superficial deposits of the country rest is the existence of peat, which was formed by the growth of bog plants on the swampy lands in rear of the dunes. This peat is thickest in the district of Utrecht and the province of North Holland, the thickness averaging about 15 feet, and in some places attaining 30 feet. Occasionally the peat exists at a level as low as - 19 metres (- 62 feet) A.P. Through this peaty swamp the rivers Rhine, Maas and Scheldt formerly forced their way to the sea by constantly shifting channels. At the same time they deposited the river-clays, which to-day form the most fertile soil of Holland. The remains of

¹ For a description of the sub-glacial strata of Holland and their correlation with the Crag beds of Suffolk, see F. W. Harmer, "On the Pliocene Deposits of Holland and their relation to the English and Belgian Craggs, with a suggestion for the establishment of a new zone, 'Amsteliën,' and some remarks on the geographical conditions of the Pliocene Epoch in Northern Europe" (Quarterly Journal of the Geological Society, vol. 52, 1896, p. 748). The depression in which the Pliocene strata of Holland rest is a shallow basin, the sides of which rise to the west, east and south towards Norfolk, Germany and Belgium respectively. A boring 1,098 feet in depth at Amsterdam did not reach these beds. A rise of 500-600 feet in the Pliocene sea-bed in the south of England and north-west of France was probably contemporaneous with a subsidence over the Dutch area of possibly more than 1,500 feet. The embouchure of the Rhine and its tributary rivers, after crossing the present site of the North Sea, appears to have struck the Essex coast at Walton, and thence flowed north into a sea-basin east and west of Cromer. From the geological point of view Holland is thus the alluvion of a system of vast rivers and estuaries, and its superficial deposits are the product of ice-borne debris from wide reas.—A. E. C.

Roman buildings, such as those at Katwijk, and near Domburg on the island of Walcheren, show that the protecting range of sand-dunes was formerly much wider, and probably of less elevation, than it is at present. It was also more continuous. The weakening of the line of defence afforded by the dunes, due partly to the action of the rivers, and partly to sea-storms, caused a penetration of the sea into the interior of Holland, and between the tenth and thirteenth centuries the Zuider Zee came thus into being. The principal spots in Holland where the protection of the dunes has broken down, and artificial protection has become necessary, are Westkapelle, on the island of Walcheren, where the sea-embankment, built in the fifteenth century, is about 3,800 yards long, and Hondsbosse and Petten, in North Holland, where the embankments, also constructed in the fifteenth century, extend for about 5,250 yards.

Up to the sixteenth century the dunes were continually changing, both in contour and in position; but at that date the planting of these with grasses was commenced. The grasses planted by the conservators of the dunes are principally the helm-grass (*Ammophila arenaria*) and *Triticum junceum*. The roots of these grasses run in all directions, and mat the surface of the sand, thus preventing its dispersal by wind. It is, to the English engineer, an extraordinary sight to see the face of a threatened sand-dune defended by methods so apparently elementary. Where there is a tendency to erosion of the dunes, the practice in Holland is to plant small tufts of helm grass spaced about 12 inches apart. In an old sand-dune the grass will not germinate unless new-blown sand is on the surface; but where the roots of these grasses penetrate, the system is wonderfully effective. On the island of Schouwen the Author saw a sand-dune (Fig 2, Plate 1) threatened with undermining, for the protection of which the engineer depended largely on wisps of grass planted at intervals. In addition to binding the slopes by vegetation, groynes are also frequently adopted as a means of checking erosion. On the less exposed foreshores these groynes are formed of fascine-work protected with basalt blocks, longitudinal rows of short piles being driven to hold the mass together. Groynes on the de Muralt system, described later, are being substituted in some cases for the older type of groyne. As a rule, these groynes are carried vertically but little above the line of the shore. The present condition of the Dutch coast indicates that the dune barrier is now, for practical purposes, almost everywhere stationary. At a point immediately east of the Osse breakwater in the island of Schouwen, the Author was fortunate enough to find an instance in which a work such as this had actually re-established

an ancient line of sand-dunes, which had been recently denuded by natural means. In the North Sea islands (Texel, etc.), which are of vital importance to the defence of the northern Dutch coast-line, and in the province of North Holland, the maintenance of the dunes is in the hands of the Government. In South Holland and Zeeland this duty is performed, in some cases by polder-boards, sometimes by the province, and sometimes by private landowners. From the thirteenth century onwards small polder-boards have been amalgamated to form larger corporations, but all the polder-boards are under official jurisdiction.

The dune barrier, on which the existence of the kingdom of Holland depends, is in many places 1 to 3 miles wide, and in some places it attains a height of 130 feet.

The protection of the dunes on the land side is as important as the maintenance of their seaward slopes. The gradient of the sand on the landward side varies considerably, owing to the fact that sand is blown over the crest of the dunes and falls on their lee side, drifting to a flat slope. In order to arrest this landward travel, the Dutch practice, for many generations, has been to plant trees—mostly fir, beech, and oak—at the foot of the dunes, and to plant shrubs which grow in sandy soil on the slopes. The effect of these trees and shrubs is twofold. The roots of the trees hold the sand together and bind the slope so that it becomes less mobile; and sand blown over the crest of the dunes is caught by the trees and precipitated, being thus saved to the dune.

There is distinct evidence that in some cases an entire range of sand-dunes has, within historic times, shifted bodily landward. In one instance a Roman village, thus buried in sand, was slowly unearthed.

The fineness of dune sand is shown by the following figures:—

Residue on a sieve of 2,500 meshes per square inch	. . .	1 per cent.
" " " 5,800 " " " "	. . .	4½ "

The origin of these sand-dunes is obviously due to the former existence of large areas of sandbank which, probably owing to some elevation of the land, became exposed to wind-action. The prevailing west and south-west winds caused the throwing-up of sand-hills, just as sand-ripples are formed on the seashore. This effect is the result of minute differences in size and weight of the grains of sand. As may be seen in sand-ripples on any shore, the windward slope is much steeper than the leeward slope: in the case of the sand-dunes the wind sets up a digging action and distributes the spoil at a flat inclination on the lee side.

METHODS OF ARTIFICIAL PROTECTION.

The coastal barriers of Holland consist of massive dams running parallel with the shore-line, in addition to which groynes (*golfbrekers*), 150 to 200 yards apart and about 500 feet long, are often laid approximately at right angles to the dam, for protection. The seaward slopes of the dams are sometimes built of flat slabs of stone, though in recent years these slabs have been very commonly replaced by basalt (mostly obtained from the Andernach district), which is broken into lengths of about 15 inches and carefully pitched on the exposed portions of the dams. Such work is obviously very expensive; on the Osse breakwater (Figs. 6, Plate 1) in the island of Schouwen, one estimate for basalt pitching amounted to £1,750, or £3 12s. per lineal foot.

Above the exposed level the Dutch employ a method of protection which, so far as the Author is aware, has not been used in any other part of the world. About a handful of straw or rushes is bound into a small sheaf; such sheaves are then laid on the slope at right-angles to the dam, and a wisp of straw is laid over each sheaf; by means of a special tool the Dutch workman presses the straw-band into the clay and fixes the thatching in position. This makes a covering about 1 inch thick, which has to be renewed each year. A labourer can lay 70 square yards of straw thatching in a working-day, between 7 a.m. and 4.30 p.m., for which he is paid $\frac{1}{2}$ d. per square yard, the total cost of the thatching amounting to 2·1d. per square yard. Sometimes brick tiling 2 inches thick is laid on the top of the straw; above the tiling comes random broken brick, and on the surface is basalt pitching 15 or 16 inches thick, packed with broken brick.

Basalt has been in use for about 45 years; before that a limestone rock from Dornik was principally used.

Taking a typical case, the cost of a covering such as that described is:—

	s.	d.	
Clay	3	6	per square yard.
Straw cover	0	2	„ „ „
Brick tiling	1	4 $\frac{1}{2}$	„ „ „
Basalt pitching	9	9	„ „ „
Labour	1	1 $\frac{1}{2}$	„ „ „
Total	15	11	„ „ „

In the Essex marshes low-lying clay lands have to be defended, and the practice of sea-walling, as carried on there, differs materially

from that in vogue on the sandy foreshores of Holland. Fig. 7, Plate 1, shows a typical cross section of the sea-walls in the Thames estuary, on the Essex side, under the supervision of the Author. It will be observed that, as compared with most of the Dutch sea-walls (e.g., Fig. 8, Plate 1), the English section is steeper and has less seaward prolongation. The Dutch practice is to carry the crest of the wall higher than in England; and the crests of the great defensive dams in Holland are built up to a level corresponding with 20·7 feet above Ordnance datum, whereas the maximum level on the Essex coast is 18 feet above that datum.

These Essex sea-walls are laid on the seaward side with a slope of about 2 to 1, and are usually covered with about 8 inches of chalk next to the clay. The chalk is covered with 12 inches of Kentish ragstone pitching, generally carried to within 3 or 4 feet of the top of the wall; and the toe of the slope is sometimes protected by a row of elm piles, about 5 or 6 feet long, driven by hand. Random stone pitching is also put in at the toe of the wall below low water. The average cost of protecting Essex walls in this manner is about 4s. 6d. per square yard, irrespective of the piling, random stone, and clay bed.

An extraordinary phenomenon occurs in connection with submarine slopes on many parts of the Dutch coast, namely, the prevalence of what are called "falls." Fig. 3, Plate 1, illustrates such a fall. The Author was fortunate enough to find at Westkapelle an official (Mr. Dekker) who had actually seen five falls take place near Veere, Walcheren. He described their effect as like that of an earthquake on the sea-bed, great local commotion being caused, and waves 10 or 12 feet high being developed. At some of the river-mouths there are deep channels close inshore, which are 100 to 135 feet, and sometimes even 165 to 200 feet, in depth. The sandy flats under water are very mobile; and at low water the earth-pressure sometimes sets this half-fluid mass in motion. Large areas of the flat, together with the clay on which it rests, then burst away, and an underwater avalanche is the result. Areas 20 acres in extent and 80 to 100 feet in depth have thus given way suddenly; and in the years 1887-96, 106 of these falls occurred.

The protection of the bed of the sea to avert such calamities is effected by various kinds of mattress-work (*zinkstukken*).¹ Mattresses of timber and fascines are floated to the site to be protected, sunk under a load of stone, and subsequently covered with stone pitching.

¹ Minutes of Proceedings Inst. C.E., vol. clxiv, p. 378.

These rafts sometimes measure as much as 25 yards by 300 yards; and the great art in depositing them is to secure their settlement without dislocation. With this object, the raft, when moored over the place where it is to be deposited, is surrounded by a number of boats laden with masses of rough stone. At a given signal blocks of stone are thrown into the centre of the raft, which sags with their weight and eventually takes the ground, first at the centre and the top end. It settles until it has a fair bearing over the bed of the sea to be protected, and is then covered with riprap. Concrete mattresses are now much in use, and the method is one of wide application in dealing with sandy bars at harbour-entrances. The object of sinking these mattresses is to seal over dangerous areas and avert the contingency of a fall of the sea-bed.

THE DE MURALT SYSTEM OF PROTECTION.

This system is now much in vogue on the Dutch coast, defences costing more than £50,000 having been carried out within the last few years. Mr. de Muralt is a polder-engineer for the island of Schouwen, where the problem of defence is acute.

Concrete mattresses on the de Muralt system have been adopted instead of the old type of fascine mattress, which requires frequent renewal. A series of concrete slabs, about 1 yard square and 5 inches thick, are laid on a flat which is exposed when the tide recedes. At the corners of each slab are iron attachments, by means of which adjacent slabs are linked together, forming a mattress which sometimes has an area of as much as 450 square yards. A flat pontoon is floated over the slabs, and at low water each slab is fastened by a chain to the underside of this pontoon, which rests on timber supports. The upper ends of the cables are attached to windlasses, which are distributed evenly in chess-board fashion, and are geared together, by means of shafting and bevel-gearing, so that after the pontoon has floated up with its load at high water and been towed to the intended site, the whole mattress can be lowered uniformly on to the sea-bed. The de Muralt concrete mattress is a highly efficient arrangement, and it is stated to be cheaper than the old system. Mattress-work may be laid either on a sloping or a level bed.

Above low-water mark, Mr. de Muralt adopts two methods for protecting sea slopes. One of these is employed in exposed situations and for facing dams on which heavy seas are experienced; the other is suitable for less exposed positions.

In the lighter system, concrete tiles of two types are employed (Figs. 4, Plate 1), which are 16 inches by 16 inches, and $2\frac{1}{4}$ inches thick. They are arranged with rebates at the edges, so that each pair of alternate blocks holds the intermediate block in position. Alternate blocks are keyed firmly to the slope by a reinforced-concrete pin about 18 inches long, which is driven home in the slope and secures the whole sheathing. On a slope thus defended slight settlement may take place without detriment. In several spots the Author found that this had happened where the light type of facing had been used, and that the facing had adjusted itself to each settlement without cracking or serious distortion.

The heavier type of defence is illustrated in Figs. 5, Plate 1. A number of concrete slabs, having a stepped surface and placed at intervals of about 10 inches, both longitudinally and transversely, on the foreshore or bank to be defended, are constructed in situ. Between these slabs the bank is trenched to a depth varying according to circumstances. In the trenches steel reinforcement is placed, and mass concrete is then filled in. The beams thus built up form a casement between the slabs, and are carried above and over the edges of the latter, so that in fact they form a framework, from which the slabs cannot escape. The slabs themselves are reinforced to prevent cracking from earth-pressure beneath during frost. They are free to expand and contract, which is an advantage not obtained, so far as the Author is aware, with any other system. Asphalt joints are provided in the beams, at intervals of about 4 yards, to allow for expansion and contraction of these members.

PROTECTIVE WORKS.

Travelling northward from Flushing, the principal dams on the Dutch coast are the following:—

Island of Walcheren: Westkapelle Dam.—This dam runs into sand-dunes at its southern and north-eastern extremities. Its length is rather more than 3 miles. The bursting of this dam would flood the entire island up to the town of Middelburg, $8\frac{1}{2}$ miles distant. A fall recently took place under water opposite the dam, and a portion of its stonework slipped about 12 feet (Fig. 3, Plate 1). Most of the dam is pitched with basalt, but in some parts Dornik limestone is used.

On the coast of the island of Walcheren there are also considerable lengths of sea-frontage protected by the de Muralt system.

Island of Schouwen.—Apart from subsidiary works, two sea-defence works are of special interest. These are the Osse break-water (Figs. 6, Plate 1), which was executed on the de Muralt system at a cost of £1 11s. 5d. per lineal foot, the corresponding estimate for basalt pitching being £3 12s. per lineal foot. The Langendijk (Fig. 8, Plate 1) lies east and west on the north coast of the island. It is protected partly by “stockade work” consisting of isolated piles which are driven in rows and act as wave-breakers.

Much difference of opinion exists among Dutch engineers as to the policy of adopting stockade work in the design of exposed dams. The argument on one side is that the stockade causes much broken water and consequent local disturbance of stone pitching. The other view is that its effect is to break the blow of the waves without undue surface disturbance, and that it is thus suitable for exposed localities.

On this dam the stockade work was originally in timber, but it has been replaced by reinforced-concrete piles, in two tiers 3 feet apart. The piles are round in section and 7 inches in diameter, and are pitched about 2 feet apart. Along the crest of the dam a de Muralt concrete coaming is built, 4 feet 3 inches high by 1 foot 3 inches wide. This coaming cost 5s. 4½d. per lineal foot.

Renesse.—Adjoining the lighthouse at Renesse is an interesting work constructed to prevent the undercutting of the dunes (Fig. 9, Plate 1). The toe of the dune was eroded, and there was considerable risk of a breach in the line of dune defences, which would have been disastrous. An artificial sandbank 80 feet wide was thrown up in advance of the foot of the dunes and sheathed with a covering of concrete slabs on the de Muralt system. The length of this work is 3,930 feet, of which 1,635 feet lies to the west and 2,295 feet to the east of the lighthouse.

The cost of the concrete slabbing was 4s. 11½d. per square yard, and it was estimated that had the same plan been followed, but basalt pitching on a clay foundation been used, the work would have cost 13s. 11d. per square yard.

The drift of the sand has caused a deposit between the new work and the foot of the dunes, and the area of erosion is thus now almost obliterated. Above the concrete slabbing the face of the dune is planted with tufts of helm grass spaced about 12 inches apart.

Hondsbosse Dam (Figs. 10, 10a, and 10b, Plate 2).—This work is situated in the province of North Holland, on the coast of the North Sea, and is approximately 3,900 feet long, running nearly north and south. It was reconstructed in 1874, and it was then deemed advisable to cut off the stockade-piles flush with the surface of the basalt pitching, which had become loosened by the straining

action that took place at the foot of the piles during heavy seas. The dam was originally pitched with Dornik stone, nearly all of which has now been replaced by basalt.

The dam is under the control of a polder-committee. It runs at its north end into the Petten dam, and this line of defences is one of the most important sea-works of that character in Holland, a breach 3 miles long, due to a gap in the sand-dunes, being closed thereby. The cross section of the seaward face shows the following construction :—

Basalt pitching, packed with broken brick	1 foot 5½ inches.
Broken brick	6 to 8 inches.
Brick tiling	2 inches.
Straw	1 inch.
Clay	3 feet 3½ inches.

The cost of the reconstruction amounted to 15s. 11d. per square yard.

Petten Dam (Figs. 11, 11a, and 11b, Plate 2).—This dam is about 1,100 yards long. At the junction with the sand-dunes, at its north end, there is a basalt spur groyne 150 feet long. In the angle sand has accumulated to a depth of 3 feet. Stockade-piles still remain, and have not been cut off flush, as in the case of the Hondsbosse dam.

The Petten dam is under direct Government control, and is not administered by a polder-committee. The cost of maintenance is £1,670 per annum.

As showing the vast importance of the defences provided by the Hondsbosse and Petten dams, it may be mentioned that two safety-dams have been constructed inside them. The lines of this triple system of defences are called respectively by the Dutch equivalents for the English words, “waker,” “dreamer,” and “sleeper.”

Helder Dam (Figs. 12 and 12a, Plate 2).—This is basalt-pitched and surrounds the town of Nieuwediep, which lies immediately to the west of the town of Helder. There is no second line of defence behind this dam, and it is one of the most remarkable in Holland, in that its underwater slope runs down with a uniform gradient of 1 in 1 to a depth of more than 130 feet.

Prinz Hendrik Dam, Texel.—This is on the east coast and extends in a north-easterly direction from the sand-dunes in the south of the island, for a distance of about 2½ miles. It is joined up with the harbour-works at Oudeschild. The most exposed portion is the south end, where the coast-line projects in a knuckle which is fully exposed to extreme gales from the north-east. Here the defence at low-water level consists of random blockwork placed inside

hurdling. The upper slope is 1 in 1, and the lower slope 1 in 8. It is noteworthy that the upper slope is slightly convex in section.

Zonnemaire Dam (Fig. 13, Plate 2).—This dam lies east of Brouwershaven, in the province of Zeeland. Its exposed face is protected with reinforced-concrete slabs, and along the crest is a reinforced-concrete coaming, about 3 feet high, which obviates the necessity of widening the dam at the back and thus encroaching on the cart-road at its foot.

ZUIDER ZEE RECLAMATION PROJECTS.

The Zuider Zee (Fig. 14) now covers an area of more than $1\frac{1}{2}$ million acres. Its depth increases from south to north and averages 13 to 16 feet: in the vicinity of the islands depressions exist. The average range of tide is only about 10 or 12 inches, and at the south end it is barely perceptible; north-westerly gales, however, sometimes raise the water-level 7 or 8 feet.

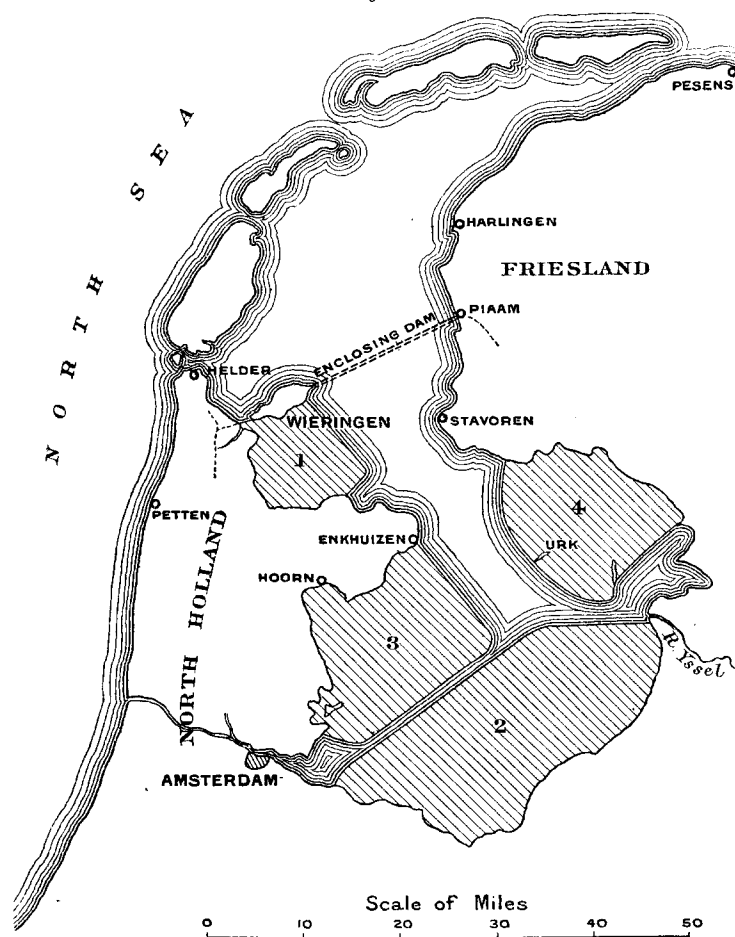
In view of the many discussions which have taken place as to the possibility of reclaiming the Zuider Zee, a short statement of its geographical conditions and a summary of modern proposals for its partial reclamation may not be out of place. The conversion of this immense area of shallow sea into dry land, and the consequent acquisition by Holland of a new province conquered by the arts of peace, is the dream of every Dutch patriot. Obviously, the expenditure of a vast capital sum on the reclamation of a tract of barren sand would be undesirable. Large areas of the bed of the Zuider Zee consist of fertile mud, which could be converted into valuable agricultural land; other areas, however, are almost exclusively sandy, and their reclamation would serve little purpose.

If a line from Veir, a little north of Enkhuizen, is laid out to the island of Urk, and then to the mouth of the IJssel, an area of about 500,000 acres is included. Four-fifths of this area is covered with rich soil 4 or 5 feet thick; the remainder is sandy. Laying out a second line from Veir to the coast of Friesland, near Stavoren, the area included is about 200,000 acres. The bottom of this area is for the most part of thick mud, the remainder being sandy. In the Zuider Zee the rivers of western Germany find their outlet.

The first serious studies in connection with the draining of the Zuider Zee were made by Van Diggelen in 1849. His project was of vast proportions, as he proposed the reclamation of the entire area, good and bad, and the control of the various rivers flowing into it. Briefly, he proposed a coastal canal, running from Hoorn to the north-west of Friesland, which was

18 CAREY ON WINNING COASTAL LANDS IN HOLLAND. [Minutes of
to have a width of 2 to 12 kilometres ($1\frac{1}{4}$ to $7\frac{1}{2}$ miles) and
was intended to be protected by two lines of dams. Two escape-
canals into the North Sea were also to be cut, one from Hoorn

Fig. 14.



MAP OF THE ZUIDER ZEE, SHOWING RECLAMATION-SCHEME PROPOSED BY
THE ROYAL COMMISSION OF 1892.

to Petten, the other discharging at Vlie. Another entirely
independent canal was designed to traverse the provinces of
Overijssel, Drente, and Friesland, collecting the land-drainage of
that area, and discharging into the sea at Pesens, to the west of

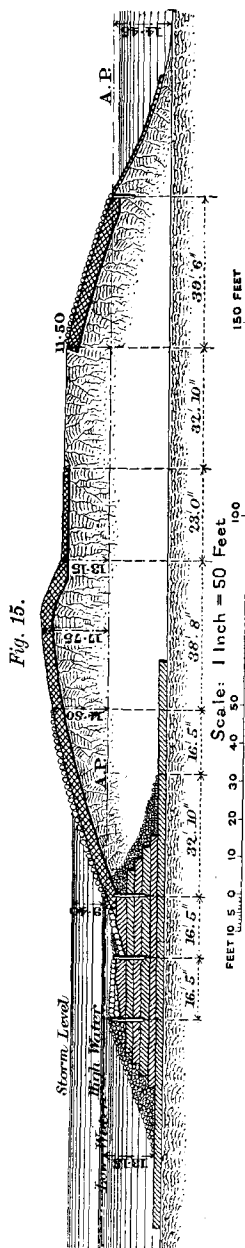
the Lauwers Zee. The northern islands of Holland were to be connected by two enormous dams, to protect the reclamation from the north-westerly storms that are so dangerous on that coast. Van Diggelen's estimate for this project was between 27 and 28 million pounds.

In 1865 the scheme was revived in a modified form. Colonel Beijerinck was deputed to report to the Dutch Government, and in conjunction with Mr. Stieltjes he spent 2 years in examining the bed of the Zee. Ultimately a State Commission was nominated, which presented a favourable report in 1873. A Bill was presented to Parliament in 1877 for embanking and draining the Zuider Zee and for the construction of a navigable canal between Amsterdam and Valhal. The State was to provide the necessary capital (£10,250,000), and the period for the execution of the works was not to exceed 16 years. The Second Chamber of Parliament passed a provisional credit for £600,000 for a complete investigation of the entire project. The question of the intended works was then submitted to the country, with the result that the ministers who had formulated the proposals described were defeated at the polls.

In 1882 an attempt was made to revive the proposals for the reclamation of the Zuider Zee. In 1892 a Royal Commission was appointed, the Chief Engineer being Mr. C. Lely. His proposal was to build a dam from the coast of North Holland via Wieringen to the coast of Friesland, near Piaam, and to drain four polders (Nos. 1, 2, 3, and 4, *Fig. 14*) successively, leaving a central lake, to be called Lake Ijssel. The Royal Commission generally approved Mr. Lely's plans. The length of the dam so designed was about 17·6 miles (29,300 metres). The original intended average section of this work is shown in *Fig. 15*. The estimate for its construction was £3,375,000; but to cover insurance of workmen and other charges, this estimate was increased to £3,700,000. Including defensive work and compensation for fishery-rights, etc., the total cost was estimated at £9,900,000. As, however, the construction of a work of such magnitude would occupy two generations, it has been argued that the slow extinction of the fishing-industry in the enclosed area would be automatic, and should not involve State expenditure.

The application of the de Muralt system in the execution of this work was proposed in 1907 by Mr. L. A. Sanders, of Amsterdam.¹ Briefly, his suggestion was to sink reinforced-

¹ L. A. Sanders, "De Toe-Komst van Cement-Ijzeren Putten en Platen op Waterbouw-Kundig Gebied," Amsterdam, 1907.



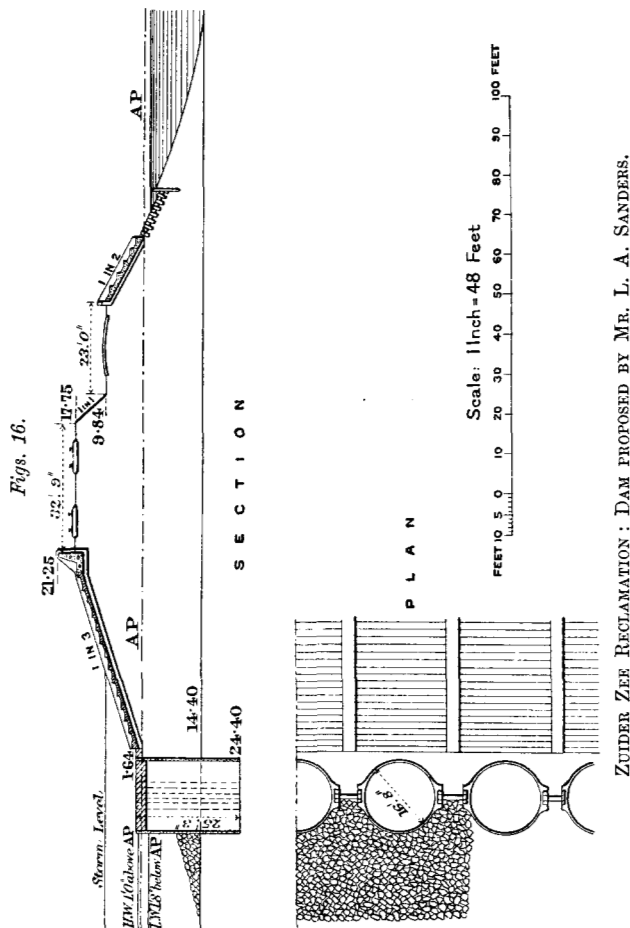
ZUIDER ZEE RECLAMATION : AVERAGE SECTION OF THE DAM PROPOSED BY THE ROYAL COMMISSION OF 1892.

concrete cylinders 16 feet 10 inches in diameter and 26 feet 8 inches high, and to drive reinforced-concrete shields between and connecting these (*Figs. 16*). The cylinders were to be filled with clay and sealed at the top with concrete 2 feet 3 inches thick. This work, carried to the height indicated, would, he estimated, permit of a clay embankment being tipped to the finished level (5·4 metres A.P.). The embankment would be wholly protected on the exposed side, and partially protected on the lee side, on the de Muralt system. He estimated the cost of such a dam at £2,700,000. Mr. Sanders's idea was to construct the isolating dam in its entirety as the first section of the reclamation-work. This plan, he stated, would represent a large saving as compared with the suggestion to make the reclamation of the four polders the first work.

The objections raised against Mr. Sanders's proposal are the risk of settlement of the cylinders, and their liability to be overturned from behind by earth-pressure or scoured from beneath by the sea. The question of the reclamation of the Zuider Zee, however, is one which public opinion in Holland will probably force to a practical issue at an early date.

In conclusion, the Author wishes to express his great obligations for the courteous assistance he received in his inspection of the Dutch coast-line. He desires especially to thank Professor Beekman of The Hague; Messrs. A. T. de Groot, Rijkswaterstaat engineer, Alkmaar; A. van Gelderen, Waterstaat engineer, Mid-

delburg; R. R. L. de Muralt, Polder-engineer, Zierikzee; and Messrs. Schotel and Dekker, in charge respectively of the Helder and Westkapelle dikes.



The Paper is accompanied by twenty tracings, from which Plates 1 and 2 and the Figures in the text have been prepared.

[DISCUSSION.]