

April 29, 1862.

JOHN HAWKSHAW, President,
in the Chair.

No. 1,065.—“On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea.”¹ By JOHN PATON, M. Inst. C.E.

DURING the professional engagements of the Author in Denmark, for several years, he became familiarized with some of the principal features of the country, and collected such information regarding the Sea Dykes, as he considered might be of practical utility. He examined the shores of Schleswig and Holstein, and also the line of the coast of the Jutland Peninsula. His present object, however, is not merely to give a description of the dykes, which enclose some of the richest and most productive lands in Europe, but to draw attention to the vast importance of reclamations from the sea. The surface of marsh lands actually recovered and protected by the dykes is about 900,000 acres,² a reclaimed district far greater than exists in any other part of Europe—probably in the world—occupying an area as large as the Bedford Level and the Great Fens of Holland combined.

Denmark is singularly interesting to Englishmen, for the enterprising spirit and energy which distinguish the people were, in a great measure, derived from the ancient Scandinavians; and, independently of their conquests and discoveries, led to the construction of works of practical utility, which can be examined with advantage and satisfaction at the present day. Even in the fifth century, the renowned Vikings were a great seafaring people. They are said to have discovered America five hundred years before Columbus crossed the Atlantic;³ they constructed sea dykes and reclaimed—although imperfectly—thousands of acres of land from the sea; they built

¹ The discussion on this Paper was taken in conjunction with the two following ones on a similar subject, by Mr. Oldham and Mr. Muller, and was continued over portions of three evenings, but an abstract of the whole is given consecutively.

² “The area of the marsh is stated at 65 square miles” (Danish).—Trapp’s Stats. Kalender, 1861, page 4.

³ Rev. Abner Morse on “Traces of Ancient Northmen in America with Geological Evidences of the location of their ‘Vineland,’” Boston, 1861; also other writers, viz., “Discovery of America by the Northmen” (Beamish, 1841).

the famous "Danneverke"¹ (a rampart wall constructed for the purpose of defending Schleswig, or South Jutland, from German invasion), which, for more than a thousand years, has stood the test of time, resisted the armies of Germany, and actually served the same purpose in 1850, which it did in the ninth century. Conquerors they were in a double sense, and of a far greater enemy than man; for while they visited with terrible retribution the invaders of their shores, they were endeavouring to restrain the ravages of the ocean. Denmark was then a wild inhospitable shore, described by Tacitus as covered with the gloom of forests, and deformed with wide extended marshes. And though it is generally supposed that such districts, with their humid soils, are bad incentives to enterprise and vigour, yet it is scarcely possible to find, among the vestiges of the past, engineering works more remarkable for their solidity and durability, or which have been more generally advantageous. These facts are the more extraordinary, when taken into consideration in connection with the changes to which these coasts have been subjected,² and the commercial importance of the navigation of the North Sea, the amount of shipping frequenting it being probably greater than in any other part of Europe.

Respecting the tracts of land which have disappeared, Mr. Trapp (whose name is so well known in Denmark) says,³ "It is well understood, that the changes in the relations between land and sea, which were earlier supposed to be caused by a regular increase or decrease of land, is now, according to more modern observations, considered to be derived not from changes in the volume of water on the earth, but from movements in the firm crust of the earth itself." The upheaving of the land, therefore, corresponding with what has been called a decrease of water, and the subsidence with encroachments or increase of water,—both of which movements have occurred extensively on the coasts of Denmark,—have had an essential influence on the geographical features of the country. Mr. Trapp shows the line of demarkation between the elevation and depression of the land to be north and south of a line drawn from the Nisum Fiord to Nyborg in Fynen (Plate 16); and further alludes to many places where the old beach is lying far above the point where the waves can now reach, strata of shells showing they have been undisturbed since they were deposited by the sea, creeks transformed into fresh-water lakes, and places that are called islands (or holms) perfectly land-locked; all which signs show that Denmark participates in the great Scandinavian rising which he assumes to be at the rate of one foot in a century, although it does not extend over the whole country. On the south of this line of

¹ *Vide* Appendix No. 2, page 448.

² *Vide* Appendix No. 1, page 448.

³ Trapp's "Statistisk and Topographisk Beskriwelse."

demarkation, there would appear to have been no alteration which would indicate general depression of the land for many centuries; and, a gradual sinking, as contrasted with the rise in Northern Scandinavia, cannot be traced. On the Island of Römö there is an old Viking harbour, which Professor Forchhammer states, has been known not to have undergone any variation for many centuries. Although now separated from the sea by a marshy alluvial plain, it is evident that no material elevation of the surface has taken place. The alteration of the coast line—which has occurred principally in Schleswig—is a much older phenomenon, since this harbour lies on the east side of the island, which owes its insular nature to a separation from the main land, and of course the harbour must be posterior to the separation.

Although there has not been any general depression, yet it is evident that a great part of the west coast has, for centuries, been yielding either to the force of the ocean, or to some other powerful influences, which the natural barriers have not been able to withstand. The land has been overwhelmed, rich and populous districts protected by dunes, and sometimes even with costly dykes, have been destroyed, and the face of the country entirely changed. It is worthy of remark, that the remaining portions of land left by the inundations, gradually formed together again, where the tide came in slowly, and consequently, by a rapid deposit of sediment taking place, some of the 'halligs' (small islands not embanked) became connected with the main land and were enclosed, but were afterwards totally washed away.

In order to appreciate the peculiarities and importance of dyke construction in Denmark, the Author has considered it necessary, that some of the most prominent features of the coasts should be pointed out. With this object in view, he has collected from the principal Danish authorities, accounts of the chief storms which have occurred on the Jutland coasts during the last two thousand years,¹ and which will be referred to in the course of the following observations. The form of the coast at three different periods, together with other testimony, indicates that the old boundary of the main land of Schleswig has been outside the present islands. The present collective area of these islands amounts to 160 square miles, whereas, when they were connected, they comprised an area of 1,200 or 1,500 square miles, now overflowed by the sea, but formerly covered with fertile fields, houses, and churches, and inhabited by a thriving peasantry. The present form of coast has probably existed since the great storm flood of 1643. Although it is probable that the traditional map of North Friesland, extracted from Danckwerth

¹ *Vide* Appendix No. 3, page 449.

(Plate 15), represents the character of the country two, or three centuries before the Christian era, yet for a period long antecedent to that time it must have been in the same state ;¹ for not only are vast submarine forests known to exist, but also submarine tumuli, —ancient burial places, in which stone and flint weapons have been found within the last few years, identical with a period when neither iron nor bronze was known,—assigned by Professor Worsaae, in his *Primeval Antiquities of Denmark*, to an age from three to four thousand years ago.² Almost everywhere on the coast, under the present surface of the sea, remains of these forests may be traced, with their roots still spreading in the ground. On the west side of the island of Sylt (Plate 16), and at many other places, submarine bogs are found, in which are distinguishable the fen plants of fresh water, together with trunks of trees and branches of the birch tree. All the plants found in these mosses, or forests, are fresh-water, or land plants. These peat bogs are diffusely spread over the coast, covered sometimes by the sea to the depth of 12 feet.³

It is stated by Mr. Trapp, that these signs of land, so situated, are not confined to the west coast of Schleswig and the Marshes, but “are observable in Jutland, on the west side of Nisum Fiord, and on the east side of Mariager Fiord ; also in Zealand, near Isefiorden, where a fresh-water peat bog is covered with a layer of blue clay, containing shells. They are also further observed on the south-west side of Bornholm, where large fir trunks lie fastened at the bottom of the sea, in a depth of several fathoms below the surface.”

It is quite clear, from the observations on these shores, that although there has been a violent and sudden depression of the coast, probably about two thousand years ago, nothing of the kind has occurred for a number of centuries due to general causes. But it is beyond all doubt, that there is a subsidence, originating partly from the swampy peat mosses below the marshes being compressed, from several causes, and partly on account of the water on which the marsh rests, being slowly filtered through the soil which surrounds it.

It appears from the investigations and researches of Professor Forchhammer, (to whom the Author is indebted for valuable infor-

¹ “The European races in the earliest period held the same relative situations as the tribes descended from them still continue to occupy.”—Pritchard’s “Origin of the Celtic Nations and Physical History of Mankind.”

² In the neighbourhood of Husum, in a tumulus covered by the sea, were found by Mr. Grove, (a gentleman well known in the neighbourhood) flint knives, weapons and other fragments. It was covered by a submarine peat bog, and was precisely similar to the other tumuli of the stone period, which lie scattered along the land.

³ Similar peat mosses are found under the marshes in Holstein, Hanover, Holland, and the east coast of England.

mation,) that a great part of the marsh lands rests on peat mosses, some being firm,¹ where they happen not to be heavily pressed by the weight of the marsh, and others on water containing peat, which continue to sink until far below the level of the sea. This is known to be the case in the Wilster and Cremper marshes, in Holstein. (Plate 16.) They are still gradually, but slowly, subsiding, and they probably cover an area of 20 square miles. Now as these marshes are illustrative of what the Author believes to have occurred extensively on these coasts, as also in other places, he will briefly allude to the following facts:—A boring having been made, for the purpose of testing the nature of the ground, the rod, after passing through a trifling deposit of loam and a few feet of peat bog, suddenly dropped 16 feet; and immediately a stream of gas rushed upwards, which, on being ignited, burned for several days². Other investigations were then made, and it was proved, that the marsh rested simply on a bed of water. In fact, it was a floating peat moss. This, however, was not the only curious feature; for during the storm in the North Sea in 1825, when the tide rose to a great height, and nearly approached to the top of the dykes, a number of salt-water springs burst forth from the marsh, and spread consternation among the inhabitants. Fortunately, the water fell as suddenly as it rose, and the marshes were thus saved from utter annihilation, from which they had only a narrow escape.

For a long period these districts were a source of anxious solicitude to the inhabitants and to the Danish Government, and no exertion, or expense, was spared to remedy the formidable and threatening evil arising from these peculiarities. Thousands of cubic yards of stone were thrown into the Elbe, (Plate 17, figs. 7, 15, 16, and 17,) at the point where the current impinged most strongly against the bank, and where there is a depth of 90 feet of water at spring tide, with a current of 8 feet per second. After considerable difficulty, the objects sought to be accomplished by these operations were obtained, and the current was diverted to the Hanoverian side of the river; thus modifying, at all events, one threatening evil, but still not removing the chief cause for anxiety, which appeared to be beyond human agency. Somewhat similar peculiarities were noticed in a district of the Eiderstedt, on the north bank of the Eider. (Plate 16.) The water in many of the wells, during the great flood, rose to an extraordinary height, and in other places several feet above the ground. But, although it was remarked that the water was not salt, there is little doubt that this phenomenon would have occurred had the pressure continued. The

¹ Other large tracts, which rest on old sea-sand, do not sink any more.

² Forchhammer.

marsh, however, although resting on peat bog, is more solidified, and is consequently less liable to permeation and an eruption of the sea, than the one previously alluded to. It is no uncommon occurrence for the dykes, in consequence of their weight, to exercise a great local pressure, causing a more rapid sinking than in other parts of the marshes.

These facts are important, because they, together with the curious storm floods which will be afterwards alluded to, afford the means of accounting for the tremendous disasters recorded, and which have been hitherto attributed to the bursting through of the protecting lands, or dykes, but which in reality may have had, and in several of the most important instances can be shown to have had, nothing whatever to do with them. This, it is believed, can be confirmed by that remarkable case, the formation of the Zuyder Zee, the site of which was originally a tract of fertile land of nearly two millions of acres,¹ covered by towns and villages, although in reality it was only a marsh resting on peat moss. This occurred, according to popular belief, by the bursting through of the isthmus between Steveren and Medemblick; but there is reason to believe the destruction of the isthmus was the effect, and not the cause, of that great eruption. It would appear to be a case precisely similar to that which has been stated with regard to the Holstein marshes; for only the year previously to the disaster, salt-water fish were found in the wells of the district, thus proving their immediate connection with the North Sea, and on this discovery some of the people left the country. The pressure consequent on the sudden and great elevation of the water in the North Sea was greater than the marsh was able to withstand, and the eruption from below overflowed and destroyed it, the isthmus then giving way as a necessary consequence.

It is quite possible, that other similar disasters in Holland, such as those resulting in the formation of the Bies Bosch and the Dollart,²—the former stated to have been formed in 1421, when seventy-two villages were destroyed by the bursting of a dyke,—may have had their origin in a like cause. The Author believes that wherever any serious breach has occurred in a main dyke, either in Schleswig, or in Holstein, it has rarely been by the direct action of the sea on the outward face, but rather on the inner slope, the waves rolling over the top and undermining the foot. Other circumstances of a similar nature, but on a vastly extended scale, to those above alluded to, have no doubt operated in the variation of the Peninsula, indicated between the period of its traditional state and the time of the Waldemars in 1240.

¹ A small lake formerly occupied the centre of this district.—“Encyclopædia Britannica.” Eighth Edition. Vol. xi. p. 581.

² *Vide* Appendix No. 3, A.D. 1277 and A.D. 1243, Dollart.

Independently of the two great phenomena,—the general subsidence of the southern portion of the Peninsula, no longer operating, and the gradual elevation of the northern portion of Scandinavia, including Norway and Sweden, still progressing,—other local peculiarities appear to have exercised considerable influence on the features of the country. Thus, for instance, the Island of Amrom is stated to have risen 20 feet from the earliest recorded flood. Features almost identical with these may likewise be traced in other great marsh districts. In Mr. Jackson's Paper on "The Engineering of the Rhine," it is stated that "the coast of Holland is continually changing, in a greater, or less degree, and during the sixteenth and seventeenth centuries it rose to the extent of 20 feet."¹ It is also well known that in the fens of Lincolnshire, which are for the most part below the level of the sea, vast peat bogs lie buried.

By comparing the catastrophe called the Cimbrian Flood, with those of later date, and especially with the last great storm of 1825, it has been ascertained to have reached about double the height of the greatest storm floods known in history. Professor Forchhammer states, that the difference between the height of the Cimbrian Flood, and the present daily water level, is 40 feet (Danish), or 41·3 feet (English); but he attributes this great elevation of the sea to some extraordinary and once-occurring agency. He states that "spring tides and strong westerly gales cannot explain such a height of flood; even if we have recourse to Plutonic movements of the bottom of the sea, we must imagine them to be infinitely stronger, in order to explain these floods by means of them." The upheaving of the Island of Amrom, after the general subsidence of large portions of the peninsula, does not appear to have been participated in by any of the other islands in the North Sea; at least, there are no positive traces of it, and, indeed, referring to the ancient map of Heligoland, a contrary result is observable. It is well known, that the area of that island was much greater in earlier ages. Thus, in the eighth century, it is stated to have been a thousand times larger than it is at present. It is certain that in the year 1216 a great storm flood devastated all the marsh lands, and that Heligoland lost so much, that although, in 1030, there were nine parishes, but two remained after the great catastrophe.² The White Cliff has been destroyed within a recent period. By comparing these records of storm floods with the maps of 1240 and 1860, (Plate 16,) the evidence and opinions of scientific men in the north of Europe, and the traditional map of Friesland, (Plate 15,) there can be little doubt that those shores have witnessed, within a comparatively recent

¹ *Vide Minutes of Proceedings Inst. C.E., vol. vii., p. 237.*

² *Vide Appendix No. 3, page 449.*

period, most singular variations, a correct knowledge of which is of great importance in the design and construction of the dyke works.

Although in many places an encroachment may take place on the land, by the sea washing away the shores and cliffs, yet it is limited in extent. Tetens says, that more marsh land has been restored since the embankments have been made than has been washed away; for not only are the inner marshes always lower than the outer, but the foreshore seems to be continually increasing. Besides this, it has been found, that many of the sluices now lie much too high, (thereby showing gradual relative depression of the land,) and consequently that they are incapable of taking off the land water. The marsh soil in Eiderstedt has certainly not decreased since dykes were introduced.¹

Amid all the changes which have occurred on these coasts, there would appear to have been no considerable variation—certainly since the time of Waldemar,—more than 600 years ago,—in the channel at the Lyster Deep; and probably even from the most remote ages, it has continued to be the deep inlet on the western side of the Peninsula. It now forms the only inlet, where a vessel of even ordinary size can enter. From the Eider to the Skaw, it is the only place, on this most dangerous and inhospitable coast—beset with sand banks stretching far out to sea—which could be made available as a harbour. This is the more remarkable, as all the drainage of the country falls to the westward, the deep fiords being on the eastern side. The entrance to the Liimfiord (an arm of the Baltic) at the Agger channel is gradually filling up with sand, and will only admit vessels drawing 5 feet of water. This opening to the North Sea was formed by the great storm of 1825, making an island of the northern part of Jutland; there was then a depth of 10 feet of water. The spit of land separating the North Sea from the Baltic is recorded to have been in existence for about a thousand years—previously to its being broken through, on the night between the 3rd and 4th February of that year, by a storm from the south-west.² It is stated by Mr. Juel, in the “Slesvigs Proviñcial Efterretninger,” that the five great floods, in which upwards

¹ Suderstrand, an Island about half the size of the present Eiderstedt, consisting principally of Dunes, in existence in the thirteenth century, is entirely gone. No doubt in the fearful flood of 1362, it met the same fate as Nordstrand in 1634, when the greater part of that Island was destroyed.

² This same storm seems to have equally affected the coast of Holland, covering with water an area of upwards of 300,000 acres, and doing immense damage. It is also stated, that a dyke constructed of masonry gave way, whereas other portions formed of fascine work were not injured. (*Vide* Mr. Jackson's Paper on the “Great North Holland Canal.” Minutes of Proceedings Inst. C.E., vol. vi. pp. 81-134.)

of thirty thousand persons perished, scarcely equalled it, either in the height of the water, or in the grinding and rolling motion of the waves. The most singular feature, however, about this flood was, that although there had been a number of storms of less violence during the winter, which had blown off tiles in the towns and unroofed the houses in the country, not a single tile was knocked down, or a thatch disturbed.¹ Though the wind is reported not to have been stronger than could have been expected with a flood of 4 feet over ordinary level, the water in the wells rose 6 feet, and sprang several feet high out of great holes in the marshes; while at the highest floods of 1791-94 and 1803, it stood on the east sides of the islands of Sylt, Fohr, and Pelworm at 10 feet above the ordinary height, this storm flood was 16 to 17 feet, and in some places in Holstein even 20 feet above the ordinary level. It is stated to have risen so rapidly, that at Simonsberg, it reached a height of 15 feet in one hour, and afterwards rose still higher. In the Eiderstedt the flood lasted an incredibly short time, and the water fell with equal rapidity.

This singular flood, as well as others almost as remarkable, must be attributed to agencies different than those arising simply from the effects of the violent gales of the North Sea. No such gales could have produced the effects there noticed. These storms seem, undoubtedly, to have been connected with earthquakes, or volcanic movements of the bottom of the sea, and the phenomena which were observed during, or immediately after the earthquake in Jutland, in 1841, corroborates this opinion. It will be impossible in this Paper, to do more than allude to these observations. It may, however, be noticed generally, that from the twelfth to the nineteenth century, no less than two hundred and fifty-two earthquakes occurred in the Scandinavian Peninsula and Iceland, the movements in the former being usually from S.W. to N.E., or almost invariably the direction in which the most disastrous storm floods have affected the Danish coasts.² At Agger the water is stated to have risen from 6 feet to 8 feet, and the rise was also distinctly perceivable in Trontheim Fiord. The islands (excepting Pelworm) suffered but little, owing probably to

¹ Vide "Slesvigs Provincials Efterretninger," p. 164.

² Vide "The Earthquake Catalogue of the British Association, with the Discussion, Curves, and Maps, etc. By R. and J. W. Mallet. 8vo. London. 1858."—During the great Earthquake of Lisbon, the sea was so much agitated along the coasts of Holland and Friesland, that vessels were dashed against each other and moorings broken, and shocks of Earthquakes and tremblings were felt in Denmark, Rendsborg, Elmsborn, and Meldorf. The wells and springs rose so high as nearly to inundate the land in places, and the River Eider was particularly agitated. Many other cases might be alluded to, showing disastrous inundations occurring on the low-lying coasts of Holland and Friesland, simultaneously with shocks of earthquakes in neighbouring localities.

the circumstance of the protection afforded by the dunes, which extend along the west of Jutland, and in the direction of the old line of coast, passing through Fanö, Römö, Sylt, and Amrom. (Plate 16.) The Author has examined them on the latter islands, where they are upwards of 100 feet in height. They disappear at Amrom, and are again seen on the west coast of the Eiderstedt. The disappearance of the dunes between these places is probably owing to the washing away of the marshes on their eastern sides, which could not take place in the other islands, owing to the circumstance of the land being too high for the sea to overflow them. It may be remarked, that the sand is in places singularly productive in grasses, far more so than is usually supposed. One island in the Baltic, within the Author's own knowledge, (and where he is now engaged in reclaiming 12,000 acres from the sea,)¹ has frequently realized an annual rental of from £3 to £4 per acre, by the sale of the grass alone; although at that particular locality, there is a depth of from 6 feet to 10 feet of sand, which, however, has been levelled by occasional floods, being only separated from the sea shore by the low sand dunes.

In making excavations between the main land and the Lyster Deep, covered with 6 feet of water at high tide, the Author has found, beneath 1 foot or 2 feet of sand, immense masses of partially decomposed land plants, apparently in the position in which they grew. This fact in itself would prove the great fertility of these districts, and show that although vegetation has seemingly perished, it has left extensive traces behind, which may ultimately enter once more into important usefulness when the district is reclaimed.²

Without entering into further particulars of the peculiarity of the coasts, it is now proposed to call attention to the details of the construction of the dykes. (Plate 17.) The construction of dykes on the coast of Denmark is of great antiquity, since Römö, Sylt, and Amrom had them in the earliest periods. They are not only mentioned by Saxo Grammaticus, but in much earlier records. Thus in the storm flood of 1075, the dykes, which certainly in those days were the now existing summer dykes, are alluded to as having been broken through. The North Frisians had them in 734, when Charlemagne attacked their southern kindred in Holstein, for they called

¹ This work has been executed under the Author's direction as Engineer, by Mr. J. R. Allen, of Preston; the pumping engines being supplied by Messrs. Galloway, of Manchester.

² Mr. Trapp states, that the levelled district from the Flyve sand on the west coast gives also good crops of grain, and he attributes this fertility to the fact of its intermixture with mica particles, which appear as regularly in the Flyve Sand as in the marsh clay. The sand also contains Titanic iron, and great quantities of amber, which are being continually cast up on the western shores.

their country 'Spadeland,' because the spade was so much used, as well for tilling the ground as for protecting the dykes, which they endeavoured to strengthen after each destructive flood. These dykes were also used as a means of defence; for the country, with its watercourses and channels, was a wild and almost impassable labyrinth, to those unacquainted with its intricacies. The early dykes were not, however, for regular enclosures, which were only fully developed in Denmark in the tenth century, and the larger enclosures in the fifteenth century, but constituted only slight protective works.

The present 'Halligs'—the remnants of large tracts of land—are instructive as to the earliest plans adopted for sea embanking. They are inhabited, but are only used as pasture lands, being subject to frequent inundations, and not being more than 2 feet or 3 feet above the ordinary flood level. In early days, ditches were dug in the marshes, and mounds were formed in the centre, upon which the residences were erected, and round which the tide continually flowed. Thus the dweller on the 'Hallig' had only this little mound and the strength of his house to depend upon for his security. Any one travelling through the Eiderstedt may notice this peculiarity in the marshes even at the present day. These little elevated spots were called 'Warfts;' and by degrees, as the land became cultivated, the dykes were extended until whole districts denominated 'Koogs' (in Holland 'polders') were enclosed, and the country assumed the rich appearance it now bears. It may be remarked, that the preservation of these 'Halligs' and 'Islands' is of vital importance to the whole of the Schleswig marsh lands, for it is certain, that if they ceased to exist, a vast extent of main land dykes would require to be reconstructed. The sea, now broken by the islands, would then expend its full force on the main land, and what is worse, the forelands, now forming so rapidly, would be destroyed, which are at the present moment so essential to the safety of the dykes. It is a curious fact, that while the forelands are forming, the 'Halligs' are rapidly decreasing, so that the beneficial influence they exercise will cease with time. It is even stated, that there is a loss of 4 feet yearly of the edge of the beach.¹ The works, however, now being carried out will ultimately stop this destruction.

The Island of Pelworm possesses, in its isolated position, a vast influence on the maintenance of the marsh districts, notwithstanding all the strange vicissitudes it has experienced. It is supposed, by some people, that it will inevitably disappear in the course of time; but the Author is of opinion, that it ought to be secured

¹ In the year 1713 the 'Halligs' paid taxes for 8,056 Tönder, while the taxable area in 1778 was reduced to 4,980 Tönder, showing a decrease in 65 years of about one half the area.—BRUN.

from such a fate at almost any expenditure of money, not only because of the intrinsic value of the island itself, but on account of its importance as an advanced protection to the Schleswig coasts. The dykes on Pelworm, as also on the other islands, are not so high as on the main land, owing to the circumstance of the tides not rising to the same extent, as where the current is completely stopped, and where the breaking of the waves is more dangerous. The nature of the soil would also appear to be the great difficulty with regard to this island, and renders the utmost caution, combined with the soundest skill and judgment, requisite. It is below ordinary flood level, is gradually sinking¹ like other enclosed lands, contains layers of peat, which not having as yet become sufficiently compressed, are unable to withstand the pressure resting on them, and thus the island will continue slowly to subside, as it has done for centuries, until this compression is accomplished, unless the intervening space between the main land be enclosed. It is therefore a question of moment, whether the strong and perfect stone dykes, extending 6 miles in length, will absolutely free Pelworm from danger.²

On the 'Hallig' of Nordstrandischmoor, which previously to the storm flood of 1634 formed part of Nordstrand Island, the layers of peat were covered, close to the surface, with a deposit of loam and soil.

The dykes in the two districts of Ditmarsh and Eiderstedt, the former in Holstein, the latter in Schleswig, or South Jutland, may be classified as summer dykes, inside dykes, and outside, or sea dykes. The summer dykes are the most ancient, and seldom exceed 8 feet in height. They are built far inland from the present line of coast, and were constructed by the early settlers on the 'Warths,' as a protection against occasional tempests. They are now almost superfluous, but serve as an additional security, in case of the sea dykes giving way. They also, like many of the other dykes, afford the means of communication between the different 'Koogs,' a roadway being formed on the crest. The districts are now divided into what are called 'Deichbands,' that is, an Association of a number of 'Koogs,' for the maintenance of the sea dykes, to which each proprietor contributes his quota, according to the situation and the advantages afforded to his property. The inside dykes formed, originally, the sea dykes, and vary in height from 8 feet to 10 feet over ordinary high water. Like the

¹ "In Pelworm, a greater or quicker sinking has shown itself during the last century: for this part of the marsh was formerly the highest, as the 'Hallig Hoog' is still the highest 'Hallig.'—Bruun, *Marsch Oer*, p. 35."

² The extensive 'watts,' or spaces between high and low water, on the west of this Island, having no protection, consist entirely of sand, where little vegetation can strike. The stone dykes at Pelworm have already stood the ravages of the sea undamaged for ten years.

summer dykes, they were for a long series of years the only means of protection to the country. In the Rivers Eider¹ and Elbe, and on the coasts which are subject to the tides, and to considerable variation on account of the winds, the sea dykes are of a more permanent construction than in the rivers where no tide occurs, and the elevation of the water arises from continuous land floods, occurring perhaps but once, or twice in the year. A considerable portion of the River Eider has been embanked, extending for many miles from the sea nearly as far as Rendsburg.¹ It had originally two outlets to the sea, and formed a junction with the Rivers Hever and Treene.

The dykes are erected at various heights, along certain parts of the coast, according to local circumstances; an excessive height being found undesirable. As a general rule, the highest known flood level is taken as a point of departure, and the height of the wave is then added. As, however, the height of the outer ground, called 'watt,' being the space between high and low water, has a considerable influence on the height of the wave, the following normal sections have been considered by Captain Carstensen, the Dyke Inspector in Schleswig, to meet the requirements in his district:—

	Feet, Danish.
1st. For exposed situations, with low outer ground	18
2nd. Ditto, with higher outer ground, or less exposed with low outer ground	17
3rd. Unexposed, with high outer ground	14, 15, 16

One of the chief considerations in the first formation of the dyke is the space requisite for the cess, as the dykes are necessarily so high that they cannot have one slope on the outward side. Generally, in Schleswig, (Plate 17, fig. 1,) a slope of 3 to 1 from the top is used to a height of 10 feet or 12 feet over ordinary flood, finishing with a cess of 8, 10, 12, or 15 to 1 according to circumstances. The section is, therefore, entirely relative to the position which it occupies, the extent of the foreland, its height above ordinary water level, and its exposure to the direct action of the waves and wind. Thus, in illustration, the dykes on the Islands and the Elbe, may be compared with those on the mainland of Schleswig. The variations in the height of the water on the coast and other peculiarities, render modifications in the profiles necessary.

¹ This river is navigable for vessels drawing 10 feet of water as far as Rendsburg, and its length to the Baltic being only 90 miles, it reduces the dangerous passage round the Skaw nearly 900 miles, and has been of great importance to the trading interests of the country. In Schleswig generally the tide recedes from 4 to 11 feet below ordinary flood,—at Husum, Friedrichstadt, and Tönning about 9 feet, and at the Islands 10 feet. At Rendsburg the difference between high and low water is 2½ feet, with moderate winds.

Even the same dyke has often a different section. During some of the great storm floods, the water rose to a height of 14 feet on the sheltered parts of the Holstein dykes; while in others, scarcely more than a mile distant, it was 20 feet above the ordinary level, and rushed over the top of the dykes with considerable force. At Meldorf, with a south-western wind blowing right on the land, before which there is a broad foreland, the water rose only 8 feet to 9 feet above ordinary level; while at Brunsbüttele, on the Elbe, it was upwards of 14 feet; and again, scarcely three-quarters of a mile distant—where the water was sheltered from the wind—not more than 8 feet. The variations in the rise of the water, (which appear to diminish northward,) on the Jutland coast, are equally remarkable on the Baltic side, but as is well known, they are due entirely to the winds.¹ These facts will show the importance of local peculiarities, which would appear not to exist on the coast of Holland, or probably in any other part of Europe, and of which the later constructors of these important works have not failed to avail themselves, rather than depending entirely on theoretical considerations. The width of the top, in the smaller dykes, is from 8 feet to 10 feet, and in the larger ones, from 10 feet to 20 feet. The crests, as previously stated, are used as roads, sloping on one, or both sides to allow the water to drain off: indeed the breadth of the top depends, in a great measure, on whether the dyke is to be used for a road, or not. Although a high level for the crown is of much importance, and some dykes have been made higher since 1825, it is not always desirable, as for example in the Island of Pelworm. The dykes have, almost universally, flat slopes on the seaward side, on which their strength and security depend; and although this increases the cost of the work, it is undoubtedly preferable to incur this additional expense in the outset, rather than to risk the construction of a weaker form; still there are limits which both slopes should not exceed. Generally the inner slopes of the dykes have an inclination of $1\frac{1}{2}$ to 1. The outer, or sea slopes vary considerably, being in the Eider and the Elbe sometimes 3 to 1, but where they are exposed to the sea 6 to 1, and even more, according to local circumstances. Thus in illustration, attention may be called to the curved sea slopes of the Pelworm dykes, the Friedrichenkoog dykes, the King Fred. VII. Koog, and the dykes at Kronprindzen Koog and Brunsbüttele, (Plate 17, figs. 12, 13, and 14), in Holstein, four, or five of the best and strongest forms of construction, and which are peculiarly adapted to their respective localities. It must be observed that the stone facing is considered by some, a dangerous mode of defending the dyke, as it prevents the natural rising of the ground,

¹ *Vide* Appendix No. 1, page 448.

causes a depression at the foot of the facing, and is very expensive. Its application, on a large scale, is only justified under peculiar circumstances, by the want of straw, and by the scarcity of labour in case of danger. In exposed localities, these convex dykes are highly important. The height is taken at 4 feet over ordinary flood, and the projection of the stone, say three times the height above the outer ground, with a cess, or grass slope forming a tangent to the circle.

In fixing the width of the top and the inclination of the dyke, due consideration has to be given, not only to its position, but also to the quality of the material to be used, which consists sometimes of clay, and at others of moor, or bog earth. It is usual for the dimensions of the dyke to be enlarged, or reduced accordingly; and where it has to be built on a place still covered with trees, they are removed, and the ground is cut up, so as to form a complete junction with the new embankment. The best material which can be used for the dykes is clay, mixed with sand; and as the marsh ground itself is usually of this nature, it is generally used. Clay alone, without intermixture with sand, easily bursts after exposure to the rains, or dries suddenly by excessive heat. Common soil is frequently used, and is considered good, though not equal to the sandy clay, as moles, rats, and foxes can more readily make passages through it, which at high water may sometimes become dangerous, and the holes are not easily stopped. Where good materials cannot be procured, in sufficient quantities, for the formation of the dyke, it is customary to cover the water slope with clay, several feet in thickness; and if the material is of fine sand, or of bog earth, both slopes are covered with clay. In other cases, also, where dykes are made of sand, or earth, it is necessary to fill up the interior with clay, laid a considerable depth in the ground, as experience has shown that the water will, without this precaution, sometimes find its way through the ground, and issue behind the dyke.

Respecting the formation of the dyke itself, this usually corresponds with the work at ordinary embankments, excepting that in filling up for the dyke, it is desirable to keep the earth parallel with the outer slope, filling in with those portions from the inner side of the bank. When this is done, and the works are sufficiently solidified, the slopes are covered with grass sods, 6 inches thick, and one foot square, which form an important feature in the Schleswig dykes, and every care is taken to improve the growth of this grass, no plants or trees being allowed on the banks. Indeed over the level of ordinary flood, grass sods are nearly always used, either uncovered, or covered, with straw matting, and in exposed places they are connected by straw bands.

In cases where excavations have been made for materials for

the bank between the dyke and the sea, they are not cut in a direction parallel with the current, or in connection with one another, small banks being left between the excavations, to prevent the formation of a stream from a sudden influx of water. Wherever suitable earth is to be had outside the dykes, it is always taken, but where circumstances require it to be used from the inside, it is only done with extreme care, a breadth for the berm, or cess, of 50 feet to 80 feet being left.

Where every ordinary tide reaches the foot of the dyke, and there is a low exposed 'watt' or outer ground, the works comprise—

1st. Pitching the sea slope with stone.

2nd. Pitching only the foot of the dyke, and increasing the slope.

3rd. Covering the sea face with straw matting.

4th. Protecting the dyke with fascine and hurdle works.

All these plans have been carried out with uniform advantage, under the circumstances in which they have been applied. Of course the best protection which can be afforded to the foot of the dyke, is a good foreland lying on its seaward side, and the probability of damage decreases with the height of this foreland. Where, however, there is deep water, this cannot be obtained, and the breaking of the waves is not only increased, but the dyke is exposed for a longer period to their operation. Everything which can tend towards the increase of foreland seems to be adopted as the surest course; such as groynes, coverings of straw and brushwood, &c., by which the expense of covering with stone is reduced. There is no feature of greater importance in connection with the dykes than the projecting works, or groynes. Where they are short and low, although they prevent the outer ground from being hollowed out, they do not cause any raising of it. It has been found, that where they have a height of 2 feet above ordinary flood, with a length of 1,300 feet to 1,700 feet, they afford practical protection to the dykes, as they cause the outer ground to rise considerably, and they are indeed quite indispensable. Where the object is rapidly to increase the alluvium, they are constructed with the following section:—Height, 2 feet to 5 feet; width at the top, 4 feet; with slopes of 4 to 1 on the west, and of 3 to 1 on the east sides. The earth work is rounded off so as to increase the section, and is covered with grass sods and straw matting. Some of these works have been constructed of great length, one of 7,689 feet (Plate 16, General Plan), with the object of ultimately connecting the Hamburger Hallig with the main land.

In the first instance, above alluded to, of pitching with stone, the sea slope is covered with a layer of clay and small stones,

about 1 foot in thickness, on which are packed stone blocks of at least 300 lbs. weight, the smallest section of the stones lying uppermost. When constructed on sound ground, this form is almost imperishable, and affords a complete resistance to the greatest storm floods, and also receives but little damage from the ice thrown against it in the winter.¹

Much steeper slopes are used with the solid form ; generally an inclination of 2 or 3 to 1 may be adopted. The pitching is carried to a height of from 12 feet to 16 feet above ordinary flood. Where the stones are procured with difficulty, or in cases where the ground may not be equally favourable, the curved form is used, or the foot of the dyke only is covered, as mentioned in the second case. Here the slope is lengthened, and assumes the general character of the dykes having a considerable foreland. It answers well under certain conditions, naturally not causing so great a depression at the foot as with the stone-faced dykes.

In the third case,—protecting the slopes with twisted straw bands,—it has been found, that although they have some disadvantages, particularly as regards their durability, they are considered in the end most generally advantageous. They are used, first in urgent circumstances, such as in winter, or where loss of time would increase the danger, or the loss of earth ; secondly, when grass sods are not to be procured, and the material is clay, or sand with a considerable portion of clay ; and thirdly, to repair all damages under ordinary flood. In all cases where the earth is not covered with grass, the straw must be spread over as thickly as possible. The rye, or wheat straw, 2 inches or 3 inches thick, is fastened to the earth, with straw bands, formed during the work, by stitching down, perpendicular to the spread straw, the one end of a portion of the straw about 1 inch thick ; the loose end is then turned round, and stitched down again, about the middle, into the dyke 6 inches or 9 inches ; the number of the stitches is three, or four per foot in both directions. When there are four per foot, the distances between the straw bands are first made two to a foot, and then care is taken that the two new stitches come between the first. Other straw ropes are then fastened, and interwoven together, and the same operation is continued ; the entire face of the dyke being sometimes covered in this way, the ropes being laid diagonally along the bank. As this straw matting can only be used with soft materials, it has to be renewed at least once a year, but generally twice, and very often three times. In the latter case, where the situation is exposed, the yearly expense is so considerable, that the construction of a stone dyke is preferred,

¹ Colonel Christensen and Captain Irminger, officers of great ability, have proposed and carried out successfully considerable modifications of these stone slopes.

and is considered more economical. The average cost, including work and materials, is 3 shillings for 256 Danish square feet, or about 1½ penny per square yard English.

The fascines generally used, consist of brushwood bound together in bundles; the best are composed of willows. They have a length of about 10 feet, a middle thickness of 1 foot, and are bound as shown in Plate 17, figs. 9, 10, and 11. The mode of construction, for securing the foot of a dyke with these fascines, consists in several layers being placed one over the other, each row being covered with rough stones. In the direction A B (Fig. 10) they are laid close together, and bands, made of reeds, or willows, are then fixed to them by small stakes, which are driven into the ground. In the same manner the other layers are made and fixed to the first layer, and to the ground, to depths varying according to circumstances from 2 feet upwards, until the required height is obtained, it being customary to place four, or five layers, giving a height of 6 feet or 8 feet.

Another method of covering the slopes, and of protecting the foot, consists in laying fascines, with the butt ends at the foot of the slope, at distances of 1 foot 6 inches from each other; the brushwood is then divided, giving an equal thickness on the dyke of 6 inches. When this is done, strong willow bands of fascines are laid obliquely, at equal distances of 1 foot 6 inches, ascending from the foot of the slope, and are fixed by strong stakes into the dyke, the intervening spaces being filled up with stones.¹ The slope is sometimes covered with clay and gravel. Various other fascine, or bush works are adopted, suitable to the more exposed localities, as for example at Schehlenkuhlen, on the Elbe. (Plate 17, figs. 15, 16, and 17.)

The Author has found that sea weed, together with stones, has also been adopted on some of the dykes, and it has been strongly recommended by one of the Dyke Inspectors. He has used it himself in a sea embankment on the Island of Lolland. At Beitenburg, in Holstein, where a clay dyke was found to be sinking, on ground which was broken by the inundation of 1825, a dyke of hay was constructed by Colonel Christensen. In this way he succeeded completely in keeping the water from the marsh, and was enabled to construct a solid bank before the autumnal storms began.

Notwithstanding that all the modern dykes have been constructed with reference to the great storm flood of 1825, a combination of circumstances may arise, rendering it necessary to adopt additional means of security, at moments of emergency, and therefore, at

¹ It appears, from Mr. Jackson's Paper on "The Great North Holland Canal" (Minutes of Proceedings Inst. C.E., vol. vi., pp. 81-134), that fascine work somewhat similar in description to this is used in Holland.

certain exposed places, means of protection are at hand. Small stakes are driven into the dykes at distances of 4 feet apart, and planks are secured to these, the space between being filled in with earth. In another method, fascines are used in lieu of planks. In this manner a dyke can be easily and quickly raised 3 feet or 4 feet. Where fascines and planks are not easily procured, a number of stakes are driven into the dyke, and clay, brushwood, stones, and sand-bags are rammed between the spaces, and the heads of the stakes are then bound together. By these means a sudden danger has been more than once averted, and the districts have been saved from inundation.

According to the laws regulating the 'Deichbands,' all the inhabitants of the 'Koogs' have an interest in the protection and security of the main dyke, and contribute towards its maintenance, relatively to the position of their lands, their exposure to danger, and the intrinsic value of the soil. The Government at the same time exercises a controlling power through the Dyke Inspectors—always engineering officers of great skill and judgment, and whose lives are devoted to perfecting the works under their control.

In some instances, sluices have been a considerable hindrance to enclosures, several streams passing through the foreland, necessitating works of an extensive and costly nature. During the last few years, vast sums of money have been expended in these works (which can only realize a profit after years of labour), and most important projects are still being carried out. These beneficial changes are mainly due to their Excellencies M. Wolfhagen and the Holstein Ministers, and to the liberal and enlightened views of his Excellency M. Fenger, who has provided the ways and means for carrying out the works, and whose elevated mind and professional reputation are justly esteemed by his country. There are few cases, indeed, where the expenditure is not justifiable, more especially where such reclamations give additional security to the existing 'Koogs.' Thus, for instance, as in the foreland 'Friedrichen Koog,' lately enclosed from the designs and under the direction of Captain Carstensen, lying south of Hoyer (Plate 16, General Plan). This unites a most favourable situation and form, with a superior soil, and, besides affording the means of improving the drainage, it is found highly advantageous in financial respects. The height of the foreland was about 2 feet over ordinary flood level. The quay, or protecting dyke, erected previously to the construction of the main bank, and placed about 500 feet distant, was of great service, in enabling the work to be carried on with regularity and without interruption. It is sometimes carried to a height of 6 feet or 8 feet over ordinary floods, and is usually erected one year before the other. The area of this enclosure is 2,000 acres, and the total cost, including the stone sluices, (which amounted to

£17,000,) the roads, bridges, and ditches, has been about £48,000; the land realizing nearly £70 per acre, or an immediate annual rental of £3 per acre.

In concluding these remarks, the Author considers that the true test of successful engineering enterprises is not so much the perfection of the gigantic works which have been raised up as monuments of skill, but rather the benefits they have conferred upon mankind. If reclamations from the sea are judged by this standard, the advantages are incalculable, and it can be shown that even as they exist at the present moment,—although they require the closest practical and scientific attention,—no other engineering works are of more paramount importance, or have conferred greater benefits on the world.

By considering all the changing and chequered events of which Denmark has been the scene, for a lengthened period of 2,000 years; looking to the Danish coasts as they existed only 600 years ago; and remembering the small amount of scientific knowledge exercised in the enclosure of land at that time, it is impossible not to be impressed with the skill and judgment which have been manifested in the construction and completion of these works. From the earliest times the descendants of the great Vikings have gone on, amid difficulties and perils, year after year, century after century, with unabated zeal and untiring energy, adding to the security and extent of their lands, converting them from desolate tracts into rich and fruitful corn fields. They are, however, now well compensated for the troubles they have encountered during long ages of vicissitude. Originally a trackless waste, now some of the richest land in Europe marks the same locality, and, together with other parts of the kingdom of Denmark, furnishes corn to England, to an extent only surpassed by two other great states of the world. A surplus of about two million quarters of grain is exported from Denmark; the total production being about nine millions to ten millions of quarters annually. The two Duchies of Schleswig and Holstein supply three millions of this amount. By this excess of production over consumption, in a great measure owing to the reclaimed districts, the absence of all poverty in the country can be accounted for. In addition, however, to the grain crops, there are large numbers of horses, and upwards of 70,000 head of cattle and 150,000 sheep annually grazed and fattened on those fertile marshes, and most of them are exported for the English market.¹

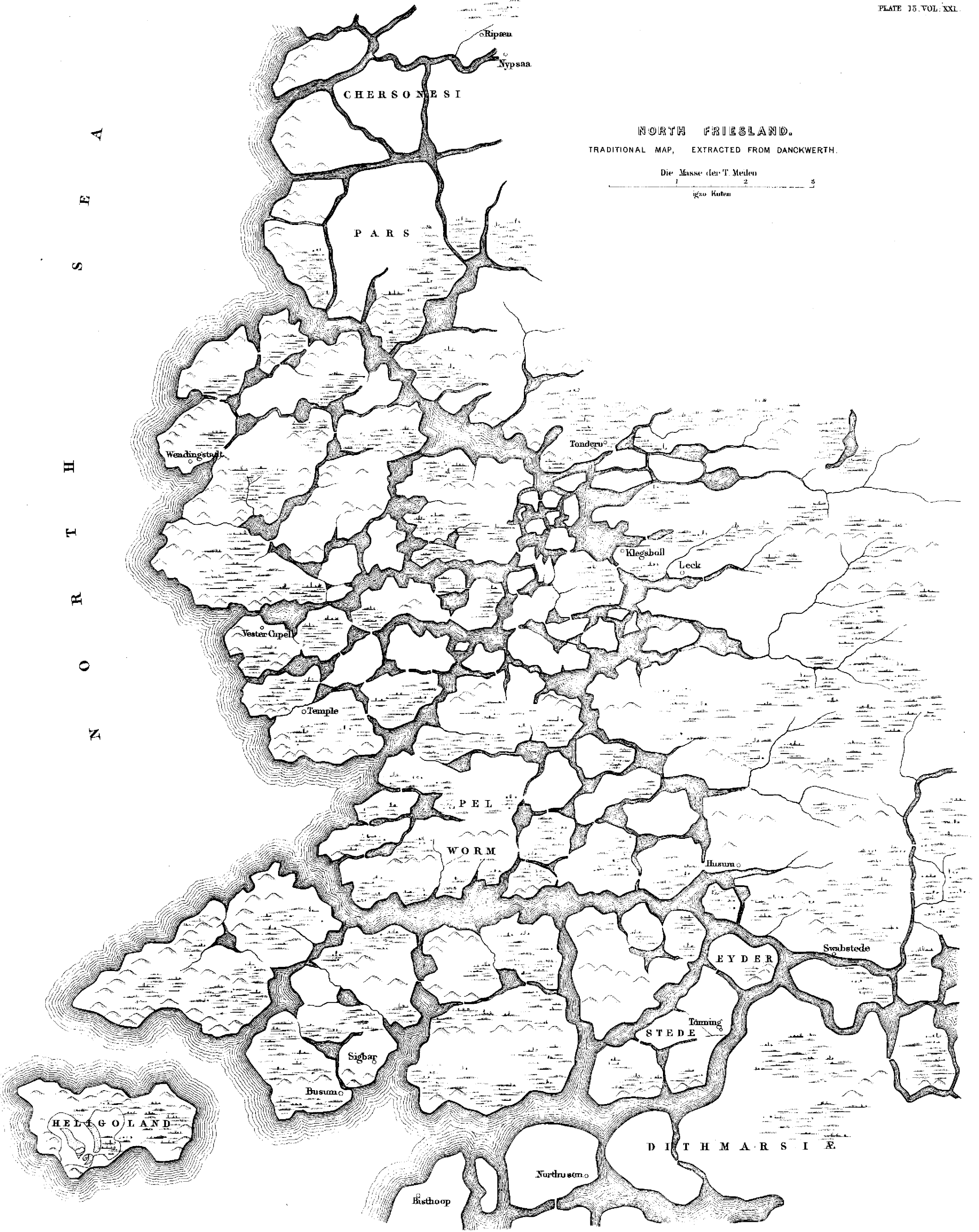
¹ The total number of horned cattle in Denmark may certainly be calculated as from 1½ to 2 millions. In 1860, the horses in Denmark, Schleswig, and Holstein are stated at 600,000, and the sheep in the Duchies about 323,000. The grain exported from Schleswig and Holstein in 1855 was 643,075 quarters.—“Trapp's Statistics.”

By comparing these results with those of other reclamations, and considering what might be derived from further extensions, an estimate may be formed of the probable results of reclamations from the sea in their most extended sense. If attention is confined, in the first instance, to the great reclamations termed the Bedford Level and the Lincolnshire Fens, although not nearly so exposed a country as Denmark, it is known that in early times the districts were almost as desolate as North Friesland, yet the level of the Fens now contains more than 600,000 acres of the richest land in England; and considering the comparatively short period (about 200 years) in which this has been accomplished, it is almost as marvellous as the Danish works, or as those in Holland, and is another forcible example illustrating the triumph of engineering skill over natural disadvantages. In the earliest times, that district was a dense forest, then it became a swamp, probably through some great subsidence, and was inundated by the sea in the thirteenth century, when so many disasters occurred on the Danish coast, and was first attempted to be reclaimed in the fifteenth century. Without venturing to calculate the advantages which have been already derived from these monuments of industry, or the benefits they have conferred on the country, it is believed that the present value of the Fen districts cannot be less than £50,000,000, while the annual yield of corn is enormous.

In Holland, vast reclamations have been effected contemporaneously with those in Schleswig, and works have been carried out there, which are estimated to have cost not less than £300,000,000, and to be by no means in excess of what is actually required. The area, however, of the marsh districts enclosed by the dykes is stated by Mr. Hyde Clarke, and in Dugdale's¹ 'Treatise on Embanking,' not to be so extensive as that of the English Fens.

Now, independently of the results from other enclosures, such as Romney Marsh, the earliest embanked district in England, and Haarlem Lake, each covering an area of 70,000 acres, the three cases mentioned have an area of more than 2,000,000 acres, representing an annual revenue of about £8,000,000 sterling, a sum equivalent to more than the net passenger receipts of all the railways in the United Kingdom, and they are probably capable of affording a larger supply of grain than is now imported from America, Russia, and Prussia combined. It has been estimated by

¹ "Through the exertions of Colonel Vermuyden and his successors, a district has been reclaimed from the sea in England larger than the Province of Holland itself." "Sir W. Dugdale, in his 'History of Embanking and Draining,' reckons that the amount recovered in England is equivalent to the whole United Provinces."—(*Vide* "The Engineering of Holland," by Hyde Clarke, in 'Weale's Quarterly Papers,' Part iv., vol. iv., p. 5.)

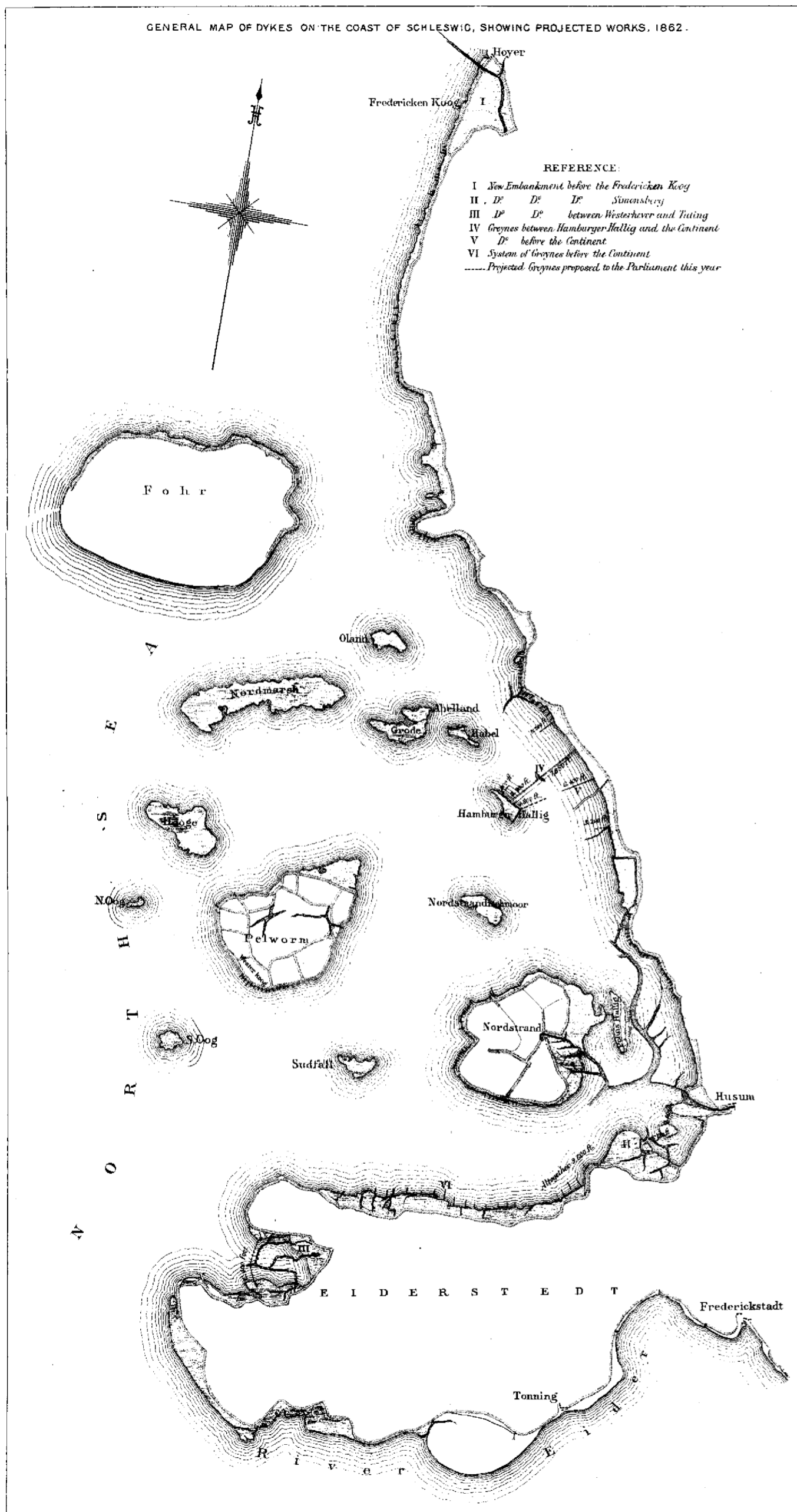


JOHN PATON DELT.

Minutes of Proceedings Institution of Civil Engineers Vol XXI Session 1861-62.

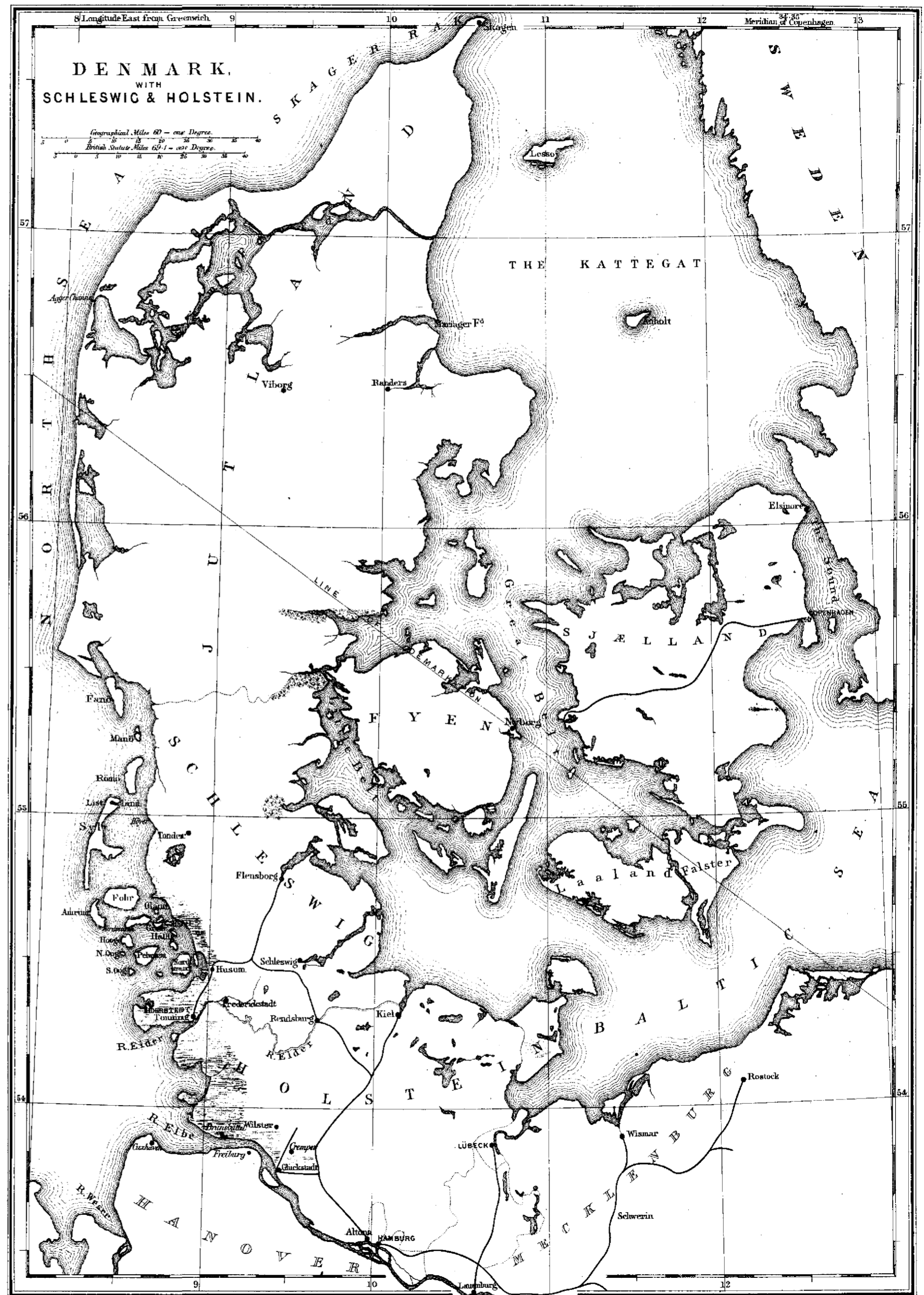
WILL. BROS. LITHRS. 25, ABLE ST. HOLBORN.

GENERAL MAP OF DYKES ON THE COAST OF SCHLESWIG, SHOWING PROJECTED WORKS, 1862.



REFERENCE

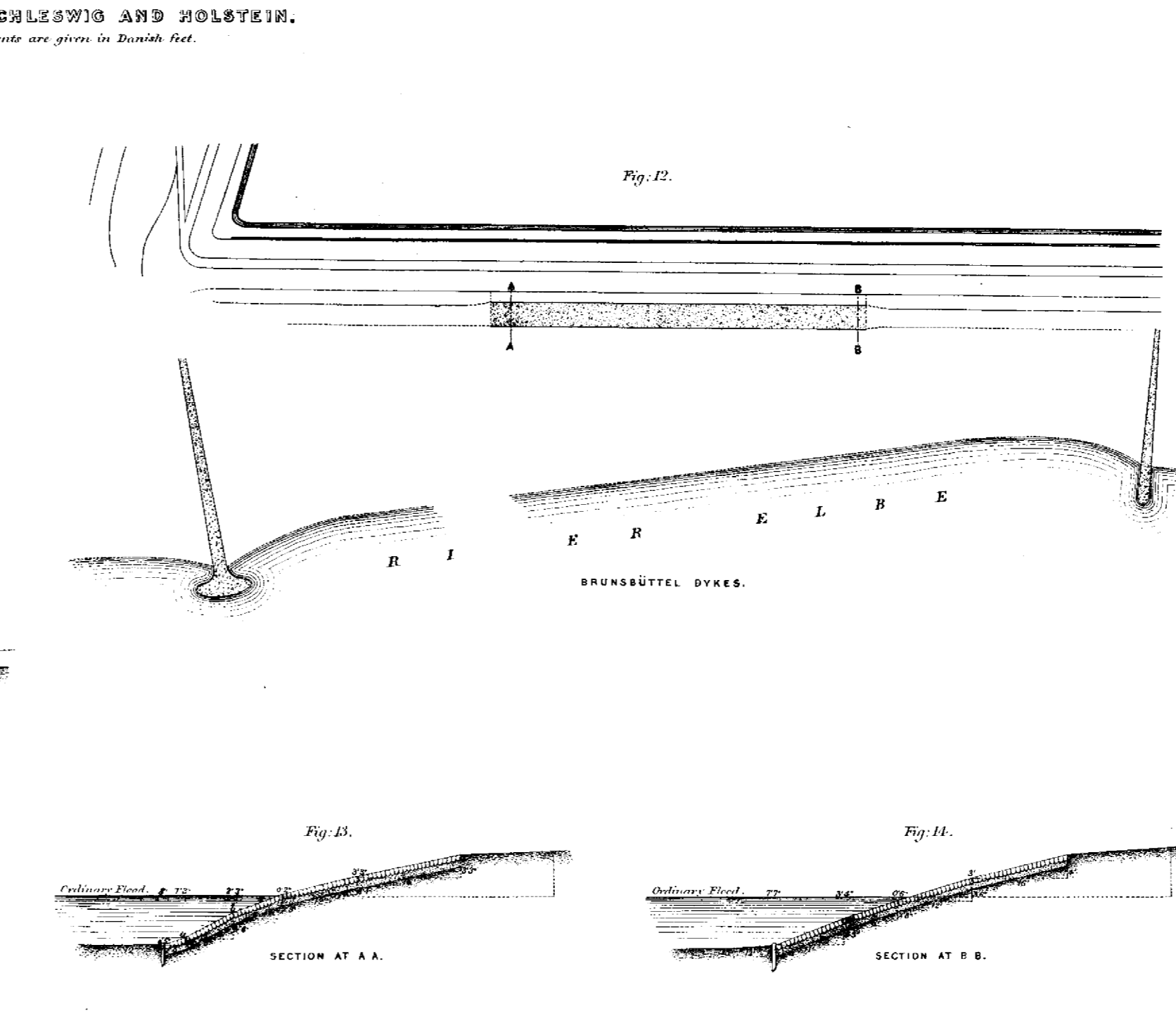
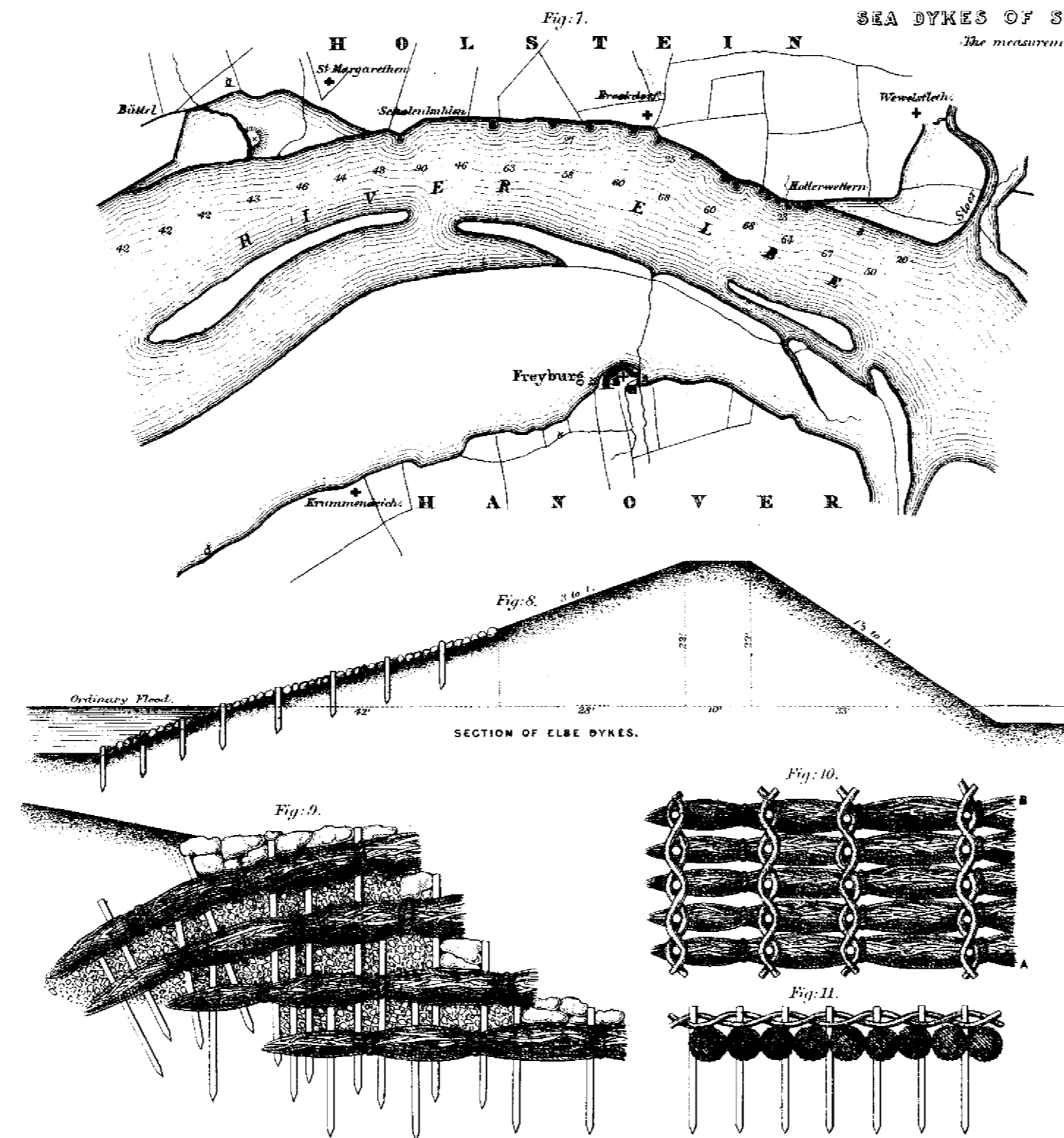
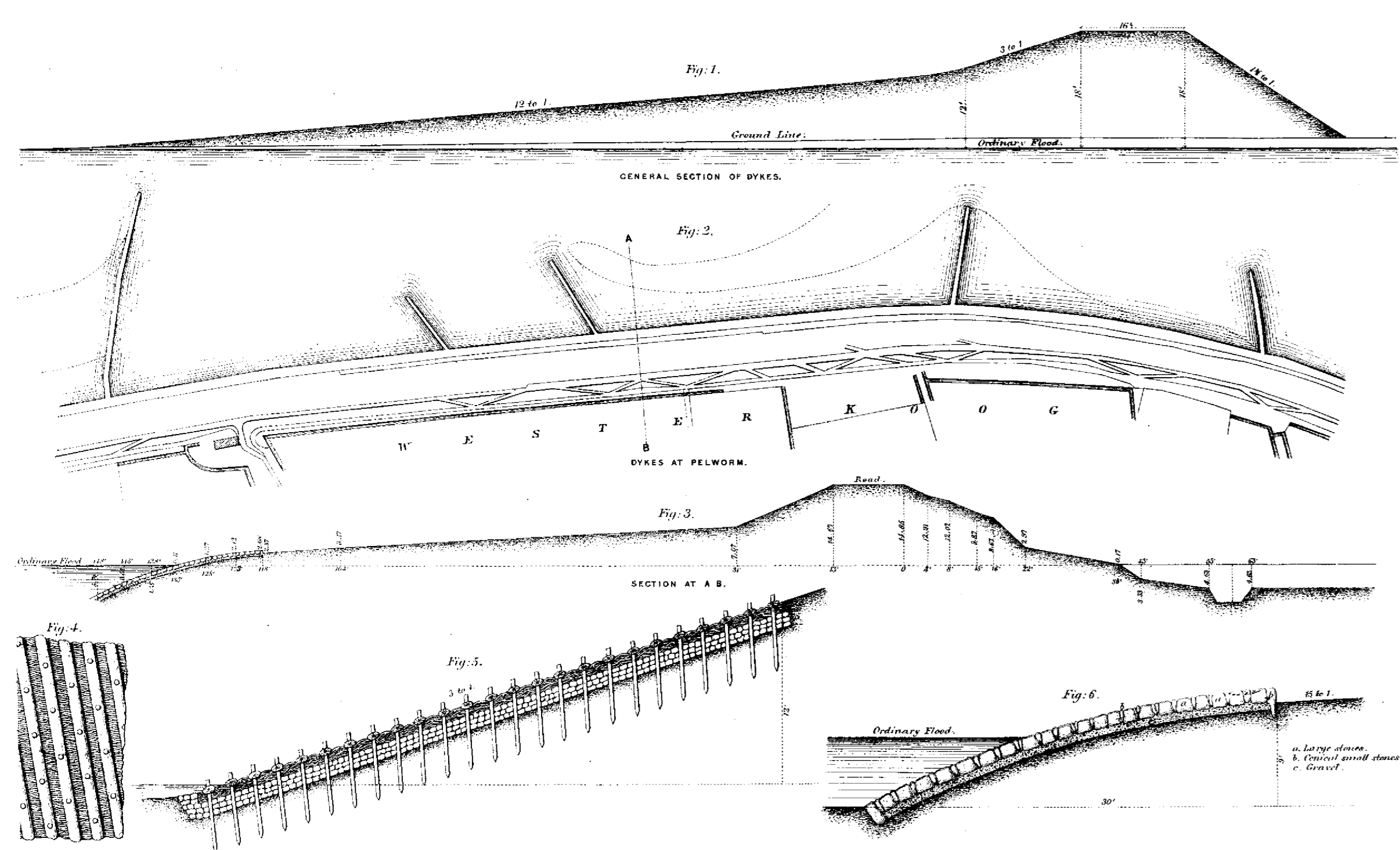
I *New Embankment before the Frederickien Kooj*
 II *D^o D^o D^o Südensbürg*
 III *D^o D^o between Westershever and Tuting*
 IV *Greynes between Hamburger Mallig and the Continent*
 V *D^o before the Continent*
 VI *System of Greynes before the Continent*
 ----- *Projected Greynes proposed to the Parliament this year*



DENMARK,
WITH
SCHLESWIG & HOLSTEIN.

Geographical Miles 60 - one Degree.

British Statute Miles 62.1 = one Degree



Mr. Hyde Clarke,¹ that there are at least 600,000 acres of land, worth from £20 to £60 per acre, which might yet be reclaimed in England and Ireland, and if to this calculation be added similar districts in the two other countries alluded to, the importance and magnitude of these resources can scarcely be overrated. It must not be forgotten, also, that at the present day these reclamations can be carried out, and the results accomplished, at a far less expenditure than formerly; because, as in all great engineering works, the experience has been gained and paid for. Vast districts, which otherwise would have remained submerged, can now, through the aid of steam power (so economically applied for these purposes), be recovered with greater facility than in the earlier days of reclamations from the sea. It is a remarkable fact, however, that notwithstanding the immense success and manifold advantages which have been derived from these important works, such projects should still be regarded by influential people with suspicion and distrust, although they unquestionably present, under judicious care, the means for the soundest and most profitable application of capital. The Author trusts that ere long such impressions will be removed, and that capital will flow once more in this channel, and be applied to the development of these great resources.

The communication is accompanied by a series of diagrams from which Plates 15, 16, and 17 have been compiled.

¹ Vide "The Engineering of Holland," by Hyde Clarke, in 'Weale's Quarterly Papers,' Part iv., vol. iv., p. 12.

APPENDIX, No. 1.

KING WALDEMAR'S rent roll, or register of taxation, under the head of 'Vesterland,' states the islands along the coast (Plate 16) to be as follows:—Fanö, Manö, Römö, Listland, Sylt, Fohr, Amrom, Oland, Gjestanaka, Hoola Minor, Hoola Major, Hossa, Holm, and Heligoland. It is remarked of them all, that they are inhabited, so that the smaller islands and 'Halligs,' which at that time were innumerable, were not included as being of any importance on the West Coast.

To the map of North Friesland (Plate 15), which the Author has extracted from Danckwerth (a kind of Danish Doomsday Book), he has added the word 'traditional,' because he believes it to represent the country at a much earlier date than is usually supposed. But although traditional, no doubt reliance may be placed upon its general accuracy, for traditional records form an important feature in Scandinavian history, and in many instances are as truthful, as if the events they chronicle had been inscribed on the page of history, at the time of their occurrence. In the Icelandic Saga of the 'Burnt Njal,' (Mr. Dasent's) some singularly interesting accounts are given of occurrences which, although only traditionally recorded, are beyond all doubt.

With the east wind there occurs the highest water. In the Fiord at Flensburg, the water has risen 10 feet over ordinary level; while the same winds blow it away on the western side. In March, 1856, the navigation of the Elbe, for some miles down the river, experienced a complete stoppage, for want of a sufficiency of water, in consequence of the easterly winds which had continued for some days; and even the city canals could not be traversed by lighters.

After a great flood, the people in Nordstrand (Plate 16, General Plan) constructed some dykes themselves. The Dyke Inspector, in reporting upon these works, stated their deficiencies to be, the steep front slope, the wooden bulwarks before the dykes, the insufficient height of the crest, and the total neglect of the 'watt,' or area in front of the dyke towards the sea.

APPENDIX, No. 2.

The Great Danneverke, which has been alluded to, is an earthen wall, or rampart, and originally extended from the town of Schleswig to Hollingstedt, about 12 English miles. It was constructed for the purpose of protecting South Jutland, or Schleswig, from southern invasion, which in earlier times was continually taking place. It is most admirably situated as a line of defence, the position being chosen entirely with this object. In earlier times it was protected, and even in later days also, by extensive and impassable morasses. On the south-western side, from Hollingstedt, the land was impassable to an invading army on account of the swamps. It was first commenced in 808, when the portion called Kuhgraben was built by the Danish king, Godfried; and although other kings at later periods—among the rest King Canute—assisted in it, the great credit of the work is due to the celebrated Queen Tyra, who almost rebuilt it in 937. She called together all the inhabitants of the southern country who could lift a spade, and watched over the progress of the work herself from day to day. It had different heights, varying from 30 to 50 feet, with a corresponding proportional breadth; also a ditch, in some parts on the southern side 60 feet broad and 50 feet deep, besides forts at stated distances. It was principally constructed of earth, but in places partly of stone and timber, and was covered with grass, like the dykes. It has proved of immense service to the Danish kingdom. The great Queen Tyra executed it with

such extraordinary vigour and good will, that the workmen gave her a more lasting memorial than is ever accorded to engineers of the present day, having placed over her tomb the Runic inscription, "Honoured shall she be in Her grave as the Guardian Angel of Denmark."

The Danneverke has been greatly strengthened in the last year or two, and now presents the most formidable defence against an attacking enemy. A few heavy guns, well served, would render it almost impregnable.

APPENDIX, No. 3.

ACCOUNT OF THE GREATEST STORM FLOODS ON THE COAST OF DENMARK, ETC.

In the year 340 before the Christian era, a great flood occurred in the Cimbric Peninsula, extending not only over Denmark, but also over Holland. It is termed the Cimbric Flood.

- A.D.
 516 Great storm flood, by which the whole of Friesland was covered with water, and six thousand men were drowned.
 793 On the 7th November, the North Sea flooded the whole of Friesland, and vast numbers of men and cattle were lost.
 806 In December there occurred a storm flood, which overflowed Friesland, and did much damage.
 860 The North Sea rose to a great height, and broke through the dykes. The Rhine also, in the Stifts Belan and Utrecht, overflowed.
 1015 A flood devastated the land.
 1020 Storm and high water on the Elbe and Weser, when the latter river changed its course.
 1075 and 1094 The sea broke over North Friesland, from which the dykes did not recover for many years.
 1102 Storm laid waste part of Heligoland.
 1114 Great storm. Hever rose to an extraordinary height, broke through the dykes and embankments, and swept away the chapel at Gardsand.
 1135 High flood. Water broke in everywhere, and much damaged not only Flanders, but also the lands on the Elbe.
 1158 A violent tempest occurred, that tore up large trees by the roots, and blew down churches and houses. Innumerable men and cattle drowned.
 1164 February 16. Dreadful hurricane, thunder, and lightning, which set fire to and blew down houses. The flood inundated Friesland and all the marsh lands on the Weser and Elbe. Many thousand men and innumerable cattle were drowned.
 1170 Flood. The Netherlands covered by the sea, causing considerable damage. Shell-fish taken at the town walls of Utrecht.
 1175 and 1176 Floods which covered vast portions of Holland.
 1187 High flood. Timbers from houses and men carried away to distant parts of the country.
 1195 Oct. 10th. Tempest which destroyed whole forests.
 1204 Dreadful tempest. All the marsh lands were inundated, and innumerable men and cattle were drowned.
 1210 A large forest, called Apenhold, destroyed by a storm flood (Danckwerth, p. 70).
 1216 A tremendous storm flood broke into all the marsh lands, and buried in the Eiderstedt and Ditmarsh upwards of ten thousand men. Heligoland lost so much by this flood that out of nine parishes it had in 1030, but two remained. Nacksand also, a considerable wood on the site of the present beach, between high and low water mark, at Römö, was laid waste and destroyed by this flood.
 1219 Nov. 27. Great flood, by which the whole of North Friesland was overflowed, and about forty thousand men were drowned. The island of Nordstrand greatly destroyed, and several churches sunk in the waves.
 1220 Flood, resulting in the loss of several thousand men.

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- 1230 and 1237 Flood producing great mortality, scarcely one man or woman in every ten of the population left alive.
- 1238 High flood, when a large parish—Bollertsand, at present a sandbank near Römö—with its villages, was overwhelmed by the sea.
- 1240 Eclipse of the sun. The largest and best part of North Friesland and of Heligoland drowned or washed away (Gerhardt. vol. i., p. 235).
- 1248 Dec. 28th. High flood on both banks of the Elbe. A parish on the west side of Römö with a wood (Holzing) destroyed by this flood (Kuss, p. 14).
- 1266 Flood, covering a large part of Friesland.
- 1277 Tremendous flood in the North Sea, by which the Dollart and forty-three parishes were destroyed, and eighty thousand men were drowned in Friesland.
- 1288 Flood over West Friesland.
- 1300 Tremendous flood, rising several ells (an ell is equal to 2 feet English) above the dykes. Seven parishes in Idomsharde and eight other parishes in Nordstrand were destroyed. Also Lyst church and Wendingstadt town, and a great part of Pelworm, with many churches.
- 1320 Dec. 6th. Flood, particularly at Lubeck, the Trave rising several ells above its ordinary level. Holstein was also inundated. Scarcely fourteen days after another flood almost as high occurred.
- 1334 Tempest which flooded Holland and Friesland.
- 1338 Flood over Ditmarsh and Eiderstedt. All the marsh lands inundated, the water standing for some time on the land.
- 1342 The whole of the Eiderstedt and Ditmarsh flooded, and the lives of a large number of men and cattle destroyed.
- 1344 Flood, when many people perished.
- 1354 Great flood, called Mandrankel (men drowning). An incredible number of lives lost in the marsh lands. The dykes were damaged, so that years elapsed ere the country could recover from the effects.
- 1362 During the night of the 8th September, a tremendous storm flood occurred, called Great Mandrankel, when nearly thirty parishes, with their churches and vast numbers of people, were destroyed, and great portions of the islands of Sylt and Föhr were submerged.
- 1363 Fearful tempest; blew down steeples and buildings.
- 1380 May 1st. Flood damaged vast extent of country.
- 1400 Nov. 19th. Tremendous inundation.
- 1412 Nov. 18th. Great flood, three thousand six hundred persons drowned.
- 1413 The water broke through the dykes and overflowed Crempner Marsh.
- 1416 The Island of Mandoe lost a great deal of land by flood. It was formerly 2 miles (Danish) long by 1 mile broad, and had three churches.
- 1421 Nov. 19th or Dec. 1st. Great flood.
- 1434 and 1435 Tremendous flood.
- 1436 Fearful tempest. Large trees blown down, the water rose to an incredible height, and broke through the dykes, causing considerable damage, especially in Ditmarsh, Pelworm, and Nordstrand, where men and cattle perished in great numbers.
- 1444 Tempest. Meldorf steeple blown down.
- 1470 Jan. 6th. Flood 1 ell higher than in 1412; broke in at Offenburg in Eiderstedt.
- 1471 At Nordstrand, Ditmarsh, and other places, the flood broke through the dykes with dreadful violence, and damaged the north part of Ditmarsh and Eiderstedt.
- 1474-80 Inundations in the marshes. The Eiderstedt overflowed.
- 1483 Oct. 16th. The fifth Galler flood; vast damage in the Eiderstedt and Nordstrand, as well as in Pelworm parish.
- 1491 Sept. 14th. Inundation; much corn carried away and cattle drowned.
- 1501 The sixth Galler flood.
- 1504 Hertzthorn parish, including the church, destroyed in a storm.
- 1508 Nov. 11th. Great flood: also in many places in Holland, doing vast damage.
- 1511 Sept. 1st. High flood; several places under water, and much corn drifted away.

- 1514 High flood, laying large districts in the Eiderstedt under water.
 1515 Flood; also over the coast of Holland.
 1521 Feb. 26th. Very high water, that did much damage in Hamburg.
 1521 March 15. Water broke through the dykes in Ditmarsh, and damaged buildings.
 1524 Flood; houses and gardens washed away.
 1530 Nov. 5th. High flood in Holland, and destruction of men and cattle in North Friesland, where fourteen hundred men were drowned.
 1532 During the night between 1st and 2nd November, when there was a total eclipse of the moon, a tremendous tempest occurred, with a south-west wind. The water rose 6 feet above the dykes, and covered the marsh lands with 12 feet of water. Several thousand people were drowned, and all their effects carried away.
 1533 Flood filled all the marshes and did vast damage to Nordstrand.
 1539-61 High floods over Eiderstedt, Ditmarsh, and Nordstrand, &c.
 1570 On 1st Nov., a fearful storm flood over all the coasts from Flanders to Denmark. Four hundred thousand men said to have perished, including twenty thousand in North Friesland. In Eiderstedt the water stood 10 feet over the marshes, and did great damage to the islands.
 1571 1st Nov. Flood over all the marshes.
 1572 21st Aug. Flood over Eiderstedt and the islands, doing much damage. This was called the Corn Flood.
 1574-84 Floods over the whole of North Friesland and in the Elbe.
 1591 Great flood occurred.
 1593 On Christmas Eve, a dreadful tempest arose, whereby Hadstedt, Bredstedt, and many other places had the dykes damaged and destroyed, from which they did not recover for some years.
 1594 On 22nd Dec., flood in North Friesland.
 1597 Sept. 25th. After three days' tempest, another high flood arose, doing great injury to the country. Men, cattle, and corn perished.
 1601 High flood over Holland, with a north-east wind.
 1602 Feb. 14th. Flood, inundating the lands and filling the rivers Fleth and Tetenbull.
 1610 Tremendous flood, similar to that of 1570, covering vast districts.
 1612 High flood; Nordstrand in great jeopardy, many people drowned, and great damage at Ditmarsh and other places. This flood was also very high in Hamburg, doing immense injury, and filling even the churches.
 1615 On 1st Dec., Flood over North Friesland; number of men drowned. In Sudermarsch, all the lands under water, and great damage done.
 1625 On 20th Jan. a tremendous storm from the south-west, and on 26th February another high storm flood. Pelworm, Eiderstedt, and other marshes overflowed. The water stood $3\frac{1}{2}$ feet high in St. Katherine church, Hamburg.
 1627 Strong south-west storm, which in Nordstrand caused the flood to fill Pelworm Old Koog, and others. This storm continued the whole succeeding month, and in 1628, on the 27th and 28th Jan., a fearful flood, with rain and a south-west wind, arose, filling Pelworm Koogs, which had already been repaired, so as to stand ordinary floods. Cattle and horses drowned and swept away.
 1629 and 30 In January and August, Pelworm, the Eiderstedt, and other parts overflowed, by a severe south-west storm, the water reaching Tondern and Ribe. The works for the enclosure begun at Tetenbull and Oldensworth on May 15th, 1599, were greatly damaged by this storm, and the sluices were carried away.
 1634 The Great Nordstrand flood, and one of the most destructive. The wind from the south-west (spring tides); but at midnight the wind veered round to the north-west. All the districts were flooded, and a great part of Nordstrand was destroyed.
 1639 Aug. 21st. Pelworm exposed to great peril, from very high water and tremendous tempest.
 1643 In June a dreadful storm arose, together with high flood, exceeding that of 1634 in height; and again

- 1648, at Shrovetide, between 14th and 15th February, a more dreadful hurricane arose, combined with an earthquake. Not only were all the marsh lands seriously threatened, but a number of houses and buildings were affected by undulations. Huge forest trees with their roots were torn out of the earth, and many steeples carried off churches.
- 1651-53 Very high storm floods.
- 1655 On 4th August, a storm with south-west wind. Dykes broken.
- 1659-61 Great floods, bursting Bredstedt dykes.
- 1662-64 Several great floods, bursting the dykes.
- 1665-66 Storm flood extending over England, Scotland, Holland, and Friesland.
- 1682 Inundation over the whole Continent.
- 1717 A fearful and most disastrous inundation over all the marsh districts and islands, doing enormous damage. In Gluckstadt the water stood 12 feet high in the houses.
- 1756 A disastrous flood on the west coast; Pelworm injured.
- 1791-94 Destructive floods, with south-west and north-west winds.
- 1821 Dec. 1st. Continued westerly gales had prevailed for eight weeks, with high floods, when on the 21st Nov. a storm commenced, lasting till 2nd Dec., with earthquakes like gusts of wind, and terrific torrents of rain and hail.
- 1823 On 11th March, hurricane from the north-west.¹ On Nov. 30th, a storm commenced, which increased as the spring tide approached, and raged without cessation, and without any ebb of tide, day and night for five days. During the last twelve hours the tempest was frightful. The water was 10½ feet over ordinary flood at Gluckstadt; but it fell suddenly 2 and 3 feet at different places. Altogether the dykes stood this storm remarkably well, but some disasters occurred.
- 1824 In November and December a storm flood occurred, continuing almost without interruption for more than two months, spreading dismay through the seas of Europe. Considerable damage was done; but although the waves went over several of the dykes, and even old grass-grown dykes that had not suffered damage for forty years received serious injury, still not a single breach occurred during this attack. All the banks erected according to the most approved construction suffered scarcely any injury, after this incessant storm had raged without interruption day and night for sixty-five days, till January, 1825. Still greater apprehensions were occasioned by an inundation of fresh water, which, owing to the large amount of rain that had fallen during three months, accumulated against the inside of the dykes, without its being possible to get rid of it by means of the sluices; the high level of the sea keeping the sluice gates shut.
- 1825 Terrific storm floods from the south-west, wind suddenly veering to the north-west. The water in the wells rose 5 or 6 feet, and in some places sprang several feet high, out of holes in the marshes. The dashing of the waves was so violent, that the billows receded to the lowest part of the slope, and again rose 2 feet above the top of the dyke. A watering trough of stone, at Hoge, above 1,000 lbs. in weight, was flung a distance of 50 paces.

APPENDIX, No. 4.

In the preparation of the foregoing Paper, the Author is greatly indebted for valuable information obtained through the kindness of the following gentlemen:—

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¹ In the winter of 1822, two hundred and fifty ships were lost, and about two thousand five hundred men perished.

Professor Forchhammer.
 Cancelliraad Juel.
 Capt. R. Carstensen, Dyke Inspector.
 Cancelliraad Griebel.
 Fyr Ingenieur Grove.

He has also consulted the following authorities, and is likewise indebted to Mr. Gundersen :—

- "Danckwerth," Landes Beschreibung.
- "Saxo Grammaticus."
- "Heimreich Nordfriesische Chronik."
- "Kuss, Annals of remarkable occurrences in Nature, Schleswig and Holstein."
- "Bergsoes, Danske Stat."
- "Baggesen, Danske Stat."
- "Forchhammer (Professor and Etatsraad) Om den forandrede Vandhøide ved Danske Kyster."
- "Trapp's Statistisk Geographisk Beskriwelse over Denmark."
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- "Tetens, Reisen in die Marschländer om der Nordsee."
- "Rafn, Annals of Northern Antiquities."
- "Nordisk, Conversations Lexicon."
- "Schröder, Topographie von Slesvig."
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- "Worsaae, Primeval Antiquities of Denmark."
- "C. Bruun, Slesvigske Marsch Oer."
- "Lövenskjold, Storm Floods in 1825."
- "Fogh," and others.