ANNUAL REPORT

OF THE

STATE GEOLOGIST

OF

NEW JERSEY,

FOR THE YEAR 1870.

NEW BRUNSWICK:
NEWARK DAILY ADVERTISER PRINT.
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GEOLOGICAL SURVEY OF NEW JERSEY.

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STATE GEOLOGIST.

GEO. H. COOK, New Brunswick.

To His Excellency Theodore F. Randolph Governor of the State of New Jersey, and ex-officio President of the Board of Managers of the State Geological Survey.

DEAR SIR:—I have the honor herewith to submit my annual report, on the Geological Survey of the State, for the year 1870.

With high respect,

Your obedient servant,

GEO. H. COOK,

State Geologist.

RUTGERS COLLEGE,
New Brunswick, Dec. 31, 1870.

REPORT.

During the year which has just closed:

Edwin H. Bogardus, the chemist of the Survey, has been fully occupied with the analysis of soils, ores and marls, and other fertilizers. His work has extended through the whole year.

Prof. Edward A. Bowser, Civil Engineer, has surveyed the Passaic River from Millington to Chatham, and the Pequest River through the Great Meadows, and has prepared profiles and maps of them. He was employed only a part of the year.

In accordance with a plan submitted to the Board of Managers and approved by them, I have spent between four and five months of the last year in a visit to the Drained Lands of England and Holland, in examining some of the most noted of the Swedish, German and English Iron Mines, and in studying the condition of Agriculture in the different countries visited.

PUBLICATIONS OF THE SURVEY.

There is a continued inquiry for the results of the Survey as published in the Geology of New Jersey. Copies of the work have been deposited in all the public libraries of the State and in those of the cities and towns adjoining. A list of libraries in which it can be found, was published in last year's Report of the Survey.

Both the book and maps are sold to any who wish to purchase at the mere cost of paper, printing and binding. A descriptive list of the publications and their prices and places of sale will be found in appendix C.

PROGRESS OF THE WORK.

In the last annual report it was stated that the chief operations of the Survey would be directed to putting the results of the work in form for practical use. And that in carrying out this leading idea the investigations and conclusions would be arranged and published under the following general heads:

1. On Fertilizers found in the State, and the means of making them more quickly and generally useful.

2. On the Marshes and Tracts of land subject to protracted Freshets.

3. On the soils of the State, their origin, chemical and physical properties, and distribution, with suggestions for their most productive management.

4. On the Iron and Zinc Ores of New Jersey.

5. Additions to the Scientific and Economic Geology of the State.

Upon each of these topics materials have been collected, and progress has been made in preparing them for publication.

I.

On Fertilizers found in the State, and the Means of making them more quickly and generally useful.

In the last report, Analyses of Marls, from the largest marl diggings in the State were presented and an attempt was made to establish the principles for their valuation. Tables were given to show the prices of the different fertilizing constituents of the marl, with which by a very simple calculation the value of each specimen could be determined. The results obtained in this way were interesting, and, as I think, relatively correct, though of course not entirely convincing to some of the dealers in this very useful substance. But I consider the matter to be of too much public importance to leave it without further inquiry, and have therefore had carefully averaged samples taken from the pits of the several companies which deal in marl, and herewith present the results.

ANALYSES.

	1	2	3	4	5	6	7	8
Phosphoric Acid..	1.47	1.60	1.28	2.46	1.34	3.17	4.67	1.14
Sulphuric Acid...	0.00	0.00	1.37	0.17	0.00	0.25	0.51	0.14
Silicic Acid......	50.85	51.10	51.92	57.35	46.82	59.05	52.70	38.70
Carbonic Acid....	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.13
Potash	5.33	6.46	5.36	4.47	5.59	4.72	3.81	3.65
Lime............	1.65	2.13	1.68	3.36	2.02	4.65	5.52	9.07
Magnesia........	2.95	3.85	3.38	2.09	3.10	2.66	2.70	1.50
Alumina.	6.89	9.15	5.40	5.86	6.48	6.67	8.66	10.20
Oxide of Iron....	21.34	18.20	19.82	15.03	23.93	11.27	15.92	18.63
Water	8.40	6.75	8.70	8.20	9.70	7.50	6.40	10.00
	98.88	99.24	98.91	99.89	98.98	99.94	100.89	99.16

1. Marl from the pits of Dickinson Brothers, Woodstown.
2. " " " " West Jersey Marl Co., Barnsboro.
3. " " " " Pemberton Marl Co., Pemberton.
4. " " " " Vincentown Marl Co., Vincentown.
5. " " " " Cream Ridge Marl Co., Hornerstown.
6. " " " " Squankum Marl Co., Farmingdale.
7. " " " " Squankum & Freehold Marl Co., Farmingdale.
8. " " " " at Marlboro, Mon. Co.

To compute the value of these marls the prices of different commercial manures, as given by our best authorities, were presented in full. I here present them again only changing that of Prof. S. W. Johnson, and substituting in its place the prices he gave in his report "On Commercial Fertilizers," made to the Connecticut Board of Agriculture, in June, 1870. I reprint also my reasons for the prices I assume for the potash and phosphoric acid in the marl.

Tables for Calculating the Value of Greensand Marl, and for Comparing it with other Fertilizers.

TABLE I.

Stockhardt's Table of the gold values of the chief elements in fertilizers, copied from Caldwell's Agricultural Chemical Analysis.

Form in which the substance exists in the fertilizer.

	price per lb. in gold.
Phosphoric Acid, soluble in water as in super-phosphate,	$ .12½
Phosphoric Acid in Peruvian Guano,	.10
Phosphoric Acid in steamed bones finely ground, in rape cake, poudrette, etc.,	.08¼
Phosphoric Acid in Baker guano,	.07½
Phosphoric Acid in coarse bone-meal, fresh human urine, etc.,	.07
Phosphoric Acid in coarse broken bones, fresh human excrements, stable manure, etc.,	.05½
Potash as potassic sulphate,	.06½
Potash as potassic chloride and in other forms,	.05½
Nitrogen easily soluble, or in compounds that are readily decomposed, as in ammonia nitrate, dried blood, meat, urea, etc.,	.22
Nitrogen in finest bone-meal, poudrette, etc.,	.19½
Nitrogen in coarse bone-meal, rape meal, horn-meal, wood-dust, fresh human urine,	.16½
Nitrogen in coarse broken bones, horn shavings, woolen rags, fresh human excrements, stable manure, etc.,	.13¾

TABLE II.

The English valuation of these substances is given in Vol. 20, p. 74, of the *Country Gentleman*, by Dr. Voelcker, Consulting Chemist to the Royal Agricultural Society of England. It is as follows, allowing two cents for each English penny:

1. Nitrogen in the form of ammonia,	16 cts.	per lb.
2. Nitrogen in animal or vegetable substances,	12	"
3. Nitrate of Soda,	4	"
4. Phosphate of Lime, (bone earth),	2	"
or Phosphoric Acid alone,	4	"
5. Soluble Phosphate of Lime, or Bi-Phosphate of Lime,	9	"
6. Salts of Potash,	2½	"
7. Gypsum,	2 cts.	per 10 lb.
8. Lime,	2 "	12 "
9. Carbonate of Lime,	2 "	25 "
10. Magnesia,	2 "	10 "
11. Organic matter, (humus),	2 "	20 "
12. Common Salt,	2 "	10 "

PRICES FROM PROF. S. W. JOHNSON.

Prof. S. W. Johnson, of the Sheffield Scientific School, New Haven, has given a new table of prices for some of the most important manures, in a Report on Commercial Fertilizers, made to the Connecticut Board of Agriculture in June, 1870. It has been deduced from the prices of various chemical fertilizers, after a careful re-examination of the whole subject; and is as follows:

Potash,	7	cents per lb.,	currency.	
Nitrogen,*	30	"	"	"
Soluble Phosphoric Acid,	16½	"	"	"
Insoluble Phosphoric Acid,	6	"	"	"

The phosphoric acid in the marl is combined mostly with lime, though a little of it is probably combined with oxide of iron. The phosphates of lime and iron are both in very fine

*Ammonia is 14/17 Nitrogen, and according to the above price for Nitrogen, Ammonia should be worth a little under 25 cents a pound.

powder, or else in soft grains, so that while they cannot be quite as soluble as super-phosphate, they are much more soluble than any bone-dust. Judging from Stockhart's table of prices and qualities of fertilizers, I think the phosphoric acid in our marl should be rated between that in guano, which is 10 cents a pound, and that in steamed bones, which is 8¼ cents, and there fore propose for it in our calculations, 9 *cents as the price per pound.* The potash in the marls is combined with silicic acid, forming silicate of potash, which is not readily soluble in water. Johnson's price, 7 cents a pound, is for soluble potash as it is found in carbonate of potash (pearl-ash,) sulphate of potash, muriate of potash (chloride of potassium,) or crude potash. The potash in the marls, is only dissolved out slowly by the action of water containing carbonic acid, and so becomes available. Until there is some more decided reason for fixing a different price, I will set down its value at 2 cents a pound.

The value of the several marls given in the above table would then be easily made. Considering the phosphoric acid and potash as the only parts of the marl worth transportation, their values range from $3.50 to $8.50 a ton ; and I believe, that in comparison with the prices paid for concentrated manures, they are worth that price to the farmer. The cost must be taken when they are upon the soil, and not, as might be thought, when in store. I am confirmed in my opinion of their value by the testimony of successful farmers, who have used them for twenty years or more ; and who assure me, they can better afford to incur an expense from $5 to $8 a ton, than to farm without them or to use any other purchased fertilizers ; and also confirmed by my own observations in all parts of New Jersey where marl has been used. It gives lasting fertility to the soil. While all other fertilizers are exhausted and the soils become poor, I have never seen a field which has once been well marled that is now poor. One instance was found where poor and sandy land was marled more than thirty years ago, and has ever since been tilled without manure, and not well managed, which is still in good condition. Occasionally marled fields are seen that do not grow crops as large as they once did, but all their fertility is immediately restored by a dressing of lime; an effect which could not have been produced by the lime on unmarled land.

The principle of computing the value of manures in this way, is a correct one, and is accepted everywhere. The prices depend upon the benefits received from the use of the different fertilizers; those benefits being ascertained by the experiments of different persons continued for a number of years. Of course such prices are not yet very accurately settled, and further experience may materially alter some of them. It is very desirable that the attention of observers should be directed to this subject, and if changes can properly be made in the prices, that they be made, and reasons given therefor. I am in the frequent receipt of inquiries as to the value of marl from different pits. In answer to those inquiries I would refer to the analyses and to these lists of prices, and ask the inquirers to compute the value of the marls from them—and if from trial they find reason to modify the prices, it will be esteemed a favor to have them send their conclusions, with the reasons for them, to the office of the Geological Survey.

Other investigations are in progress upon our natural fertilizers, and the subject will be taken up and discussed at length in a future report.

II.

On Marshes and Tracts of Land subject to Protracted Freshets.

In the last Annual Report a survey and profiles were given of the Passaic, Rockaway and Whippany Rivers, in Morris, Essex and Passaic counties. It comprised that portion of the streams about their junction and extended from thence downwards to Little Falls, and up the Passaic to Lower Chatham Bridge, up the Rockaway to the Parsippany turnpike Bridge, and up the Whippany to the village of that name.

There is a large area of land on the borders of these streams which is subject to long continued overflow; and on which in some seasons the crops are entirely spoiled by the water. The object of these profiles and maps was to show the real condition of the streams and to furnish data upon which to base plans for making them fulfil their proper functions in draining the country through which they find their way. The natural obstruction to the flow of water, in these streams is found in a ledge of rocks at Little Falls. This obstruction has been increased by the erection of a dam just below the reef which is raised a foot and a half higher than the reef itself.

The bed of these rivers is deep for the amount of water to be carried, but the current is very sluggish on account of its slight descent. In fact, for nearly eighteen miles up the Passaic from Little Falls, the bottom of the stream is lower than the dam, so that all the current there is comes from the piling up of the water along the more remote parts of the stream and so making an inclined surface down which the water can make its way by this force from behind, instead of being moved by the ordinary power of gravity.

To prevent the overflow of these streams it is necessary to increase the quickness of their currents, and so to enable them to carry within their banks, all the drainage water of the country.

By the profiles it was shown that the form of the rocky reef at Little Falls was such as to admit of its being lowered five and a half-feet at a very moderate expense; and that any further lowering could only be effected by an enormously increased expense. It was remarkable too, that if the rock were lowered to that amount, a grade line with a descent of seven and a half inches per mile would fit the natural bottom of the stream as well as the rock when thus cut down, and that the slope would be almost uniform from lower Chatham Bridge to the Dam. Only a few and comparatively insignificant bars of boulders, gravel, sand and mud would have to be opened to render the descent regular.

The descent in the Whippany can be made somewhat greater, as it should be on account of its smaller size. The expense attending these improvements is not great, and could very easily be met by the owners of the land to be benefitted.

The dam and the water power originally obtained from the reef itself, present more serious dificulties, and become the causes of the heaviest expenses in carying them out. But an examination of the reasons which call for the improved drainage will show that it must be made, and it should be begun at once.

The damage done by freshets in a single year, has more than once been enough to pay all the reasonable expenses of this improvement. There are 11,400 acres liable to overflow; most of these are in meadow and in favorable seasons yield valuable crops of hay. When this hay is spoiled the owners lose it and the labor they have provided to gather it, so that it is not extravagant to estimate the total loss at $100,000, and some consider it to be much more. And this loss has occurred a number of times and sometimes two years in succession. The occurrence of such freshets, and so much stagnant or sluggish water renders the whole region unhealthy, and fever and ague prevail to a great extent in some years.

The thorough drainage of these valleys would render the whole district more healthy and would greatly increase the productiveness and value of the land. In addition to these great advantages to the residents and land owners, the improvement is of general importance to the State, and it would render one of its most lovely valleys attractive and desirable as a location for the country homes of those who do business in our great cities. It is to be hoped that this important work will be begun soon and carried forward with prudence to completion.

During the past season the Survey has been continued up the Passaic from Chatham to Millington and also up a short branch of the Passaic, called Dead River.

There is a fall of twenty feet in the Passaic within about three miles of Chatham, and there are four mills upon it, each of which has a dam. The upper of these is so high that the water is checked in its current for twelve or more miles up the stream, and the low lands along its borders are laid under water with every large rainfall. The meadows are not so extensive as they are upon the same stream below Chatham, but what there are are rendered almost worthless by the frequent floods.

The greatest injury however, is to the health of the residents and the attendant disrepute of property which would otherwise be amongst the most desirable in the State. For the condition of the stream, location and extent of its obstructions, and the obvious means of overcoming or removing them, a careful survey of the stream has been made by Mr. Bowser and his report and profiles are herewith presented. (See appendix A.)

The great meadows in Warren County, have also been Surveyed during the past season. These meadows occupy almost the whole of one of those beautiful subordinate depressions of the great Kittatinny Valley. They lie upon both sides of the Pequest River, in the townships of Independence and Hope, and extend from Danville in Warren to Tranquillity in the borders of Sussex County, a distance of eight and a half miles in a strait line; and they have for a considerable portion of this distance, a width of one and a half miles. They cover an area of fifty-five hundred acres. The soil in these meadows is a black and peaty earth, full of water, and liable to frequent overflows from the sudden rise of the Pequest. It is too flat and wet to be cultivated, and the greater part of it produces only wild and and sour grass of but little value. A part of it along the stream is swampy and covered with heavy timber.

The right of soil in these meadows is held at a very low price, but if properly drained they would become both valuable and productive, and an ornament to the country, instead of being as they now are, an unnecessary blur upon its surface. The original cause for this flat tract of country is found in two reefs of rock which cross the Pequest near Vienna. Projects for draining and improving these meadows have frequently been discussed, and some of them begun, but nothing has been carried through. It has been questioned whether it would be most effectual to remove the obstructions in the stream and leave it to pursue its present channel, or to make a new cut from the river at the lower end of the meadows in a nearly direct line across the ridge back of Danville Church, and on to join the old bed again about a half mile below. Levels and measurements have been taken on both these lines by Prof. Bowser, and his report and maps are herewith submitted. (See appendix B.)

In regard to all these improvements, it should be observed that their completion will require considerable time, some of them several years, if they are to be done effectually and with a due regard to economy. The first object to be secured is a good and sufficient outlet. The work must in all cases begin at the lowest point; and when that is made free and clear, the next point of obstruction up the stream should be removed or opened, and so on in succession. By this means the current is increased from the first, and made to assist in cutting away the soft bars and other obstructions of recent origin. The depth of water is diminished and the labor and expense of working in it is made lighter. In a few years, by pursuing this course, the work can be done so as to secure full and permanent benefit to the whole district needing drainage, and to the State. Any other plan will be expensive and wasteful, and will need to be gone over again; and in the end the method given in these reports must be carried out.

ON MARSHES AND RECLAIMED LANDS.

In former reports reference has been made to our tide marshes and the importance of reclaiming them. In the report of 1869 there were two maps of marshes—one of that about the head of Newark Bay and the mouths of the Passaic and Hackensack Rivers, and the other of those along Salem Creek and the head of Delaware Bay. In these maps the outlines of the marshes were shown, the character of their soils, whether peat, clay, or sand, and their depth to solid ground. The means which have been used for their improvement in Salem and other Southern counties were described, and the extraordinary fertility of the soil upon them was shown at length. The beginning of work for reclaiming the marsh between the Passaic and Hackensack Rivers, near the head of Newark Bay, was also reported. This latter work is progressing; the tide water appears to be effectually shut out, a large tract of land has been plowed, some portion has been cropped, and the enterprise of bringing it into cultivation bids fair to be a success.

The large extent of marshes and salt meadows in our State still unimproved makes this subject one of much interest to the people. And the amount of work to be done and of capital to be invested renders it very important to have the fullest information in regard to what has already been learned by experience in other countries in reclaiming similar lands. To learn more of such works, I have made a visit to the drained lands of England and Holland, and present the following report upon them.

In England the largest drainage works are in what is called the Fen-country. This is an extensive tract of wet, swampy, and marshy land lying on the east coast, beginning about eighty miles north of London, in the counties of Norfolk, Cambridge, and Lincoln, and near the mouths of the Rivers Ouse, Nene, Witham, and others. There are a number of tracts along the east coast, and some of large extent, but they all have the same character and their management is similar. The drainage of the Fen-county about the Nene and Ouse was first undertaken by the Duke of Bedford, and hence is known as the Bedford Level. It comprises about three hundred thousand acres. Much of this land lies below high water level, and so was liable to the overflow of the tides; but its greatest damage was from floods in the rivers which pursue their crooked and sluggish courses through it. These streams carried the drainage water from as much as five thousand square miles of the higher country, and in heavy rains or in wet seasons they overflowed their banks and laid the whole of this flat country under water. In dry seasons some of the land could be cultivated and summer crops secured, but in wet seasons all crops were destroyed. From the earliest periods of English history, attempts were made to prevent the damaging effects of these overflows, but for a long time with only indifferent success. The leading features of the plan pursued by the Earl and Duke of Bedford in their works between 1630 and 1653 were to convey the upland waters through the level to the sea by means of straightened and embanked rivers, and to prevent the tide from entering and overflowing any portion of the Level. The Level was divided into three parts; the North Level containing 40,000 acres, the Middle Level 140,000 acres, and the South Level 120,000 acres. Each level was defended by high barrier banks.

Another feature in his scheme was to cut large new straight drains within each level to carry the ordinary rainfall to the rivers into which they could be discharged by sluices.

The two great defects of this plan were—first, the omission to provide for the improvement of the natural outlets to sea at Lynn and Wisbeach. It went no further than getting the water out of the Fens into the drains and rivers running through the Level, and gave no attention to the discharge therefrom; whereas its first great work should have been to secure for these drains and rivers the best outlet possible to sea, for without that all internal works, however good, must eventually fail. The second defect was in not making the new drains and cuts of sufficient depth. They did not understand or properly consider the nature of the soil to be excavated. This soil was a deep bed of peaty earth which had been growing and accumulating for centuries, and for drains to be permanently efficient, it was necessary that this bed should be cut quite through to the natural soil on which it rested. This was not done, and the consequence was the peat bottoms of the drains began slowly to rise up towards the surface of the water, and so to impair and finally ruin them. While this was going on, a process of a directly opposite character was going on in the drained lands around. While one was rising the other was subsiding. This soon made it necessary to provide other means for passing the drainage water from the lands into rivers and large drains. Associations of neighboring farmers were formed for more effectually draining small districts, and these associations partially attained their objects by erecting scoop-wheels for lifting the water, and wind-mills to drive them. These were in a measure successful, but not to the degree that was needed. In 1821, after years of opposition, a deep cut was made to shorten the course of the River Ouse near Lynn. At this place the river took a bend almost at right angles to its general course for a length of five and a half miles, forming almost a semi-circle, while the diameter joining its two ends was only two and three-quarter miles across. The substitution of this straight cut for the former long and tortuous one was attended with most remarkable and beneficial results. The Ouse at the upper end of the cut had its low water line reduced seven and one-half feet, and there was a corresponding lowering of the water surface in all the connecting drains. Various internal improvements were carried out at the same time, to secure the full benefit of this lower outlet, and steam was substituted for the irregular and uncertain force of wind.

Since then an Estuary Cut for two miles below Lynn has still further straightened the outlet of the Ouse to the sea, and has caused a depression of the low water mark at Lynn of from three to four feet, and has given a greatly increased efficiency to drainage by sluices. It has also diminished the lift for the water which has to be raised from the ditches into the drains and rivers. The system of works necessary to keep up this drainage has been planned by some of the best English engineers, and the constant attention of several professional engineers is now required to keep the various parts in working order, and to make such new erections or changes as are needed. But it is a marvelous success, and the country which was formerly a worthless marsh is now the most productive land in England.

To Mr. Alfred S. Ruston, of Chatteris, England, I am indebted for many particulars relating to the fens. He went with me to examine various farms, to explain their modes of culture and the system of drainage which is now in operation. He gave me all the particulars I could ask for, in full detail, and I cannot do better than use his own words in presenting them:

"If fen-lands are to be perfectly and successfully drained, the true principle is first of all to secure the best possible outfall for the discharge of the waters, and then to construct the internal works of corresponding dimensions and depths, giving where practicable a natural drainage, and where not, reducing the pumping power to a minimum; and sooner or later I conceive this will be the principle adopted by all the drainage levels in the kingdom.

"One important and somewhat startling fact in connection with the review of the drainage history of the great level during the last two or three centuries strikes one, and that is, that all the great works which have contributed to drain the land effectually, rescuing it from all risk of winter floods, and making it really valuable, have been made during the present century. At the beginning of the century the lands were little more than summer lands, and men were considered demented who ventured to sow a whole field with wheat. But now the fens are the great corn-producing lands of the kingdom, and have been not inaptly termed 'the granary of England.'

"The subsidences of Fen lands after they become drained is a subject deserving attention. The more we drain the lower our lands become, and we are beginning to enquire what is to be the end of all this. I am informed by Mr. Lawrence, the agent to Mr. Wells, that when Whittlesea Mere was drained, to ascertain accurately what the subsidence was, a Doric column was placed in the ground, on which feet and inches were marked downward from the capital, which was the original surface of the land. That surface is now seven feet below what it was when they began to drain the mere eighteen years ago; and in the middle level on all our old drained lands we find the subsidence is still going on at the rate of an inch per year. We learn this from our drainage engines, which are continually requiring the centres of their water wheels to be lowered, or the ladles to be lengthened or they would soon lose their dip altogether. The increased facilities of discharge through the improved out falls must continue to be felt until the peaty subsoil shall well nigh disappear. One of Lord Orford's companions on referring to their passage through Salter's Lode Sluice, tells us that the tide rises at that place five or six feet. On the 21st of February of the present year, it rose to twenty-two feet three inches at 11:15 P. M. The effects upon drainage of this altered state of things, and consequently upon subsidence, must be obvious to everyone.

"The Fen rivers and drains so useful and essential for the discharge of the flood waters of winter are scarcely less valuable for the supply of fresh water in the summer. It is not easy to overestimate the immense value of a good and a liberal supply of fresh water for the whole Fen County during the dry summer months, and I need hardly say every effort is made to obtain this. The practice of irrigation has not found much favor in the Fens, and it is questionable whether it would be of any great good where the waters possess so few fertilizing elements. Irrigation appears to depend for its success very much upon the chemical substance contained in the waters. An analysis of the water will pretty correctly indicate what will be the effects of its overflow Cultivation and drainage have gone on hand in hand, each successive improvement in the one, leading to a corresponding improvement in the other. During the early drainage history, most of the low-lying Fen lands were kept in grass, as they could not be profitably brought under cultivation in consequence of their liability to inundations during every recurring flood. Some farmers ventured to sow a few oats on the higher lands, but it was not until May was well in and the winter rain-falls had passed away to sea. By-and-by oats were grown more largely, and wheat was cultivated to some extent.

"Then came the system which prevailed very generally in the Fens for a good number of years, and which was to let the land keep in grass for two or three years, then pare and burn, and sow with coleseed to feed with sheep during the winter months, to be followed by oats, and then wheat; and again sown down with seeds to remain two or three years, often three. This virgin soil, under such management produced coleseed of most extraordinary fattening qualities, and perhaps there has never been any natural food that would compare with it, or that would in so short a time produce so much weight of mutton. It was otherwise with the seeds, for after the first year they contained comparatively little nutritive properties, and their long countinuance on the land made a fine refuge and breeding ground for the wireworms, to which the succeeding crops oft times bore indubitable testimony; and to this day they remain the greatest foe the Fen farmer has, and it is a very unusual year when his oat-crop is not more or less ravaged by them. Probably the greatest improvement next to drainage, and consequent upon it, is the practice of claying fen lands. The value of clay, I believe, was first accidentally discovered by some of it which had been thrown from the ditches having been spread round the outsides of the field, and which produced most marvellous effects upon the growing corn crops.

Our father's were not slow to learn, and were very soon led to adopt a system of claying which still continues, some lands having been gone over three or four times. The plan is this: pits or trenches are made down the fields, from two and a half to three feet wide, and from twelve to sixteen yards apart; two spits of clay are taken therefrom, and spread upon the intervening land, the peat or clunch subsoil being thrown to the bottom of the trench, and when all is finished, the pits are ploughed in, and the land being loose, and easily moved, is soon levelled again. The cost of claying is governed by the depth at which the clay is found from the surface of the land; but improved draïnage occasioning a continual subsidence, as I have already observed, is bringing it within easy reach, and thousands of acres can now be done at a cost of thirty shillings per acre, and under; and no money expended on a Fen farm, yields so quick and so bountiful a return. The application of clay to these light soils not only gives solidity, but being possessed of considerable fertilizing properties, greatly enriches them. Happily the Fen lands very largely rest upon a clay bed; but the clay is not of a uniform quality. That which is blue and of a soft buttery nature, contains the most lime, and is the best fertilizer. Some is silty and some stony and hard, and these do little more than solidify. Perhaps the next great improvement consequent upon the drainage of Fen lands is their deep cultivation, to which reference has already been made. To talk of turning over a furrow slice thirty inches in thickness must sound to a clay-land farmer something like a piece of exaggerated nonsense; and may put his credulity to the test, but it is no exaggeration. Deep cultivation on Fen land is generally accomplished by horse power, as the great underground forest offers considerable obstacles to the application of steam. A pair of horses in a common plough go first, and take a furrow four or five inches thick, and are followed by a huge implement made expressly

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for the purpose, and which is pulled by six, eight or ten horses as the case may be. This plough buries the furrow turned over by the small plough, and brings the subsoil well on to the top, that its vegetable properties, by exposure to the atmosphere, may become speedily decomposed, and made available as food for plants. One object in putting the top furrow down is to get it as far as possible beyond the reach of atmospheric influences, with the idea that under these circumstances the twitch or couch and weed roots will die and decay. It certainly is a very clever and ingenious way of cleaning land, if it can only be done; but my experience and observation lead me to the conclusion that it far oftener fails than succeeds. I think land should be quite clean before it is deep ploughed. There can be no doubt but deep cultivation tends to preserve moisture in the soil in dry seasons, and to facilitate drainage in wet ones. It also unlocks those hidden treasures in which are so many elements of fertility, and consequently increases the producing power of the land. Drainage, clay, and deep tillage, to which should be added super-phosphate of lime and the water-drill, have completely metamorphosed the country, and altogether changed its modes of husbandry; and perhaps there is now no country so utterly defiant of system. Every one sows what he thinks he will, and by proportionately liberal management labors under no apprehension that his soil will become exhausted; nor will it, if he treats it generously and cultivates it wisely. Although there is no uniformity of system in the cultivation of fen lands, there is, however, a five-course-shift which has found favor, and which prevails more largely than any other, and to which several farmers pretty strictly adhere. This is the order of it: mangolds, kohl rabi, coleseed or cabbages, which are gradually growing into favor; oats, wheat, seeds, wheat. The green crops and the oats are sown with artificial manure, the farmyard manure being reserved for the wheat crops. This rotation appears well suited to the fens, and has been pursued with considerable success; but as I have intimated fen farmers break away from the restraints of system to follow their own inclinations. A ride through the fen country at the proper season will show the truth of this. In addition to the crops usually found on a farm will be seen coleseed, turnip seed, linseed, mustard, and cress growing as seed crops, and potatoes and carrots extensively cultivated for the London and other large markets. Turnips are not at all suited to fen soils. They grow of a woody, fibrous quality, coarse and long in the neck, and possessing scarcely any nutrime t; they are almost valueless as food for stock, and are consequently not cultivated.

"Kohl rabi and mangolds are much better, but these, like the hay, straw, and other products of fen-lands (coleseed excepted) are very deficient in fattening properties. I have already referred to the water drill and super-phosphate of lime and their value in the successful cultivation of fen-lands. Our fen-soils appear to yield much larger supplies of ammonia than phosphates; hence the free application of phosphatic manures is accompanied by much greater and more palpable results than is the case where ammoniacal manures are used. Probably there is no part of the kingdom where the application of phosphates to the soil has produced such startling results, and especially where they have been applied with the water-drill. The fens have not been especially famed for the breeding of either cattle or sheep, but from very early times they have been noted for their good breed of cart-horses. The decreased average of grass seeds, consequent upon the increased average of corn and other crops, has largely tended to diminish the number of animals bred; but the show of cart-colts, both as regards number and quality, on the first of July of every year, is pretty good evidence that fen-farmers have not altogether lost their long-enjoyed and well-merited reputation.

"The Great Level generally, even now, under its more perfect drainage and improved cultivation, offers very few tempting residential inducements, and formerly, under other and more unfavorable circumstances, it repelled rather than invited residence. Hence it is not uncommon, in many parts of the fens, to find both farmer and laborer residing in the town or village rather than upon the farm.

"The value of fen-lands has increased or decreased just as the drainage has been efficient or otherwise. In 1651 Lord Arundel, one of the Earl of Bedford's associates, in draining the Great Level, became so discouraged by the reverses and losses sustained by the adventurers that he sold his share, for 3s. 9d. per acre, the same land now being worth probably from £30 to £50 per acre. Many farms in later times have been sold at very little over their present annual rentals, and some at even less. Through the kindness of Mr. Richards, Trimblington, I am able to present the assessments to the poor rates of certain lands in the parish of Doddington, made at different periods, showing the influence which improved drainage has had upon the value of fen lands:—"

	Acres.	Rateable Value.
1736	200	£40 0s. 0d.
1784	200	60 0 0
1822	200	100 0 0
1869	200	238 0 3
1784	60	15 0 0
1833	60	21 0 0
1869	60	68 1 4
1757	20	2 0 0
1784	20	5 0 0
1869	20	26 0 0

The above statement has been written by Mr. Ruston since I enjoyed the benefit of his explanation on the ground, and he has favored me with the printed copy. His residence is in what is called the black-fens, the soil being black with muck and decaying vegetable matter for a depth of from two to ten feet. The clay, of which Mr. Ruston speaks, is the earth under the peat, and is quite calcareous. There are portions of the fens nearer the western border—for example, near Peterboro—and the Whittlesea Mere where the whole substance is black and more like turf. Such cannot be cultivated until they are burned over, so as to get an accumulation of ashes, or else are covered with earth brought from the upland, or from pits sunk through the peat down to the solid ground. Pits are sunk through the turf nine feet deep in some places, to raise the bottom earth to the surface, and the land is dressed with it at a cost of from $12 to $18 an acre. I saw good crops of grain, cabbage, and turnips growing on ground prepared in this way. The fens containing turf are, however, the most expensive and difficult to reclaim, and there are considerable tracts which have not yet been cultivated.

The parts of the fens nearest the sea-shore or on the river banks are the best. The soil contains a large proportion of sand and clay sediments, and is not liable to settle, and it needs no claying. It has been filled up by the deposits from muddy water and the wash from the river floods. It is the very best and most productive of all these reclaimed lands.

The banks which are built to confine the streams and hinder them from overflowing the country on their way to the sea, as well as those along the sea-shore, are of the most substantial kind. They are constructed after the plans of engineers, and built under their directions. Generally they do not differ from the banks of canals or other structures which are required to resist the pressure of water.. From the nature of the fen soil—the layers of peat, sand, and mud in it—great care is necessary in preparing the foundations of the banks. Those which are built now are usually six feet wide on the top, and built with a slope of two base to one rise; and to keep them firm they have a foreshore of from six to fourteen feet, and the middle of the bank is puddled with clay. This puddling is done by digging a trench three feet wide along the middle of the foundation, and sinking it down to the solid bottom. The trench is then carefully puddled with clay quite to the surface, and up as far as the nature of the materials in the bank require, in order to make them water-tight. Like all other works of this kind, there have been numerous and expensive failures in the banks from lack of good foundations. In 1862 a most extraordinary accident took place from the undermining of the sluice gates of the main drain of the Middle Level, at its confluence with the River Ouse. This drain has to carry an immense quantity of water. Its bottom is seven feet below low-water mark, and forty-eight feet wide; its sides have a slope of two base to one rise, and spring tides there have a rise of nineteen feet, so that its width at the high-water line is one hundred and fifty-two feet. The sluice gates were like canal lock gates, and in three pairs of thirteen feet each, thus making a clear water way of seventy-eight feet. The water in this drain runs out through the sluices during low water, until it almost comes to low-water mark. From some imperfection in the foundation these sluice gates gave way and the tide-waters were let into the drain. They rushed up and again poured out of the drain with great velocity, and throughout a distance of twenty miles they ebbed and flowed. This state of things continued for several days, when one of the banks of the drain burst and let the water in upon this low but rich and cultivated country, and completely inundated six thousand acres of land. The damage done by the flooding was enormous.

The method resorted to for again stopping the drain is very curious, and may be worth the description. With great pains and at a large expense a solid, strong dam was built across the drain so as to completely shut out the tide, and then sixteen syphons, each three and a half feet in diameter, were laid so as to draw the water out of the drain above the dam, carry it directly over the top, and discharge it into the drain below. The syphons are set in operation by means of a steam engine and air-pump, and they are guarded by valves so that they may not carry water up stream during the flow of the tide. They have now been in operation eight years, and have answered their purpose completely. The water in the drain flows up to the dam with a strong current, runs over it in the syphons, and then, a great river of water, it runs off in a rapid current towards the sea.

Some of the oldest of the banks are still settling, with the long-continued drainage of that country, and every year they have to make repairs, at large expense, of cracked and settled banks.

When the water in the streams is high the drains cannot discharge all the water that falls on the fens into them; and with the continued settling of the soil the sluices come to be more and more incapable of discharging all the water. When the drainage was first completed, wind-mills were used to pump the water from the ditches into the drains; but they were too uncertain in their action. When the water was abundant, and there was no wind, the lands would be overflowed, and now steam engines have almost entirely taken the place of the old wind-mills for driving the pumps. There were formerly as many as seven hundred on the fens between Lincoln and Cambridge—a few are still left, but the place of most of them is taken by about sixty steam engines, which range from ten to eighty horse power.

The water is chiefly raised by scoop-wheels, and not by pumps. These wheels are almost like the paddle wheels of a steamboat, and they are set so as to fit closely, but without touching, between parallel stone walls, and the bottom is curved upwards in front. When the wheel turns it presses the water forward in the narrow passage and upward till it is raised sufficiently to run over into the drain. Such wheels will lift economically to a height equal to one-third their diameter. The height to which the water has to be lifted varies in different localities. From two to ten feet are common cases.

Some very large rotary pumps have recently been erected for the drainage works near Boston, in Lincolnshire, and it is claimed by the ablest engineers that they are cheaper to work, and more efficient than the scoop-wheels.

The amount of water raised is enormous. At one place in the Deeping Fen the engines raised three hundred tons a minute to an average hight of seven feet, and the whole fen of 25,000 acres is drained by two engines of sixty and eighty horse power.

The way of determining the power needed for any drainage is to take the greatest rainfall in any month, make the proper allowance for evaporation, and then calculate the number of tons of cubic feet of water that will remain on the whole number of acres to be drained. Then allow that the engines can be kept at work twenty-five days in a month and twenty hours each day, which is five hundred hours a month. Then provide an engine and pump which are capable of doing the work, and the plan is completed.

The machinery and power necessary to drain these lands is now well understood, and is put in operation. The water is kept in the ditches at a level which is from two to three feet below the surface of the ground, varying somewhat with the crops that are to be grown. It is found that the presence of the water within that distance from the surface is favorable for the growing crop, and a security against drouth. The last summer was one of unexampled dryness, and the fen farmers found it was very useful to them to have water in the ditches, and great care was taken not to let the water out below a certain level; but on the contrary to dam it back so as to hold it up to the proper height.

Mr. Ruston informed me that a portion of the fen near Chatteris, in which he is interested, contains 10,000 acres, besides 2,000 acres of upland, and it is drained by an eighty-horse engine at a cost of six pence an acre per year. This is the cost for the year, but it is not by any means the annual tax, as additional to the expenses of the year, there are large debts which have been contracted and must be paid; also, parliamentary and other expenses. The tax in 1870 was 1s. 9d. an acre on most of the land, and 10½d. on the rest. The heaviest taxes that can be imposed upon these lands are 3s. 6d. and 1s. 9d. an acre. The taxes in some other parts of the fens are a little higher, being from 4s. to 6s. an acre.

The first cost of these improvements has been enormous—95,000 acres out of 300,000 were given to the first Earl of Bedford for making the drains and connected works—and there are many districts in this Great Level where farmers have combined to make additional improvements at their own costs. It is said that there are more than a hundred acts of parliament relating to the fen drainage. The parliamentary expenses are very large, as every bill is strongly opposed and must be fought through. The Middle Level has a debt of £500,000, and arrangements have to be made for paying it off within twenty years of the time it was contracted. The expense of the syphons in the Middle Level drain were £62,000. Other sums of money equally large are spoken of in connection with different parts of the fens; but it is found by experience that they are small when compared with the value of the land or its extraordinary fertility. It bears all these expenses, and continues to increase in its power of yielding productive crops and supplying food to the rest of the kingdom.

THE NETHERLANDS have long been noted for the great extent of land liable to overflow. The country itself is very flat and low and has no ranges of hills to break the uniformity of its surface. It is open to the North Sea along its north and west borders, and on the south is crossed by the Rhine, which brings down an immense volume of water from the hilly and mountainous parts of Western Germany. In North and South Holland there is a border of sand hills, dunes, or, as we should call them, beaches, along the sea, but the more southern provinces have no such protection, and are exposed to the direct action of the waves. In both, however, the country is liable to be overrun by the sea, the only difference being that the water naturally runs off quickly in the southern provinces, while in the northern the dunes hold it back and so favor the growth of turf and the accumulation of muck. Along the Rhine the country is equally exposed, and when great floods occur in that river and the water comes down to the flat country where its current is checked, it overflows its banks, covering the whole country and causing frightful damage to life and property.

In dry seasons some of the ground could be cultivated or pastured, and so support human life. But the dangers to which they were exposed obliged them to maintain a constant struggle with the floods,—and the history of the country is full of accounts of the making of dikes and their failures. At first, the dikes were made of reeds and grass, later, of logs and beams of wood; more recently of earth, and in exposed parts they are faced with stone, brush, straw and grass. The kingdom has an area of about 12,000 square miles, and full one-half of it is so low as to need protection from the water. Heavy banks or dikes are built along the shore of the sea and the borders of the rivers to keep out these floods.

The leakage water and the rain-fall were drawn off from the higher portions of this land by means of tide-sluices which opened so as to allow the water to run out at low tide, and closed, to hinder any from running in at high-water. The larger portion, however, was too low for this mode of drainage, and rain and leakage waters had to be raised by pumps. In some localities the water has to be raised only one or two feet; in others ten, fifteen, twenty, and in a few places even twenty-two feet, before it will run off into the rivers or sea.

The magnitude and importance of these works can hardly be estimated. The oversight and management of them is entrusted to one department of the Government, the Water-staat, and there is a special corps of engineers devoted to that branch of their profession.

The chief works of drainage have grown with the exigencies of the case. At first very slight dikes would be required, but as the land was drained and occupied it settled, making it necessary to increase the height and size of the dikes, and also carrying the surface of the water in the ditches lower and lower until the sluices were no longer able to drain it off, and the erection of pumps and windmills to drive them then became a necessity. This mode of driving pumps has been the favorite one in the Netherlands for various reasons. The country is flat and the winds that sweep over it are strong and steady, furnishing an abundance of power at a cheap rate. Steam engines which are their chief competitors, require fuel, which is expensive, and in times of disturbance might not be easily obtained.

In wet seasons, or in still weather when the mills could not work, the land suffered much. This led to the growing of such crops as are least injured by water—and hence pastures and meadows are much more common than fields of grain or other cultivated crops. For the best of pasture and meadow the water in the ditches only needs to be kept eighteen inches below the surface of the soil—while for growing grain or other cultivated crops to the best advantage, the water must be kept three feet below the surface. Though windmills, then, would furnish the cheapest power, there were seasons when the country suffered greatly for want of an agent more under control. Especially was this the case where lands were entirely under water and needed to be pumped dry before any improvement could begin. It is said that ninety lakes have been drained in Holland, and while some of the smaller could be pumped dry by windmills, the larger ones needed the steady power of steam. One of the greatest engineering works of the age is the draining of Haarlem Lake, a large body of water which lay but a short distance south-west of Amsterdam.

"*The origin and history of this great enterprise is as follows: In the year 1539, the North Sea, long restrained by artificial dams and dikes, as well as by some natural ridges of sand, suddenly burst its barriers, and brought horror and desolation into the fertile flats of North Holland. Twenty-six thousand acres of rich pasture land, with meadows, cattle and gardens, were covered by the waves, and the village of Nieuwenkirk was submerged and all its inhabitants lost, in the tremendous calamity. The inundation resulted at first in the formation of four lakes, but the barriers of soft alluvial soil which separated them were gradually destroyed, and the four lakes became merged into one. The degradation of the shores also continued, until, at the commencement of the eighteenth century, the waters covered an area of 45,000 acres, with an average depth of thirteen feet below low water in the Zuyder Zee. This lake constituted what has since been known as the Haarlem Meer or Sea. The people of Holland saw with much alarm, the rapid extension of its boundaries, and at an expense of about $160,000, succeeded

*Ann. Sci. Disc. 1853; p. 31.

in partially arresting its progress; an expense of about $20,000 per year was moreover entailed for the preservation and repair of the works of defence. More than two centuries elapsed after the time of the first inundation before any one began to dream of recovering this vast tract of country, and then, for a long period, all plans proposed were deemed impracticable. At length, on the 9th of November, 1836, a furious hurricane from the west drove the waters of the lake upon the city of Amsterdam, and drowned upwards of 10,000 acres of low land in the neighborhood. On the 25th of December following, another hurricane, from the east, drove the waters in an opposite direction upon the city of Leyden, the lower parts of which were submerged forty-eight hours, and 19,000 acres of land were inundated. The enormous loss occasioned by these two storms induced the government to determine on the drainage of the lake, and a credit of $3,200,000 was voted by the States General. In May, 1840, a commission was appointed to superintend the work.

"The first operation was to cut a canal round the lake, to isolate it from the neighboring waters, and to afford the means of navigation to the enormous traffic which previously passed over the lake amounting to 700,000 tons per annum. This canal was thirty-seven miles long, one hundred and thirty feet wide on the west and one hundred and fifteen feet on the east side of the lake, with a depth of nine feet of water. On the side next to the lake, the mouths of all water courses entering it, were closed by earthen dams, having an aggregate length of three thousand yards, made in ten feet depth of water. Other great works were executed by enlarging the sluices at various points, and erecting powerful steam engines to assist in discharging the water from the canal during the time of high water. The water of the lake has no natural outlet, being below the lowest practicable point of sluicage. The area of water enclosed by the canal was rather more than seventy square miles, and the quantity to be lifted by mechanical means, including rain water, springs, leakage, &c., during the time of drainage, was estimated at 1,000,000,000 tons. In determining the motive power to be employed, two points were to be kept in view: first, the cost of draining the lake; second, the cost of annual drainage; for, when once the work was accomplished, the site of the lake could only be kept dry by mechanical power. With the exception of a few steam engines, the wind had hitherto been the motive power employed to work the hydraulic machines used in the Netherlands to keep the country dry. And the power of 12,000 windmills, having an average aggregate power of 60,000 horses, is required to prevent two-thirds of the kingdom from returning to the state of morass and lake, from which the indomitable energy and perseverance of the Dutch people have rescued what is now the most fertile country in Europe.

"The Haarlem Meer Commissioners were convinced that the old means must be laid aside, and new ones adopted to suit the magnitude and peculiarities of their work. They accordingly determined to erect three gigantic steam engines of a peculiar construction, which was accordingly done, and the whole put in operation in 1848. These engines consume but two and a half pounds of coal per hour, for each horse power, and are capable of raising one hundred and twelve tons of water ten feet high at each stroke, or of discharging 1,000,000 tons in twenty-five and a half hours.

"A short description of one of these engines may prove interesting. It has two steam cylinders, one of eighty-four inches diameter, placed within another of one hundred and forty-four inches diameter; both are fitted with pistons; the outer piston is of course annular, and the two pistons are united to a great cross-head, or cap, which is furnished with a guide-rod, or spindle; both pistons and cross-head are fitted with iron plates, and together, with parts of the engine attached, have an effective weight of nearly ninety tons. The engine house is a circular tower, on the walls of which are arranged eleven large cast-iron balance-beams, which radiate from the centre of the engine. Their inner ends, furnished with rollers, are brought under the circular body of the great cap, and their outer ends are connected to the pistons of eleven pumps of sixty-three inches diameter each; the stroke of both ends is ten feet, and the discharge from the pumps sixty-six cubic metres or tons of water per stroke.

"The action of the engine is very simple; it is on the high-pressure-expansive-condensing principle. The steam is admitted first beneath the small piston; and the dead weight of ninety tons is lifted, carrying with it the inner end of the pump balances, and of course allowing the pistons to descend in the pumps.

"The equilibrium valve then opens, and the steam in the cylinders passes round to the upper surface of the small and annular pistons; puts the former in a state of equilibrium, and presses with two-thirds of its force upon the annular piston, beneath which a vacuum is always maintained; thus the down-stroke of the engine, and the elevation of the pump pistons and water, is produced by the joint action of the descending dead weight in the cap and pistons, and the pressure of steam on the annular piston. The engine has two air pumps of forty inches diameter, and five feet stroke each. The water is lifted by the pumps into the canal, from which it passes off towards the sea sluices. The total weight of iron employed for the engine, pumps, &c., is six hundred and forty tons. The cost of the machinery and buildings was $175,000."

"*The last openings in the surrounding dike were closed in

*From Buysing's Waterbouwkunde.

the beginning of June, 1848, and one engine was started on the 7th of that month. The water in the lake then stood at twenty-five and a half inches below the Amsterdam Level.* On the 11th it had been lowered to thirty-two and a half inches, and after thirty days' operation the water stood at three feet below. In October the level was reduced to three feet one and a half inches, which left the banks exposed to all kinds of danger from the approaching stormy season. The two other engines were set at work February 26, 1849. In one years' time they brought down the surface of the water to six and a half feet below A. P. By this time some difficulty was experienced in bringing the water to the engines on account of its shallowness near the shores. Two of the engines stood almost exactly at the opposite ends of the lake, and a conducting drain was dug between them, which divided the lake into two nearly equal parts. A cross drain was also dug, cutting the first at right angles. They were cut to the full breadth of sixty-five and a half to eighty-two feet, but only to the depth of ten feet, and later to that of thirteen feet, equaling the average depth of the Mere, which was, for the time, satisfactory. Afterwards these ditches had to be lowered to nineteen and three-quarters feet, and in 1857 they were deepened to twenty-one and one-third feet. The last portions of water were troublesome to drain off to the pumps, and the engines could only work intermittently. In June, 1852, the water of the Mere finally disappeared, and in July the ground became quite dry. The work thus lasted four years and one month, but as only one engine worked for the first part of the time, it is considered that the whole is equivalent to three years and seven months' work of the three engines.

*The datum plane to which all levels are referred in Holland is on a level with an established point of reference in Amsterdam. This mark is usually spoken of as A. P. (*Amsterdam Peil.*)

"The first engine made an average of from eight to nine strokes a minute, and the other two an average of from six to seven; and in the whole time nearly 14,000,000 strokes each. The whole amount of water that was raised was 832,000,000 tons."

"The total expense of the undertaking, from 1839 to 1855 inclusive, has been $3,600,000. The land was at first valued at thirty-three dollars an acre. Subsequent examination proved that the soil laid bare by the draining operations was of far greater value than was originally supposed. Thus, in 1853, 1,936 acres brought $230,000, or $118 per acre; and though subsequent sales have not realized such large prices, yet the land commanded a much higher price than the first valuation. 'This result,' says M. D'Endegrest, 'surpassed all expectation, inasmuch as the grand object of the drainage was rather to put an end to the encroachments of the lake than to make a lucrative speculation of it.' It is stated that a great number of farms are springing up on all sides, and that the cultivation of the rich land is affording employment to many hundreds of laborers. The total amount of land available for agriculture is estimated at 44,400 acres; and by proper care and supervision it is confidently expected that no water overflows will take place.

"The value of the land recovered by Holland from the Lake of Haarlem is increasing at a rate which insures payment of all the outlay for the drainage in a comparatively short time.

"No ill consequences were experienced from intermittent fevers, as was dreaded when the surface was first laid bare, and the numbers of dead fish had no other effect than to fertilize the soil."

A visit to this dry lake in 1870 proved very interesting. It is traversed by excellent roads, the ditches are kept clear, and the water is low in them, about three feet below the sur-

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face. Farm houses are located everywhere about the bottom of the lake, and trees, shrubs, and all the appendages which belong to pleasant and prosperous farmers' houses, are found here just as though they were not beneath the level of the sea. For some years after the lake was drained the lowest parts continued wet and unpromising, and the land was held at a low price, but by reducing the drainage level still further, this portion has become quite as dry as any part of it, and the soil being heavier it is now more valuable than any of the rest. With the exception of some strips along the edge, from which the peat has still to be cut or burnt off, every acre is now productive. I saw here one of those remarkable Dutch dair[illegible] the cow stables, cheese house, and dairyman's dwelling all under the same roof, and all perfect models of neatness.

The yearly expense of keeping this Haarlem Meer *polder** dry is not great. My informant, who was a land owner in it, told me that his taxes there were ten florins per hectare, and that they were seven florins per hectare in one of the small lakes which he had drained. These prices are equivalent to $1.62 and $1.13 an acre, which is not high for the work done and the valuable service rendered in always having a full supply of water only three feet below the surface.

The success of this enterprise has led to the undertaking of several others of the same kind, and to the projection of still more. The Great Ship Canal now in course of construction between Amsterdam and the North Sea passes for twelve miles of its length through the Y, a large body of water which is about four feet deep. The canal is built by dredging out the material and depositing it in the banks on either side. After this is done it is designed to pump out the water from the rest of the Y, and thus to secure 12,000

*Polder is the Dutch name for a plot of reclaimed ground surrounded by a dike.

acres of good land. This is considered entirely practicable, and the company estimate the reclaimed land to be an important part of their compensation.

The Zuyder Zee, though covering a large surface, is quite shallow, and the project of dyking it off from the North Sea, and then pumping the water out of it, is now under discussion. The work is one of great magnitude, and must take a long time to get in operation, but it is neither impracticable nor visionary. The whole of it covers an area of 1,200 square miles; but part of it may be divided off for completion at first. The Haarlem Meer polder includes 18,000 hectares, which this year are worth 1,200 florins per hectare, or nearly $200 an acre; and the whole is worth 21,600,000 florins, or $8,640,000.

The following rules in regard to the construction of dikes are copied from Storm Buysing's Hydraulics, the standard text-book for Dutch engineers:

"FORM OF DIKES.—Dikes in general should have height enough to turn water; and by their form and the material of which they are made they should possess strength enough to withstand the pressure which water and other forces bring to bear against them. Hence they should rise at least from twenty inches to two feet above the highest known level of the water. Their shape should be that of a trapezium. They must be made of good adhesive earth, and they must not only be mutually united together in all parts, but also with the foundation on which the dike is laid. The breadth of the top may vary from nineteen inches up to twenty, twenty-three, and even twenty-six feet. The outer slope has an inclination of from two to eight and even ten base to one rise. The inner slope is just enough to hold up the earth; usually from one and a half to two base to one rise. It may even be necessary in some cases to give the inner slope a curved outline.

"THE FORE-SHORE.—The dikes are generally separated along their outer and inner borders from the adjacent lands by ditches, and the spaces between the ditches and the foot of the slopes are called the outer and inner *berm*. The breadth of these vary—for the outer berm thirty-three feet and for the inner one twenty feet is usually thought sufficient. Sometimes these berms are left as the natural surface of the ground raised them; but in case the land is not smooth and regular, they are often brought up to a uniform height, when they aim to lay them with a gentle slope, say one in twenty from the bank outwards, so as to facilitate the running off of surface water.

"Experience shows that the dikes which lie directly on the brink of the shore are much more liable to injury than those which lie further in, and have some land before them; and however much ideas may differ about the minimum of breadth in the different circumstances, which depend upon the position, yet all are agreed as to the supreme importance of this protection; and in laying out new dikes and diking new polders this must be looked to.

"Most of our existing systems of drainage lack this protection, and lie directly exposed to the force of the waves or current; yet these dikes once had land in front of them at most points, but it has been slowly worn away by the action of water. Now, to change the situation of the dikes is impossible, and we must limit ourselves to the employment of the best means of defence, and regulate these according to the situation.

"In laying out new dikes the first consideration is that the species of earth be suitable for making and keeping them up. Material for the outer dikes must be had without coming nearer to the dike than the outside line of the berm; that is, along the shore an edge of unbroken earth must be left of from thirty-three to sixty-six feet wide; and at intervals of perhaps three hundred and twenty-five feet jetties or projecting banks of earth twenty feet wide, standing out at right angles to the line of the dike, should be left to supply material for the repair of the dike, filling holes, or for other uses of the like character.

"Along the banks of great rivers, and along the seashore, the berm or fore-shore is sometimes made much wider, even to 325 or 490 feet.

"LOCATION.—In selecting a location for dikes on new ground, there are many more circumstances to be considered than for determining the fore-shore—first, the direction must be such that with the shortest dikes the greatest surface possible may be enclosed; second, the dike must as far as practicable run parallel with the stream or else at right angles to it, and, third, that direction must be avoided which would be exposed to our prevailing storm winds from the southwest, west, and northwest. But above all the quality of the ground on which to found the dike must be considered, and the firmest and highest possible selected, and that which is not cut up by brooks or low ground. When corners or tongues of land come in the way, it is to be decided whether their outline should be followed, or partly cut through and diked, as in cases where the cost of a longer dike may not be compensated by the increased value of the piece of land to be diked. The line of the dikes must avoid all acute angles, and when necessary, making them outward rather than inward, because they hold the water driven by the wind better than the others. Different lines can be united by curves, to which the two are both tangent.

"FOR THE CROSS-SECTION of a dike it is not enough to obtain strength, but sufficient strength to resist the force of the water on the dike must be obtained at the lowest possible cost. The height forms the first consideration; the highest water levels ever to be expected at that point form the guide to this, and observations of extraordinarily high freshets after storms give them. Those of January 14 and 15, 1808, February 4, 1825, and February 24, 1837, are the highest ever known, and rose as high as seven and a half to eight and a quarter and even nine feet above the ordinary high-water mark, varying with the position as regarded wind at the point of observation. These heights were measured with perfectly smooth water; the waves are by no means equal. Where dikes turn from the wind there are scarcely any waves, so that a dike from two to two and a half feet above the highest known water level is quite sufficient for these. While in dikes affected by the storm wind the waves rise, according to observations taken in Zeeland, as much as eight feet above still water. The waves are higher where the dike is without a berm and has great depth, than where it has a high and broad berm. They also rise on steep slopes much higher than on more gradual ones.

"The height of the dike must be most regular, sloping from those points most menaced by waves down to such parts of the dikes as are protected from the wind, where less height is requisite.

"For example, the Southern Dike, between Rammekens and Veissingen, on the island of Walcheren, is only ten feet above high tide, while it rises at Veissingen to sixteen and a quarter feet. The Westkappel Dike, which is also very favorably situated with regard to the wind, is fifteen and a quarter feet above high-water mark.

"On the Island of Schourien, when the Dike of Scharrendijke was improved in 1842–3, it was raised to twenty-one feet above high water. Other less exposed portions along the Zeeuw streams are from ten to eleven and a quarter feet above.

The Helder Sea Dike from the end of the dunes at Huisduinen on to Nieuwe Diep, running almost east and west, and consequently much exposed, is from twelve and a half to fifteen and a half feet above ordinary high tides; the other North Holland dikes along the Zuyder Zee are from eleven to twelve feet. The Gelder and Overyssel dikes average from eleven to twelve and a half feet; those in the vicinity of Vollenhoof are thirteen feet above, and those along the coast of Groningen from thirteen to fifteen and a quarter feet above.

The height above ordinary high and low water thus regulates the height given in descriptions and plans, and this is indicated by immoveable marks at different points, such as bolts, beams, or panels in sluices, or similar things. The ordinary tides are thirteen feet or less.

"The breadth of the top of the dike varies from twenty inches to twenty, twenty-three, or twenty-six feet. The first consideration here is the strength required of the dike, and the second whether the top shall or shall not be used for carriages and horses. Riding on top of the dike is generally considered as injurious to the dike and dangerous for the traveler, nevertheless it seems advantageous to give so much breadth to the tops of the dikes that they may serve as roads when needed; for in time of danger they are often of great service for the transportation of materials, while in case of overflows they afford communication for a long time when the ordinary lower roads are made impassable by the water. Hence where the ordinary roads do not cross dikes a breadth of at least ten feet should be left, while on such as usually serve the purpose of roads from sixteen to twenty feet is necessary.

"On the inner side that slope is taken at which the soil is in no danger of sliding down; the most cohesive soils will almost stand with a slope of one base to one rise, less cohesive one and a half to one, and always with an inclination of from one and three-quarters to two rise to one base. If the dikes had only to resist the pressure of the water on their sides, then (providing the dike were of good adhesive material) the cross-section might be triangular in shape, the side slopes of which should have the natural inclination of the earth; but this is not advisable, since perfect coherence and solidity are never attainable in a raised mass of earth, and this lack must be supplied by a greater amount of earth. Again, the jar of the water and the motion of the waves form the chief cause of the destruction of dikes, and hence the outer slope, which has first to resist this force, must be put in condition to withstand it.

"The force with which water and other bodies come against a slope, increases in proportion to the angle made by the slope with the horizon, hence a slight inclination affords more resistance than a steep one, which experiments have confirmed.

"According to theories advanced by Woltman on the effects produced by water and ice upon dike slopes, sea dikes are effectual with less strength at their foot than nearer the top, and a convex surface should be chosen for the outer side of sea dikes, though a smooth form should be retained where the slope varies but little.

"The consideration that the ice is never driven by low water against the dikes, but always at high tide, and that the beating of the waves against these dike slopes can be injurious only when the winds are in a certain direction and at high tide, naturally leads to the conclusion that the slope below high-water mark may be less smooth than above. As the portion of the slope below high water is unfavorable to a natural covering of grass, it must be artificially protected, and this protection is less costly with a steep slope than with a gentle one. As all sudden crossings and sharp angles are to be avoided, the outer slope should have a convex form.

"The Species of Earth of which the dikes are made must be such as will cohere and hold firmly to the foundation; the more cohesive the earth the more desirable it is, and the more solidity may be expected from the dike. Hence clay is the most desirable material for dikes, and it can generally be found along our coasts where dikes have been or must be laid. Sometimes they are made by preference from alluvial earth, where clay is not near, and its transportation would be too costly and troublesome.

"Sand has very little cohesiveness and will not make strong, water-tight dikes; pasture or marshy earth has too little specific gravity, frequently even less than water, and hence must be excluded with sand from the dike.

"Garden and surface soil, though far below clay, still as its fine particles readily pack, is much more desirable than pasture ground or sand, particularly for covering slopes where grass is wanted.

"The clay is not always pure, nor always obtainable in sufficient quantities, so that a mixture of clay and poor earth must often be used. But if care is taken to put the best and purest clay on and near the outer slope, and the poorer kinds in the body of the dike, then such kinds may be used without much danger. There are instances of dikes made from very sandy soils, with a covering of only three feet of clay on the outer slope, which, nevertheless, turned water well. Such layers of clay should be used with the utmost care and every little injury must be immediately repaired, for if the ground once give way so far as to admit the water to the sand or poor earth, little dependence can be placed upon stopping the water.

"Before commencing the making of the dikes, direction and profile are carefully marked out on the ground, and the precise borders of the inner and outer banks, marked with a sharp instrument. Within these the sods are torn up as much as possible, and the ground always dug up deep seven to eight inches, made soft and cleared from all roots of trees, plants or anything which might hinder the proper cohesion and union of the soil. The sods, both from under the dike and from the ditch, are to be carefully piled up to be afterwards used in covering the new work. As the outline of the dike and size of the ditch are enlarged, it will seem that the new dike is to be higher than that previously calculated for, for the earth is not so firmly united when first dug out as it subsequently becomes through the weight of the dyke and the evaporation of the water, but the subsoil will also be more or less pressed down by the weight of the dike until the resistance of this packed subsoil equals the weight imposed. It is difficult to give a definite idea, as the position of the foundation depends upon the nature of the ground, the weight of the dike and the extent of the surface necessary to support this weight. The greater or less sinking of the body of the dike depends partly on the greater or less firmness and humidity of the soil, but also much upon the carefulness of its treatment. So the height of the dike is made one-seventh or one-tenth greater according as more or less sinking is expected, but the breadth of surface remains the same that it is to be after the final settling of the height of the dike, so that the inclination of the two slopes is steeper. But since the top of the dike will sink most, as most earth is heaped there, and the ground has at just that point to bear the most weight, while on the contrary there is no sinking at the foot of the slope; after its final settling the dike will have less inclination.

"The banks are built in thin layers and packed by the constant passage of horses and carts, and sometimes by means of stamps or by puddling.

"The planting of dikes with trees may be very advantageous; along genuine sea dikes it is impossible to keep them alive; but dikes less immediately exposed to the sea air are often planted with trees. The rapid drying of the dikes renders the growth of wood slow, and the grass grows thin and poor under them, while the motion of the trees in high winds, affecting the roots, loosens the soil, so that it seems unadvisable to plant dikes where trouble in resisting the water is anticipated. Whenever there is an opportunity to plant osiers and willows along the dike, at a distance of twenty or twenty-six feet, such planting is highly desirable for it destroys the power of the waves and of ice, thus strengthening the dike. The osiers and willows are generally cut every three or four years. In order that the dike may never be exposed, an arrangement ought to be made to cut a part every year, so that the larger portion of the protection may remain standing."

In concluding these statements regarding the success which has attended drying the low-lying lands of England and Holland, I may call attention to several points separately.

1. From the statements made it is obvious that the reclamation of salt marshes or lands liable to be overflowed by the tide is attended with a heavy outlay of money. In the English fens the expenses have come in so many forms that it is not possible to get them together, but they have been enormous. In the Netherlands, also, the expenses have been wonderfully large; the dikes on the Island of Walcheren, which is on the most exposed part of the coast, have been several times almost destroyed, and it is said they have cost money enough to build them of solid copper. In our own State the Swartwout improvement on the Passaic and Hackensack marshes, in 1830-6, failed from not being thoroughly carried out; and the later enterprise of the nurseries on the same ground, was brought to an end from an unwillingness to invest money enough in it to construct substantial banks and sluices to

shut out the tide and drain off the water; and in our southern counties where diking is a success, there have been many heavy losses from the failure to put in a sufficient amount of money and labor to build solid and permanent banks. To make the dikes stand they must be built of earth, or at least must have a core of earth, and not be entirely of peat or spongy sods. The foundations must be more carefully prepared. Along the banks of rivers and streams the ground is usually solid enough to hold up the dikes, but it should always be sounded for old sloughs or water-courses, which, though covered with solid earth, may still be very soft and insecure. In all banks crossing the marshes away from the water-courses the material of the marsh is soft and yielding, and secure banks can be built on such ground only by making a core of puddled earth in the bank from the solid ground under the marsh up to high-water mark. The peculiarities of our marshes in respect to solidity of material were plainly shown in the maps accompanying the Geological Report for 1869.

The expenses of reclaiming lands will be least when the largest plots are enclosed within the same bank. The bank for a large plot needs to be no heavier or higher than for a small one.,—and the lengths of bank to go around fields of the same shape are in proportion to the square roots of their areas. It takes but twice as long a bank to go around four hundred acres as it does to go around one hundred,—but three times as much to go around nine hundred acres—and only four times as much to go around sixteen hundred acres. The Dutch *polders* or plots of enclosed and drained ground formerly averaged about twelve hundred acres each, but the newer ones are much larger; the Haarlem Meer polder contains 45,000 acres, and all the projected new ones are very large. The drainage districts in the English fens are also very large, the smallest of them including many thousand acres. It is by dividing the expenses over so many acres that they are made light enough to be paid and still leave the farmer a margin for profit.

It should also be remembered that when our drained lands settle so much that they cannot be longer drained by sluices, then pumps will have to be used. The amount of rain that falls in this country is nearly double that of England or Holland, and, of course, will cost twice as much to pump it up so as to run it over the dikes.

And finally when such costly works are to be undertaken, the plans for their location and construction should be entrusted only to skilled engineers and workmen. By this means the parties interested may have a fair understanding of the expenses they must meet, and also a reasonable prospect that their improvement will be a permanent one when done.

2. *The worth of these lands when properly reclaimed can hardly be overestimated.* Wherever there is a sufficient amount of clay or mud mixed in with the grass roots and other organic matters of the marsh it will make a soil inexhaustibly rich. When such lands are brought into cultivation, with good management, they can always be depended on for yielding large crops. They are easily tilled, and cost less than other lands for fertilizers. The water level being only two or three feet below the surface, crops upon them are very little, if at all, damaged by droughts.

It should, however, be distinctly understood that marsh lands are not all composed of soils like those mentioned above; very large portions of marsh lands are found in which there is no earth, clay or mud, nothing but muck and grass roots or turf. Such lands will not produce crops without manure; and to make them really good soils, they must be clayed like the English fen-lands, which have been described, or else have upland earth put on them to the amount of two hundred or three hundred yards per acre, and must be fertilized with mineral manures like uplands. Lands of this quality will sink very much when drained, and in many places may become so low as not to be capable of drainage by sluices; and they will very soon need pumps to drain them. When remote from market, it is very questionable whether it will pay to give them the *thorough* drainage which is needed for cultivated land. In the neighborhood of Salem some of the drained meadows are only used for growing grass, and not cultivated. This is the case also in Holland, where by far the largest part of the drained land is in meadow or pasture, and is considered to be more profitable than the arable land. The water needs not to be kept so low in the ditches, the cost of drainage is lessened, and damage from floods is much less to be dreaded. Pasturage and the raising of hay may possibly be adapted to these flat grounds to an extent much greater than has yet been reached.

The improvement is well begun, both in East and West Jersey, and there is abundant encouragement for continuing it. There is room, however, for failures, and every project for drainage should be carefully examined and well understood before its execution is undertaken.

3. The effect of draining marsh lands upon the health of the adjacent country, is a most important subject of inquiry. The English Fens were formerly noted for generating fever and ague. They are universally conceded to be much more healthy now than before they were so well drained. And though I inquired frequently, I could not learn that the drained lands were considered less favorable to health, than the drier uplands. In Holland one of the strong inducements to drain the Haarlem Meer was to do away with the sickness which followed the floods, overflows, and consequent stagnant water caused by storms driving across the lake. No injury to health has been observed to follow its drainage.

There was some sickness in the polder in 1868, but it was not serious, and there is no reason for connecting it in any way with the drainage.

Some lands in our own country are said to have been made unhealthy by drainage for a year or two after the work was done; and such might possibly be the case with these newly drained land. It is not likely to be so however, and in the end the general healthiness of the country must be improved.

Musquitoes and green-headed flies, those pests of our salt marshes, would certainly find a less favorable breeding ground if the water was all drained from the surface, and this of itself would be a great saving to the community. It would tend greatly to the comfort of human beings, and would save the stock of the country from a vast amount of worrying and loss of flesh. I saw a few gnats in the English fens, but none in Holland. The season was late, however, when I was in the latter country.

Our muskrat, which is so troublesome to the managers of dikes, is quite unknown in Europe. They have a water-rat which burrows in the banks of streams, but he is by no means equal to our muskrat in his power to do damage.

In writing these cautions in regard to planning and managing works of drainage, I do not desire to discourage them, for such lands are by far the most profitable and productive of any that I have seen abroad. We have large areas of lands capable of such improvements; it is for the interest of the owners and of the whole community to have them improved. And the experience which has been gained both at home and abroad is sufficient to indicate the proper way of making them.

III.

On the Soils of the State, their Origin, Chemical and Physical Properties, Distribution, and Suggestions for their Most Productive Management.

A large number of soils have been collected from different parts of the State, and most of them have been analysed. There is, however, much more to be done in this department of the survey, and the results will be presented together in a special report upon the subject.

For the purpose of calling out information which may be in possession of some of our intelligent farmers I reprint from the report of last year the average of a large number of soils and subsoils, from the rich valleys of our own and the neighboring states, which are underlaid by magnesian limestone. The first column gives the soils and the second the sub-soils.

ANALYSES.

Silica	67.88	65.31
Per -oxide of iron	4.57	8.11
Alumina	12.88	13.10
Oxide of Manganese	.44	.37
Lime	.96	.59
Magnesia	1.47	1.34
Potash	2.90	3.87
Soda	.43	.69
Phosphoric Acid	.78	.80
Sulphuric Acid	.03	.04
Organic Matter	6.61	3.72
Water	1.61	1.70
	100.56	99.64

These soils have been noted for their fertility, and have been cultivated ever since the first settlement of the country. They are specially adapted to the growth of wheat, and have always yielded good crops even under the worst of management. The analysis shows that they contain an abundance of all the essential elements of fertile soils; the phosphoric acid, potash, lime, magnesia, and sulphuric acid. The practice of farmers is to enrich these soils by the addition of lime, and by raising clover. It is not thought profitable to keep any stock upon them except sufficient teams to do the work. Plans to increase the supplies of barn-yard manure, like those pursued in less favored soils, are not thought necessary. Lime causes the mineral ingredients to become soluble, and clover supplies the elements of ammonia.

For comparison with these I present the analyses of two soils from the Miami Valley, in Ohio. The Specimens were collected by my associate Prof. Jacob Cooper, and analysed in the state laboratory. The first was taken from a fence border and has never been cultivated. The second is from a field which has been cultivated eighty years without manure and still yields excellent crops.

ANALYSES.

Silicic Acid and Sand	57.60	65.20
Per. Oxide of Iron	2.23	3.78
Alumina	2.18	3.89
Lime	9.43	4.65
Magnesia	4.44	3.90
Potash	0.23	0.43
Phosphoric Acid	0.29	0.29
Sulphuric Acid	.11	.11
Carbonic Acid	10.35	5.85
Chlorine	.03	.02
Organic Matter	9.70	7.23
Water	3.05	4.10
	99.64	99.45

Analyses like these joined to the experience of farmers in working the soils, must finally help to explain some of the difficulties in agricultural science, and I would invite correspondence on the subject.

IV.

On the Iron and Zinc Ores of New Jersey.

The mining of iron ore has been actively carried on during the past year. No accurate statistics have been collected to show the whole amount that has been mined, but it is said to be considerably larger than in any former year; and the demand for our ores is increasing more rapidly than the supply. It is proposed to re-examine and extend the survey of our magnetic-iron ore district the coming season. An examination of some of the large mines of magnetic iron ore in Sweden will furnish a subject for comparison with ours, and a report upon our mines, embodying also the results of the visit to the Swedish, German, and English iron mines, will be prepared as soon as possible.

The zinc mines of our State continue to yield an abundance of ore of the best quality.

V.

Additions to the Scientific and Economic Geology of the State.

THE COPPER ORES OF NEW JERSEY.

Ores of copper have been found in various places since the first settlement of the State. The mines at Belleville, Somerville, Flemington and New Brunswick, have been woked at different times for a hundred years past.

The ore is disseminated through the Red-sandstone or is found near the meeting of that rock with the trap. It is not uniformly distributed, and mining it has not been profitable.

There is an immense quantity of rock discolored by the one or two per cent. of copper which it contains, and some of the new processes for extracting copper show ore as lean as this to be worked with profit. While abroad I visited the copper works at Stadtberg, some thirty miles west of Cassel, in Germany. A thick stratum of black and flinty slate that contains from a quarter per cent. to two per cent. of metal is the source from which the copper is obtained. The ore or rock is partly worked in an open quarry, and partly by underground mining, and being in large quantity is got out at small expense.

When visited in October the mine was producing about 2,500 tons of ore a month, and the average yield of copper was one and a half per cent. The metal is extracted from the rock by acids, and not by heat and furnaces, as is usually done.

The ore is taken directly from the mine without roasting or drying, and is crushed to fragments. The pieces are not as large as hickory nuts, but the greater part are of an appreciable size and not in powder. This crushed ore is put in vats of perhaps a hundred tons capacity, and is then covered with dilute muriatic acid; the quantity of acid being regulated so as to suit the amount of metal in the rock. The acid is drawn off at the bottom of the vat from the rock, and pumped on the top again several times in the course of the three or four weeks required to extract the copper. The liquid which holds the copper in solution, when it has been brought to a proper strength by acting on different vats of ore, is run into a vat where it can be kept in motion by a revolving agitator, and scrap sheet iron is added to it to precipitate the copper. It is soon entirely separated from the liquid, in the metallic state, but in the form of powder or small spongy grains. This precipitated copper is separated from the remaining scraps of iron by tumbling them in a cask perforated with holes through which the copper gradually sifts out. The copper is then taken to the smelting furnance and refined and prepared for market in the usual way.

The whole process is carried on very economically, labor is low, not more than one-third of our prices, and the acid is cheap, being the waste product from a soda factory; costing from one and a half to two cents a pound at the works; the liquid from which the copper has been precipitated is used over and over again as long as there is anything valuable in it, and the sediment of oxide of iron which settles from the waste liquids is dried and used for paint. The ores which contain five per cent. or more of copper are picked out and worked in the dry way. The buildings and apparatus are of the most inexpensive kind—mere sheds answering for the former, and wooden vats backed with clay being all that is used for holding the large quantity of rock which has to be acted upon by the acid.

With very careful management the process has been carried on profitably, even upon ores containing only a quarter of one per cent. With the present low price of copper, however, the managers are not so well satisfied with the profits as they have been.

An immense quantity of ore as rich as that of Stadtberg can be found in New Jersey, and descriptions and localities of it are given in the Geology of New Jersey, pp. 219–224 and pp. 675–680.

When at the German works the question arose as to whether the process used there upon the hard black slate was applicable to our softer and more ochrey rocks, and for the purpose of testing this question, some trials have been made in the State Laboratory, upon two of our New Jersey ores, with the following results, viz:

1. A common sandstone, discolored with the green carbonate of copper which appeared to have penetrated it everywhere, was analyzed and found to contain two per cent. of copper. This sandstone was pulverized and mixed with two and a half per cent. of commercial sulphuric acid. After di-

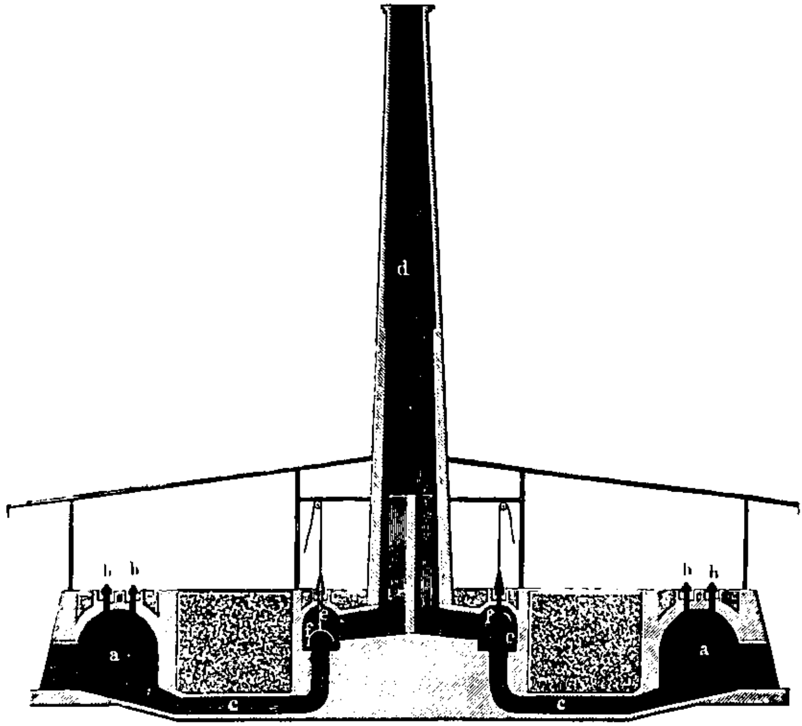
gestion the liquid was drawn off, and the copper that had been dissolved was precipitated. About one and two-tenths per cent. of metal were obtained from this first digestion, and very little of the oxide of iron or alumina in the rock was dissolved.

2. A specimen of shale, blue with carbonate of copper was analyzed and found to contain six per cent. of copper. A quantity of acid more than sufficient to dissolve the oxide of copper was put on the crushed ore and digested. The proportion of copper dissolved was not so great as in the other, and the acid was consumed in dissolving a quantity of carbonate of lime and magnesia which exist naturally in the rock.

The experiments show that the process is applicable to our copper ores in Red sandstone rocks which contain oxide of iron and alumina, but is not applicable to those which contain much carbonate of lime or carbonate of magnesia.

ON BRICK MAKING.

The use of bricks for building, is constantly on the increase in all the older sections of our country. And the advancing price of lumber must tend still further to turn the attention of builders to bricks as a material for construction. We have immense beds of brick clay both on the east and west sides of the state, lying on navigable waters, so that they are within cheap communication of the great markets. While in Berlin I had an opportunity of witnessing the working of a new form of Brick Kiln which is said to require only a third or even a quarter as much fuel as the old mode of burning. Berlin is almost entirely built of brick, two hundred million large brick are used there every year, and they are all burned in these new kilns, the older mode having been entirely driven out of use there, since 1859, when the present were introduced.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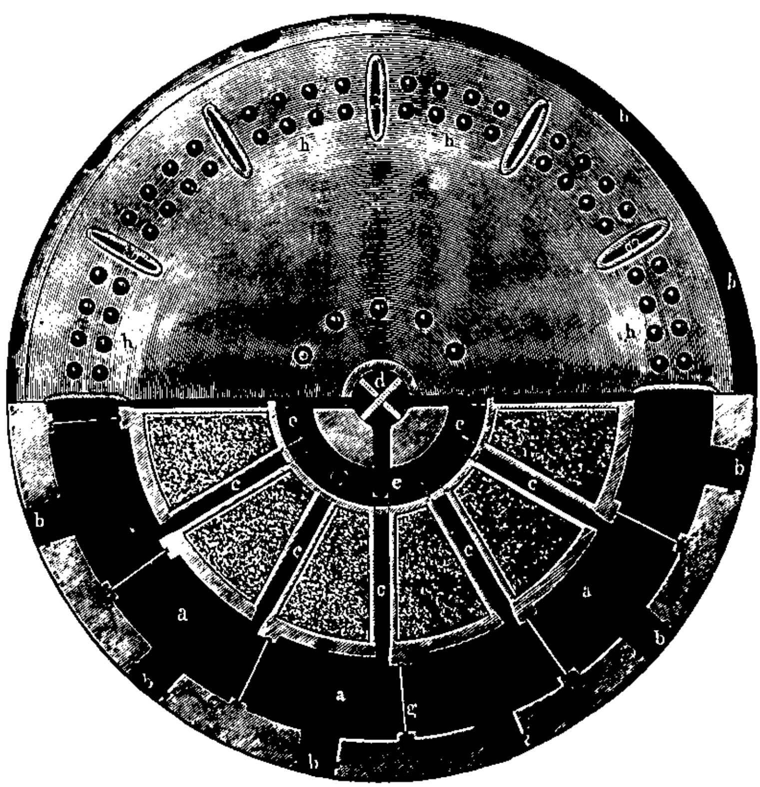
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The ingenuity with which these kilns have been made to apply well known principles of science, and the success which has attended their introduction abroad, leads me to present an illustration of them, in plan and vertical section. The kiln is a permanent structure built of bricks, and the burning is carried on in an arched passage way that has the form of a railroad tunnel, only it curves round so as to return into itself and so make a complete ring. The letters *a. a. a. a.* in the cuts show this chamber. This is connected with the chimney *d. d.* by several flues, in the cut twelve, marked *c. c. c. c.* The ring-like chamber or passage has doors or openings *b. b. b. b.* entering it through the outer wall. There are as many of these as there are connecting flues, and it is intended to have as many of each as there are working days from the time of putting in the green brick to the time when they can be taken out, burned and cool. This kiln is for twelve days work. The flues on their way to the chimney pass into an annular chamber marked *e. e. e. e.* where each one is provided with a seperate valve or stopper *f. f.* The vertical section shows one open and another shut. Between each two doors or openings *d.* are grooves built in the side walls, into which dampers or partitions can be lowered as shown in *g. g. g.* on the part of the plan which has the covering represented. By means of these the whole chamber can be divided into twelve compartments each with a flue and doorway. When working however only one damper is in its place, all the flues are closed except one, and all but two of the entrance doors are bricked up. The round openings marked *h. h. h. h.* are intended for dropping in the fuel, and are usually covered with a loose piece of sheet iron, or brick. All the space inside the annular kiln is filled in with sand or other cheap material.

The working of the furnace can now be easily understood. If the observer is supposed to face one side of the furnace where he can see the two open entrances which may be numbered (1,) (2,) and so on from right to left, he will see men placing green bricks in the compartment (1) and taking out finished bricks from (2). The damper or partition is in between (12) and (1) and the flue from (12) is open. The fuel is being fed in small pieces at a time, into (7.) This is done by dropping it through the small holes in top of the arch, and allowing it to fall among the red-hot bricks which were laid in so as to allow of this mode of drop ng in the fuel. As the kiln is in constant operation and each day a new compartment is filled and one emptied, it will readily be understood that (3,) (4,) (5,) and (6,) are filled with brick which have been burned respectively four three two and one days, and that (8,) (9,) (10,) (11,) (12,) are filled with unburned bricks that have been in respectively five, four, three, two, and one days. The air which is to consume the fuel to burn the bricks is entering at the openings (1) and (2) and is drawn through the burned bricks taking up heat from them and growing hotter and hotter until by the time it reaches the fuel it is almost red hot, and ready to make a genuine hot blast for the fire and it does make a remarkably hot and clear fire. The air and gases from the combustion then pass on through the unburned brick, heating warming or drying them, and giving up its own heat so that when it reaches the chimney it is almost cold again. To-morrow (8) will be fired, and so on.

In principle it is admirably arranged, and in practice it burns the bricks evenly so that very few are damaged,—the labor of firing is very light, and needs no skill,—the amount of fuel is small, much less than in the ordinary kiln, and the quality of the fuel is very common; coal dust, chips, fine peat or any other refuse that will burn at all, can be used:—our anthracite coal dust should find a use in this kiln.

I visited the works near Potsdam where many of the bricks for Berlin are burned. There were thirty of these kilns within a circuit of two or three miles, each of which was turning out from one and a half to three million bricks a year. The fuel used is a poor quality of turf, very light and crumbling, worth at the works two and one fourth thalers a klafter, or about fourty-four cents a cubic yard, which is the quantity they were using to burn one thousand brick. The size of the brick is eleven inches by five and a half by two and three-fourths, which is twice as large as ours.

The kiln is patented by Frederick Hoffman of Berlin, and he has already three hundred of them in Prussia, and as many more in different countries of Europe. In our own country twelve or fourteen of them have been put up, and are now in operation. Hoffman's agents in this country are Wedekind & Dueberg, Baltimore, Maryland. They have a kiln there in which they claim, to turn out 15000 brick daily, with a consumption of one ton of coal or at an expense of thirty-three cents a thousand, for fuel.

The kiln is equally well adapted to the burning of lime, or of pottery.

If so large a saving as that of two thirds the fuel, can be effected, by this invention it is a matter worthy the attention of our brick makers; and I gladly call attention to it.

ON THE DRIFTING SANDS OF THE SEA BEACHES.

When in Holland my attention was called to the care taken to fix their sand dunes, and prevent them from drifting over the meadows and cultivated grounds. For this purpose they plant common *beach grass*—known to botanists as the *Arundo arenaria*, *Ammophila arundinacea A. arenaria*, *Psamma arenaria*, *P. arundinacea*, and in Gray's and Wood's botanies as *Calamagrostis arenaria*. It is known by the common names of *sea-reed*, *sand-reed*, *bent*, *marrum*, and *star* or *mat-grass*. The same species which grows in England and Holland, is found on our seashores. It grows in the dry, drifting sands of the sea beaches, and thrives nearer to the salt water than any other dry-land plant of vigorous growth. All domestic animals reject it as food, but its numerous wire-like leaves successfully withstand the blasts of wind and sand which are driven across the beaches, and retain their erect position, and with their thick matting, tough and spreading roots, restrain and hold in place the drifting sands which otherwise continue to move inland, overwhelming and destroying everything in their way. When this grass gets well rooted it holds the sand, and makes it a protecting barrier instead of a moving destroyer. This property has been so well understood abroad, that stringent laws for its protection have been passed in England, Scotland and Holland, and they are strictly enforced. In England it is a penal offence for any one, the lord of the manor not excepted, to cut or pull the *sand-bent*, or to be found having it in possession within eight miles of the coast.

The sand-dunes along the coast of Holland, almost west of Amsterdam, are entirely bare of trees, and some of them nearly one hundred feet high. The winds sweep across them with more violence than any of the storms that visit our coast, yet they are held in place by this grass. The Great Canal from Amsterdam to the North Sea cuts directly through them down to the sea level, and the sandy banks of the canal are being planted with this grass at once. That set out last spring had grown and was covering the surface well, and the work of planting was still in progress when I was there on the 18th of October last. The grass is propagated by transplanting its roots and not by sowing the seeds. The plants are taken from any old plantation where the sand is full of roots. From five to ten spears of the grass with good roots, are set together in the loose sand, holes for the bunch being opened with a common trowel to the depth of from eight to twelve inches. They are set in rows eighteen inches apart, and the plants are eighteen inches apart in the rows. The work was done in the same way that cabbages are set out, and very rapidly. In that climate there was no difficulty in making the plants grow.

The sea is making great inroads on our shores; two Surveys, made about thirty years apart by the U. S. Coast Survey, show that our entire coast from Sandy Hook south for twelve miles, has either washed away or been moved inland nearly a hundred yards. Probably the same thing is true of the entire coast to the south point of Florida. This sea-bent is one of the easiest means of holding the sea in check. Our beaches will grow cedar and other valuable timber if the force of the wind can be checked long enough for them to get started. Hitherto no care has been taken to preserve the timber on the beaches, but whenever it was wanted it has been cut off, and the ground left open to the full sweep of the winds; soon the sand is all in motion, moving inland. New growths of wood could soon be started if the sand was fixed by a mat of grass. Our climate is hotter, and it may be necessary to have more regard to the season, transplanting in spring or autumn rather than in the heat of summer. In some places the land washed away is of little value, but in others it is very important in itself and for the protection it affords to other property. Premiums from our agricultural societies might be used to call out competition in the cultivation of grass or trees on our sea beaches.

APPENDIX A.

Report of Levels and Soundings taken on the Passaic River from Chatham to Millington Bridge, and also on Dead River, by Prof. Ed. A. Bowser.

A line of levels was run from Chatham Bridge to Millington Bridge, and al o on Dead River as far as the second bridge from its mouth. From these levels the heights of the benches were determined at all the intervening bridges. The heights along the surface of the water were found by leveling from these benches. The heights along the *bottom* were determined by sounding in the channels of the rivers, and subtracting the depths from the heights of the surface. In the accompanying profiles, the top of Beatty's Dam, at Little Falls, is the datum plane. The heights of the points, both along the surface and the bottom of the rivers, were measured from this plane.

It will be seen, by a careful examination of this profile,

1st. That the bed of the Passaic from Chatham Bridge to Page's Dam, has a rise of twenty feet, while each dam, viz: the first just above Chatham Bridge, the second, Edward's, and the third, Bunnell's, backs the water up to the dam next above it.

2d. That the bed of the river from Page's Dam to Smally's Bridge, distant eight miles, following the course of the channel, has a rise of six feet, while the bed of the river at Smally's Bridge is two feet *lower* than the top of Page's Dam.

3d. That the bed of the river from Smally's Bridge to the mouth of Dead River rises five feet; from the mouth of Dead River to the bridge opposite the Church, two feet; from the Church Bridge to Millington Bridge, five feet. On Dead River, from its mouth to the second bridge three miles up, it rises eight feet.

We see then that while the river, from Page's Dam down to Chatham Bridge, has a sufficient fall, Page's Dam must back the water up to the mouth of Dead River. So that an ordinary rain, when the mill-pond is full, will flood the Passaic Valley from the dam to the mouth of the Dead River.

By the "New Formula," deduced and used by the Hydrographical party, in their investigations on the Mississippi, a fall of eight inches per mile, in a stream the size of the Passaic above Chatham, will give it a velocity of about one and a half feet per second. This fall can be obtained by cutting Page's Dam down eight and seven-tenths feet, which will make the grade line at the dam thirty-seven seven-tenths feet above the datum plane. This grade line prolonged will strike Bunnell's dam two feet below the top, or thirty-seven feet above the datum plane. Bunnell's Dam, therefore, will require cutting down two feet.

The grade line between Page's Dam and Turkey Bridge, as the profile indicates, is from two to three feet below the bed of the channel, and about half a mile above Page's Dam it is five feet below the bed, and the bottom is rock. Between Turkey Bridge and Townly's Bridge, the bed of the river, wherever the grade runs below it, is mostly loose earth and sand bars, which, with a little work, will be washed away by the action of the running water when all obstructions below Turkey Bridge have been removed. At Townly's Bridge the grade is forty-one and one-half feet above the datum plane, or one foot below the bed of the channel. From this bridge to the mouth of Dead River, and on Dead River, to the second bridge, the grade is from one to three feet below the bed of the river.

Dead River and the Passaic, for half a mile below the mouth of Dead River, have at present a *fall* sufficient to carry off the water if the obstructions below were removed, but they are entirely to *shallow*. For this reason it will be desirable to cut them down to the grade line to furnish a channel sufficiently deep to keep the water within its banks and below the surface of the ground. The work of doing this will not be great as the most of it is loose earth, not having had any current to wear it away. From about half a mile below the Church Bridge up to Millington, there is at present a large fall. To drain this valley, then, requires that the bed of the river be cut down to this grade line; and this will necessitate the destruction of Page's Dam and at some future time the lowering of Bunnel's Dam.

When this is done, and only when this is done, the Valley of the Passaic from Millington to Chatham, and also the Valley of Dead River, can be well drained.

The principal cost of this improvement will be in paying for water-power that will necessarily be destroyed.

APPENDIX B.

Report of the Levels and Soundings taken on the Pequest River, in Warren County, by Prof. Ed. A. Bowser,

A bench, named first bench, was made on a maple tree on the right bank of the Pequest, 2,286 yards below Vienna, at the entrance of a valley running up towards Danville Church. The datum plane was assumed ten feet beneath this bench. A line of levels was run from this bench up the Pequest to Adam's Bridge, and also up Trout Brook to Trout Brook Bridge, and benches established at all the bridges and at intermediate points. The heights along the surface of the river were obtained by leveling from these benches. The heights along the bottom were determined by sounding in the channel, and substracting the depths from the heights of the surface. The heights of the points, both along the surface and the bottom of the river, were measured from the datum plane ten feet beneath the first bench.

By inspection of the profile, we see that the bed of the river, from first bench to Steam-mill Bridge, has a rise of ten feet, while the rise from first bench to the bed of the river, one hundred and ten yards above Steam-mill Bridge, is only four and a half feet, making the bed of the river at the latter place five and a half feet lower than it is just below Steam-mill Bridge.

The water in the river just below the Steam-mill Bridge, on April 14th, 1870, was three feet deep, while one hundred and ten yards above the bridge it was eight and a half feet deep, and two and a half feet deep on the surface of the meadows. If the bottom of the river, from the point one hundred and ten yards above the bridge where the water was eight and a half feet deep, could be made to have a fall sufficient to give the water a velocity of at least one and a half feet per second, its surface would be kept five feet lower than it is possible to keep it with the present reef at and below the bridge. If this had been the bottom on April 14th, the water surface, being five feet lower, would at that time have been two and a half feet below the banks.

By applying the "New Formula" used by Captain Humphrey and Lieutenant Abbott in their investigations on the Mississippi, we find that, in a stream the size of the Pequest on April 14th, a fall of one foot per mile would give it the above mentioned velocity of one and a half feet per second.

The grade line on the profile represents this new bed from the bottom of the river one hundred and ten yards above the Steam-mill Bridge, down towards first bench, with a fall of one foot per mile. It will be seen that at the Steam-mill Bridge the grade is eight and three-tenths feet above the datum plane and five and a half feet below the bed of the river, which is rock. At the first bridge above Vienna, the grade is four and three-tenths feet below the present bed of the channel—the latter rock—and continues from two to five feet below the bed of the river for three hundred yards. Just below Vienna Bridge is another reef three feet above the grade. Between Steam-mill Bridge and the first bridge above Vienna, there is considerable loose earth and some rocks, besides the three reefs, varying from one to three feet deep to the grade line.

It will be seen that the grade does not run below the bed of the channel between Vienna Bridge and first bench, while it reaches the latter five feet above the datum plane, or one and one-third feet above the present bed of the channel. Thus we see that the reef at Steam-mill Bridge can be cut down five and one-half feet, and the bed of the channel from that point down have a fall of one foot per mile, without any cutting below Vienna Bridge. This will be equivalent to removing a dam from Steam-mill Bridge, five and one-half feet in height.

The grade line on the profile, with a rise of one foot per mile, reaches Long Bridge eighteen feet above the datum plane, and five feet below the bed of the river. Although the Pequest above the Steam-mill Bridge, after the bed below the bridge is cut down to the grade, will have *fall* enough, yet the present channel is entirely too *shallow* to carry off the water. For this reason it will be necessary to cut it down to the grade line, which is from two to five feet below the present bed. The river will then be deep enough to carry off the water without overflowing its banks, and still have a fall of one foot per mile. As the bottom of the river along this meadow is mostly mud and sand-bars, it will not be difficult to make it two or three feet deeper. From Long Bridge up to Adams' Bridge, the rise is five feet; from Long Bridge to Trout Brook Bridge, it is six feet. A fall of three feet per mile can be obtained here, and the channel dug deep enough to keep the land dry.

PROPOSED CUT-OFF.

The profile of the "cut" from the Pequest, one hundred and ten yards above the Steam-mill Bridge, through by Danville Church to the Pequest at first bench, and also that of the branch cut striking the Pequest four hundred yards above first bench, represents the heights along the surface of the ground above the same datum plane that the heights on the river are referred to.

The grade, represented in the profile, leaves the Pequest at a point one hundred and ten yards above the Steam-mill

Bridge, and eight and one-third feet above the datum plane, —which, it will be seen, is in the grade line drawn in the profile of the river—and, with a fall of two feet per mile, reaches the Pequest at first bench five and six-tenths feet above the datum plane; or, by the branch cut, reaches the river five and ninth-tenths feet above the datum plane. Both of these routes were leveled for the purpose of ascertaining which would be the most favorable one for the "cut" that the citizens of Danville and Vienna have talked of for some time as being more favorable to the draining of the Great Meadows than the present channel of the river.

By reference to the profiles it will be seen that the cut to the first bench will be fifty six feet deep at the highest point, and the other forty-nine feet; and that the latter is shorter than the former by seven hundred and fifteen feet.

With a cross section of thirty feet bottom, and a slope of three base to two rise the excavation in these cuts down to the grade line will be as follows:

	Cubic Yards.
From one hundred and ten yards above Steam-mill Bridge to junction of cuts....................	77,365
From junction of cuts to first bench.............. ...	232,511
" " " river four hundred yards above first bench..........................	187,296
Total excavation from one hundred and ten yards above Steam-mill Bridge to first bench.........	309,876
Total excavation from one hundred and ten yards above Steam-mill Bridge to point four hundred yards above first bench.....................	264,661

With the same cross section of thirty feet base, the amount of excavation in the present channel of the river between first bench and the point one hundred and ten yards above Steam-mill Bridge will be:

	Cubic Yards.
Excavation in rock on the three reefs..	13,363
" " loose earth.......................	10,641
Total excavation in rock and and loose earth between first bench and one hundred and ten yards above Steam-mill Bridge..	24,204

This will give the channel from Steam-mill Bridge down, a fall of one foot per mile, while the amount of excavation in the proposed "cut" from the same point one hundred and ten yards above Steam-mill Bridge through by Danville Church to the Pequest at the upper point four hundred yards above first bench will be 264,661 cubic yards, or more than ten times the amount in the river. And I do not think there is any reason to conclude that, in either cut, there will be found less rock than in the river. Yet the "cut" will drain the swamp no deeper than the river in its present channel, if the latter be cut down to the grade line. It would seem then from the above that the cheapest plan to drain the Great Meadows, and the one that will make the drainage thorough, is to cut down the present river bed to the grade represented in the profile.

By reference to the *map* of the Great Meadows, it will be seen that very much cutting can be saved by straightening the Pequest, in many places, between the Steam-mill Bridge and Long Bridge. The area of the swamp is about 5500 acres. The soil is a black muck. The figures on the map denote the depth of the muck down to a sand or gravel bottom. When properly drained, the Great Meadows will be far the most valuable land in that section of country.

The chief expense of this improvement will be in cutting through the rocks at the reefs which may cost $20,000.

APPENDIX C.

Publications of the New Jersey Geological Survey.

Geology of New Jersey, 899 pages large octavo, illustrated by 108 photolithographic engravings and woodcuts, and six mine maps; and accompanied by a portfolio containing the following maps, in sheets:

1. Azoic and Paleozoic Formations, including the Iron-ore and limestone districts; colored; scale 2 miles to an inch:

2. Triassic Formation, including the Red Sandstone and Trap-rocks of Central New Jersey; colored; scale, 2 miles to an inch:

3. Cretaceous Formation, including the Greensand Marl Beds; colored; scale, 2 miles to an inch:

4. Tertiary and Recent Formations of Southern New Jersey; colored; scale, 2 miles to an inch:

5. Map of a Group of Iron Mines in Morris county; printed in two colors; scale, 3 inches to 1 mile:

6. Map of the Ringwood Iron Mines; printed in two colors; scale, 8 inches to 1 mile:

7. Map of the Oxford Furnace Iron-ore Veins; colored; scale, 8 inches to 1 mile:

8. Map of the Zinc Mines, Sussex county; colored; scale, 8 inches to 1 mile:

Price of the book and portfolio of maps, $6.50

Geology of New Jersey, as above, without portfolio of maps, but containing a folded and colored map of the State, on a scale of 5 miles to 1 inch. Price $4.00.

Single copies of either of the above maps, colored and in sheets, 50 cents.

Geological Map of New Jersey, on a scale of 2 miles to one inch; colored and mounted on rollers. It gives the Geology of the State the same as Maps 1, 2, 3, 4, in the portfolio, and is essentially these combined in one map. Size 5½ by 7½ feet. Price $8.00 per copy.

The prices are fixed to merely cover the cost of paper, printing and binding; the expenses of the Survey and preparing book and engravings being paid by the State.

These publications can be had from Prof. Geo. H. Cook, State Geologist, New Brunswick, on remitting the price, or through the booksellers.

The books are also kept for sale at these prices by William T. Nicholson, of Trenton; Sampson & Morgan, of New Brunswick; M. R. Dennis & Co., of Newark, and D. Van Nostrand, of New York city.

The work is in the following public libraries, where it can be consulted:

In all the State Libraries; in some other of the large public libraries in different parts of the United States, and in all the public libraries in New Jersey and in the adjacent cities of New York and Philadelphia. It is also in the offices of most of the County Clerks.