DEPARTMENT OF THE INTERIOR,

CENSUS OFFICE.

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Appointed April 1, 1879; resigned November 3, 1881.

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Appointed November 4, 1881. Office of Superintendent abolished March 3, 1885.

STATISTICS OF POWER AND MACHINERY EMPLOYED IN MANUFACTURES.

PROF. W. P. TROWBRIDGE,
CHIEF SPECIAL AGENT.

REPORTS

ON THE

WATER-POWER OF THE UNITED STATES.

PART II.

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PART II.

WATER-POWER OF THE UNITED STATES.

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REPORT

ON THE

WATER-POWER OF THE NORTHWEST.

BY

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SPECIAL AGENT.

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NEW YORK, *October* 1, 1881.

Professor W. P. TROWBRIDGE,

Special Agent in charge of the Statistics of Power and Machinery for the Tenth Census.

DEAR SIR: In accordance with the directions received on May 28, 1881, I respectfully submit the accompanying report on the water-power of the northwest, as a report of progress.

As will be seen on examination of the papers, the region discussed in detail includes only those drainage areas surrounding the basin of the extreme upper portion of the Mississippi river.

First, there is a general discussion of the entire region, including the upper Mississippi basin; then follow the sections devoted to the different drainage areas, in the following order:

Western drainage area of lake Michigan, Saint Louis river, and streams of the south shore of lake Superior. Drainage basin of the Red River of the North.

Very little information was obtained about the rivers of the extreme northern portion of Minnesota and the upper peninsula of Michigan; those regions are in a wild, undeveloped condition, and no personal examination was made, although a considerable amount of water-power exists there.

Next I consider the extensive water-power of the Mississippi itself.

In writing this report the aim has been to keep in view all the features of the country of significance in their relations to the subject of water-power.

Thus, in describing a drainage basin, the general plan which it has been endeavored to carry out is to give the prominent characteristics of the region as regards topography and the drainage system, to state the geological history in its relations to the hydrography, to describe the industrial occupations of the inhabitants, and the manufacturing interests, with the facilities for traffic, and to consider the size and flow of the streams, the amount of fall and water-power, with its distribution, giving a detailed description of the important powers.

The territory visited during the winter and spring of 1880–'81 included the region above mentioned, all the eastern portion of the Mississippi basin down to the Gulf, with the exception of the Ohio river, a number of the rivers flowing into the gulf of Mexico, and all the western portion of the Mississippi basin down to the central part of Iowa.

In order to complete this district in proper season, it was impossible to obtain full and detailed information of all the different powers by personal examination, and long excursions away from the railroads were out of the question; hence the method was pursued of visiting the important water-powers, and there obtaining all the information available relative to the streams above and below.

Areas of drainage basins were calculated by means of a planimeter, either from the maps of the United States land office or from large and detailed state maps. The lengths of streams were also usually measured on these maps, and where that is the case the figures can only be considered approximations. It cannot be claimed that even the maps issued by the United States government for this region are correct in all their details, but errors from this cause would not occur to any great extent in calculating drainage areas.

Estimates of the flow of the streams, the elevations, etc., were obtained, where possible, from the records of the United States engineers, to whose invariable courtesy this report is much indebted. In some cases no data are available except rough estimates as to the capacity of the powers. It was impracticable to make accurate personal measurements, and nothing of that kind was attempted. Where no reliable figures for the flow are available, an approximation has been made by comparing with neighboring streams and estimating it from the rainfall. In all such cases the calculations are made for an ordinary low-water stage, as that is the volume of the streams used in practice in estimating powers. Wherever actual gaugings are available they have been used to the exclusion of all estimates

from the rainfall, as they are generally more to be relied upon for practical work. Particular attention has been paid to geology in its bearings upon the water-courses, as the water-powers owe their characteristics to so great an extent to the nature of the surface over which the streams flow.

With the hope that this report may receive your approbation,

I have the honor to be, most respectfully, yours,

JAMES L. GREENLEAF,

Special Agent of the Tenth United States Census.

NOTE.—The reports on the Mississippi and its tributaries and the rivers of the Gulf of Mexico which I visited, the drainage of lake Erie in the United States, and the water-power of Niagara Falls, will be found following in order the report on the Red River of the North. The succession in which the divisions are taken is, to some extent, the result of circumstances attending the requirements of the press; but it will be noticed that the regions around the Upper Mississippi basin are first discussed, then the Mississippi basin, passing south, then the Gulf drainage, and, finally, the streams of Lake Erie and the Niagara river. The remarks in the letter transmitting the earlier reports will apply equally to these later ones.

JAMES L. GREENLEAF.

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GENERAL REMARKS UPON THE WATER-POWER OF THE NORTHWESTERN STATES.

SYSTEM OF DRAINAGE AND AREAS OF DRAINAGE BASINS.

The territory under discussion includes the entire state of Wisconsin, the upper peninsula of Michigan, the state of Minnesota, with the exception of the southwestern corner, and the northeastern portion of Dakota. The eastern and most of the northern boundary of this region is a continuous water-line. On the east lakes Michigan and Superior form the boundary, and on the north lake Superior and the system of lakes and water-channels separate Minnesota from the British possessions. The approximate length of this water-line is 1,200 miles. On the west the boundary is the eastern water-shed line of the Missouri river.

A peculiar interest is connected with this section from a geographical point of view, as from it are gathered the waters which feed the frigid, the tropical, and the temperate seas.

The extreme source of the Red River of the North, which flows into Hudson bay; of the Mississippi, which pours its mighty flood into the Gulf of Mexico; and of the Saint Louis river, properly the head of the great lakes and the Saint Lawrence, are all situated on a straight line, 170 miles long, passing a little south of east through the northern part of the state of Minnesota. The Upper Mississippi, passing through the center of the region, is the great channel into which half its area drains southward.

Encircling the drainage basin of the Upper Mississippi is a belt of country, varying on the east and north from 2 or 3 miles to 100 miles in width, whose drainage is either eastward through the great lakes or northward by means of the Red River of the North. This naturally suggests a division of the water-power into that of the great lakes, that of the basin of the Red River of the North, and that of the basin of the Upper Mississippi.

DRAINAGE AREAS.

		Square miles.
Mississippi river in Dakota, Minnesota, and Wisconsin		82,130
Red River of the North in the United States		39,577
Lake Michigan in Wisconsin and Illinois	14,917	
Lake Michigan in upper peninsula of Michigan	7,834	
		22,751
North shore of lake Superior in Minnesota, including the Saint Louis river basin of 3,225 square miles		*a* 15,965
South shore of lake Superior in Minnesota	236	
South shore of lake Superior in Wisconsin	3,106	
South shore of lake Superior in upper peninsula of Michigan	7,834	
		11,176
Total area of entire region		171,599

PRINCIPAL LINE OF WATER-SHED.

The water-shed line which defines the basin of the Mississippi from the surrounding belt has a total length from the southern end of lake Michigan to where it strikes the southern boundary of Minnesota of 1,350 miles, thus distributed: Illinois, 70 miles; Wisconsin, 555 miles; Minnesota, 590 miles; Dakota, 135 miles. In Illinois this line is only 4 or 5 miles from the lake shore, receding but little to lake Winnebago, in Wisconsin; thence northward it is about 100 miles from lake Michigan, and then 30 miles from lake Superior. In Minnesota it takes a bend of about 75 miles to the north, and then turns southwest, entering Dakota at about the center of its eastern boundary; but it soon re-enters Minnesota, and crosses the southwestern corner of the state into Iowa.

a An indeterminate portion of this is tributary to lake Winnipeg, as mentioned beyond.

ELEVATIONS OF WATER-SHED LINE.

At the foot of lake Michigan this line of water-shed is elevated only a few feet above the lake, which is 589 feet above the sea. It rapidly rises in Wisconsin to 400 feet above the lake (989 feet above sea-level), then sinks to 230 feet above the lake at Portage city, Wisconsin (819 feet above sea-level), and then rises to 950 feet above lake Michigan (1,539 feet above the sea) at the boundary between Wisconsin and the upper peninsula of Michigan. Here the water-shed turns west, with an average elevation above lake Superior of 1,000 feet (1,609 feet above sea-level), sinking in the western part of Wisconsin to 600 feet above lake Superior (1,209 feet above the sea).

At the western end of lake Superior the water-shed line sinks very low, so that an engineer recently proposed a scheme for supplying the cities of Saint Paul and Minneapolis, in Minnesota, with water from lake Superior, the aqueduct crossing the line of water-shed by means of a siphon. The cause of this sinking is its crossing the western end of the synclinal trough occupied by lake Superior.

In Minnesota the water-shed line, in passing north, rapidly rises to about 800 feet above lake Superior (1,400 feet above sea-level), and about the headwaters of the Mississippi, in the northern portion of that state, it is at least 1,600 feet above the sea. It falls in passing south, and where it enters Dakota it is only 995 feet above sea-level. In Dakota it rises again, in one locality to at least 1,500 feet, and Spirit lake, near where the divide passes from Minnesota into Iowa, is 1,694 feet above sea-level, and, according to the *Geological Report of Iowa*, is the highest point in the state.

ANCIENT HYDROGRAPHY.

It is of interest in this connection to notice the indications which are left upon the face of the land of the ancient courses which the waters of the Northwest pursued to the sea. They are discussed in some detail in the pages devoted to the different streams, and here only a general view of the entire field will be taken.

The geological epoch known as the glacial age had much to do in giving to this region its present topography, and particularly in altering the courses of many of the streams to their modern channels. Some of them still pursue their old courses, which they had eroded previous to the deposition of the glacial drift, while others were completely changed in direction, or rather were abolished, the water finding another place of escape.

From the conclusions reached by the different geologists who have studied the subject it may be gathered that, before or during the advance and recession of the ice-cap, almost the entire district under discussion drained into the Mississippi, whose mouth was then near the present mouth of the Ohio river. The valley of the Red River of the North was then occupied by a large lake, which extended far up into the British possessions, and the entire basin of the river, instead of being tributary to Hudson bay, drained in directly the opposite direction along the course of the Minnesota river, which is but a poor representative of the ancient stream, into the Mississippi above the site of Saint Paul. To state it more correctly, the Mississippi entered it there, for the Mississippi above the junction was much the smaller stream of the two.

Then, again, the Mississippi had another important tributary on the east, which the changes of the glacial age transferred to lake Michigan. In the western drainage area of lake Michigan the Wolf and the Upper Fox unite to form the Lower Fox river. Formerly the Wolf, instead of flowing into lake Winnebago, entered the modern valley of the Wisconsin river at Portage City, and so reached the Gulf of Mexico, and this reduced the western drainage area of lake Michigan to a comparatively narrow strip along the lake shore. This narrow area was almost completely covered at one time by the waters of lake Michigan, which rose relative to the land about 200 feet, and even overflowed to a considerable extent up the valley of the Wolf.

Lake Superior, as demonstrated by Professor N. H. Winchell, emptied into lake Michigan by an old channel across the upper peninsula of Michigan, while the topography at the southern end of lake Michigan itself gives evidence that this lake once had an outlet, by way of the Illinois river valley, into the Mississippi, and it is also in place to mention that lake Erie in former days flowed to the Gulf of Mexico by way of the Maumee and Wabash valleys.

From the Red River of the North in the United States and from the Wolf river the Upper Mississippi received approximately the drainage of 45,000 square miles more than is now tributary to it. Hence the ancient drainage area of the Mississippi in Dakota, Minnesota, and Wisconsin was approximately 127,000 square miles, reckoning from modern water-sheds; but it must not be forgotten that during the glacial age water-shed lines were, to a great extent, obliterated in the latter part of that period, great floods of water pouring from the southern extremity of the ice-cap, irrespective of the topography which underlaid the covering of ice.

TOPOGRAPHY AND CHARACTER OF THE COUNTRY.

From the elevations just given for the line of water-shed surrounding the basin of the upper Mississippi it will be seen that there are considerable inequalities in the general surface; yet the extremes of elevation of this crest line do not differ by more than 1,100 to 1,200 feet, and are many miles distant from each other.

Although it is possible to conceive of a mountainous country in which the lines limiting the drainage basins would be comparatively level, yet in the degree of their undulations they generally give some indication of the nature of the topography, as is exemplified in the present case. While there are in places rather abrupt changes of several hundred feet in the level, still Minnesota, Wisconsin, and the surrounding region are not mountainous, but may fairly claim to represent the medium between the mountainous districts of our country and the extensive plains which lie to the westward. In Minnesota especially, which has an area of 83,365 square miles (only 11,000 square miles less than the combined areas of New York and Pennsylvania), there is represented almost every variety, from a rugged surface to a remarkably level prairie.

Taking a general view of the entire region, the highest land may be considered to be in northern Wisconsin and Minnesota, near the shores of lake Superior. From this there is a rapid fall of from 600 to 1,100 feet in 15 to 35 miles to the lake, and a long gradual slope to the south, draining for the most part into the Mississippi river.

LAKE SUPERIOR REGION.

About lake Superior occurs the rugged part of the region we are considering. On the north shore especially are high rocky cliffs and slopes, on the south shore several hill ranges, and in Michigan rocky cliffs; but nowhere is there a truly mountainous section.

COUNTRY SOUTH OF LAKE SUPERIOR.

After crossing the water-shed, and passing southward in Minnesota and Wisconsin, the surface is undulating, and in places almost hilly; but, to a large extent, the streams appear to have carved their channels into the surface without striking topographical features which would seem to have guided them. Following the law of gravitation, they have taken the general southerly slope, and worn their channels through the soil, often into the underlying stratified rock.

In the southern counties of Wisconsin and Minnesota the erosion of the streams has produced bluffs 200 to 500 feet high, and given to the immediate vicinity of the Mississippi and its tributaries a very picturesque appearance; but ascend from the valleys of the streams, and the gently undulating surface is once more seen.

In places, as along the water-shed separating the basins of the Upper Mississippi and the Red River of the North, the undulating surface develops into a marvelous mixture of knolls, ridges, and small hollows, with very little level, except the surfaces of the innumerable lakes. This is the effect of the glacial action, of which mention will be made on subsequent pages. While there are no abrupt changes of elevation of any considerable magnitude away from the vicinity of the great lakes, the rise in the general surface, unnoticeable though it may be, is often of importance, and serves to give activity to the streams.

DISTRIBUTION OF THE TIMBER.

In the northern part of Wisconsin, the upper peninsula of Michigan, and in northern Minnesota, from the east to the headwaters of the Mississippi, occurs the pine, which has made lumbering one of the chief industries of that region.

In northern Wisconsin and Minnesota are extensive tracts of land, consisting of tamarack and cedar swamp, interspersed with a thin pine growth; but in central and southern Wisconsin the pine is more and more replaced by a hard-wood growth, which occurs in groves, gradually becoming less prominent as the prairie region of Illinois is neared. In Minnesota the pine is gradually replaced by hard wood, and this continues toward the south and west in groves, which are finally restricted to the water-courses. Passing down through the center of the southern portion of the state is an exception to this in the "Big Woods", which is a large body of hard-wood timber, forming a peculiar feature of southern Minnesota. To the east, and particularly to the west of the big woods, the timber is very light, and is almost entirely confined to the river bottoms; also southward, in Iowa, the prairie features largely predominate.

PRAIRIE REGION.

It is in the southern, but especially in the western, portion of Minnesota that we find the typical American prairie, and one may travel mile after mile without meeting a tree, unless he descends to the banks of the streams, where may be found a few elms or cottonwoods. Within late years, however, the farmers have planted trees about their dwellings as a protection from the "blizzards", which rage over the country in winter.

While the surface of the prairie is usually rolling in character, along the valley of the Red River of the North it is a level plain as far as the eye can reach, without a tree or rock to break the outline, except along the river, where there is a belt of foliage.

CHARACTER OF THE SOIL.

The soil of the region under consideration exerts a striking influence upon the character of the growth and productiveness. To the varying nature of the glacial drift, which, with its modifications, forms the soil and subsoil of this whole region, with very slight exceptions, is due the division of the country into pine land and prairie, and into comparatively unproductive soil and a ground bearing the richest harvests of grain.

The heavy clay soils, which for many feet in depth cover the southern and western portions of Minnesota and extend westward into Dakota, contain, in almost inexhaustible store, the salts necessary for the successful growth of wheat, and remarkable yields are recorded, especially from the valley of the Red River of the North. In the lower and western portion of Wisconsin also wheat is very successfully raised. On passing into Iowa and Illinois the soil becomes more loamy in character, and is better adapted to the raising of corn, for which those states are noted. Large quantities of winter wheat are also grown in Illinois. In the Northwest the wheat is practically, without an exception, spring wheat; that is, grain sown in the spring. It has a hard shell, and yields a very superior quality of flour.

In northern Minnesota and Wisconsin the soil is lighter, as a rule, and in many places sand is the most important constituent. This is a congenial ground for the pine, and, as a consequence, we have the pine forests, which are fast disappearing through the gang-saws of the mills. The drift is not always homogeneous, and sometimes a sand ridge, covered with pine, will extend far into an area of clay soil, with its hard-wood growth, the distinction being very marked.

Although there are iron mines in Wisconsin, and copper and iron mines in the upper peninsula of Michigan, and although great quantities of lumber are cut, the Northwest is essentially a farming country.

CHARACTER AND DISTRIBUTION OF THE WATER-POWERS.

STREAMS OF THE PRAIRIE REGION.

There is a popular idea that in a prairie or semi-prairie country, like a large portion of that under discussion the streams are necessarily sluggish, and the water-power small, if there is any. It is true that the typical water-course of the prairie is not the bold, dashing torrent of the mountains, but it is equally true that it is not uniformly a meander, which can scarcely draw its slow length along.

The true prairie is not necessarily a level plain. The slope of the general surface is often considerable, and this gives rise to swift water, and even rapids, in the streams, thus affording many available powers. This is the case in the prairie of the Northwest, and, while extensive falls are uncommon, there is a general distribution of moderate water-powers all along most of the streams.

One point to be noted in this connection is that such water-powers are not in inaccessible valleys, with rugged mountains upon either side, hemmed in by high, rocky cliffs, and in a country whose sterile soil yields only a niggardly reward to industry; but they are situated in the midst of one of the most fertile sections of our country, where great fields of grain give promise of work to keep the millstones turning day and night, and where the gently rising banks and facilities of approach afford every advantage for their inexpensive improvement.

The characteristic occupation of the Northwest decides the channel in which the utilization of the water-power shall take its course, and an improved power is not complete until it has one or more flouring-mills converting the wheat raised right at hand into flour, either for home consumption or to supply a distant demand.

By the facilities for communication with other sections of the country crude materials of different kinds can be as readily carried to these cheap powers as the cotton of the southern states has been carried to the looms of New England.

The pine forests have supplied work for some of the largest saw-mills of the world, and poplar, spruce, and pine keep many wood-pulp and paper-mills busy. The hard woods, as oak, hickory, and ash, are used for the manufacture of wagons and tools, to supply the demands of the farming population, and there are many machine tool works. There are comparatively few woolen-mills.

STREAMS OF THE RUGGED REGION.

There are sections of this northwestern region where the country is rough and rugged without being strictly mountainous. These sections are mostly in the northern portion of the district, and the streams are not generally

so accessible as those farther to the south, nor do they lie so directly in the line of eastward traffic; but, with the further development of the country, their importance will become much greater.

In the wild, unsettled region in the extreme northeastern part of Minnesota north of lake Superior, and in sections along the south shore of that lake, there is little demand for water-power, and not much probability of it in the near future, although the Canadian Pacific and Northern Pacific railways may develop that region.

VALUE OF THE WATER-POWERS.

Water-power is now very cheap, and even at the extensively improved sites $10 per year per horse-power is above the average. Good powers may be obtained for $5. In the manufacturing centers of the New England states such rates would be considered extremely low. Many unimproved powers can be had at very moderate rates even for this region, while in some localities the power will be almost given away, the theory being that such improvements will enhance the value of other property. In some localities the people are also very anxious to have a flouring-mill erected for their own convenience, and special inducements are offered. However, powers in favorable localities are generally appreciated, and are held at greater value by the riparian owners.

DISTRIBUTION OF THE WATER-POWERS.

The division into drainage basins has been already given, and the statement made that, considered in a general way, there was a long, gradual inclination toward the south in Wisconsin and Minnesota, draining into the Mississippi, and a more rapid slope northward in Wisconsin to lake Superior, which slope is continued through a portion of the upper peninsula of Michigan. Beside these, there is the drainage toward lake Michigan from Wisconsin, and to the Red River of the North from Minnesota and Dakota, while a portion of Minnesota drains into the north shore of lake Superior.

UPPER MISSISSIPPI BASIN.

The most extensive drainage basin is that tributary to the Mississippi river, and, although the slope is not so great as in other sections, we look there for the greatest manifestation of water-power. The total fall from the extreme sources of the Mississippi to Saint Paul, a distance by river of about 500 miles, is very nearly 1,000 feet. This to a considerable extent is concentrated in rapids, which, with the large flow of the stream, would furnish very fine powers if improved. About 75 feet of fall is concentrated in Saint Anthony's falls and the rapids at Minneapolis, near Saint Paul, and at this place, in a condition of considerable development, is situated one of the finest water-powers of the United States, the total theoretical power, in a fair stage of the river, being estimated at 120,000 horse-power. Railroads run beside this power, and the manufacturing already done gives Minneapolis a high rank among our manufacturing cities. It is said to be the second or third milling center of the world, and only finds its superior in that respect in Germany.

The tributaries of the Mississippi are, many of them, large streams. The Wisconsin, Chippewa, Saint Croix, and Minnesota rivers abound in good powers, especially the upper waters of the Wisconsin—as Grandfather Bull, Father Bull, Little Bull rapids. These powers in northern Wisconsin are mainly undeveloped, except so far as used for saw-mills.

WESTERN DRAINAGE AREA OF LAKE MICHIGAN.

Although the western drainage area of lake Michigan is narrow, there is a peculiar concentration of a large portion of its drainage in one river, the Lower Fox, giving rise to important water-powers, which receive attention upon a later page. The thriving city of Appleton is situated upon one of these, and to its well-developed water-power is chiefly due its prosperity.

North of the Lower Fox river, into Michigan, there is a considerable descent in the streams, and in the upper peninsula of Michigan these streams are of small size, the Ontonagon and Escanaba rivers having the largest drainage areas. But many of these rivers have considerable fall in their passage, either to lake Superior or to lake Michigan, and are, to a great extent, in a wild, unsettled section of country. They are small, but from their rapid descent the amount of water-power is large. As may be gathered from preceding remarks, the country is undeveloped and this power unused, but some of the rivers, from their location, are of prominence. Especially is this true of the largest, the Saint Louis river, which will receive attention on the following pages.

BASIN OF THE RED RIVER OF THE NORTH.

The Red River of the North is entirely a prairie stream. Upon its upper waters are several fine powers, one having a total fall of over 80 feet. The water-power is practically limited to the upper portion of the stream and its tributaries.

STREAMS OF THE WESTERN PORTION OF LAKE SUPERIOR.

There are in the extreme northern part of Minnesota several streams flowing into the chain of lakes and marsh land which connects the Lake of the Woods with lake Superior. Some of these streams are rapid, and

must have a considerable fall. The Vermillion river, as described in Dr. Owen's report, has several sharp rapids in its course, and the outlet of all this basin toward lake Superior, the Pigeon river, has many heavy rapids and falls; but this region is hardly explored as yet, and is entirely undeveloped. The Lake of the Woods has also a connection with lake Winnipeg, in Manitoba, by the Winnipeg river, and hence the drainage of northern Minnesota is not capable of exact calculation. In view of this fact, the 15,965 square miles represented as draining into the north shore of lake Superior cannot be considered as entirely tributary to that body of water. The Winnipeg river is stated in one report to have a fall of 349 feet in its length of 165 miles. This places the Lake of the Woods 1,050 feet above the sea and 450 feet above lake Superior. In one place Winnipeg river is called White river, from its foaming rapids.

GEOLOGY OF THE REGION IN ITS BEARINGS ON THE WATER-POWERS.

CAUSE OF THE FORM OF THE DRAINAGE SYSTEM.

The details of this subject are treated to some extent in describing the several water-sheds, but a general view of the entire region from a geological standpoint cannot be out of place, especially as rivers derive their characteristics in such an important degree from the condition of the rock and loose material over which they run. It has been observed that, viewed in a broad sense, there is a comparatively abrupt inclination toward lake Superior, and in Wisconsin and Minnesota a long, gradual dip southward, which determines the main features of the system of drainage of that region.

It is well understood that, subsequent to the formation of the Archaic rocks, a succession of seas, or of advances and recessions of the same sea, deposited the stratified rocks of the succeeding periods of time.

The old Silurian ocean which washed the shores of the Archæan land deposited as it receded the Potsdam sandstone, the Saint Peter's sandstone, the lower magnesian limestone, depositing its sediment upon this old Archaic continent. It was a natural consequence that the successive superimposed strata should take the slope of this ancient rock, which formed the bed of the primeval ocean, and as each succeeding sea had its shore line upon the lately-formed rock, so also each stratum, as seen at the present day, has its line of outcrop upon the preceding one.

In the North American continent a belt of the Archaic land runs through Canada, a spur forming the Adirondacks in the state of New York, and this belt of primitive rock continues west through the upper peninsula of Michigan, northern Wisconsin, and central Minnesota, where it outcrops, with a dip southward through those states. The sedimentary rocks were deposited upon this Archæan base, taking its southerly dip and outcropping in successive belts, which are crossed in going from north to south in their successive order of deposition.

Although much complicated by erosion and otherwise, these geological conditions exist to the Gulf of Mexico, where the late Tertiary deposits are now being overlaid by the alluvium of the modern age. The lake Superior slopes are inequalities in the surface of the Archaic rock, and are due to upheavals.

Thus we see the origin of the existing drainage system. The streams in ancient days, as at present, finding the general surface dipping toward the south, flowed southward, and the glacial action, and the changes accompanying it, did not materially alter their courses, with the exception of the cases mentioned under the first division of these remarks.

GLACIAL AGE.

To the action which took place in the glacial age is due, in a very marked degree, its modern surface features. In treating of the Red River of the North the history of the glacial age is given to some extent. Suffice it to say here that a solid mass of ice, thousands of feet thick, forced its way south, grinding up the soil and rock surface, and in its recession left the *débris* as glacial drift all over the surface, with the exception of a small area in the region about southwestern Wisconsin. This drift, sometimes modified by subsequent action, consists of clay, sand, gravel, and bowlders in varying proportions, and forms, almost without exception, the soil of the entire region. The streams have worn their channels in it, and some are already down to the underlying rock, while others have not yet succeeded in wearing through the surface-covering of drift, in some places from 200 to 300 feet thick.

ORIGIN OF THE MINNESOTA LAKES.

These lakes, which form such a peculiar feature in northwestern scenery, are due to the ice age. With very few exceptions, they lie in hollows left in the drift when it was deposited. The theory is that the ice-cap held on its surface and in its mass vast accumulations of drift, which were deposited as it melted in irregular heaps and ridges, the hollows left being filled with water until an outlet was formed.

RELATIVE INFLUENCE OF METAMORPHIC AND SEDIMENTARY ROCKS ON THE STREAMS.

Many of the streams flow entirely or in part over the metamorphic and igneous rock of the Archæan belt, and such streams have usually sharp rapids along their courses, instead of a more uniform descent.

The hard nature of the rock resists erosion better than the sedimentary rocks over which the streams flow further south. It must not be understood, however, that there are no rapids or falls over the sedimentary rocks. There are many falls, due to the passage of a stream from a hard layer to a soft underlying one, and numerous rapids on the hard layers of limestone rock. All the rapids of the Lower Fox river are over the Trenton limestones, and the falls of Saint Anthony are caused by the superposition of the Trenton limestone on the soft Saint Peter's sandstone. Even in the drift moderate rapids occur where there are accumulations of bowlders, and, as might be expected, the beds of the streams are worn much deeper below the general surface in the region of sedimentary rocks than where the Archæan rock underlies the soil.

FLOW OF THE STREAMS AND CONDITIONS AFFECTING IT.

IMPOSSIBILITY OF ACCURATE CALCULATIONS.

The primary requisite for a stream of water is the rainfall; but while this is so evident, it is hardly correct to say that the discharge from a given area depends on the rainfall upon that region. The flow of the streams which drain the surface of the land depends so much upon the topography, the character of the soil and underlying rock, the temperature and winds, and the storage capacity, that it is impossible to determine any definite ratio between the discharge of streams and the annual precipitation. The most that can be done is by experiment, observation, and calculation to find, as nearly as possible, the effects which the different circumstances met with in nature have upon the waters of the earth in making their circuit between the clouds and the sea.

It is the object here to consider the conditions affecting the flow of the rivers of the Northwest.

AMOUNT OF AQUEOUS PRECIPITATION.

First, the annual precipitation is not so great upon these inland states as upon those bordering the ocean. The heaviest precipitation upon the area under discussion averages about 35 inches, while the lightest does not exceed 15 inches per annum. This is, of course, to the detriment of the water-powers; but it is offset to a large degree by other considerations, as will presently be noticed. The diminution in the precipitation is general from east to west, with local variations, perhaps owing to the proximity of the great lakes. In the upper peninsula of Michigan and northeastern Wisconsin the annual precipitation averages at least 35 inches; around lake Superior, 30 to 35 inches; and upon the upper waters of the Mississippi and the sources of the Red River of the North, 25 inches, which is the amount used by the United States engineers in making calculations for the reservoir system on the upper Mississippi. From the sources of the Red River of the North westward the amount of annual precipitation rapidly falls down to 15 inches, or even less in Dakota. Most of the rain and snow of this region appears to be due to the condensation of the moisture in the warm currents of air which sweep up the valley of the Mississippi from the Gulf, and the sudden decrease of moisture at the eastern portion of Dakota marks the margin of the main effects of these vapor-bearing Gulf currents.

CLIMATIC EFFECTS.

The high northern latitude causes cold winters, but the summer temperature is much influenced by the warm air from the Gulf of Mexico. In the far Northwest the climate is very much modified by the softening influence of the Japan current in the Pacific ocean, whose effects are felt even in Dakota, tempering the winter climate to a great extent.

The temperatures given below are averaged from the report of the Smithsonian Institution. More detailed tables are furnished on succeeding pages. For the basin of the Red River of the North in the United States the summer temperature averages 65 to 70 degrees, and the winter temperature 8 to 10 degrees Fahrenheit above zero. The temperature about the sources of the Mississippi is about the same. On the western drainage area of lake Michigan the average summer temperature is 68 to 70 degrees, and the average winter temperature about 20 degrees Fahrenheit above zero. This large difference of 50 to 60 degrees between the average temperatures for the two extreme seasons of the year, together with the fact that the winter winds are more generally dry winds from the northward than those of summer, must exert considerable influence upon the distribution of the precipitation throughout the year.

Turning again to the report of the Smithsonian Institution, and selecting characteristic data, we find these results:

DISTRIBUTION OF ANNUAL PRECIPITATION, IN INCHES.

Region.	Locality.	Spring.	Summer.	Autumn.	Winter.	Total.
Basin of the Red River of the North	Fort Ransom, Dakota	5.14	4.96	3.38	1.82	15.30
	Breckinridge, Minnesota	5.41	12.05	3.17	2.45	23.08
Western drainage area of lake Michigan	Appleton, Wisconsin	7.65	10.24	6.92	3.70	28.51
	Embarrass, Wisconsin	8.14	12.49	8.21	5.73	34.57

TIMES OF FRESHET AND DROUGHT.

Of all four seasons the summer has the heaviest precipitation and the winter the lightest, almost exclusively consisting of snow. On this depends one important feature of the streams, viz: the June freshets. But the effect of the cold winter temperature is not confined to the distribution of the precipitation. After it has reached the earth, the icy grasp of winter, to a large extent, holds the moisture fast until the warmer air of April and May releases it, and then there is a spring freshet, caused by the melting snow and ice.

The fall rains, which are relied upon to fill the springs for the winter's flow, often produce high water in the streams. In normal years the low water takes place in late summer and early autumn, before the rains of fall have replenished the streams, and in winter, when the sources of supply are to so large an extent frozen solid. It is evident that the cold winter must have an injurious effect upon the steadiness of flow, which is not experienced to nearly so great an extent by the southern rivers. Those streams have in this respect the advantage of the northern water-courses, but it will be shown how the injurious influence of the cold winters is remarkably counteracted.

EFFECTS OF MOUNTAINOUS AND OF LEVEL COUNTRIES.

In a rocky, mountainous country, where the only level land is the narrow flat at the bottom of the valley, the rain, as soon as it falls, rushes immediately down the mountain side and is wasted in sudden floods—a state of affairs most inimical to the interests of water-power; and it is largely from this cause that in the New England states the creating of artificial reservoirs becomes such an important item in the improvement of them. In the Northwest the case is, to a certain extent, just the opposite. The tendency is for the rain to soak into the ground and gradually find its way to the water-courses; and hence what would be in the one place a disastrous flood is here distributed through several days, or even weeks, and gradually disappears.

The only streams we have dealt with that in this respect at all resemble the typical mountain stream are some of those discharging into lake Superior; but even with these the effect of rocky, steep drainage is much mitigated by level lands upon their upper waters. There are also some streams in the comparatively level prairie which are very unsteady, but these are hardly more than drains for the surface water, and, not being fed by springs or lakes to any extent, cannot be taken for comparison.

INFLUENCE OF SAND AND GRAVEL BEDS.

The drift, as has been described, is very irregular in character, and where the clay is replaced by sand and gravel the absorption of the moisture is very great. This seriously diminishes the flow of the streams in the immediately locality, but, nevertheless, is often of great value in maintaining the flow at some other place, for the water issues in copious springs at a lower point. Thus, on the south shore of lake Superior there is an extensive sandy ridge upon which there are no streams, but at its base are a large number of beautiful springs of clear running water, which feed the Bois Brulé and neighboring rivers, often bubbling up from the sandy bed of lakes. In northern Minnesota, also, there are sand ridges exerting their influence upon the rivers there. In scarcely any place can this effect of sand ridges be more marked than in the state of Mississippi, where the sand-hill streams often have a mill within a few rods of their source, and are an unfailing source of moderate power throughout the year.

In some localities it is difficult to see how this absorptive power of sand and gravel beds can have any effect but positive injury upon the water-powers, as the water-bearing layers strike too low to feed the rivers in the water-power regions.

For example, the valley of the Red River of the North is underlaid by water-bearing beds, which receive their supply from where they outcrop on each side of the river and within its basin. The result is that water which would otherwise flow into the tributaries of the main river is carried down beneath the river bed, and, if returned at all to the stream, it is far below the region in which its water-powers are situated. Several fine artesian wells in the valley are fed by this storage.

INFLUENCE OF FISSURED ROCK.

The old Archaic rock which underlies the soil over so large a portion of the Northwest is hard and solid and impervious to water; but the newer formations are not so resistant, and to them some loss is doubtless due. Thus, there are many artesian wells in eastern Wisconsin which get their supply from the rocks, which there have a southeastern dip. Water percolates from the outcrop down through fissures, and probably a considerable amount thus finds its way to lake Michigan underground without ever entering the legitimate surface channels. At many places along the Mississippi valley are artesian wells, fed by water drained in this manner from the surface streams. What effect this has in reducing the flow of the streams it is impossible to determine, but that it exerts some influence is self-evident.

ACTION OF WOODLAND.

The woodland which yet covers so large a portion of Wisconsin, Minnesota, and Michigan cannot but be of value in steadying the flow of the streams. The grasses, roots, and decaying vegetation of a forest retard the escape of water, while the shade also prevents excessive evaporation. It must not be overlooked that trees, in growing, take up and dissipate an enormous amount of moisture, which is returned as rain, but is kept from reaching the streams. This very action, however, in making the distribution of the precipitation more uniform, would have a tendency to equalize the flow of the streams, and the universal testimony throughout cleared countries which were once well wooded is to that effect. Sir Gustav Wex, in a treatise on the subject, bears testimony to this result from the cutting of the European forests; the older of our states testify to it; and even in Ohio, which has been settled almost within a half century, the complaint is almost universal among the millers about the change for the worse in the steadiness of many of the streams. There the cause is largely the draining and plowing of the land, whereby the water reaches the creeks in a much shorter time than when the land is marshy and overgrown with thickets.

EFFECTS OF PRAIRIE CULTIVATION.

In some prairie regions, however, the effect of cultivating the land has been very different; drains have made marshes and areas of land tributary to the streams where evaporation formerly took all the water which did not sink into the soil, and some streams have been very materially increased in their volume by this means, as well as improved in their uniformity of flow.

In Kansas the curious result of farming has been to increase the rainfall. The theory is that the breaking of the tough prairie sod makes the soil more pervious to moisture, and hence immediate surface discharge is decreased, absorption and evaporation are increased, and consequently the rainfall is augmented.

LAKES OF THE NORTHWEST.

It has been said that the injurious effects of the cold climate upon the streams in diminishing their discharge are remarkably counteracted, and surely a glance at the map will satisfy all familiar with the effects of lakes of the truth of this statement.

If natural reservoirs are of any value in regulating the flow of streams, certainly the rivers of the Northwest must be extremely steady. A very large portion of Wisconsin and of Minnesota, but especially of the latter state, is almost literally covered with lakes, varying in size from the smallest pond to bodies of several hundred square miles in extent. The map of the lake region of the Red River of the North will serve to illustrate this. A count from large and detailed state maps of Minnesota and Wisconsin, and from the land-office maps of Dakota and the upper peninsula of Michigan, gave these results.

DISTRIBUTION OF LAKES ACCORDING TO STATE BOUNDARIES.

	Number.
Minnesota	4,920
Wisconsin	2,465
Upper peninsula of Michigan	523
Eastern Dakota	133
The entire region under discussion	8,041

DISTRIBUTION ACCORDING TO DRAINAGE BASINS.

UPPER MISSISSIPPI RIVER.

Minnesota	3,817
Wisconsin	1,859
Dakota	46
North of the Northern Pacific railroad	954
West side of river and south of Northern Pacific railroad	2,023
East side of river and south of Northern Pacific railroad, in Minnesota	420
Total in Minnesota, Wisconsin, and Dakota	5,256

RED RIVER OF THE NORTH.

	Number.
Minnesota	700
Dakota	87
Total in Minnesota and Dakota	787

RAINY LAKE REGION AND NORTHERN SHORE OF LAKE SUPERIOR.

Minnesota	365

SOUTHERN SHORE OF LAKE SUPERIOR.

Wisconsin and Minnesota	186
Michigan	164
Total in Minnesota, Wisconsin, and Michigan	350

WESTERN SHORE OF LAKE MICHIGAN.

Wisconsin	438
Michigan	359
Total in Wisconsin and Michigan	797

DATA CONCERNING THE LARGER LAKES.

Drainage basin.	Lake.	Locality.	Area.	Drainage area.*
			Sq. miles.	*Sq. miles.*
Upper Mississippi	Mille Lacs	Minnesota	186	226
	Leech lake	do	176	1,238
	Lake Winnibagoshish	do	68	1,350
	Cass lake	do	34	1,008
Western shore of lake Michigan	Lake Winnebago	Wisconsin	199	6,046
Red River of the North	Red lake	Minnesota	250	2,149
	Otter Tail lake	do	20	1,442
Rainy lake region and northern shore of lake Superior	Lake of the Woods	Minnesota and the British possessions	†1054	
	Rainy lake	do	234	
	Vermillion lake	Minnesota	59	536

*Including water surface.

†This is less than the true amount, as the extreme northern extension of the lake was not represented upon the map from which the measurement was taken.

The maps show that by far the greater number of these lakes are about the headwaters of the rivers, and hence their effect in regulating the flow is much more general than if they were distributed farther down stream. If it were not for the immense number of natural reservoirs these streams would be very unsteady.

COMPARISON OF LAKELESS WITH RESERVOIR STREAMS.

We are not without cases whereby we may judge of what the conditions of the water-powers would be did not these lakes dot the surface of the land. In Dakota there are comparatively few lakes, and the streams are very unsteady, the headwaters of many of them literally freezing solid in winter. It is true that the precipitation is much less there; but, allowing for the difference in rainfall, a simple calculation shows that the ordinary low-water discharge is only about 20 per cent. of what it would be were the topographical conditions similar to those in the lake region to the eastward in Minnesota. This calculation is made on the assumption that the evaporation bears a constant ratio to the amount of precipitation, which is not strictly correct; but the result serves to give an idea of the effects produced by the lakes. As was just mentioned, the discharge per square mile of the lakeless regions is sometimes reduced absolutely to zero at the headwaters of the streams.

The influence which the lakes exert cannot be better illustrated than by the estimates of the ordinary low-water discharge per second per square mile of drainage area for different places along the Red River of the North, as given in the table at the close of the section devoted to that river.

The remarks preceding the tables explain their peculiarities. The tables are derived from a comparison of the upper Mississippi above Saint Paul and of the Red River of the North at the crossing of the national boundary-line. It must be borne in mind that the sources of the Mississippi abound in lakes, while, except at the extreme headwaters, the Red River of the North has comparatively few lakes. The very light rainfall over a large portion of the basin of the latter stream would also account for much of the difference in the nature of the two rivers.

River.	Area drained.	Estimated ordinary low-water flow per second.
	Square miles.	*Cubic feet.*
Red River of the North at the national boundary	39,577	2,800
Mississippi river at Saint Paul	36,741	About 7,000

The ordinary low-water discharge of the Mississippi at Saint Paul is more than twice that of the Red River of the North at the national boundary, while the area tributary to it is 3,000 square miles less. The following estimates of the ordinary low-water discharge for several of the streams of the Northwest were obtained mostly by comparing actual gaugings with the drainage areas. Of course they are liable to error, due to not making the gaugings at a strictly ordinary low stage of the river, but they are believed to be approximately correct. In the case of the Menominee and the Saint Louis rivers, where no actual measurements were obtainable, the discharge was estimated by comparison with neighboring streams. Both these latter have the greatest precipitation of the entire region upon their basins:

River.	Locality.	Estimated ordinary low-water discharge per square mile of drainage area.
		Cubic feet per second.
Red River of the North	Mouth of the Pelican river	0.416
	Breckinridge, Minnesota	0.217
Mississippi	Aitkin, Minnesota	0.340
Lower Fox river	Foot of lake Winnebago	0.418
Saint Louis river	Mouth of river	0.400
Menominee river	do	0.400

Mr. G. F. Swain, special agent of the census, who has written a report upon the water-power of the Atlantic states, kindly furnishes the following information:

The ordinary low-water flow of the streams of the Atlantic coast without reservoirs, which have a rainfall of 50 inches per year, rarely exceeds 0.40 of a cubic foot per second per square mile of drainage area, while some with 38 to 40 inches of rainfall give only 0.30 of a cubic foot per second in the same stage, as is the case with the Potomac river.

In the lake region of the Northwest, with a precipitation of less than 30 inches per annum, the ordinary low-water flow exceeds in some cases 0.40 of a cubic foot per second per square mile of drainage area.

What speaks more eloquently for the lakes of the Northwest than these figures? When a stream like the upper portion of the Red River of the North is observed year after year, and is seen to scarcely vary four feet in depth from the drought of summer or the chilling cold of a northern winter to the melting of the snow and ice in spring, and when one is told that a three-feet rise on the beautiful river of the Lower Fox is unusual, then it is that the true value of the lakes is appreciated.

INFLUENCE OF SWAMPS.

In giving credit to the lakes we must not forget the influence of the swamps, which are mingled with them in northern Wisconsin and Minnesota, in maintaining the flow of the streams. The moisture retained by the roots and thick, matted growth is dealt out gradually. It cannot be denied, however, that the action of the swamps is not entirely beneficial. The evaporation from their luxuriant vegetation and the shallow, stagnant pools of water is enormous, while in cold winters they often freeze entirely solid, and then the flow from them ceases completely. For example, a person familiar with the Kankakee river, in Illinois, stated it as his opinion that the swamps at the headwaters of that river were of more injury than good to the stability of the flow. It is probable that in a moderately level country, with a rigorous climate, swamps alone are of questionable value where a permanent water-power is required throughout the year; but deep-seated springs, where they exist, exert a greater influence in regulating the flow. With lakes the case is different. It is true that extensive evaporation takes place from their water surfaces—about 0.15 of an inch per day from April to October, inclusive, at the sources of the Mississippi—but their depth, as compared with their surface, is much greater than in swamps, and they usually receive the drainage from considerable areas, which is protected in their depths from evaporation; also in winter a covering of ice (three to four feet in Minnesota in the winter of 1880–'81) protects the waters below from freezing, and thus a constant supply is given to the streams throughout the coldest weather.

CLASSIFICATION OF THE LAKES.

It must not be supposed that each one of the lakes in the region engaging our attention is filled to the brim by full-flowing streams, while a small river rushes through its outlet. From the very fact of their proximity to each other, the drainage areas of many must be extremely small; in fact, some have hardly more area tributary to them than the water surface which they expose to the rain and snow. Such lakes usually constitute a separate system of their own, and are of no value to the main stream in whose basin they lie. Other lakes receive a supply of water which is greater than their loss from evaporation and filtration, and these pour their tribute into the water-courses.

The lakes of the Northwest may be divided into three classes: 1. Those lying in the course of the main streams, being in a certain way expansions of their surface. 2. Those which have an outlet into the main streams. 3. Those without any visible outlet.

FIRST CLASS.—To this class many of the important lakes belong, serving a most useful part in catching the surplus water of the streams and parting with it gradually, and often there are side streams and lakes directly tributary to them. In this connection it is proper to mention a peculiarity of some western streams, viz, in having lakes tributary to them which are connected by a short, sluggish channel with the water of the river. When the main stream is high, the water backs up in this short channel and fills the lake, to be let out gradually. Lakes which thus equalized the flow were called, in the language of the Chippewas, *Pokegama*, and several pokegamas will be noticed upon the maps of Minnesota and Wisconsin.

SECOND CLASS.—Of the second class of lakes, some give large additions to the volume of the rivers, while the outlets of others are only small brooks. No correct estimate of the importance of these lakes to the maintenance of the flow of the rivers can be gathered from their actual size; the extent of the area tributary to them must, of course, be taken into account. The following example illustrates this point: Mille Lacs, in Minnesota, has an area only 13 square miles less than that of lake Winnebago, in Wisconsin, as shown by the figures in the table; but the area tributary to lake Winnebago is 6,046 square miles, while the line of water-shed limiting the drainage area of Mille Lacs is nowhere more than 6 miles from its shores. The result is that the broad channel of the Lower Fox is the outlet of the one, and the comparatively small stream of the Rum river drains the other.

LAKES WITHOUT INLETS.—Some of the lakes have a running stream leading from them, but on making their complete circuit no apparent inlet can be discovered. The surface drainage from the surrounding shores is insufficient to account for this. They are fed by springs in their beds, which beds are almost without exception in the glacial drift, which often contains layers of sand and gravel. To the presence of these water-bearing strata is doubtless due the existence of the springs.

A land surveyor informed me that while his party was surveying in western Minnesota in the winter they came to one of these lakes, and, noticing in the distance a singular round hole in the otherwise unbroken ice surface, they went out to examine it. One of them, being too curious, broke through the edge, but managed to hold to the ice until assistance came, the force of the current of water being so great as to hold him out horizontally. This place was far removed from where the current at the outlet could have any effect.

THIRD CLASS.—Of the third class of lakes there is an immense number. Often they are small ponds, filling hollows in the land, but some of them are of considerable extent. There are two causes, one or both of which may operate to produce them, and these give rise to a secondary division of the third class, viz: 1. Lakes having no outlet. 2. Lakes having a subterranean drainage.

To division 1 belong the lakes which have been already alluded to as having very small drainage areas. The supply of water which they receive does not suffice to raise their water surface high enough for them to find an outlet (except perhaps in very wet seasons, when they come for the time under the second class), and they are really stagnant pools, in which the surface is lowered by evaporation. They merge into marshes and reed swamps, such as are found in large numbers in portions of northern Iowa. These lakes, of course, contribute little to the value of the water-powers.

Division 2 takes by far the greater number of the lakes of the third class, and as the water is usually comparatively pure, although the soil is rich in salts, it is fair to conclude that there are very few of them with absolutely no outlet, the same causes that have been mentioned as giving rise to springs in the lake beds acting equally as well to give a means of outlet to the lakes. It is extremely probable that many lakes which apparently have no connection with the streams feed them with a steady supply of water, which filters down through the sand and gravel, where these occur in their beds and banks. There are many probable examples of this. The area of lake Minne-wa-kan, in Dakota, is 107 square miles. Although this lake is claimed to have no outlet, it is thought to aid the volume of the Sheyenne, a tributary of the Red River of the North. In some cases the filtration may take place and the water be discharged at some distant point, thus being a positive source of loss to the volume of the streams of the locality. Nevertheless, it is fair to assume that most of the northwestern lakes exert a beneficial influence upon the water flow of that region; certain is it that their entire absence would make a great difference in its steadiness.

In many cases it is entirely practical to raise the level of the lakes by dams at their outlets, and thus largely increase their storage capacity. The discharge could then be regulated at pleasure, and the permanency of the water-powers still improved. No surveys with this object in view have been made so far as known, with the exception of those carried on under the direction of Major Charles J. Allen, corps of engineers, U. S. A., for the reservoir system of the Upper Mississippi river, and a survey along the Rock river of Illinois for the same purpose. These demonstrate the feasibility of establishing artificial reservoirs upon the Upper Mississippi, which would much improve its navigation and be of great value to the water-power interests. The small cost of land makes artificial reservoirs comparatively inexpensive.

GRADUAL FILLING OF THE LAKES.

It is the inevitable tendency for the decaying vegetation gradually to fill up the lakes, changing them into marshes and peat-bogs. All the different stages in the process, from the open lake to the bed of peat, are now to be seen.

SUMMARY.

Reviewing the preceding pages, before taking up the detailed discussion of the different drainage areas, the prominent facts are briefly these:

1. The region under discussion embraces Minnesota, Wisconsin, the upper peninsula of Michigan, and the northeastern portion of Dakota. In this section of country the main system of drainage is toward the south, being comprised in the basin of the Upper Mississippi, and around this, to the northeast and west, are lesser systems, draining north and east.

2. The country is mainly undulating, but there are considerable changes in the elevation of the general surface. The main features of this change are a long, gradual slope southward, with a short, comparatively sharp declination toward the great lakes. There are, of course, many local modifications of this.

3. As a natural consequence of the facts given in sections 1 and 2, the largest streams are in the Mississippi basin, but the most rapid ones are in the drainage areas surrounding it. It will not answer, however, to consider all of one class sluggish and of the other rapid; the distinction is only a broad one.

4. Because of the condition mentioned in section 3, the actual water-power is quite generally distributed throughout the entire region. The idea that there is no water-power in the prairie is an erroneous one.

5. The great difference between the summer and winter temperatures, and the prevalence of dry winds during the latter season, have the effect of causing an unequal distribution of the aqueous precipitation throughout the different seasons. The cold of winter freezes solid until late in the spring great amounts of water, which in a southern climate would go to maintain the winter flow of the streams.

6. The level nature of the country, as compared with a mountainous region, and the woods, where present, tend to equalize the discharge of the streams through the different seasons, but especially is their uniformity of flow due to the unrivaled system of natural reservoirs furnished by the lakes of the Northwest. These, to a great extent, counteract the effect of the winter's cold in decreasing the volume of the streams.

7. The Northwest is comparatively a newly-settled region, and large tracts of land are yet in their wild state; hence many water-powers are at present of little value because of their location. The easy access to almost all sections of the country, and the rapidity with which the population is increasing, will soon bring these water-powers mostly into use; and the ease with which railroads can be built directly to them, and the fact that so many of them lie in the midst of a region of great natural resources, give to them a special value for the future. At present, water-power can be bought or leased at extremely moderate rates.

THE WESTERN DRAINAGE AREA OF LAKE MICHIGAN.

GENERAL REMARKS.

From south to north the length of the drainage surface is 350 miles. At the southern end it is a mere strip of land, averaging about five miles wide, and in some places scarcely three miles. At the southern end of lake Winnebago the water-shed suddenly turns west, and after reaching the center of the state of Wisconsin, 100 miles west of lake Michigan, it again runs nearly parallel with the lake. At the south, in the neighborhood of Chicago, the water-shed is only slightly elevated above the lake-level; but as it passes north through southern Wisconsin it gradually rises to 100 feet, then 200 feet, and at the point where it takes its bend westward it is from 400 to 500 feet above the lake. Near its extreme western extension, at Portage, in Columbia county, the line of water-shed passes through a sandy plain scarcely elevated above the Wisconsin river, which belongs to the Mississippi system. It is there only about 230 feet above lake Michigan. From Portage north it gradually rises, so that where it crosses into the upper peninsula of Michigan the elevation is somewhat more than 950 feet above the lake. At the most northern point, where the waters of the Menominee extend so far toward lake Superior, the elevation of the crest is nearly, if not quite, 1,000 feet.

Green bay, an arm of lake Michigan on the west, intercepts all the streams in the northern portion of the region under consideration, and the trough in which it lies continues clear across the drainage area in a northwest direction, drawing off a large part of the flow in that section. In reality, the western drainage area of lake Michigan may be considered in two sections:

First. The area tributary to lake Michigan directly, which is the narrow strip extending from the southern end of the lake along the east shore of lake Winnebago, and then northeast on the peninsula between Green bay and lake Michigan.

Second. The area tributary to Green bay.

On account of its being so closely identified with the lake Winnebago basin it has been thought best to discuss the physical geology of the region in the section devoted to the Lower Fox river.

Stated briefly, the facts, as gathered from the state geological reports of Wisconsin, are that the slope of the old underlying rock of the state is southeast, and the overlying strata also slope southeast; hence the general direction of the drainage is southeast.

The Green Bay valley extends southwest across the drainage area and intercepts most of the flow before it reaches lake Michigan. This valley owes its existence to the dip of the strata, the varying hardness of the different kinds of rock, and the action during the glacial epoch of the ice-cap.

The section directly tributary to lake Michigan is widest opposite lake Winnebago, where it averages about thirty miles across, and it is there that the chief streams occur. These are the Milwaukee, the Sheboygan, and the Manitowoc rivers, with drainage areas of from 500 to 800 square miles each. Their headwaters rise near lake Winnebago, 300 to 400 feet above lake Michigan. The streams of the northern and southern portions of this section are necessarily unimportant, from the limited area which they drain.

The section indirectly tributary to lake Michigan through Green bay contains the large streams of eastern Wisconsin, the principal of which are the Upper and Lower Fox and the Wolf rivers, comprising the lake Winnebago system, and north of these are the Oconto, Peshtigo, and Menominee rivers, and in Michigan the Ford and Escanaba rivers.

The northern portion of the section west of lake Michigan is comparatively undeveloped, and the water-power is unused, with inconsiderable exceptions. All of the streams have rapids and many available sites, which will undoubtedly be improved in the future.

South of Green bay the country is more settled, and, as a consequence, the water-power has been to some extent developed. The fine series of powers along the Lower Fox river, which are prominent among those of the Northwest, lie in this region.

AREAS OF DRAINAGE BASINS.

		Square miles.
Milwaukee river		831
Sheboygan river		738
Manitowoc river		553
Lower Fox river:		
Upper Fox river	1,672	
Wolf river	3,763	
Lake Winnebago	611	
Lower Fox river below lake Winnebago	403	
		6,449
Oconto river		1,017
Peshtigo river		1,123
Menominee river		4,113

BASIN OF THE LOWER FOX RIVER.

Interest naturally centers in the Lower Fox drainage basin, because of its size and valuable water-powers, and to the discussion of these much of the space allotted is devoted. The upper waters of the basin are not remarkable for power. The Wolf river, although it is rapid in its upper part, has little fall in its bed below Shawano; the Upper Fox is likewise a sluggish, idle stream; and all the waters of a section of 6,046 square miles are gathered into lake Winnebago without any remarkable water-powers resulting. But lake Winnebago is nearly 170 feet above Green bay, and the flow from this large drainage surface must descend that height in a distance of about 35 miles. The waters are gathered in lake Winnebago, stored in that large reservoir of nearly 200 square miles area, and then sent speeding down the rapids to Green bay, and thus the power which would otherwise be scattered over a large area is here concentrated, where it can be completely used.

MENOMINEE RIVER BASIN.

The Menominee River basin is the next both in size and importance, although it is in a wild, unsettled region of country. From sources to mouth it descends about 950 feet, and many rapids and falls are the result. The drainage area of 4,113 square miles supplies a goodly volume of water, and many fine powers are awaiting development.

A description of this river is given in its proper place.

The Oconto and Peshtigo rivers likewise have a rapid descent, and, although much smaller than the Menominee, give rise to water-powers of value.

RECORDS OF PRECIPITATION AND TEMPERATURE FOR THE WESTERN DRAINAGE AREA OF LAKE MICHIGAN.*

Place.	Spring.	Summer.	Autumn.	Winter.	Year.	Length of observations.	Summer temperature.	Winter temperature.	Length of observations.
	Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*		° ′	° ′	
Waukesha	5.32	10.30	6.92	3.15	25.92	Mar., 1856, to Nov., 1856	69 78	20 75	Mar., 1856, to Mar., 1859.
Milwaukee	8.67	10.07	7.67	5.13	31.54	Jan., 1841, to June, 1877	67 02	24 00	Jan., 1837, to Dec., 1870.
Manitowoc	6.83	10.73	7.06	5.14	29.76	Feb., 1858, to Dec., 1874	65 30	23 72	Oct., 1851, to Dec., 1870.
Wautoma	5.50	6.25	1.98	3.16	25.92	Jan., 1871, to Dec., 1874	...	...	
Fort Winnebago	5.58	11.46	7.63	2.83	27.50	Aug., 1836, to Aug., 1845	68 24	19 81	Jan., 1829, to Aug., 1845.
Weyauwega	6.74	17.85	14.23	5.31	44.13	Mar., 1861, to Dec., 1873	68 18	19 82	June, 1860, to May, 1867.
Waupaca	5.50	14.50	6.02	3.93	25.92	Jan., 1867, to Apr., 1874	70 17	20 48	Dec., 1863, to Dec., 1870.
Menasha	6.83	10.73	7.06	5.14	29.76	Oct., 1857, to Mar., 1858	65 30	23 11	Oct., 1857, to Mar., 1858.
Appleton	7.65	10.24	6.92	3.70	28.51	Jan., 1856, to Apr., 1871	67 48	20 15	Jan., 1856, to May, 1870.
Green bay	6.18	9.35	10.43	4.46	32.42	June, 1858, to Sept., 1865	68 10	18 62	May, 1858, to Sept., 1865.
Embarrass	8.14	12.49	8.21	5.73	34.57	Jan., 1864, to Dec., 1874	66 82	18 25	Oct., 1856, to Dec., 1870.
Wausau, on the Wisconsin	6.19	10.30	7.02	3.15	25.92	Feb., 1859, to July, 1859	69 68	17 46	Nov., 1858, to Dec., 1859.
Sturgeon bay	5.87	9.66	8.27	5.01	28.81	Feb., 1870, to June, 1874	68 22	19 14	1870.
Escanaba, Michigan	8.52	13.72	10.57	3.28	36.09	Oct., 1872, to June, 1876	...	...	

*Obtained from the publications of the Smithsonian Institution.

DISTRIBUTION OF THE PRECIPITATION.

The annual precipitation on the western drainage area of lake Michigan varies from an average of 26 inches to an average of about 35 inches. In the section nearest the lake the precipitation is lightest, probably not averaging more than 27 to 28 inches. In this region run the Milwaukee, Sheboygan, and Manitowoc rivers.

In the section west of Green bay the annual precipitation is greater. Along the Upper Fox river it is about 30 inches, and increases toward the north. The heaviest precipitation is on the region about the Menominee and the streams north of it, where the average is not far from 35 inches per annum.

It will be noticed that the topography is such that the largest streams, draining the greatest area, are situated in the region receiving the heaviest precipitation. The character of the country must also have some influence upon the streams.

The Lower Fox drainage system contains, beside the large reservoir of lake Winnebago, several smaller lakes and extensive lowlands, which prevent rapid drainage. The northern streams run through tracts which have scarcely felt the hand of industry. No careful farming and drainage conducts the rainfall rapidly to the water-courses, but the roots and grasses, with the shade of the forest trees, act beneficially in preventing the rapid melting of snow and in holding back the water for a more gradual distribution throughout the seasons.

LOWER FOX RIVER.

The Indian name of this river was Neenah. The outlet of lake Winnebago, in eastern Wisconsin, it starts from the north end of the lake, and, flowing in a rather direct northeast course 37½ miles by water, it finally reaches the level of lake Michigan in the head of Green bay.

That which makes this stream of special importance to a report of this nature is the magnificent system of water-powers which it affords. These are building up manufacturing interests to an extent that is destined to make the Lower Fox River valley stand pre-eminent among the manufacturing centers of the West. But the interest centering in the river is not confined to that derived from its development within the last few years. Owing to its peculiar relations, both to the Mississippi and to the important waterway along the great lakes and the Saint Lawrence to the Atlantic, the Lower and Upper Fox have, as well as the Illinois river, the distinction of being one of the two routes by which the early Jesuit missionaries and explorers made their perilous canoe voyages through the unknown wilderness to the Mississippi. Through the succeeding years the example of these adventurous Frenchmen has been followed, and, later, along these two routes were established, to a certain extent, continuous water channels from the gulf of Saint Lawrence to the Mississippi.

RESOURCES OF THE REGION.

Before the time of railroads in that country the great advantages of the water route brought much traffic along the river, and thus early gave it a prominence. Since that time the productiveness of the country has made it prosperous, but especially are we to look to the splendid water-power afforded by the river for the rapid growth of the valley—a growth which is yet in its youth.

Already are the manufacturing towns of Appleton, Neenah, and Menasha looked upon as among the industrious centers of the state, and the Lower Fox river is destined to play a most important part in the further development of manufactures.

Stated succinctly, the facts are these: The crude materials are on every hand, the means of transportation are abundant and increasing, and the power for manufacturing is supplied in a prodigal manner. Let enterprise step in and make the three serve each other, and we have the conditions which have made Appleton, and which are to make the valley, one busy scene of manufacture.

NATURAL PRODUCTIONS.—Along the river and in the counties adjacent is fine wheat-producing soil, and west are the great grain-fields, with which it is connected by railroad.

Lying west in its own drainage basin, and north in Wisconsin and Michigan, are the pine forests, not yet robbed of their heavy timber, and within easy access grow the hard woods, which are suitable for the manufacture of agricultural implements and the innumerable other applications of that useful article. Great quantities of poplar for the manufacture of wood-pulp and the making of paper are at hand, and spruce and pine, which are used for the same purpose, are easily obtained from the forests near by. The water of the river is of excellent quality for the manufacture of paper.

The railroad leads direct to the iron region along the Menominee, in the upper peninsula of Michigan. Woolen goods are manufactured, and lately it is found that the raising of flax is successful, and flax-mills are being projected.

Thus is seen what are the productions immediately surrounding the river, and, with the facilities of tranportation enjoyed, there is no reason why a large section of country should not be tributary to it.

The value of the manufactures of Appleton for the year 1880, amounting to $3,182,000, are given in a succeeding table. This place has a population of over 8,000 people, and is the most prominent town of northeastern Wisconsin.

TRANSPORTATION FACILITIES.

RAILROADS.—The means of transportation are most excellent, lying as the valley does in the neighborhood of one of the great lakes, and embraced by important railroad lines. It is a pretty good indication of the natural advantages of the valley when three large railroad companies should compete with each other in the possession of a trade which they see booming in the future, and which is well represented by the traffic of to-day. Numerous lines lead from the valley in all directions. The Chicago and Northwestern railroad runs from Chicago, along the Lower Fox river and by way of the Menominee iron range, through Michigan; the Wisconsin Central railway and branches leading to Chicago, run east of the Lower Fox to Green bay, and on the west tap the wheat regions, while a branch running north passes through the pine region and the Penokee iron range, near lake Superior; and the Milwaukee, Lake Shore and Western railroad connects Appleton with a lake port on the east, and, extending west, connects at New London with the Green Bay and Minnesota railway, which runs from the head of Green bay to the Mississippi at Winona. An extension is also in course of building by the Milwaukee, Lake Shore and Western railroad northwest through the undeveloped country in that direction. These railroads run to and along the river, and the facilities of connection with the manufacturing establishments are exceptionally fine.

WATERWAYS.—As regards water communication, the advantages of the valley are also fine. Depére is at the head of lake navigation, and forty miles east from Appleton is the lake shore, where there are also ports. There is a scheme for connecting with the Milwaukee, Lake Shore and Western railroad a line of steamers to run across the lake to Michigan and connect with railroad lines in that state. Along the valley itself is a system of navigation, which in that portion of its course is in a good working condition. It is a portion of the Fox and Wisconsin transportation route between the great lakes and the Mississippi.

In 1836 the first government survey was made of this route, and since that time there has been a more or less continual attention bestowed upon it. The system consists of a series of slack-water dams and locks, with canals around the west rapids up the Lower Fox river to lake Winnebago, then lake and slack-water navigation along the Upper Fox to Portage. There the river runs within 1½ miles of the Wisconsin river, and across the low, sandy plain intervening a canal is cut, connecting it with the latter. The navigation is then down that stream to the Mississippi.

Although the scheme would seem to be an excellent one, the route at present, regarded as a through line, is of little if any value, and is practically unused, except for local traffic. The main difficulty is with the Wisconsin, which has such a shifting, sandy bed that it is extremely difficult to train it. Much money has been expended in the effort to improve this river, and until it is done the route will be of little importance, except locally. The portion

along the Upper and Lower Fox rivers is more easily controlled, and is used locally by small boats. For example, barges have been employed in shipping granite from quarries at Montello, on the Upper Fox, to Portage, whence it is sent as paving blocks to Chicago. A large amount of wood is annually taken down the river to the blast furnaces at the lower end, and the pulp-mills keep several boats employed. Considerable lumber is carried, and the rates of freightage by water are very much less than by land. In such ways the canal is useful. The portion along the Lower Fox river from lake Winnebago down is in by far the best condition, and if all was like it the route would be of considerable importance. The navigation route has its influence on the development and control of the water-power of the Lower Fox, as will be noticed farther on in this report.

PHYSICAL DISCUSSION OF THE LOWER FOX DRAINAGE BASIN.

It will be noticed that a distinction is made between the Upper and the Lower Fox rivers. The reason for this is simply that, except in name and a certain relation to the transportation route which they bear in common, they are no more the continuation, one of the other, than the Lower Fox is a continuation of any other stream which feeds it.

System of drainage.—It will be seen on the map that the drainage system consists, with very inconsiderable exceptions, of two prominent streams, the Wolf and the Upper Fox, running into lake Winnebago, and this emptying by the Lower Fox into Green bay, an arm of lake Michigan. The Lower Fox, then, is the outlet whereby a section of the state 155 miles long and averaging 39 miles wide drains into the lake.

The peculiar form of this drainage basin will be noticed. Starting in a point about 25 miles from the northern line of Wisconsin, it gradually widens out to 60 and finally to 70 miles wide on an east and west line at the southern extremity, in latitude 43° 30′. On the eastern side of the basin is its outlet, the Lower Fox. The two rivers which collect its waters previously to depositing them in the reservoir of lake Winnebago are the Wolf river on the north and the Upper Fox on the southwest, the Wolf river being by far the larger stream, running nearly the whole length of the basin, and having a drainage area over twice as large as that of the Upper Fox.

Overflow from the Wisconsin river.—Another singular feature is, that the Wisconsin, which is at Portage 5 or 6 feet higher than the Upper Fox, actually overflows into that stream in high water, and is mainly the cause of its freshets, adding no inconsiderable amount to the flow from the basin.

Peculiarity of the Fox River valley.—Giving additional interest to the study of this drainage system is the prominent character of the Fox River valley. The depression filled by Green bay is continued southwest, forming the Lower Fox valley and the basin of lake Winnebago. There the valley appears to branch, one arm extending as the valley of the Upper Fox and the Wisconsin valley from Portage down, the other running south as the valley of the Rock river, which flows into Illinois. This valley and branches are no product of the imagination, but are strongly marked, the east and south slope being very steep, while the other slope is gradual, especially on the portion running north and south. One point specially to be noted is that the valley is continuous from the Upper Fox down the Wisconsin, only a low, sandy plain separating the two streams.

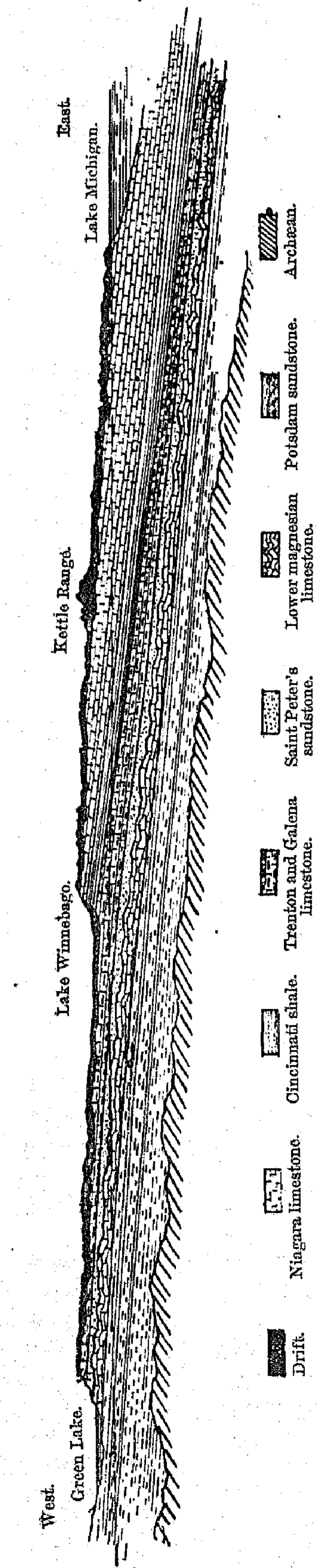
It is evident that there have been great changes in the hydrography of this region.

GEOLOGICAL HISTORY.

The geological structure, as indicated in the state geological report, is this: First, a rib of the old metamorphic rock, extending south through the center of the state, sloping east and west, and also with a slight general declination toward the south. Upon this the seas of the successive epochs deposited their rock layers, the outcrops of these successive layers forming, as would be supposed from its shape, a succession of concentric curves about their Archæan base. Beginning on the east side of the state, they run south, then curve to the west, and finally run northwest in Minnesota and Iowa. A section through this succession of strata is given. Following the slope of the old base, the different strata inclines to the east; farther south the slope is south, and then in Iowa and Minnesota southwest; and some of these strata are harder and less liable to wear than the others. Then, the hard lower magnesian limestone is underlaid by the softer Potsdam sandstone, and immediately above it is the soft Saint Peter's sandstone. The hard Trenton group of limestones is underlaid by the Saint Peter's sandstone, while above it are the soft Cincinnati shales. Lying on the Cincinnati shales is the hard Niagara limestone.

The general slope of the surface of these rocks, as was mentioned, is toward the southeast in eastern Wisconsin; hence the natural tendency of this drainage in the time preceding the glacial period was toward the southeast. What is more natural to suppose than that the earlier streams, as they cut into the rock, would halt on coming to the outcrop of the hard strata, and, eating their way through the softer underlying bed, and following along the line of outcrop of this hard rock, would cut their valleys in a south and north direction? Also, from the general slope of the strata, the tendency would be to greater erosion nearest the east bank, undermining the hard rock, and thus making the east slope of the valley precipitous. Such are believed to have been the main features of the early drainage of eastern Wisconsin, and most strikingly is this view upheld by the present courses of the Wolf, Upper Fox, and Wisconsin rivers. The glacial action has not so modified the surface as to destroy the salient features of the old preglacial topography.

ANCIENT VALLEY OF THE WOLF RIVER.—The modern Wolf river, rising in the Archæan region of northern Wisconsin, runs southeast until it strikes the stratified rock, whence it runs in such a valley as is just mentioned, following the cliffs of the hard lower magnesian limestone, with its bed in the Potsdam sandrock. At lake Poygan it turns east, owing, it is believed, to glacial action, but the old valley keeps straight on along the Upper Fox, and then bending to the west, without a change, becomes the valley of the Wisconsin river to its mouth. It is a well-ascertained fact that the upper Wisconsin, until the glacial action choked its course, drained through the Devil's lake into the Wisconsin valley at Sauk City, 20 miles below Portage, and the conclusion is inevitable that the Wolf river, and nearly all the present drainage of the Fox River system, ran southwest to the Mississippi in the preglacial time.



GEOLOGICAL SECTION ON AN EAST-AND-WEST LINE THROUGH THE SOUTHERN END OF LAKE WINNEBAGO, WISCONSIN. (From the Geological Report of Wisconsin.)

GREEN BAY AND LAKE WINNEBAGO VALLEY.—East of the old valley just described is the Green bay and lake Winnebago valley, of similar characteristics, and the more prominent of the two, but in the preglacial times it could hardly have had its present dimensions. The valley was probably started by the erosion of streams, but was dug out to its present size by the glacier. The western slope is gradual; but the eastern slope is precipitous, being cut out of the soft Cincinnati shales, overlaid by the hard Niagara limestone.

The bed is the hard Galena limestone of the Trenton group. The eastern side of the valley, which forms the eastern limit of the Lower Fox drainage basin, rises abruptly 100 to 200 feet above the water in Green bay, and continues a line of cliffs along the east shore of the present lake Winnebago, and then south, although largely covered up with drift in the southern part of the state. The geological section given previously, from lake Michigan west through Fond du Lac, shows both of the old valleys.

GLACIAL ACTION.—Succeeding this preglacial condition came the glacier, sending an immense sheet down to cut out the valley of lake Michigan, and a tongue up the Green Bay valley, gouging this out to its present size. On the peninsula between Green bay and lake Michigan was formed the prominent Kettle range, a medial moraine. The glacier tongue extended down the Rock River valley, and on the west spread out over the Fox River basin well toward the Wisconsin river.

The floor of the Green Bay valley has a rapid rise, so that at lake Winnebago it is about 170 feet above Green bay. The portion of the old valley now occupied by the Upper Fox was largely filled up with drift, and it seems probable, from the geological reports, that to the action of the glacier in cutting down the intervening lower magnesian rampart and in filling up to a certain extent the Upper Fox valley is due the change in flow of the Upper Fox and Wolf rivers through the newly-enlarged Green Bay valley to the lake. It is also likely that the change in flow is partly due to the depression toward the north, which occurred during or after the recession of the glacier.

EXPANSION OF LAKE MICHIGAN.—This depression caused a large body of water, which was nothing more than the expansion of lake Michigan. The probable shore-line of this ancient lake is shown by the dotted lines on the map. The outline is taken from the state geological report. The lake, in advancing upon the drift left by the glacier, carried off the finer particles, depositing them in deep water, and forming a beach-line of sand and gravel, the finer deposit receiving the name of lower red clay. During a second advance of the lake a similar process was gone through with, and the upper red clay deposited. There were subsequent modifications of these. The red clay forms to a large extent the soil of the Fox River valley, and is of fine quality, and the ancient shores of the expanded lake are traced by this deposit. The lower red clay ascends the Lower Fox valley to a few miles north of Fond du Lac. On the west it extends up the Upper Fox to above Berlin, and along the Wolf river to beyond Shawano. It seems probable that the deposit referred to by some as the deposit from a former great enlargement of lake Winnebago is really the deposit from the waters of lake Michigan when it occupied this area, as the shore-line laid down for the old boundary of the lake corresponds very closely with the so-called old shore-line of lake Winnebago.

ORIGIN OF LAKE WINNEBAGO.—Lake Winnebago is due, according to Professor Chamberlain, to a slight drift barrier thrown across the valley. The old channel is at the eastern corner of the lake, and is filled with drift. The rock bottom is lower than the limestone terrace over which the present outlet passes, and, if once opened, it would drain the lake.

SUMMARY.—Thus we draw the conclusion that in preglacial times the greater part of the present Fox River basin drained into the Mississippi; that during the recession of the glacier the flow changed to its present direction; that following or accompanying the recession of the glacier was an advance of lake Michigan, rearranging the drift and depositing the red clays; and that lake Winnebago is a comparatively modern reservoir, formed in the valley by the drift deposition of the glacier.

The history of the region, its manufacturing and commercial facilities, and physical geology have been described. It now remains to give a general idea of the water-power, and its special advantages, before describing in detail particular localities.

LEGAL CONDITIONS OF THE WATER-POWER.

LEGAL HISTORY OF THE WATER-POWER.—As the present ownership of the power depends in a large degree upon past legislation in relation to the navigation route, a brief account of the changes this has gone through will be necessary. The dates and early history are obtained from the annual review of the Appleton *Post*.

In 1846 Congress passed an act granting a large amount of land to the state of Wisconsin, soon to be admitted, for the purpose of making a navigable route from lake Michigan along the Fox rivers to the Wisconsin, and in 1848 the legislature of the new state just admitted accepted this grant. In 1853 the state, after expending $400,000 upon the improvement, passed the whole matter, including the land, over into the hands of a company called the Fox and Wisconsin Improvement Company. This company sold some of the land, and issued bonds to the amount of $500,000. With this they commenced active work, and in June, 1856, the first steamer passed through from the Mississippi river to Green bay. On the advent of railroads the route fell into disuse, and the company being unable to pay expenses and interest, the holders of the bonds brought suit against it. The result was the sale in Appleton of the franchises, property, and land-grants of the company, the purchasers organizing in 1866 as the Green Bay and Mississippi Canal Company. In 1870 the United States appraised the value of the locks and canals at $145,000, and, paying the company that amount, took possession of them. Since that time the government has had control of the navigation route. The Green Bay and Mississippi Canal Company did not dissolve, but still retained its land-grants, water-power franchises, and other property.

In this condition the company exists at the present day, and, as may be imagined, are very influential owners along the river. They claim the right to all surplus water after the wants of navigation are fulfilled, and, therefore, the right to tap the canals at any point and draw off the water, provided they do not interfere with navigation, as also the right to take all the surplus flow of the stream at the head of each set of rapids and use it at that level. They do not claim ownership of power which is improved at a level below the head of a rapids by persons owning the land and using water which has passed the tail-races of the company. They own, by the original grant and subsequent purchase, a large number of valuable sites at the several powers along the river; but there are cases where, while the Green Bay and Mississippi Canal Company own the power, others own the land. In one case the arrangement has been made of forming a water-power company consisting of the owners of the property and the individuals forming the Green Bay and Mississippi Canal Company, thus combining their interests; in another case a company has been at work improving a power to come from the upper level of a rapids. They own the land, but the Green Bay and Mississippi Canal Company claim that they have no right to the power, and as soon as they begin using it intend, it is said, to bring suit to compel them to pay rent.

CLASSIFICATION OF THE POWERS.—There are, then, with the exception of some powers in use which have their rights from long-established usage, four different classes of powers from a legal point of view. Some of these powers are developed and in use, some in process of development, and others are not yet touched. They are:

1. Powers from the first levels of rapids, where the Green Bay and Mississippi Canal Company control both the power and the land.

2. Powers from the first level of rapids, where the Green Bay and Mississippi Canal Company, as individuals, go into partnership with the owners of the surrounding land, forming an hydraulic company.

3. Powers from the first level of the rapids, where persons owning the land intend to utilize the power, and the Green Bay and Mississippi Canal Company intend to bring suit to make them pay rent for such use.

4. Powers below the first level of the rapids, where persons owning the land have improved or may improve the power without molestation from the Green Bay and Mississippi Canal Company.

Of the above classes of powers it seems probable that the third will either have to pay rent or form some such arrangement as in the second class. The first, second, and fourth classes are on a substantial basis.

RATES OF LEASE.—The improved powers are standing, in most cases, waiting to be utilized, and offering the most advantageous terms to manufacturers. Much is already taken up, especially on the upper portion of the river, but even there there is a large amount of unutilized power. There are also opportunities for companies to form, as has already been done in several cases, for the purpose of improving water-power sites and leasing the power, and the rates of lease, which have been extremely small, are being increased as the demand increases.

Prices are about the same all along the river. In the winter of 1880-'81 the rates at Appleton were these:

For a large water-power of from 500 to 1,000 horse-power, with the necessary land, and a short lease of 10 or 15 years, the rates were even as low as $1 to $2 per horse-power per year.

A power of from 100 to 300 horse-power would bring $3 to $4 per horse-power per year.

A 50 horse-power site of one-half acre would lease for from $2 to $3 per horse-power per year.

At Kaukauna a 100 to 300 horse-power site will bring $2 to $5 per horse-power per year. Power has been recently leased there for a wood-pulp mill of 300 horse-power at the rate of $5 per horse-power.

There is a probability that the scale of prices will increase, so that an ordinary lease will bring as much as $5 per horse-power per year. Even this is very small compared with the eastern rates.

GREEN BAY AND MISSISSIPPI CANAL COMPANY.—The Green Bay and Mississippi Canal Company formerly consisted largely of eastern capitalists, who already had large investments, and did not take special interest in the development of the water-powers along the Lower Fox. Lately, however, the company was reorganized, putting the control into the hands of persons interested in the development of that region. Their policy is said to be to make a rapid and general improvement of their powers along the river, to give manufacturers the option of buying or leasing, and to offer very favorable terms. The president is John Van Nortwick; vice-president, H. J. Rogers; secretary and treasurer, A. Ledyard Smith, of Appleton.

There are several other companies and individual owners, of whom subsequent mention will be made in the detailed descriptions.

CHARACTERISTIC FEATURES OF THE RIVER AS A WATER-POWER STREAM.

PAST AND PRESENT.—When the Lower Fox flowed untrammeled through the wilderness, its course of 37½ miles was bounded by wooded clay bluffs, from ten to seventy feet or more in height, in some places rising abruptly from the river's edge on each side, in others receding so as to leave a narrow meadow along the river bank. Through this channel ran the clear, dashing river over its limestone bed, from 300 to 1,000 feet wide, now flowing placidly along, then dashing into foam over some sudden rapid in its descent of 165 feet to Green bay. The principal rapids were at Grand Kaukauna and Grand Chute, the site of Appleton; but there were several other rapids, as at Cedars and Little Chute, difficult even for the light canoe of the Indian to pass. Now things are different, although in places the forest still droops to the water's edge. The interests of navigation have bridled the river, and a series of dams has changed it into long stretches of slack water, with perhaps a short rapid at the foot of the dam, except at Grand Kaukauna and Appleton, where the rapids are passed by canals extending from the head to the foot, while the river flows on over its steep bed.

GOVERNMENT DAMS.—The government dams are important to this report, as at them, chiefly, is situated the water-power of the river. The following table gives the location of the dams and distances of these places from the mouth of the river and from each other; also the elevations overcome in passing from the crest of one dam to that of the one above. The table was obtained from the United States engineers' office at Milwaukee, under Colonel D. C. Houston, major of engineers:

Locality.	Intermediate distance.	Distance from mouth of river.	Elevations overcome.
	Miles.	*Miles.*	*Feet.*
Green bay (mouth of river)	0.00	0.00	....
Depère (old) dam	7.00	7.00	*5.411
Little Kaukauna dam	6.00	13.00	7.795
Rapid Croche dam	6.00	19.00	9.221
Grand Kaukauna dam	4.50	23.50	50.121
Little Chute dam	2.50	26.00	36.158
Cedars dam	0.75	26.75	9.800
Appleton, lower dam	3.00	29.75	....
Appleton, upper dam	0.75	30.50	36.265
Menasha dam	5.00	35.50	10.424
Lake Winnebago (source of river)	2.00	37.50	....

* The rise immediately at the dam.

Beside the dams given in the table, there is one at Appleton, between the upper and lower dams, used simply for power, and independent of the government. The map shows that there are two channels from the lake, uniting about one and a half miles below to form the main river, called the Neenah and Menasha channels, from the towns at their respective ends. The government has a dam at the foot of each channel, controlling the level of the lake. The fall is about the same with both. The navigation locks are at the dam on the east or Menasha channel.

FLOW OF THE RIVER AND THE WATER-POWER.—The minimum flow of the Lower Fox river is given in General Warren's report as 2,320 cubic feet per second. The ordinary low-water flow is taken at 2,500 cubic feet per second, or 150,000 cubic feet per minute. This will give, with 10 feet head, 2,836.35 theoretical horse-power, or, with an efficiency of 75 per cent., an available power of 2,127.26 horse-power.

The tributaries of the river below lake Winnebago are small brooks of no consequence, and it can fairly be assumed that they hardly more than balance the effects of evaporation; hence the total theoretical power of the river, in an ordinary low stage, in its descent of 165 feet from lake to bay, is pretty closely 46,640 horse-power.

The following table gives the localities of the available powers, the total available head of water in feet, and the resulting horse-power at an ordinary low-water stage of 2,500 cubic feet per second:

Place.	Available head, in feet.	Theoretical horse-power.	Effective horse-power, at 75 per cent.
Neenah and Menasha	8.5	2,411	1,808
Appleton, upper dam	16.0	4,538	3,404
Appleton, middle dam	10.0	2,836	2,127
Appleton, lower dam	10.0	2,836	2,127
Cedars	9.0	2,553	1,915
Little Chute	34.0	9,644	7,233
Grand Kaukauna	50.0	14,182	10,636
Rapid Croche	8.0	2,269	1,702
Little Kaukauna	7.5	2,127	1,595
Depère	6.0	1,702	1,276
Totals	159.0	45,098	33,823

It is rare to find a stream in which such a complete utilization of the power is possible.

UNIFORMITY OF FLOW.—Foremost among the characteristics of the Lower Fox river is its steadiness. At Appleton the ordinary variation from low to high water is scarcely more than two feet throughout the year, and a three-foot rise is a very large one for this river. Lake Winnebago, like a great storehouse, regulates the supply. In a dry summer, when other streams may dwindle to brooks, the Lower Fox still fills its banks, and when winter scarcely lets the prairie stream leak between its icy fingers, lake Winnebago pours a generous flood down the valley of the Lower Fox. Nor does lake Winnebago deserve all the credit; the smaller lakes and swamps on the Upper Fox and Wolf rivers have also some effect.

It is the storage capacity of the basin that gives to the Lower Fox a special value as a water-power stream.

LAKE WINNEBAGO.—Lake Winnebago, whose major axis lies nearly north and south, is 28¼ miles long, and its maximum width is 11 miles, its minimum width, except at the extreme end, 3¾ miles, and its average width 7 miles. The area is 199 square miles, and the deepest places are about 25 feet.

Accompanying General Warren's report is a plotting of gauge readings on lake Winnebago for 1867, 1868, and 1869. These show the slowness of the changes in elevation to which it is subject. As the curve for 1868 corresponds closely to the mean where that is given, it will represent near enough the usual changes to which the lake is subject. The level was lowest in January and February, keeping nearly constant. From March 1 up to April 15 it rose pretty uniformly, reaching its highest point for the year on the 15th of April, when it was 2¾ feet above the lowest stage for the year. From April 15 to August 15 the fall was very uniform, with the exception of an undulation of about six inches in the latter part of June, due to the June rains. From August 15, through September and October, the surface was nearly constant at a low stage, but in November it rose about one foot, and in the latter part of December began slightly to fall. In 1869, owing to a wet summer, the level was high through the season.

STORAGE CAPACITY.—Whether these changes are largely caused by drawing off the water from the dams at the foot of the lake or not, the record is important as giving an indication of the times and duration of low water. The longest stage of low water is from the end of July through to the fall rains. If this can be provided for by storage, the rest of the season will be, as the fall rains fill up for the winter months. What is the present storage capacity? General Warren states that "the water-powers occasionally draw down the level of the lake nearly 2½ feet below the ordinary level maintained by the dam". It is fair to assume from the gauge plottings that, except in very extraordinary seasons, like the summer of 1867, the lake level will not fall below the crest of the dam during the summer, except in August, September, and October, a stretch of ninety days. Supposing that the extent to which it is feasible to draw down the level is 2 feet, instead of 2½ feet, leaving the extra 6 inches to counterbalance the error in calculations due to the slope of the bed at the shores, the volume ready to be drawn off when the level is up to the crest of the dam is 11,493,603,200 cubic feet.

The officers of the lake survey estimated in 1861-'67 that the evaporation on the lakes for the three months mentioned, August, September, and October, amounted to eleven inches in depth. Assuming this to be true for lake Winnebago, there is a storage left available of 6,225,701,733 cubic feet, which for ninety days would give a discharge of 800 cubic feet per second to supplement the natural low-water flow.

Colonel D. C. Houston, in charge of this district, kindly furnishes the information that on August 9, 1878, when the water was low, the discharge of the Wolf river was 1,608 cubic feet per second, and of the Upper Fox 1,043 cubic feet per second, giving a total of 2,651 cubic feet per second. Supposing that the extreme low-water flow into the lake was as low as 2,000 cubic feet per second, this, and the regulated flow from storage, would give on a low estimate an available discharge of 2,800 cubic feet per second through the low-water months mentioned, more than sufficient to keep up the ordinary low-water flow on which the calculations of the available water-powers of the Lower Fox are based.

The lake level would lower at the rate of about one-quarter to one-third of an inch per day if regulated as described, of which about one-half would be due to evaporation.

It must not be forgotten that the land about the lower part of the Wolf river is swampy and the fall slight. The high water in the lake, which sometimes reaches three feet above the ordinary level held by the dams at the outlet, floods away back, filling the swamps and lakes before mentioned, and really extending the limits of lake Winnebago to a large extent. This backwater takes a good while to run out, and exerts a considerable effect in steadying the flow.

FRESHETS FROM THE WOLF AND UPPER FOX RIVERS.—But the Wolf and Upper Fox, while they aid lake Winnebago in this way, are also the means of producing the freshets on the Lower Fox, although a three-foot rise is hardly worthy of the name. A few years back there was an extraordinary rise in the Wolf, filling its flats to the width of several miles and raising the Lower Fox unusually high. The rather singular state of affairs exists in this basin of a foreign stream intruding its surplus waters.

It has been stated in another place that the Wisconsin and the Upper Fox, at Portage city, flow through the same sandy plain, without any definite water-shed between them. The Wisconsin is 5 or 6 feet higher than the Upper Fox, and in a high stage discharges a considerable volume, largely through the channel of Neenah creek, into the Upper Fox. In the spring of 1881 there was a heavy freshet on the Upper Fox from this cause chiefly, and it had its effect upon the lake level.

SPRINGS IN LAKE WINNEBAGO.—The opinion is expressed by some that there are extensive springs in the bed of lake Winnebago, feeding it. Captain N. M. Edwards, an engineer at Appleton, for many years connected with the river, dissents from this view, and says that there is just as likely to be as much leakage as supply through the bed, which seems probable.

From the geological section previously given, it will be seen that the rock strata slope to the east from lake Winnebago to lake Michigan, 165 feet below it, and also that the stratum immediately below the lake is the Trenton limestone, over which are the drift and red clay, forming the bed of the lake. The Trenton limestone is described by Professor Chamberlain as having permeable water-bearing strata, and it is quite possible that the water, under the hydrostatic pressure of the lake, should find porous portions of its drift bed, and so, by means of the limestone strata, sink down to lake Michigan.

ARTIFICIAL RESERVOIRS.—Although the Lower Fox is so unchangeable, still, to see it rushing past Appleton when in a high stage, one would think it a wasted torrent, and it is true that an enormous volume of water passes down the river unused in high water. There is, with the present improvements, all the water needed in an ordinary low stage, but there are many more available sites at the different powers along the stream than could be supplied at ordinary low water. Mills using a small power, say 50 horse-power, could in most places utilize the space available without exhausting the capacity of the river; or even factories using a large power, but requiring much room, would not concentrate the power to the detriment of the full development of the locality. Manufactories, however, using from 500 to 1,000 horse-power in a small space, as for example, wood-pulp mills, would exhaust the power without using the available space. This is not of much account except to the owners of the land, as the power is of as much value intrinsically when concentrated as when scattered in small industries, but it serves to show that there is a limit to the amount of power which may be reached before the limit of available mill-sites is reached.

In the future, and the near future too, it may become a matter of importance to hold back the great surplus which wastes itself in a few weeks, and, dealing it out gradually, to make the freshets still less, to bring the river nearer to the average flow for the year. As the land about the Wolf river is cleared and drained, making the stream more flashy, this question will increase in importance. Where is the remedy? It is impracticable to raise the water of the lake to a higher level than is now done because of the lowlands to the west and south. As it is now, complaints are heard of overflows on the farming land along the shores.

Along the upper portion of the Wolf are many lakes and marshes, and although, so far as can be learned, no surveys have been made for this purpose, still it is thought by those interested in the subject that good sites could be found for storage reservoirs to hold back the floods until required. The land there is wild, not bringing more than $2 to $3 per acre, and could be cheaply bought for flowage. It is true that the basin narrows to a point at the upper portion of the river, but enough water could be collected to have an important effect on the Lower Fox. The development of the water-power in the future will probably justify the outlay.

The wind exerts a slight effect upon the waters of lake Winnebago, a strong wind from the north and east lowering the level slightly at the outlet. The crest of the Menasha dam is higher than that of the Neenah dam, and on the latter flash-boards 18 inches high are used when the high water is over, maintaining the level above the crest of the dam for a much longer time than would be the case otherwise. These sometimes lessen the flow farther down stream for the time.

FLUCTUATION DUE TO THE MILLS.—There is an element of unsteadiness in the Lower Fox itself, due to the improvements upon it. On Sundays the mills at the head of the stream are shut down, and all the water that passes down the river goes over the crest of the Neenah dam. The result is that, except in high water, the river

lowers nearly a foot at Appleton, and does not recover its stage until well on into Monday. At Depère, the lowest power, they feel the effects of this all day Monday.

FEATURES FAVORABLE TO WATER-POWER.—The river is not troubled with ice-gorges and damage from floating ice, because the ice on lake Winnebago quietly melts without gorging the river. There is difficulty after very cold nights from anchor-ice forming on the rapids, and some of the mills have their racks choked with it in exceptionally cold weather; but the system of slackwater navigation used in part on the river makes the difficulty less than it would otherwise be.

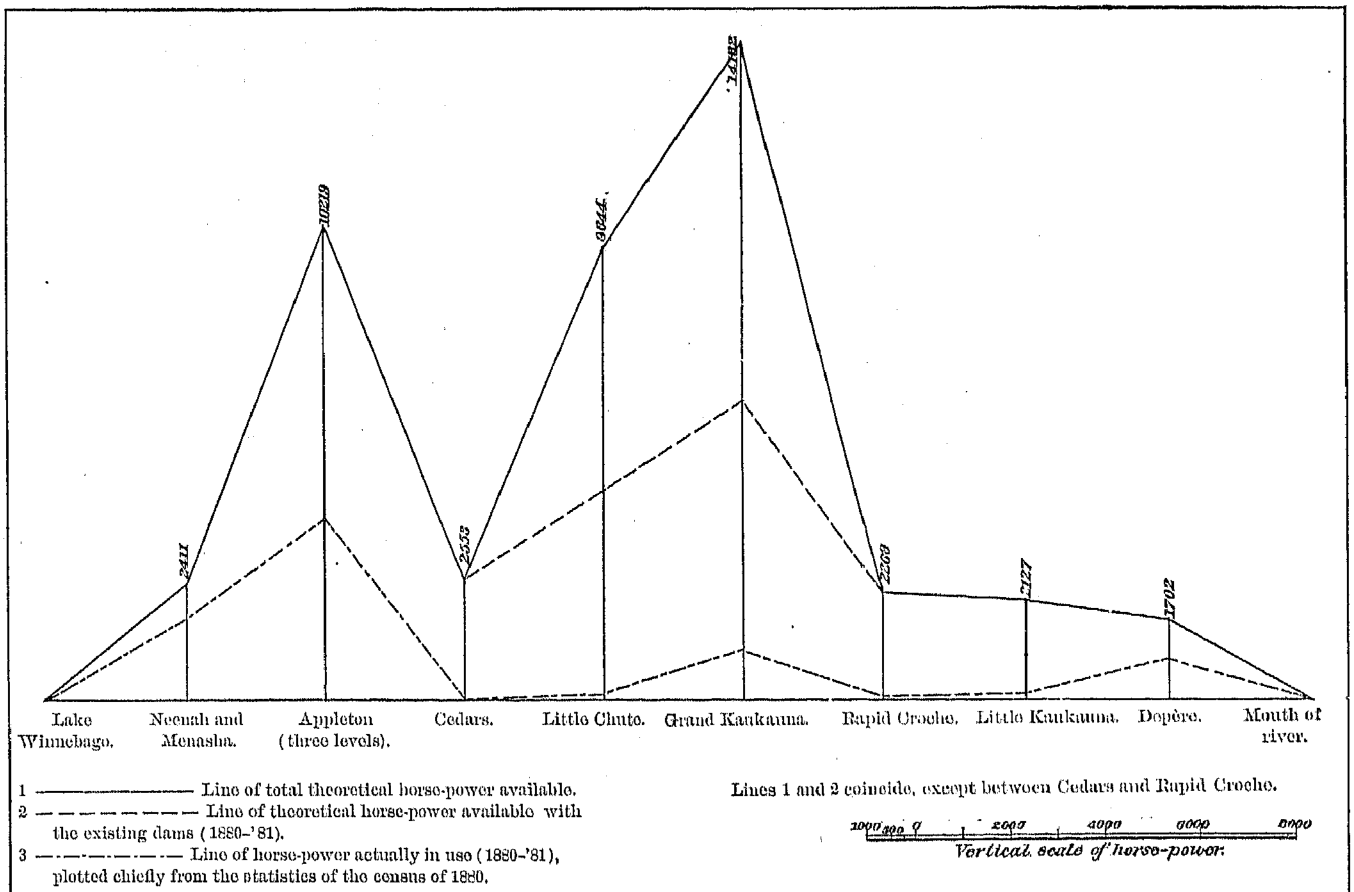
Because the stream is so uniform in its flow the mills are not stopped from backwater, as is the case with so many water-powers. Another advantage from the steadiness of the river, and perhaps one of the most important ones, is the facility for railroading right in the channel of the river, running side-tracks wherever needed to the different manufactories. At Appleton especially is this marked, because the power is there most developed. Tracks run hither and thither on a short trestle or crib work, only a few feet above the water, with no danger from freshets, and no fear of ice-gorges.

Again, because the freshets rise so little above the ordinary stage of the river, mills can be built out into the stream with perfect safety, and in some places, where the bluffs scarcely leave room for the canal, this is very advantageous.

The bed is a hard limestone at nearly all of the powers, which makes an excellent foundation. It is a good building-stone, bluish-gray, and compact in the best samples. The government has opened excellent quarries at Grand Kaukauna and on Duck creek for supplying the erection of the fine cut-stone locks on the canal, and in the work of improving the powers this stone is removed from the bed and used right at hand for the building of dams, retaining walls, etc.

DESCRIPTION OF THE WATER-POWERS ALONG THE LOWER FOX.

A table has been already given of the water-power localities, the distances apart, and the total fall between them. From the source down they are: 1. Neenah and Menasha; 2. Appleton (upper, middle, and lower levels); 3. Cedars; 4. Little Chute; 5. Grand Kaukauna; 6. Rapid Croche; 7. Little Kaukauna; 8. Depère.



WATER-POWER DIAGRAMS FOR THE LOWER FOX RIVER.

The general features have been already considered, and we will now discuss each one of the above-mentioned places separately.

The accompanying maps were thus prepared. The outlines were traced from the maps of the Green Bay and Mississippi Canal Company chiefly and partly from the maps in the possession of the United States engineers in charge of the river. The different manufactories are sketched in, chiefly from rough plans made by me in the field, but those at Menasha, Little Chute, and Grand Kaukauna were entirely located by Captain N. M. Edwards, of Appleton. It will be readily understood that the buildings are not drawn to scale, and that their location is approximate, although it is believed to be not far out of the way.

The figures 10, 15, etc., in the channel represent the average available head of water opposite those points and start with the level of the water in the pond as a datum plain.

Descriptions of the dams on the river and drawings of them are given in a separate section further on.

NEENAH AND MENASHA.

The Lower Fox starts in two channels from the northern end of lake Winnebago. These channels, which are nearly parallel, are about three-fourths of a mile apart, and flow almost west, the northern one for 2 miles, the southern for 1¼ miles, and then empty into little lake Butte des Mortes. This lake is 3¼ miles long by about half a mile wide, and is merely an expansion of the river, running north, at right angles to the direction of the two channels. At its northern end it narrows down to 1,000 feet, the width of the river there. At the lower ends of the two channels above mentioned are two towns: Menasha, on the northern side of the northern channel, and Neenah, on the southern side of the southern channel. These towns give their names to the respective channels. The population of the first in 1880 was 3,140, and of the second 4,203. The two towns are about one mile apart, and there is constant communication over the low island intervening.

The banks of the river here are quite low, being only about 10 feet above the water, and above the dams there is some slight overflow at times. These dams, situated one on each channel, act in concert to preserve the level of lake Winnebago. The navigation is now along the Menasha, or northern channel. The Menasha dam is situated a little less than 1¼ miles by water from the head of this channel. The Neenah dam is slightly over three-fourths of a mile from the head of its channel. These dams have flooded out a rapid called Winnebago rapids.

Fall and power.—The total fall from the level above the dam to the level of little lake Butte des Mortes is about 10 feet, but there is not, on the average, more than 8½ feet available for power. This gives a total theoretical power of 2,411 horse-power at an ordinary low-water stage. It is claimed that, as near as can be estimated, two-thirds of the flow the Neenah channel is entitled to, and the rest passes through the Menasha channel. Hence, the theoretical power at Neenah is 1,607, and at Menasha 804 horse-power. This power is largely employed, especially at Neenah, and the two towns rank next to Appleton as manufacturing centers along the Lower Fox.

Menasha.—At Menasha is located the government canal, as already mentioned. It runs on the right or north bank of the channel from just above the dam. For the first 1,600 feet to the highway bridge its course is southwest; it then turns and runs nearly northwest 2,720 feet to little lake Butte des Mortes. The one lock is at the extreme lower end.

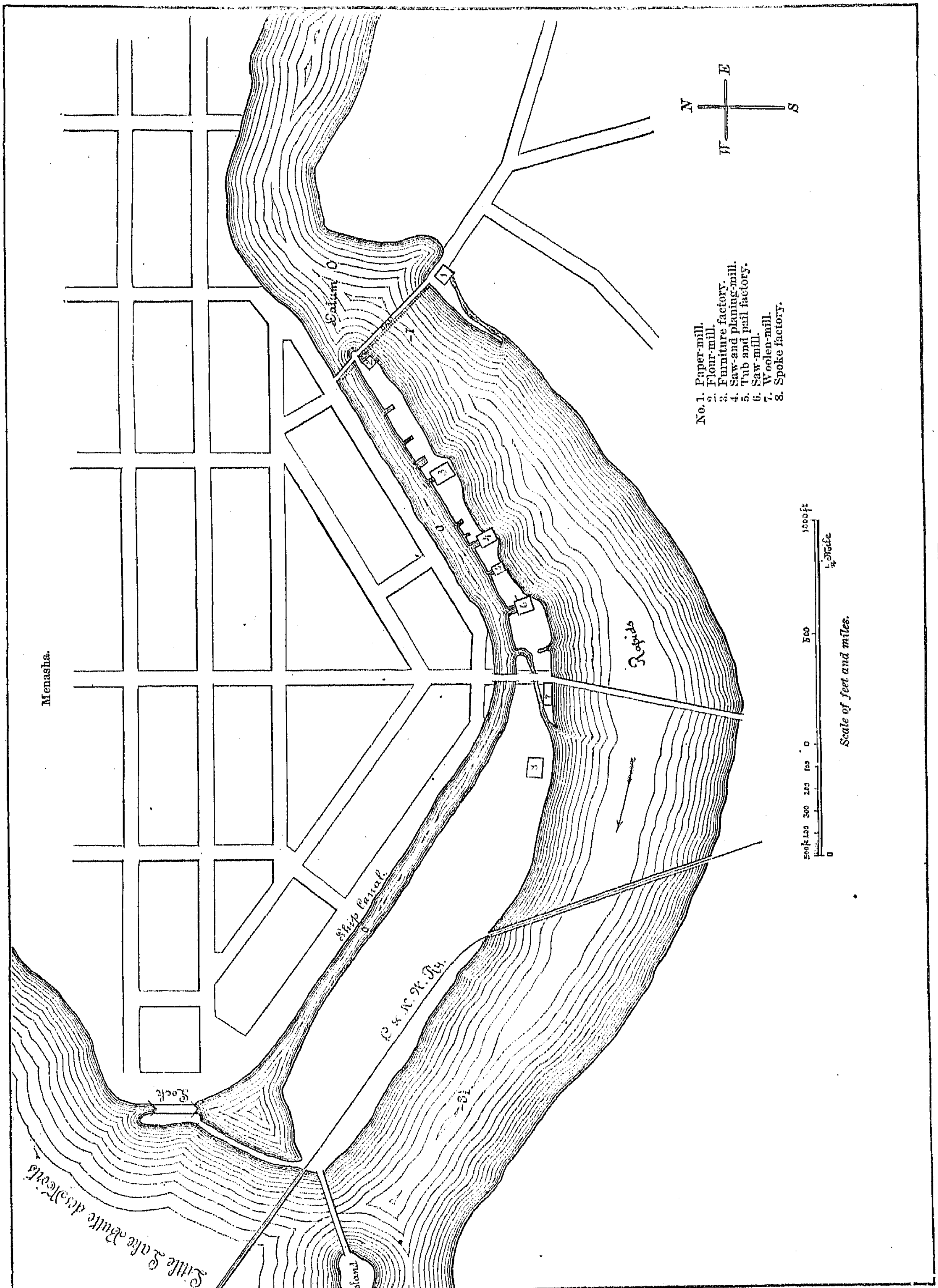
The United States government entered into a contract with certain persons, whereby they were to construct the navigation improvements at Menasha and receive the ownership of the water-power there. The Green Bay and Mississippi Canal Company has, therefore, no connection with this power.

The river channel immediately above the dam is about 745 feet wide; a short distance above it narrows down to 375 feet. The strip of land between the canal and the channel varies from 80 to 160 feet wide between the dam and the highway bridge. Below the bridge it widens out to about 425 feet. It is on this strip of land that the water-power is utilized from the canal. The lock being at the end, the water-surface is, or should be, level in the canal, giving a lift of 10 feet at the lock. The available head at the dam is 7 feet; hence the channel falls 3 feet below the dam. The available head at the manufactories varies from 7 feet at the dam to probably 8½ feet on the average at the lowest building; but an element of uncertainty enters there, because of the mills drawing down the level in the canal when all are running. General Warren, in his report of 1876, makes mention of their lowering the depth for navigation in the lower portion of the canal several feet. The first power used is right at the dam; the last is about 2,000 feet below, a few hundred feet below the highway bridge. With the exception of a paper-mill at the south abutment of the dam, and a flouring-mill at the north abutment, all the power utilized is taken from the canal.

The industries using water-power from the canal are in the following order, going down stream: Furniture factory, saw- and planing-mill, tub and pail factory, saw-mill, woolen-mill, hub and spoke factory.

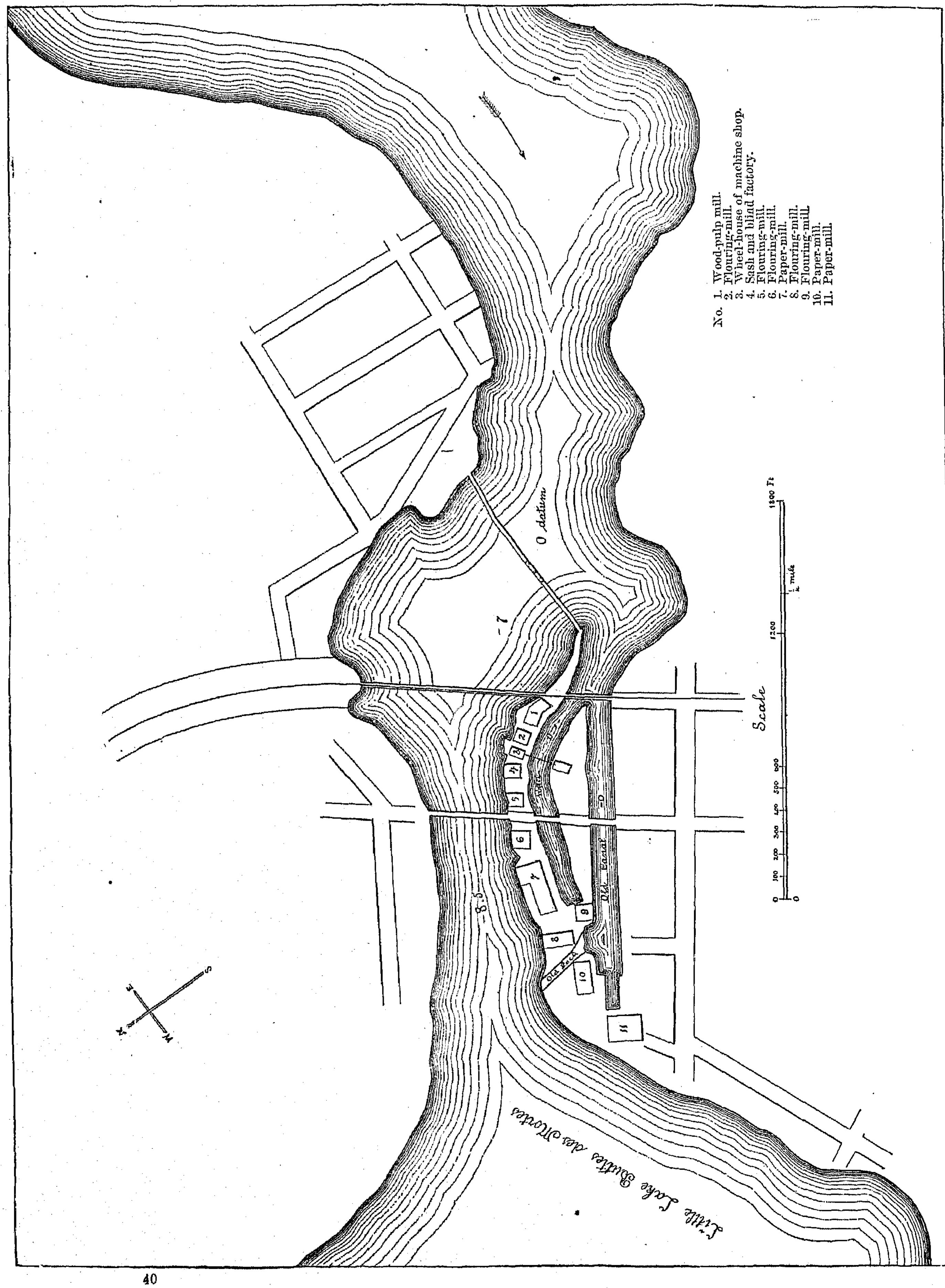
Neenah.—At Neenah the dam runs diagonally down the stream from the right bank to the side on which the town is situated. Just above the dam the channel is 600 feet wide, but 1,200 feet above it widens out to over 1,000 feet. At this point is a bar strewn with bowlders, which at times makes it difficult for sail-boats to pass. As shown by the map, a dike of earth and stone runs down stream a few hundred feet to the shore-line on the

Neenah side. Where the dam and dike join the shore recedes, and from the bay thus formed two races start: the one nearest to the shore following its bend, and stopping after having run down stream 1,000 feet; the other keeping a



LOWER FOX RIVER AT MENASHA, WISCONSIN.

straight course across the bend for 1,350 feet, until it again strikes the river bank. This canal was formerly used by the government for navigation before the move was made to the Menasha channel. The position of the old



LOWER FOX RIVER AT NEENAH, WISCONSIN.

lock is shown in the map. For distinction, the first race is called the race, and the second the canal, and it is from these two that all the water-power used at Neenah is taken.

The riparian owners on the Neenah channel improved the water-power before the ship-canal was commenced, and thus obtained a prior right under a state charter. The Green Bay and Mississippi Canal Company have, as in the case of Menasha, no interest in this power.

The strip of land between the stream and the race varies from 100 to 150 feet wide, and on it are most of the manufactories. It will be readily understood that the race would interfere with the tail-races from the canal, and hence all the power used from that is taken from below the race. The main street leading over to Menasha nearly bisects the length of both the race and the canal, and from it drive-ways lead at right angles to the manufactories.

The head of water at Menasha averages 7 feet at the upper end of the race and 8½ feet at the foot. The crest of the Menasha dam is higher than that of the Neenah, and on the latter flash-boards are used in low water, raising the level 18 inches.

The manufacturers are rather averse to the leasing of more power, as they feel it would lessen theirs. It is claimed that the river below has risen into the tail-races of the lower mills some 2 feet above its old level, owing to the raising of the upper level at Appleton.

The Chicago and Northwestern railroad crosses the river on a line with the heads of these two races.

The following manufactories are situated upon the race: 1. Wood-pulp mill; 2. Flour-mill; 3. Wheel-house of machine-shop across the race (wire-rope transmission); 4. Sash and blind factory; 5. Flour-mill; 6. Flour-mill; 7. Paper-mill. The following manufactories are situated upon the canal: 1. Flour-mill; 2. Flour-mill; 3. Paper-mill; 4. Paper-mill.

There is probably not much available power unutilized there, except in high water. However, there is a large portion of the year when there is a large surplus wasted. The formation of the bank at the eastern end of the dam is such as to make it possible to build a race there and utilize this surplus.

THE RIVER FROM NEENAH AND MENASHA DOWN TO APPLETON.

The distance from the foot of the Menasha channel to the upper dam at Appleton is 5 miles. All this distance is slackwater, caused by the Appleton dam, and the navigation is in the stream itself. The first 2¼ miles of the course are through the little lake Butte des Mortes, averaging about half a mile wide. Below that the river bends gradually, so that the course is in a general northeast direction to Appleton. At the foot of the lake the width is 1,000 feet, but it then narrows to an average of 600 to 700, and is only 400 feet wide in one or two places. The channel is gently widening between well-wooded clay banks, which rise to a height of 50 or 60 feet as Appleton is approached. Along little lake Butte des Mortes the shores are low, and in places is marshy.

APPLETON.

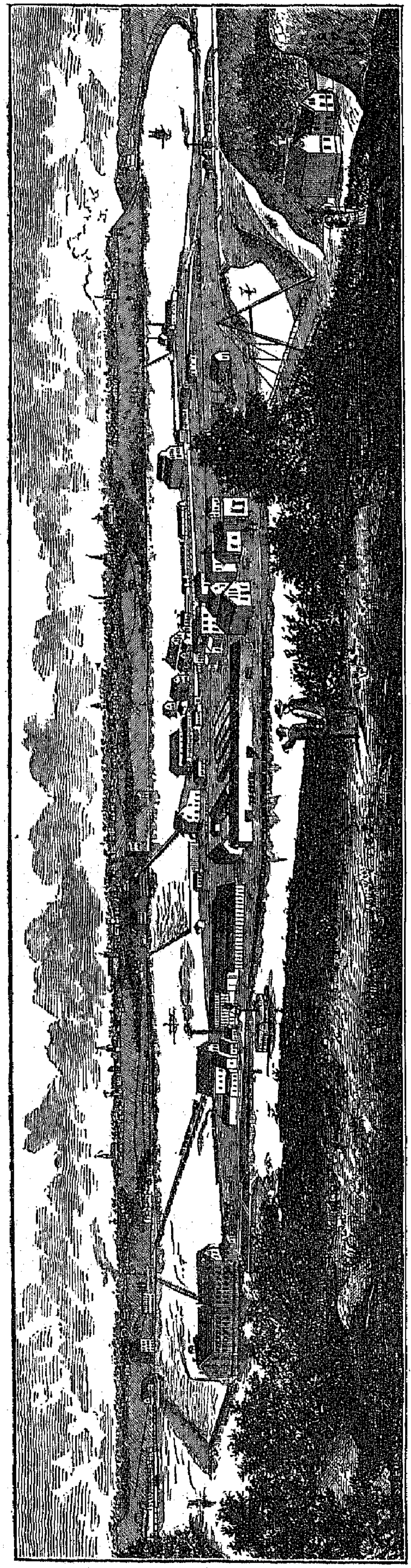
At this place is situated the water-power which has attracted so much attention to the Lower Fox valley as a manufacturing region, not on account of its having the best series of powers upon the river—Grand Kaukauna is fully the equal of it in that respect—but because it is here that the greatest development, exceeding 10,000 horse-power, has taken place. Its capabilities are by no means exhausted. Having so much the advantage of an earlier start than the localities farther down stream, it bids fair, for many years, to assert its claim to the title of the "Queen City of the Fox".

The following table, giving the amount of business transacted by the manufacturers of Appleton for the year 1880, is obtained from the annual review of the Appleton *Post:*

Farming implements	$70, 000
Furniture	75, 000
Flour	890, 000
Gas	12, 000
Hubs and spokes	86, 000
Iron	355, 000
Lumber	80, 000
Leather	85, 000
Lime, brick, etc	30, 000
Machinery	38, 000
Pumps	8, 500
Paper (print and wrapping)	850, 000
Staves and heading	110, 000
Sash, doors, and blinds	75, 000
Woolen goods	200, 000
Wood pulp	140, 000
Others	78, 000
Total	3, 182, 500
Total for 1879	2, 458, 000

Nearly all the different branches of manufacture mentioned make use of the water-power, and it will be noticed that the manufactures of flour and of paper are the largest items.

Freighting facilities of Appleton.—These are unusually good. Entering the city are the Chicago and Northwestern, the Milwaukee and Northern, controlled by the Wisconsin Central, and the Milwaukee, Lake Shore and Western railroads. In addition to these is the water communication, and there is an outlet and an inlet in all directions, north, south, east, and west, easy access to the lake ports, and a healthy competition, which will suffice to keep freight rates within reasonable bounds. The Chicago and Northwestern passes through the main town, but has a long side-track running along the river the whole length of the city, connecting with the main line at each end. The Milwaukee and Northern and the Milwaukee, Lake Shore and Western roads run up the river past the city, and have their depots near the water-power. A glance at the maps will show how the tracks pass here and there over the stream, giving the greatest facilities to the different manufactories.



View of the Lower Fox River at Appleton, Wisconsin, from the bluff on the south bank, Grand Chute island in the foreground.

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From the upper level at Appleton to the foot of the lower lock the total fall has been stated to be nearly 36.3 feet, of which, on the average, 36 feet is available for water-power. This descent is made in a distance of 1½ miles by river. Before reaching Appleton the river has been flowing nearly northeast; but at Appleton it takes a gradual bend to the southeast, and then, just above the lower dam, a more sudden one to the northeast again. These we may call the upper bend and the lower bend. On the north or left-hand bank the clay bluffs rise steep, 50 to 70 feet high, to the rather level surface back from the river, and on this the city is situated, overlooking the upper bend. Opposite the city, on the south side of the river, is a segment-shaped flat, 3,500 feet long and 1,200 to 1,500 feet wide for a considerable distance, elevated only a few feet above the river. Formerly a channel ran through this, called south channel, and the portion of the flat north of this channel is known as Grand Chute island. Back of this rise the bluffs, as on the north shore, and the river evidently washed the foot of these bluffs at some early time.

Navigation channel.—For navigation purposes the descent has been divided into two levels, the upper level and the lower level, by a government dam at the upper and lower ends of the descent, respectively. Between these two is the middle level, formed by a private dam, used entirely for water-power, and having no connection with the government.

The navigation is by the government canal from the upper level, just above the south end of the upper dam, skirting the bluffs on the south shore of the river to the slack water of the lower level. This canal is 3,600 feet long, averaging 100 feet wide, and there are three locks, with at least 6 feet of navigable depth. From the foot of this canal the navigation is by the slack water of the lower level for 1,800 feet, and then by a short canal of 1,000 feet length, with one lock, from the eastern end of the lower dam to the slack water of the Cedars dam below.

It is apparent that the water-power is divided into three levels, and each will be considered in its turn.

UPPER LEVEL AT APPLETON.

Starting from the foot of State street, a bulkhead and a dam run out into the stream about 250 feet from the north shore; and then a dam runs diagonally down stream for 700 feet to within 400 feet of the south shore. From this a stone retaining-wall, called the pier, runs down stream for 800 feet, there uniting with the south bank. The dam and the pier are built on the most substantial plans by the government, with stone from the Kaukauna quarry already mentioned, and are very fine structures. The bed of the river is hard limestone. From the foot of this stone pier starts the ship-canal. The available water-power of the upper level is from a race along the north shore at that end of the dam, from the ship-canal, and from the stone pier.

FALL AND POWER.—At the dam the available head averages 10 feet, but at the foot of the stone pier 16 feet is the usual head; and at a manufactory about 1,400 feet down from the dam, on the north bank, they claim to have an average head of 18 feet. The average available head is 16 feet, and with this head the ordinary low-water theoretical power has before been given as 4,538 horse-power; but of course there is a large portion of the year when it is much greater. The extreme variation of the head is 3 feet; the ordinary variation, about 18 inches. This is due to various causes. A low stage of water decreases the available head, owing to the mills drawing it down, and the flash-boards, when put on the Neenah dam, have also the effect of lowering the head. The wind, when blowing strong and continuously, influences the discharge from the lake, and hence affects the head at Appleton somewhat. Then there are fluctuations due to the shutting down of the Neenah and the Menasha mills, and it is said that on Sundays the head at Appleton is lowered a foot from that cause. There is no trouble from anchor ice, because it is all still water above this level; but there is difficulty sometimes from slush ice breaking off from the solid portion and choking the racks. With the north-shore race there is a difficulty from ice, which is mentioned in describing it.

NORTH-SHORE RACE.—This race is 600 feet long, and from 50 to 60 feet wide. Starting from the abutment of the dam, it runs close to the river, and between it and the river, partly built out into the water, are the mills. The access to these by team is over the canal, which is covered with planking supported by a framework of posts. The ice which passes into the canal lodges against these, and sometimes there is trouble from the flow being obstructed by it, and the head lowered.

As shown by the map, there are four mills upon the canal proper, all of them extensive. No. 1 is the Appleton Paper and Pulp Company's mills, controlling 500 horse-power, and drawing direct from the pond; No. 2 is the Kimberly, Clark & Co. flouring-mills, with a capacity of 500 barrels per day, using from 100 to 160 horse-power; No. 3 is the Kimberly, Clark & Co. paper-bag mill, which was being built in the spring of 1881, and will probably have a capacity of from seven to nine tons of paper in twenty-four hours; and No. 4 is the Atlas paper-mills, with a capacity of ten or twelve tons in twenty-four hours. The latter are supplied by the Atlas wood-pulp mills, on the opposite side of the river.

There is one more industry fed from this canal, and that is No. 5, the Appleton manufacturing works, which produce agricultural implements. They are situated on Water street, which skirts the bluff, are 1,400 feet down stream from the dam, and are supplied with water by a flume 700 feet long, leading from the end of the canal. This flume, which runs underground along Water street, is 4 feet in diameter, made of 2-inch pine plank, 6 inches wide and 16 feet long. The sections, of 16 feet in length, are connected by wrought-iron bands 4 inches wide and a quarter of an inch thick. Beside these there are hoops of ¾-inch round iron encircling the flume at intervals of 18 inches. This flume is always full of water under pressure, and the head at the wheel pit is 18 feet on the average. They use 45 horse-power by means of an American turbine 3 feet in diameter. There is no engineering difficulty in the way of continuing the canal several hundred feet beyond its present length, but the power at a low stage is already pretty well taken up, either used or leased, and it is hardly probable that this improvement will be made, as there are better localities to be mentioned for utilizing the remaining power. Under the title of "Legal condition of the water-power" it was stated that the Green Bay and Mississippi Canal Company had the right to all power drawn from the head of each rapid, but that there were exceptions where long-established usage claimed recognition. This north-shore race is one of those exceptions. A wing-dam improvement was made before the ship-canal was commenced. An official of the company said that the mills did not lease from it, and no claim was made because of long possession. The Atlas Paper and Pulp Company's mill has a side-track running to its rear, while all the lines along the river at Appleton pass in front of the mills along the north-shore race.

LONG PIER.—The power used on the south shore is almost entirely taken from this pier. The land along the canal is owned by the Green Bay and Mississippi Canal Company, and all the power taken from the upper level on the south shore is leased from them.

Along the stone pier is a series of lots, 50 by 100 feet, some sixteen or seventeen in number, owned by the Green Bay and Mississippi Canal Company. The foundation of this pier is solid limestone, and these lots are partly natural, partly built out into the stream. The average head of water varies from 12 feet at the head of the pier to 16 feet at the lower end. The water is taken through arched openings in the stone pier direct from the large bay at the head of the ship-canal. There can thus be no difficulty from drawing down the level, since the race is not large enough. There are ten of these openings in the pier, some 13½ by 6 feet, and others 15 by 7¼ feet. Two buildings use this power, both situated on the lower half of the pier; but they are large, and absorb pretty much all the room there. These are No. 6, the Atlas Paper Company's pulp-mills, and No. 7, the Western wood-pulp mills, the latter being owned by the large firm of Bradner, Smith & Co., of Chicago. The former supplies mill No. 4, across the river. The Atlas Paper Company are entitled to 1,000 horse-power at their mill, of which they use 700, and also have the control of the power from them up to the upper end of the pier, amounting to 1,500 horse-power. Thus the lots along the pier are pretty much all taken up. No. 7 uses from 600 to 700 horse-power. Each of the mills has four wheels, under 15 to 16 feet head.

The mills are situated 12 or 15 feet from the pier, and between them and the pier are wooden bulkheads at the openings in the latter. Each mill has a wing-dam running out into the river 50 feet or more, and then down

stream a short distance. By this contrivance the river is prevented from running in on the wheels, and a greater head is maintained. The wing-dam of No. 6 extends outside of No. 7, and a side-track of the Milwaukee and Northern railroad runs up to the mills, between them and the river. A wagon-road leads down to the middle level below, and also a bridge runs straight across the river to the Atlas Paper Company's mill, on the north-shore race.

SHIP-CANAL.—It now remains to describe the power upon the ship-canal from the upper level. A description of this canal has already been given, and, as previously stated, the Green Bay and Mississippi Canal Company has the right to draw water from the government canals at any point, provided they do not interfere with navigation. Hence they possess valuable power from the ship-canal, but there is only a small amount used at the extreme lower end of Grand Chute island. There are three locks on this canal: one at the foot of the stone pier, with 7¾ feet lift; one in the middle of the canal, with about 10¼ feet lift; and one at the foot, with 11 feet lift, and as the mills use from just above this last lock, they get a head nearly equal to its lift. No. 27 is a tannery, with about 10 feet head available; No. 28 is a hub and spoke factory, with about the same head; and No. 29 is a flouring-mill, with about 11 feet head, not now running. Nos. 27 and 28 discharge into the south channel, which is used as a tail-race by the mills on the middle level, while No. 29 discharges into the river direct. These use only a small amount of power.

UNUSED POWER.—As to unutilized sites at the upper level, it may be said that the most of them are upon the ship-canal. There are several unused at the stone pier, but they are already under the control of the manufactories now existing.

The ordinary low-water power of the upper level is popularly considered to be 5,000 horse-power, but with the ordinary low-water flow given by the engineers the theoretical power is 4,538 horse-power. Now, there cannot be less than 3,500 horse-power, at the lowest estimate, either used or under the control of the mills already upon the upper level, leaving 1,000 horse-power yet to be disposed of. It is true that for a large portion of the year there is much more power than this, but the estimates are made for an ordinary low stage. If this 1,000 horse-power were divided among industries, each using 50 horse-power, it would supply twenty of them, using, say, twenty lots of 50 feet front, and there is sufficient room on the Green Bay and Mississippi Canal Company's lots for this.

There are available sites at the right hand of the upper lock, where mills could take water from above the lock and discharge below, getting about 8 feet head, but the bulk of the available lots are on the flat between Mill street and the canal, and above the main street, which crosses Grand Chute island to the bridge. There they have room for twenty lots, each with a 50-foot frontage and 150 feet depth. In connection with this there is a scheme which would considerably alter the conditions of the upper and middle levels.

Thus far all of the tail-races of the upper level, except in the case of the small manufactories at the end of the ship-canal, empty into the river above the middle dam.

The Green Bay and Mississippi Canal Company have a plan, not yet carried out, however, for the utilization of the remaining power of the upper level, on the series of lots just mentioned, in a way which would discharge the water below the middle dam into the lower level. This would diminish the discharge through the middle level, but would give the Green Bay and Mississippi Canal Company an increase of head nearly equal to that available at the middle level, viz: 10 feet, giving them a total head of 25 or 26 feet. The plan is to build a conduit, which, starting from the pond just to the right of the upper lock, shall pass under the canal and then parallel to it, being always filled with water under hydrostatic pressure. The mills shall draw from it, and discharge into a tail-race leading into the south channel, and their wheels would be under a pressure due to a head of 25 feet. The power left to be utilized in this way is 1,000 horse-power at 16 feet head, requiring a flow of 551 cubic feet per second. The same volume of water at 25 feet head would give 1,563 theoretical horse-power, which is the power that would be available by this improvement.

It would hardly be practicable to run the large tail-race up to the upper six of the lots without considerable expense, because they extend out into the river; so they would only have the head of the upper level, viz: 16 feet. Supposing them to use 50 horse-power each, they would take 300 horse-power and a flow of 387.7 cubic feet per second to be utilized at the 25-foot head. This would give a theoretical power of 1,100 horse-power which, distributed among the fourteen remaining lots, would supply 78 horse-power to each.

The main lines of the Milwaukee and Northern and the Milwaukee, Lake Shore and Western railroads pass between these lots and the river; Mill street also runs alongside of them, giving easy communication with the town.

MIDDLE LEVEL AT APPLETON.

As already described, the middle level is independent of the government works, which connect the upper and lower levels by the ship-canal. This level is under the control of the individuals directly interested in the power, and is created solely in the interests of water-power. The Green Bay and Mississippi Canal Company make no claim upon the powers that may be obtainable at this level, and it comes under the fourth class of powers mentioned in describing the legal conditions of the Appleton water-power.

The dam is 2,400 feet below the upper dam, and is in itself about 450 feet long; but this does not represent the total width of the river at that point, which amounts to about 950 feet just above the dam. Below the dam the

width is about 650 feet from bank to bank. This dam is a timber frame construction, designed and built by Captain N. M. Edwards, and is described in the section devoted to that subject. The bed is limestone. From the north end of this dam a race leads down the north shore; at the south end the dam abuts on Grand Chute island, and from the basin at this end supplies West's hydraulic canal, as well as several manufactories which feed directly from it. These, with the exception of a power at the north abutment of the dam, are the three methods, and the only available ones, of using the power of the middle level.

HISTORY OF THE MIDDLE LEVEL.—Previous to 1877 there was no dam across the stream at the middle level, but wing-dams passed up stream several hundred feet from each of the abutments of the present dam, deflecting the water, the one into the race on the north shore, the other into the basin at the south end of the dam. In 1870 Mr. Edward West built the West's canal, leading from the basin down the island. Later, the individuals interested in the powers of the middle level formed a company for building and maintaining a dam, and in 1877 the present dam was constructed, and Mr. West's wing-dam removed. The other wing-dam, however, remains. This is the condition of the middle level to-day.

Mr. West is the most prominent owner on the middle level, and is identified with the early history of Appleton, having bought Grand Chute island when the forest covered it. He then predicted that the day would come when a ship-canal would pass through the valley and the water-power would be developed.

FALL AND POWER.—The average available head of the middle level is 10 feet, and with the total flow of the river, which it practically has, under the present conditions of the upper-level improvements the theoretical ordinary low-water power is 2,836 horse-power. If the contemplated improvement at the upper level just described is made—that is, using 1,563 horse-power at 25 feet head, discharging below the middle level—then the ordinary low-water discharge over the middle dam will be 2,500−551=1,949 cubic feet per second; but if the improvement is made using 300 horse-power at about 8 feet head, and 1,100 horse-power at 25 feet head, then the discharge over the middle dam in ordinary low water will be 2,500−387.7=2,112.3 cubic feet per second. In the first case, the power would be 2,211 theoretical horse-power; in the second case, 2,396 theoretical horse-power.

Thus, there are three conditions, to one of which the power of the middle level will probably be subject:

1. A continuation of the present situation, in which, practically, all the discharge of the river goes through the middle level, giving an ordinary low-stage power of 2,836 theoretical horse-power.

2. An improvement on the upper level of 300 horse-power at about 8 feet head, and 1,100 horse-power at 25 feet head, in which case the ordinary low-water power of the middle level will be 2,396 theoretical horse-power.

3. An improvement on the upper level of 1,563 horse-power at 25 feet head, in which case the ordinary low-water power of the middle level will be 2,211 theoretical horse-power.

Of course it would be possible to use the surplus power of the upper level from the north-shore race, as already mentioned, in which case the first condition would occur, or from the lower end of the ship-canal, when the equivalent of the third condition would be the result. Of all these it is probable that for some time the first condition will be the state of the power, with a prospect in the future of the second condition occurring; that is, the ordinary low-stage power of the middle level will be 2,836 theoretical horse-power for some time, with the chances of its being reduced in the future to 2,396 horse-power, or perhaps to 2,211 horse-power.

The variation in the head is the same in character as at the upper level. As the river is a mass of rapids for several hundred feet from the upper dam to the middle level, there is a chance for anchor ice to form, and the manufacturers on the middle level are troubled with this to some extent in very cold seasons.

In order to keep the water as much as possible at a uniform level in the pond and avoid the expense of extensive gates and gearing, the method was taken of using what are called needles, as described in the section on dams. They consist of scantling about 3 inches wide, which are thrust down at the crest of the dam, and thus the width of the overflow is diminished. A man is employed to attend to this matter, and to regulate the waste over the dam according to the amount of water used. The water surface can be kept within a variation of 3 inches. When all the mills are running, and the water is not high, the needles are all put in, and as the mills shut down he goes along and removes some of them. There is always a space of about 75 feet at the north end of the dam where no needles are placed.

The powers of the middle level at Appleton are divided for description thus: North-shore race (middle level); West's canal; the basin. The latter is merely a portion of the pond.

NORTH-SHORE RACE.—This race (middle level) is about 800 feet long, and runs down stream from the dam between the river and Water street. In the upper part of its course the race is of fair size, but in the lower third it is hardly more than 15 feet wide.

The old wing-wall, which collected the water before the dam was built, still exists, and serves as a bed for the railroad track to the rear of the Appleton paper and pulp mills, on the upper level. This wing-wall extends up stream about 1,500 feet, and there is a waste-weir connecting the waters on each side of it. Extending, as it does, so far up stream, it acts to a great extent independently of the middle dam, as was the case before the dam was built. It collects a portion of the tail-water from the mills on the north-shore race (upper level), but it is largely supplied by the river direct. The head is ordinarily maintained as good as in the pond proper, and often, as was the case when visited, there is a flow, with a head of several inches, through the waste-weir in the wing-dam into the pond.

About 250 feet below the dam the highway bridge crosses the river to Grand Chute island. The race, above the crossing being planked over, a broad space is made for the approach of wagons, and the railroad tracks pass along the rear of the mills at the upper portion of this race. The head varies from an average of 9 feet at the upper end of the race to 12 feet at the foot.

The mills are as follows, beginning at the upper end of the race: No. 19, a planing-mill, fed from the pond, and independent of the race and wing-dam, but mentioned here because of its locality, using only a moderate power; No. 20, Appleton flouring-mills, Mr. S. R. Willy, proprietor, the wheels of which are old-fashioned and very wasteful of water; No. 21, Lawrence flouring-mills of Hauert & Wambold; No. 22, Outagamie flouring-mills, Cross & Willy proprietors; and No. 23, Riverside flouring-mills, M. T. Boult, proprietor. The power used in Nos. 21, 22, and 23 averages from 100 to 150 horse-power each. No. 24 is T. W. Brown's pump factory, using 30 horse-power, and having a center-discharge wheel of 7 feet diameter under about 10 feet head; No. 25, a machine shop, with 12 feet head; not running in the winter of 1880–'81; and No. 26, a small woolen-mill, with about 12 feet head. This is the last power used upon the race. Between No. 23 and No. 24 there are about 300 feet of unoccupied mill-sites, and about the same distance between No. 24 and No. 25.

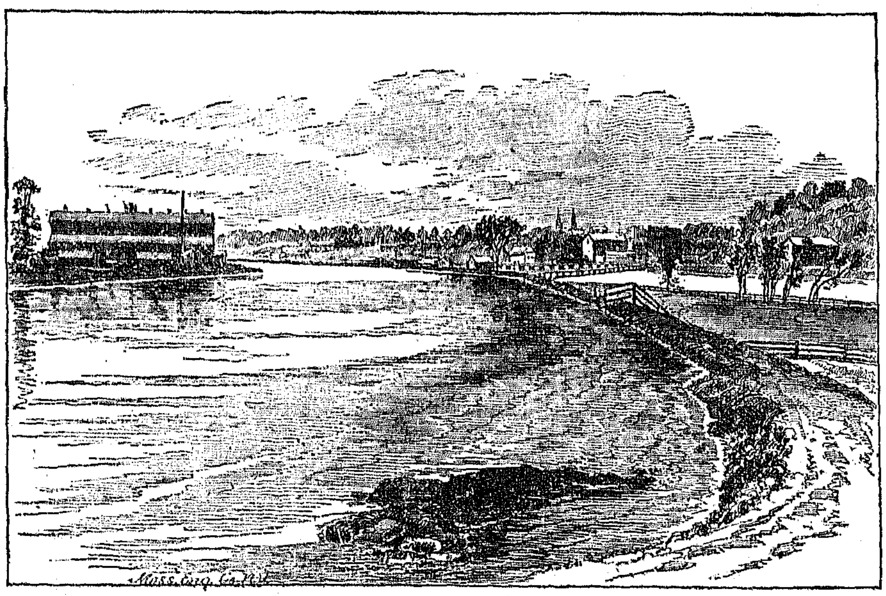
The race could be extended several hundred feet farther down the river and the mills could be built out over the stream, as is now done, because the bluffs crowd the race near the river's edge. That is a great disadvantage about the sites at the lower end of the race, there not being much room for transportation. As the mills are built out over the river on piles, the same scheme is used for obtaining a tail-race as at the pulp-mills on the upper level. Starting above the mill, a wing-dam runs out diagonally into the river, and then down stream, keeping the flow of the river away from the wheels.

There is plenty of room on Grand Chute island for using the unutilized power of the middle level, reckoned at an ordinary low stage of water, and the sites are much more favorable than along the lower part of the north-shore race (middle level).

THE BASIN.—The bridge from the main street over Grand Chute island crosses the river about 250 feet below the dam at the north end, but at the island extremity the dam is not over 150 feet above the bridge. The basin, if it may be so called for distinction, runs from the dam down to the street and there stops. West's canal starts from the northern corner of this basin. There are four manufactories using water direct from the basin, two of them above the street and two below, and the head averages 10 feet.

No. 8, above the street, is the machine and repair shops of Proctor, Wetlaufer & Co., using, on the average, 10 horse-power. Their head-race runs under No. 9, and their tail-race discharges into the south channel. No. 9 is the Champion steel horse-nail works. They use 75 horse-power, and their tail-race unites with that of No. 8. No. 10 is the Valley Pulp and Paper Company. These pulp-works were started in the end of the year 1880, and the intention is to manufacture paper later. They expected to use 325 horse-power. No. 11 is Billings & Morrison's hub and spoke factory. This, as well as Nos. 13 and 14, has a wooden bulkhead running down from the basin along the upper end of the south channel, into which the wheels discharge. The power used by No. 11 is 40 horse-power. No. 13 is the Appleton foundry and machine-shop, Morgan & Bassett proprietors. They use about 60 horse-power.

WEST'S CANAL.—This canal extends from the basin down Grand Chute island for about 1,700 feet, running nearly parallel to the south channel, as also to the main channel of the river, and there is a bend of 10 or 15 degrees in the middle of its length. The head of the canal is at the upper, and the foot at the lower bridge, leading to Grand Chute island. It is really built up upon the island, as both sides and the end are formed of embankments. The cost of construction was about $40,000. The embankments are 12 or 15 feet high at the lower end, and the canal bed is excavated in the gravel-bed formation of the island. The canal is 130 feet wide, and its bed is 17 feet below the crest of the embankments. These are earth and stone, 45 feet wide at the base and about 10 feet across the crest, which is 2 or 3 feet above the water surface. At the bulkhead there are four openings, each 22 feet wide, with a depth of water in an average low stage of 8½ feet, and between the openings are three cribs, 7 feet through. The total bulkhead opening is 88 by 8½ feet in an ordinary low stage, or 748 square feet, and the openings can be closed with "needles", if it is necessary



APPLETON, WISCONSIN: VIEW OF WEST'S CANAL FROM THE LOWER END

at any time to shut off the water and drain the canal. The head averages 10 feet. The manufactories are situated back of the embankments, those on the south side discharging into the south channel, and those upon the north embankment having tail-races leading into the main river.

The manufactories upon the north side are No. 14, Appleton woolen-mills, owned by Hutchison & Co. Their warehouse is No. 12, situated on the upper street, crossing the island. In the summer of 1881 this mill was burned, but the proprietors intend to rebuild on a much more extensive scale. No. 16 is the Appleton Chair and Bedstead Company, Mr. Atkinson, proprietor, which was burned with No. 14. It used 40, but was entitled to 60 horse-power.

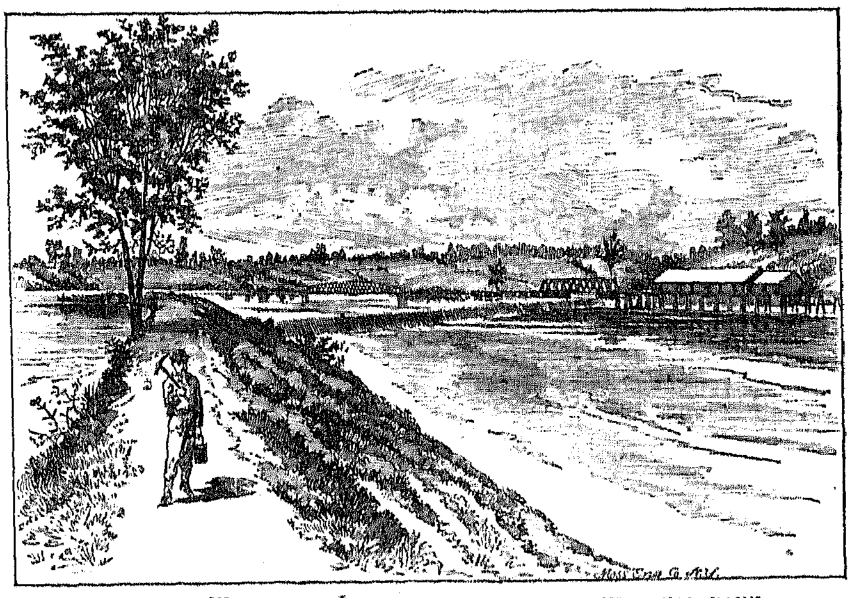
The manufactories upon the north embankment are No. 15, Appleton hub and spoke factory, Marston & Beveridge, proprietors, using 80 horse-power under 10 feet head; and No. 17, Fleming & Co.'s flax-mills, situated near the lower end of the canal. They were completing the building of these mills in the spring of 1881. This is the introduction of an industry new to the Fox River region. Just west of No. 17 a large paper-mill was being erected in the summer of 1881.

The remaining building using power from West's canal is the works of the Appleton Furnace Company, No. 18, of which Mr. A. L. Smith, of Appleton, is president. Its capacity in 1880 was from 35 to 40 tons of pig iron produced per twenty-four hours, extensive use being made of the rich Menominee ores. Situated on the street opposite the foot of the canal, they take the water in an underground flume, and control 400 horse-power. This is the farthest down stream of all the powers used from the middle level.

There is, of course, abundant capacity in this canal for a greater flow than is now used, and, as the map shows, there is a large amount of unoccupied room. At a low estimate, there must be 2,500 feet unoccupied facing on the canal, and the lots running back from it are 150 to nearly 300 feet in depth, giving fine building sites. Railroad tracks of different companies run along both sides of the canal, and the facilities for approach by team at either end are excellent. Undoubtedly the best water-power sites to be obtained on the middle level are upon this canal, and indeed, all things considered, they are hardly to be excelled at Appleton.

LOWER LEVEL AT APPLETON.

This level, as stated previously, is controlled by the government for purposes of navigation. The dam is situated just below the lower bend of the river, 4,600 feet below the middle dam and 1,300 from the lower end of Grand Chute island. The river just above is 485 feet wide. The government dam, 417 feet long, runs diagonally down, at an angle of about 45 degrees with the channel, to an embankment which runs down stream 600 feet to the lower bridge of Appleton, and back of this embankment is the ship-canal of the lower level. The embankment continues about 175 feet below the bridge to the one lock of the lower level. At the bridge the river widens out on the north shore to 600 feet across.



APPLETON, WISCONSIN: LOWER DAM, FROM THE SHIP-CANAL BANK.

For the first 1,500 feet below the dam there is a natural fall in the river of about 3 feet. Below the lower bend the course of the river is northeast, so that what was the north bank on the other levels is the west bank at the lower level, and the former south bank becomes the east bank. The river runs close to the west bluffs, except right at the dam, but on the east shore is a flat, 200 to 300 feet wide, between the river and the bluffs. There are four methods here of utilizing the power. They are: From the west end of the dam, from a west-shore race, from the ship-canal, and from the canal on the east shore, belonging to the Telulah Water-Power Company.

FALL AND POWER.—The head at the dam is only 7 feet, but farther down it is greater, and the average available head is about 10 feet. They get the whole flow of the river, and there is a prospect that this will always be the case. The ordinary low-water power of this level at 10 feet head is 2,836 theoretical horse-power, but of this only a small portion is now used. The fluctuations to which the powers above are subject are also experienced here, and there must be some additional variation in low water, due to the shutting down of the mills upon the upper level. The power No. 30, taken direct from the pond at the west abutment of the dam, is used by Messrs. Rose & Heath's saw-mill. The head is about 7 feet.

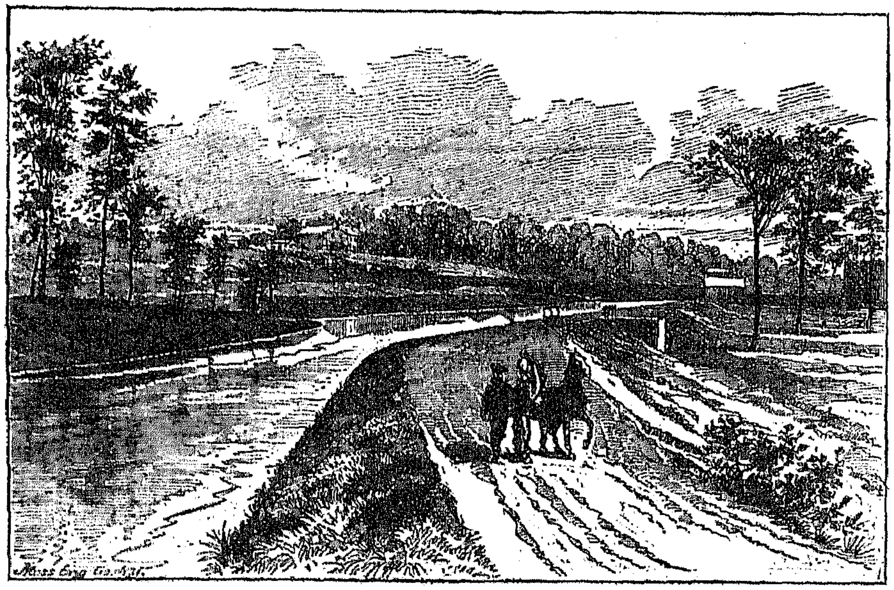
West-shore race.—The west-shore race starts from the pond, 450 feet above the dam. In 1878 it was extended 25 feet wide and 850 feet long down to about 150 feet above the bridge. In 1880 Messrs. Heath & Brothers, the owners, sold out to the Green Bay and Mississippi Canal Company, who now hold it, and in the spring and summer of 1881 they were busy making surveys for the extension of the work. By this extension the capacity will be much increased, and the plan has been proposed of running the race under the street and supplying mills below the bridge. The bluffs rise steep from the water, so that it would be necessary to build these mills out into the stream. As it is now, they own below the dam 480 feet of facing on the canal, and by building out into the bay on the west bank, already mentioned, they would have nine lots of 50 feet face and 150 to 180 feet depth. The Chicago and Northwestern railroad track runs past these lots. There are at present two manufactories upon the lower part of the race: No. 31, Dickerson's shutter works; and No. 32, Baum & Huhn's custom flouring-mill. The head at these mills averages about 8 feet.

The west-shore race is entitled to nearly one-fourth of the flow of the river, which would give it, at 10 feet head, 709 theoretical horse-power, or with an efficiency of 75 per cent., 532 available horse-power at an ordinary low stage. If this one-fourth flow is used at the upper part of the race with an average head of 8 feet, it will only furnish 567 theoretical horse-power, or 425 available horse-power. This would be sufficient to utilize all the lots with the smaller class of manufactories.

The only remaining manufactory upon the lower level is at the lock of the ship-canal, and is the only really good location on the canal. It is No. 33, Richmond Brothers' paper-mill, and has a head of about 10 feet.

Hyde & Harriman canal.—The canal of the Telulah Water-Power Company, on the east shore, has been known as the Hyde & Harriman canal. The case has been described under the heading of "Legal conditions of the Appleton water-powers".

Mr. Welcome Hyde and Judge J. E. Harriman, two well-known citizens of Appleton, owned the land, and the Green Bay and Mississippi Canal Company owned the power. These two gentlemen and the members of the Green Bay and Mississippi Canal Company, *as individuals*, organized themselves into the Telulah Water-Power Company and began improvements. Under the superintendence of Judge Harriman, ground was broken on August 15, 1880, and on November 13 of the same year the canal was completed. (*a*)



Appleton, Wisconsin: The Hyde & Harriman canal, lower level, looking up stream.

It has already been said that on the east shore the bluffs recede from the river at the lower dam and leave a flat from 300 to 450 feet wide, but about 2,400 feet below the dam they come close to the water's edge again. The canal starts at the head of the ship-canal, 600 feet above the bridge, and skirts the line of the bluffs all its length. For the first 1,500 feet it is straight, then, owing to the formation of the bluffs, it bends toward the river at an angle of about 40 degrees with its former direction, and continues straight for 750 feet more, making a total length of 2,250 feet. It could not be continued further without considerable expense, because the bluffs approach the river bank. The river side of the canal is an earth embankment all the way. At the head of the canal the cross-section is 120 by 7 feet; at the bridge it contracts to 80 feet in width, but is 11 feet deep; and in the lower portion the average width is about 60 feet. The head varies little at different points on the canal below the bridge, and averages 10 feet. At the head of the canal is a bulkhead for shutting off the water, which will be described in the section devoted to the construction. Practically, three-fourths of the flow of the river can be used in this canal, which, at an ordinary low stage and 10 feet head, will give 2,127 theoretical horse-power, or, with an efficiency of 75 per cent., 1,595 available horse-power. There are as yet no manufactories upon this canal, and of course the method of utilization will be to erect mills on the flat and facing it. The land along the upper portion of this canal is said to be owned by other persons, but the company owns twenty-five lots from the lower end of the

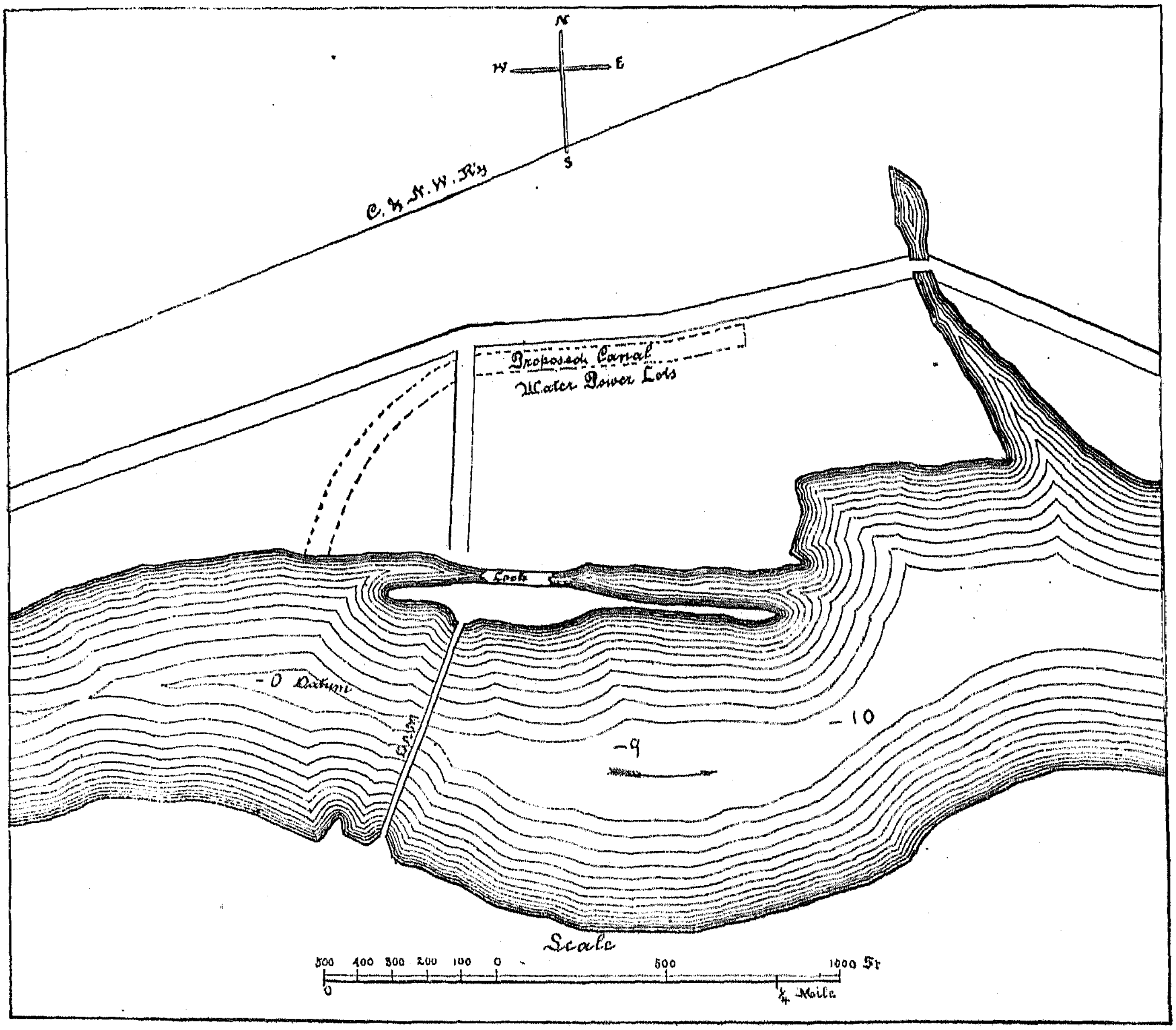
a Since writing the above, information has been received (September, 1881) that the Green Bay and Mississippi Canal Company has purchased the stock of the persons before interested with them, excepting a very small amount still held by Judge Harriman. Thus the Green Bay and Mississippi Canal Company now practically controls the lower level at Appleton, and will probably use the greater part of the water on the east side of the river.

canal up, with a frontage on the canal of 50 feet each, and a depth out to the river in most cases of 300 feet. The power would be sufficient at an ordinary low stage to supply each lot with 85 theoretical horse-power, but it is more likely that the power will be, to some extent, concentrated in establishments like wood-pulp mills, using 500 horse-power or more. The intention is to use the embankment for a wagon-road to the mills.

The Milwaukee, Lake Shore and Western railroad passes near, and the track of the Chicago and Northwestern railroad is just across the river; and so soon as the business will warrant it these roads will lay side-tracks along the canal lots, for which there is every facility.

THE RIVER FROM THE LOWER LEVEL AT APPLETON DOWN TO CEDARS.

In the engineering reports the distance is given as being 3 miles, but, measured on the United States engineers' map, it is 3.6 miles along the course of the river from dam to dam. In this distance the general course of the river is nearly northeast, but along the lower half there is a tendency to bend more to the east. The channel is gently winding all the way, and the navigation is by slack water from the Cedars dam to the foot of the canal at the lower level of Appleton. The clay bluffs, which for almost the whole distance spring close from the river's brink, are well wooded. The average width of the river in the distance named is about 600 feet; and in one or two places it widens out to 900 feet, and then again narrows to only 400 feet across.



LOWER FOX RIVER AT CEDARS, WISCONSIN.

CEDARS.

At Cedars the course of the river is nearly east. The bluffs upon the south shore rise near the river, but on the north a small creek enters, and the north-shore bluffs, which have been following close along the river bank, sweep around and run up this stream for a distance, and then again return to the river edge below, leaving a flat of 30 or 40 acres, through which the creek runs to the main stream.

The dam is situated about 1,000 feet below where the north bluff recedes from the river. Starting from the north shore, it runs straight across the current to the north bank. Two hundred and fifty feet above the dam the government canal starts from the Cedars level and runs 950 feet below the dam to the slack water of the Little Chute level, and about opposite the dam is the one lock, with a lift of 10 feet. The river immediately above and below the dam is about the same width as its length, which by the United States engineers is given as 810 feet. Below the canal the north shore recedes at the mouth of the creek, making the width for a short distance about 950 feet. There are no manufactories yet on this level, and there is no town; nothing but the dam and the lock.

FALL AND POWER.—The available head is about 9 feet, which, at an ordinary low stage, will give 2,553 theoretical horse-power, or, with an efficiency of 75 per cent., 1,915 effective horse-power. This power is, of course, owned by the Green Bay and Mississippi Canal Company.

While it would be possible to utilize the power, in part at least, upon the north bank, it is evident at a glance that the proper direction for improvement to take is to utilize the power upon the north side of the river. The Green Bay and Mississippi Canal Company own eight or nine 50 by 100 to 50 by 150 feet lots upon the strip of land between the canal and the river, which it would be easy to supply from above the lock with a head of 10 feet; but a better plan still is to start a canal where the north bluffs leave the river and run it along them to the highway which runs down the river about 700 feet north of it, and then to run the canal down the road. The mills would then be on the street, and the tail-race could be carried across the flat to the river very readily. There is a great abundance of room for this. A side-track from the Chicago and Northwestern railroad, a short distance north of the river, could be run down to the flat when the developments require it. This power is fully equal to that at the lower level at Appleton, and all it requires is improvement of its natural resources. The available sites on the north shore are most excellent, and all the power could be used there.

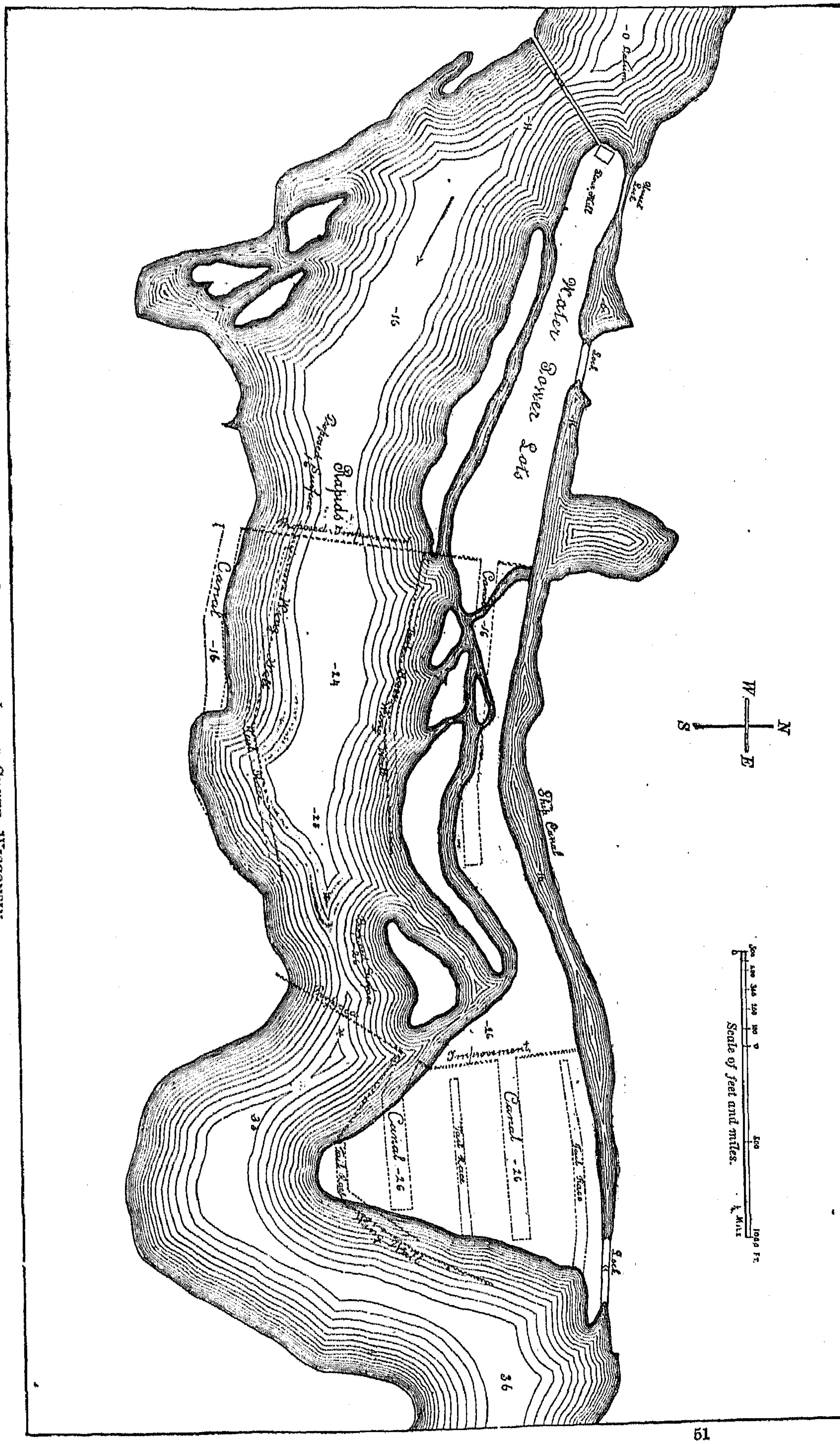
LITTLE CHUTE.

Little Chute is a small French Catholic village, started by a Jesuit mission, on the bluff overlooking the river. The dam is 4,000 feet below the Cedars dam, and, like it, is controlled by the government. Half way between the two dams the river bends so as to run southeast at Little Chute, and below the dam the river is rapid for 1½ miles, falling 38 feet from the level above. This rapid is passed by a canal built for a distance of 6,500 feet along the north side of the river. Nine hundred and fifty feet from the head is a lock of 16 feet lift, and at the foot is a composite lock of about 22 feet total lift. Above the dam the river is 840 feet wide, and it is about the same just below. Two thousand feet down a bay runs into the south bank, but the width is pretty uniform until near the foot of the rapids, where there is a sharp bend of 1,000 feet above the foot of the canal, and there the width is not over 700 feet; but at and below the canal it widens out to near its usual width. On the north side the bluffs set back slightly from the river, leaving a narrow flat, which is partly cut up into a number of small islands. At the foot of the canal there is a tongue of comparatively low land projecting about 1,000 feet toward the south, and on the south bank there is a break in the bluffs for 1,500 feet or more, where, although the bank is a number of feet above the water, still it does not rise in high bluffs. Two thousand five hundred feet below the dam, however, the bluffs start close from the water, and continue all the way down, to rise well wooded from the brink of the river.

This power is owned by the Green Bay and Mississippi Canal Company, which also possesses a large amount of the land about the canal.

FALL AND POWER.—The fall available is about 34 feet, which, at the ordinary low-water stage of the river, gives 9,644 theoretical, or, with an efficiency of 75 per cent., 7,233 effective horse-power. The only power used is by a flour-mill at the north abutment of the dam, with a head of about 11 feet, and it would be impossible to utilize the full power here without making extensive improvements. The only power of any consequence immediately available is from the ship-canal. From the head of the canal down to the foot of the lock the Green Bay and Mississippi Canal Company has room for about twenty lots of 50 feet each front on the canal and 200 feet depth down to the river. There is also room between the canal and the abutment of the dam for three more lots of about the same size; then on the north side of the lock there is room for three lots, making a total of twenty-six. The head would vary from 11 feet with the upper lots to 16 feet with the lower ones, making an average of about 14 feet head. Supposing each lot to use 75 horse-power, the total would be 1,955 theoretical horse-power, which, at 14 feet head, would require a volume of 1,231 cubic feet of water per second; but it would be necessary to considerably enlarge the canal before any such discharge as this through it would be permissible, on account of navigation. Provided the canal were sufficiently enlarged to permit the water to pass without interfering with navigation, and a sluice was built around the upper lock, manufactories could be built on the flat along the lower level for a distance of 2,000 feet or more, and be supplied from it, the head varying from 15 to about 18 feet.

If the canal was devoted to the interests of the water-power, and altered to suit the consequent conditions, a very extensive series of powers could be obtained; but the canal is for navigation, and this limits the utilization of



Lower Fox River at Little Chute, Wisconsin.

the water-power from it. If the canal were enlarged, the embankment raised, and the middle lock flooded out, a magnificent set of powers would be ready for use. At the foot the head would be about 34 feet, and by building a wing-wall and excavating a tail-race parallel to the canal the head would be very nearly that for several hundred feet above. But this is out of the question. The power, if utilized at all, will have to be made available in some other way.

IMPROVEMENTS POSSIBLE.—It is practicable to run a canal down the south bank for some 2,000 feet and utilize a head varying from 11 feet at the dam to about 20 feet at the foot. It is evident that to utilize the full flow of the river over the total fall of 36 feet it will be necessary to build at least another level at Little Chute, as is done at Appleton, for the discharge from mills at the upper portion of the rapids, using only 15 feet head, will go down the river over the remaining 19 feet of available fall in wasted rapids, unless again caught and held back for use. It is also practicable to utilize the remaining fall of the river at Little Chute by constructing two levels below the existing dam, dividing the total remaining fall of 20 feet into two parts of 10 feet each, as indicated on the map. The backwater from the upper one of the two proposed dams would be on the level of the canal at the foot of the first lock, 16 feet below the surface above the upper dam. This would, of course, reduce the head at the proposed canal from the upper level on the north shore to 16 feet at the lower end, the same as on the north bank.

The plan proposed by Captain N. M. Edwards is to leave an overflow on each dam of 600 to 700 feet, and from the extremities of this to run wing-walls down stream to the slack water below, thus restricting the river to 700 feet wide and reclaiming considerable land. Immediately back of these wing-walls tail-races would be excavated in the gravel and limestone up to the dam; next would be a series of water-power lots, and beyond these the water-power canals leading from the dam past the lots. The excavations for the tail-race, etc., would furnish excellent stone and gravel for the building of the walls of the canals and other works connected with the improvement.

For the lower one of the proposed levels the best place for improvement appears to be at the extensive flats on the north shore, near the lower lock, where there is a space for at least 3,000 feet of canal frontage. Tail-races could be excavated up to the dam and the full head utilized, and a wing-wall could be run down along the river, and behind this a tail-race be cut for mills at that point. Without this wing-wall and tail-race they could discharge directly in the river, obtaining about 8 feet head.

MEANS OF FREIGHTAGE.—The natural facilities for transportation are good at Little Chute, as the Milwaukee, Lake Shore and Western railroad can send a branch from the foot of the rapids along the south bank, and readily run side-tracks across the river on piers or trestles, as is done at Appleton. The Chicago and Northwestern railroad cannot so easily reach the river; still, as at Appleton, it can be done. As the upper one of the two levels proposed would be on the same level as the canal between the two locks, it would be possible to make a connection, so that vessels could go directly to the mills. Supposing that 9 feet head would be the actual available head at each of the two levels, the theoretical power of each at an ordinary low stage of the river would be 2,553 horse-power, or, with an efficiency of 75 per cent., 1,915 effective horse-power.

GRAND KAUKAUNA.

The name Kaukauna is derived from the Indian name of the place, *Kaukonnee*, meaning pickerel fishery. Well does it deserve the title of Grand. In a distance of one mile the river falls 50 feet. The power is undoubtedly the largest upon the Lower Fox, and it is in an excellent condition for improvement. Only since 1878 has any improvement of the water-powers been undertaken on an extensive basis, and the small village of Kaukauna, upon the north bank, has been of no prominence. Now, however, an era of improvement has been inaugurated, and the Grand Kaukauna water-powers are to claim recognition.

The railroad facilities will be excellent so soon as manufacturing warrants the laying of side-tracks. The Chicago and Northwestern railroad can easily run a branch down the river from the main road along the north side, and the Milwaukee, Lake Shore and Western railroad strikes the river valley at Grand Kaukauna on its way from the lake. They also can send branch tracks in all directions needed, as is done at Appleton. The Wisconsin Central Company will also be extending down the river, if possible, to have a share of the traffic, as soon as business will pay for the outlay.

For the first 5,000 feet below the Little Chute canal the river flows northeast between bluffs rising direct from the water's edge, but about 1,000 feet above the Kaukauna dam it turns, and runs for the length of the Grand Kaukauna rapids a little south of east. The Kaukauna dam is 2½ miles below that of the Little Chute, and makes slack water up to the Little Chute canal. The method used by the government for passing this 50-foot fall is to have a dam at the upper end, and a ship-canal 7,400 feet long, with five locks, on the north side of the river. In the middle of its course the canal is 1,000 feet from the river, and the river immediately above and below the dam is about 700 feet wide. From 1,000 to 1,500 feet below the dam the river begins to spread out in several channels between islands, numbered for convenience on the map. There are of these five principal and many smaller ones. Between these islands occur the rapids, over a hard limestone bed, from 1 to 6 feet below the surface soil. In the widest place the river spreads over a width of 2,200 feet; this is at about the middle of the rapids. The principal part of the flow would naturally pass down the northern channel.

Island No. 1, the largest, is also the highest one. It starts in a point 500 feet below the dam, and runs down stream 2,800 feet, with a maximum width of about 800 feet and an area of 27 acres. These islands are not much elevated above the river, and are, to a great extent, covered with a moderate growth of timber. The foundation of them all is the lime rock, forming the bed of the river.

The bluffs on the north bank run close to the river for about 1,400 feet below the dam; then they diverge from the river at an angle of about 35 degrees, and pass along the canal for about 3,000 feet further; and then they appear to recede to the north, leaving a broad flat for a mile below the foot of the rapids. On the south the bluffs leave the river's brink about 1,000 feet above the dam and follow along parallel with the bank, leaving a flat averaging 700 feet wide. This continues to about 1,500 feet above the foot of the rapids, where a headland juts out into the river. Opposite island No. 1 is a small valley coming down to the river, the channel of an entering creek.

The flats on each side of the river, and the numerous islands, give fine facilities for water-power improvement, the valley from bluff to bluff at the lower half of the rapids being about 3,500 feet wide.

FALL AND POWER.—With a head of 50 feet, the total theoretical horse-power, at an ordinary low-water stage, is 14,182 horse-power, or, with an efficiency of 75 per cent., 10,636 effective horse-power.

SHIP-CANAL.—Below the bridge which crosses island No. 1, 1,200 feet below the dam, there are 900 feet of frontage on the upper level of the ship-canal, with an average head of 16 feet. There is, of course, an immense number of sites below this on the ship-canal, but it is hardly probable that they will be used to any extent, because there are much better places elsewhere for taking the power, and also the requirements of navigation limit the amount of water that can be carried through the canal with its present size. The lots upon the upper level of the canal, however, will be, and are already used to a large extent. These lots are the property of the Green Bay and Mississippi Canal Company. The mills are: No. 1, paper, wood-pulp, and flour mills; No. 2, wood-pulp; No. 3, addition to No. 2, for the manufacture of artificial woodware; No. 4, planing-mill; No. 5, saw-mill; No. 6, hub and spoke factory.

Although no improvement of the water-power was undertaken on an extensive scale previous to 1880, there are two works of magnitude already finished. It is true that the sites are almost entirely vacant, but everything is ready for the setting of turbines sufficient to make Grand Kaukauna rapids the site of a large manufacturing town.

KAUKAUNA WATER-POWER COMPANY.—Several eastern capitalists, largely interested in the Milwaukee, Lake Shore and Western railroad, which first strikes the river at the south bank of Grand Kaukauna rapids, organized into an association called the Kaukauna Water-Power Company, and began improvements of a most extensive character on the south bank. The officers are: President, Joseph Vilas; vice-president, F. W. Rhinelander; general manager, H. G. H. Reed; treasurer, Charles Luling; engineer, James M. Barker.

The plan is to establish the car-shops of the railroad there, and to utilize the power in various kinds of manufacturing. A town, to be called Ledyard, has already been laid out, and the intention is to make it a great success. The locating of the shops there will immediately bring a considerable population. Starting above the dam, they have run a canal along the south bank, and intend to utilize the power along it. This power belongs to the third class, given under the title of the "Legal conditions of the Lower Fox water-powers", and the Green Bay and Mississippi Canal Company intend to bring suit, so soon as they take water from above the dam, to make them pay rent for it. Whatever be the decision, the improvement will undoubtedly remain.

The canal starts 400 feet above the dam, and for 400 feet it runs at an angle of about 45 degrees with the bank. When about 200 feet from the river it turns, and then runs nearly parallel with the south channel of the river for 2,000 feet, making a total length of 2,400 feet, and the lower fourth of its course is bent a few degrees away from the river. The greatest width is at the bulkheads, where it is 150 feet across. The smallest width is 86 feet; the depth, 11 feet. The total fall in the bed from the head-gates to the lower end is 2 feet, and the maximum velocity is calculated at 300 feet per minute. The area of flow at the bulkheads is 640 feet, and the depth 10 feet.

An embankment and a retaining-wall form the lower bank of the canal. This consists of a clay and gravelly earth embankment, held on the lower side by a vertical dry-masonry retaining-wall, with a flagstone coping. The sloping inner surface of this embankment is faced with laid stone, and the width on top is 20 feet. The inside slope is one to one, and the outside one to four. The retaining-wall is 3 feet wide on top, and the base averages 5 feet. The inside facing averages 18 inches thick, and there is a stone bulkhead at the upper end of the canal, about 150 feet from the head, for shutting off the water when repairs are necessary. The average head obtainable is 18 feet. The company has shut off the water from the south channel of the river by a dam, and intends using it for a tail-race, and, starting below the foot of the canal, has blasted a tail-race out of the limestone bed of the south channel, by which to make the available head of water nearly uniform along the canal. The closing of the south channel also gives more room. The company has a frontage along the canal, below the dam, of 1,900 feet, and at the end 200 feet additional. This would give 38 lots of 50 feet face each, and from 320 to 360 feet depth, down to the tail-race, beside four 50-foot lots facing the end of the canal.

The company claims the right to one-half the flow of the river, without interfering with navigation, and at the ordinary low-water flow of 2,500 cubic feet per second this would give, under 18 feet head, 2,553 theoretical horse-power.

About two-thirds of the way down the canal is a newly-erected wood-pulp mill, No. 8, which has leased 300 horse-power at $5 per horse-power per annum, and flumes were being built in the summer of 1881 at the extreme lower end of the canal for a cotton-mill, the first of its kind on the river.

The embankment will undoubtedly be used for a roadway, and we may be sure that the Milwaukee, Lake Shore and Western railroad will offer all the conveniences for shipping in its power. The main wagon-road leading over the river crosses the canal.

EDWARDS & MEADE POWER.—The remaining power improved since 1880, but not yet utilized, is the Edwards & Meade water-power. Captain N. M. Edwards lives in Appleton, and is the engineer of the Green Bay and Mississippi Canal Company. The owners have taken advantage of the channel branching off from the main north channel, between islands No. 1 and No. 2, and, forming it into a pocket by damming up the ends and sides, they intend to make use of the power at the lower end, where they control the land. This power comes under the fourth class mentioned in the section giving the legal conditions of the Lower Fox water-powers. This channel starts 600 feet below the bridge, and the dam is 1,000 feet below the head of the channel. The islands are low, and dikes run on each side almost the whole length of the channel. The pond averages about 200 feet wide, and at the broadest place is 275 feet across. The embankment along the south side is of earth, and the north side is bounded by a stone wall, built with limestone quarried right at hand.

Everything is done in a substantial manner. The stone wall is dry-laid rubble, with a straight batter on each side, and at every 3 or 4 feet distance on the inside is a string course of 3 or 4 inch oak plank, set into the masonry. To this is spiked plank facing. While building the wall openings were left for head-races to the mills. The dam at the end does not differ materially from the side wall.

The method of arranging the openings for flumes, so that they can be used, if required, without difficulty, is this: Heavy oak timbers and sills were built into the wall across the openings, and on these planks were spiked, flush with the inner face of the dam. When it is required to use the opening, the flume can be built up back of the planking, and then, when all is ready, the front timbers and planking can be cut away. Thus all necessity of coffer-dams around the opening while building the flume is avoided.

There is just below the head of the channel a bulkhead for shutting off the water similar to the one used on the Hyde & Harriman canal, at the lower level at Appleton. The head at the foot of the channel is 16 feet, and there is room for five 50-foot lots at the end of the pocket, and for eight or more on each side. There are also openings left at the end for extending large flumes down from the dam, by which 20 feet head can be obtained. The bed of the channel between islands No. 2 and No. 5, and also of that between islands No. 5 and No. 1, will make excellent tail-races. This power is estimated by Captain Edwards to be equivalent to from 1,200 to 1,500 horse-power, requiring, with 16 feet head, a volume of 826 cubic feet per second. A wood-pulp mill, No. 7, was erected in the winter of 1880–'81 at the lower end of the pocket, with a capacity of 2,200 pounds of dry pulp per twenty-four hours.

PROPOSED IMPROVEMENTS.—There are several improvements that have been proposed for utilizing the flow over the remaining fall of the river. The map illustrates these. It is perfectly feasible to build a dam across the main channel from island No. 2, starting 650 feet below its head, and from it run a canal along the north bank of the river. This would catch all the flow of the river except what was used from the Kaukauna water-power canal and the Edwards & Meade power. A head could be obtained by extending the canal about 800 feet down, varying from 10 feet at the head to 20 feet at the foot, but could be made nearly 20 feet all the way by excavating a tail-race, and mills could be stationed along the dam itself, as well as on the canal.

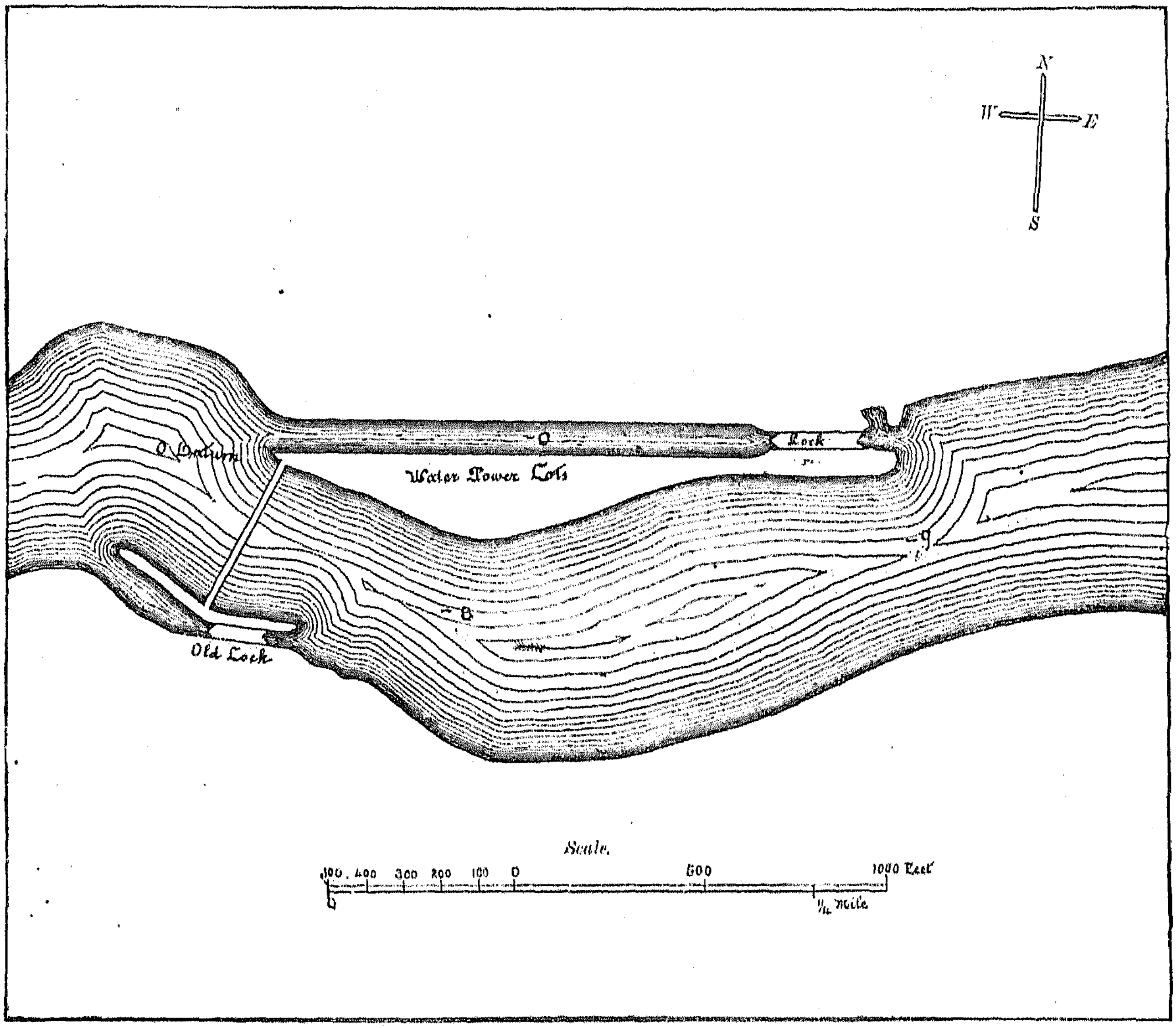
The map also shows a practicable scheme of damming up the channel between islands No. 1 and No. 3 by wing-dams, forming a pocket with the same level as the tail-race of the Kaukauna Water-Power Company's canal. A head of 18 feet could then be obtained, and mills, etc., would be stationed along the lower part of the pocket. If the south channel is shut off permanently, this power would only get the discharge from the Kaukauna Water-Power Company's canal, and this plan would require about 2,600 feet of dam, wing-dam, and dike. Tail-races should be blasted out on each side, and that on the north would also serve for a portion of the Edwards & Meade power.

We have now discussed plans for using the upper 36 feet of the fall; there remains yet 14 feet. About 800 feet below the foot of island No. 5 the river bends again to the northeast, as it flowed above Grand Kaukauna, and the rapids end just below this bend. The river is 1,600 feet wide at the bend; but below a bay projects into the south bank, and the river is there 2,200 feet wide. The bed of the river is limestone, as all along the rapids, and it is suggested by Captain Edwards to build a dam across the river where it is 1,600 feet wide. Starting from the south bank, he would run it directly across until within 200 feet of the north bank, then up the stream for about 1,000 feet, until it merged into the level of the north bank. This dam and dike would be 2,400 feet long, and the head available would be 14 feet, and it would catch the whole flow of the river. Captain Edwards' idea is to station mills, built over the river, all along the face of the dam; to make a roadway of the crest of the dam, and to run railroad tracks back and forth over the river on trestles or cribs, as at Appleton. A waterway and waste-weir of about 300 feet width would be left in the middle of the channel, which, for a river of so slight rise, seems sufficient to control the level. There would be 1,100 feet of facing on the main dam, and at least 800 feet on the wing-dam along the north shore, and it would be necessary to blast out a tail-race for mills along the latter. The theoretical

power of this improvement at ordinary low-water and 14 feet head would be 3,971 horse-power, and this would be sufficient to supply 104 horse-power for every 50 feet of available space along the dam and wing-dam at an ordinary low stage of the river.

THE RIVER FROM GRAND KAUKAUNA DOWN TO RAPID CROCHE.

From the foot of the canal the course is north-northeast for a distance of 2 miles, and then for 1.3 miles the river runs northeast to the Rapid Croche dam. The river below the Grand Kaukauna rapids is from 1,200 to 2,200 feet wide for nearly 2 miles, but it gradually contracts so as to average about 500 feet wide for the lower half of the distance down to Rapid Croche, and in places it is not more than 400 feet wide. Below the foot of the Grand Kaukauna canal the bluffs rise from the water direct, and, with trifling exceptions, they continue thus, well wooded, down to Rapid Croche. Navigation is by slack water from the Rapid Croche dam up to the Grand Kaukauna canal.



LOWER FOX RIVER AT RAPID CROCHE, WISCONSIN.

RAPID CROCHE.

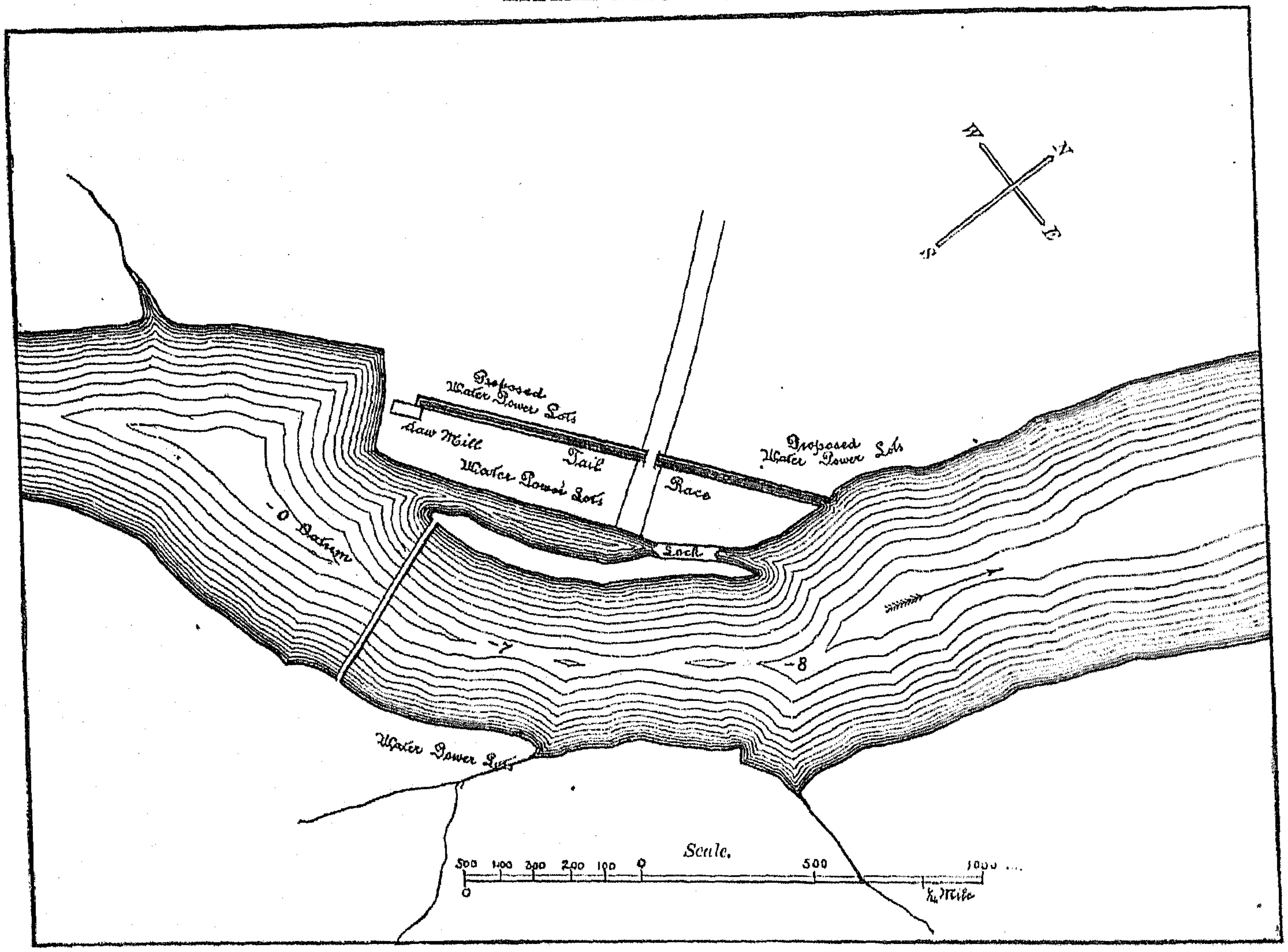
The river here runs east. The government has built a dam $4\frac{1}{2}$ miles below the Grand Kaukauna dam, and by a canal 1,760 feet long on the north bank floats the boats past the rapids of about 9 feet fall to the slack water of the Little Kaukauna dam. The river just above the Rapid Croche dam is 640 feet, and below 440 feet wide, and the bluffs come down on each side close to the river, except that between the ship-canal and the bank of the stream is a space about 900 feet long, and varying from a few feet wide at the ends to 200 feet at the middle part. This ground is owned by the Green Bay and Mississippi Canal Company, and is the proper place for utilizing the power at this locality.

FALL AND POWER.—The head available is 8 feet, and the theoretical power at ordinary low water is 2,269 horse-power; but none of this power is used. There is an old lock at the north end of the dam which was formerly used for navigation, and there could easily be a side-track laid from the railroad to the water-power.

THE RIVER FROM RAPID CROCHE DOWN TO LITTLE KAUKAUNA.

In this distance of 6 miles the general course is northeast, and the river is not so winding as in its upper part, the bluffs forming the immediate banks of the river almost the whole distance. A peculiar feature of this stretch is the narrowness of the river, below Wrightstown, which is about one-third of the way down, the average width being about 450 feet, while in many places the banks are scarcely over 300 feet apart.

LITTLE KAUKAUNA.



LOWER FOX RIVER AT LITTLE KAUKAUNA, WISCONSIN.

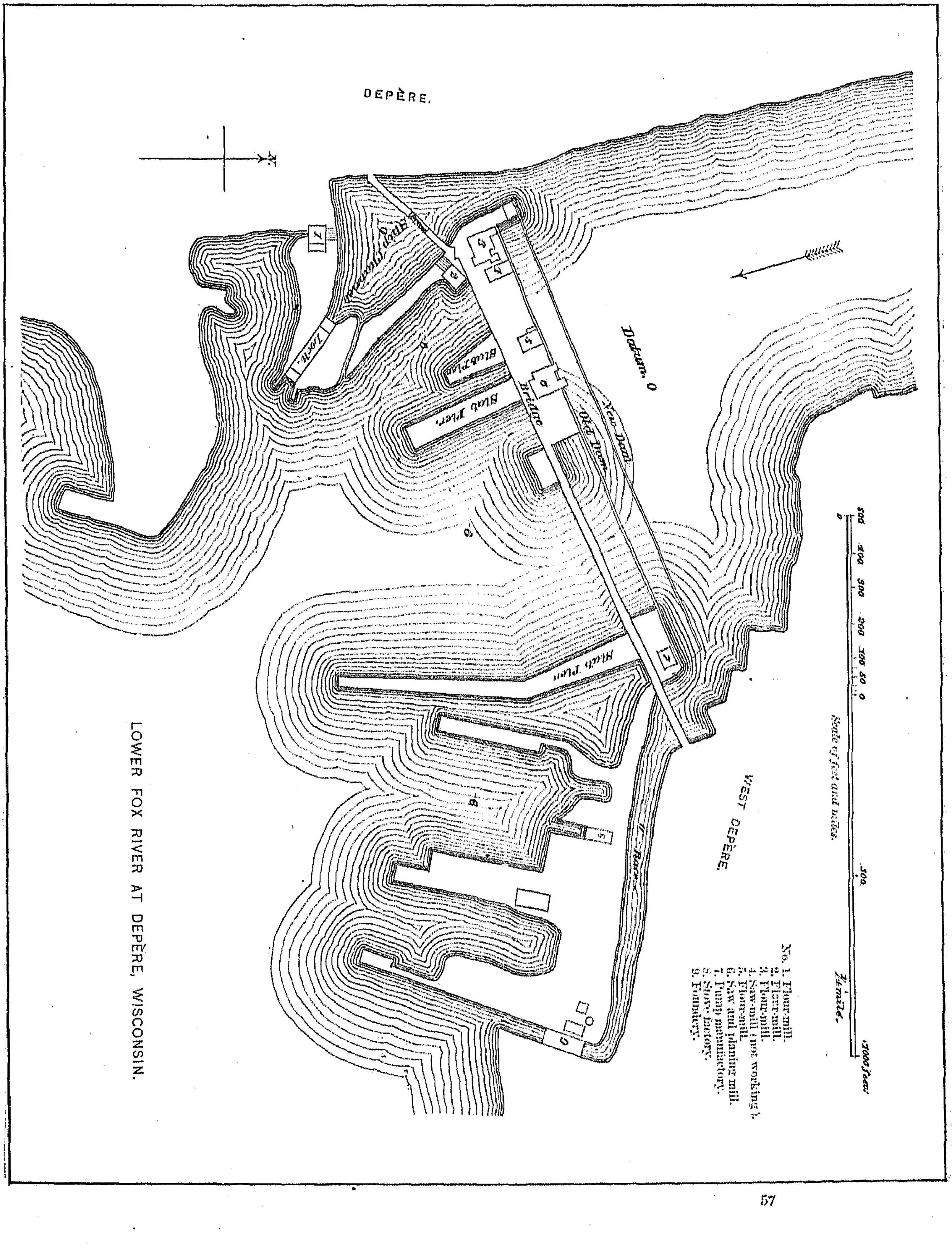
Here the river veers more toward the east, and as at Rapid Croche, a government dam and a canal overcome the rapids, amounting to about 8 feet. The canal is upon the north bank, and is 950 feet long, with one lock at the foot. The river just above the dam is 800 feet wide, and below it is about 475 feet wide. On the southern bank the bluffs rise close to the water, but on the northern bank they leave a space of several hundred feet wide between them and the river at the canal. Just below the canal a spur comes close to the river edge, but it very soon recedes, leaving a flat at its foot. It is on the space at the north end of the dam that the power could best be utilized. There is a saw-mill there now, facing the pond. With a tail-race running up the middle of the flat, there would be 1,100 feet of frontage along the ship-canal available for manufactories, with an average head of about 7½ feet. A canal could be run along the bluff back of the ship-canal, and mills be built along it, using the tail-race mentioned so far as it extended, and then discharging into the river. There would be at least 2,000 feet of available frontage, on it. There is also a chance for running a canal above the south bank and getting about 1,000 feet of frontage upon it.

FALL AND POWER.—Thus abundance of space would be provided for utilizing the total power of the river, which, at 7½ feet head and ordinary low-water flow, would be 2,127 theoretical horse-power, or, with an efficiency of 75 per cent., 1,595 effective horse-power. The Green Bay and Mississippi Canal Company owns only the land between the ship-canal and the river; the rest is in the possession of various persons.

The locality is not considered by those qualified to judge very accessible to railroads, but it is possible to reach it.

THE RIVER FROM LITTLE KAUKAUNA DOWN TO DÈPÈRE.

The river flows with hardly a bend nearly northeast for this distance of 6 miles. Along the upper portion of this section it is from 1,500 to 2,000 feet wide, but in the lower half it averages 800 to 1,000 feet across, and except just at Little Kaukauna the bluffs skirt the edge of the river on each side down to Depère. Along the upper 3 miles there is considerable timber on the bluffs.



LOWER FOX RIVER AT DEPÈRE, WISCONSIN.

DEPÈRE.

This town is an old place, and, as its name indicates, is of French origin. Although 7 miles above the mouth of the river, at the head of Green bay, the navigation on the level of lake Michigan extends to this town, where there is a government dam with a lock, the last on the river. The stream suddenly turns at Depère, and runs a little west of north for a few thousand feet; then it bends to the northeast and continues without change to Green bay. At Depère are several manufactories and quite extensive iron furnaces. The facilities for shipping are very good, both by railroad and by water, as boats from Buffalo, on lake Erie, can run up almost to the doors of the mills, with the navigation of lake Michigan unobstructed before them.

In spite of this the water-power at Depère is not in a very flourishing condition, and this is largely due to unfortunate management, which has mortgaged the property. The Green Bay and Mississippi Canal Company has no interest in the power. As was the case with Menasha, a contract was made with the riparian owner, whereby, in consideration of his maintaining the navigation improvements, he should have the right to the water-power, and he is now endeavoring to interest capitalists in improving the power on a more comprehensive scale. Apparently, this is all that is needed to make a valuable manufacturing place, and yet one notices on entering the town that something is at fault, things not having that new and neat appearance that betokens prosperity.

The slab piers shown upon the map are old, decayed piles, just ready to tumble into the water, and the bridge almost defies description. As seen in the close of 1880, it was a wooden structure, consisting of a great many short spans, with the ordinary trapezoidal form of truss. In some cases the upper chord has fallen out; in others an inclined post is gone, or else the rotten timber is scarcely strong enough to hold together, and several times have loaded teams broken through. The reason for such a state of affairs was said to be that Depère, on the east bank, and West Depère, on the west bank of the river, are two separate villages, unable as yet to unite for mutual interest.

At the dam the river is 1,750 feet wide, and just below it widens out to 3,000 feet, forming a large bay. The boats pass into a basin at the east end, and so down by a lock to the water below the dam. There are two mills situated on this basin, five upon the dam, and two upon a race on the west bank, and the head of water is very nearly the same at all of them, viz: from 6 to 7 feet, but varies, according to the stages of the water, about 1½ feet. It is low on Mondays, because the mills above shut off the flow during Sunday.

The old dam became unsafe, and a new one was built above it, instead of below, because of the mills situated on it; but the old one was not removed. This new dam is not yet entirely finished, and leaks to some extent, but it would be possible, and thoroughly practicable, to increase the head to at least 10 feet by raising it. The banks are high up to Little Kaukauna, and no damage would be done by overflow except at Depère, which could be prevented by a dike on each side of the river for a short distance. The only difficulty would be that it would back up on the Little Kaukauna dam and diminish the head, which the Green Bay and Mississippi Canal Company has it in its power to improve. The raising of the dam would require alterations about the canal and locks, but there seems to be no prospect of its being accomplished.

The bridge, such as it is, passes close along the old dam, and between the two are several mills, and also about 900 feet of unutilized frontage upon the dam. This situation is excellent for mills, like flouring-mills, for example, not requiring much storage space. On the west bank a small race runs down about 1,100 feet, supplying two manufactories. The mills are as follows: Upon the government basin (east side)—No. 1, flour-mill; No. 2, flour-mill. Upon the dam—No. 3, flour-mill; No. 4, saw-mill (not working); No. 5, flour-mill; No. 6, planing and saw mill; No. 7, pump factory. Upon the race (west side)—No. 8, stave factory; No. 9, foundry. There were also a manufactory upon the race and one at the north end of the dam, next to No. 7, which were burned down.

FALL AND POWER.—The ordinary low-water power at 6 feet head is 1,702 horse-power, and at the very highest estimate there is not probably two-thirds of this utilized at present, but if the head were raised to 10 feet, the theoretical power would be 2,836 horse-power, and there is abundance of room for utilizing the remaining power, either on the dam, the government basin, or the race. The millers were endeavoring in December, 1880, to get the Chicago and Northwestern Railroad Company to run a side-track down to their flouring-mills, which can very readily be done.

DESCRIPTION OF DAMS AND OTHER CONSTRUCTIONS ON THE RIVER.

Table of location, character, etc., of dams.

Location.	Ownership.	Time when built.	Cost.	Nature of bed.	Kind of dam.	Length.
						Feet.
Neenah dam	Government			Bedded limestone	Spar	*775
Menasha dam	Government	Old		Bedded limestone	No definite character	*483
Appleton upper dam	Government	1875	$40,000	Bedded limestone	Stone	760
Appleton middle dam	Private	1877	9,500	Gravel	Timber frame	450
Appleton lower dam	Government	1855		Bedded limestone	Spar	417
Cedars dam	Government	1878		Bedded limestone	Crib-work	810
Little Chute dam	Government	1878		Bedded limestone	Crib-work	715
Grand Kaukauna dam	Government	1878		Bedded limestone	Crib-work	612
Rapid Croche dam	Government	1878		Bedded limestone	Crib-work	525
Little Kaukauna dam	Government	1877		Gravel and bowlders	Pile	586
Depère dam	Government	1879	30,000	Bedded limestone	Crib-work	1,505

* Approximate.

STONE PIER AT APPLETON.—In addition to these is the fine stone pier or revetment wall 800 feet long, and averaging 18 feet in height, at the upper level at Appleton, built in 1880 upon the limestone layers forming the bed of the stream. Constructed of solid masonry throughout, the exterior is laid in regular courses of dressed stone, 1 foot thick. The inner face is vertical, but the outer one inclines. It is 6½ feet wide on the top, has an 11-foot base where 18 feet high, and the coping stones are doweled fast for the first 36 feet from the dam, where exposed to ice. There are ten openings, some 15 by 17¼ feet high, others 13½ by 6 feet, for supplying water to mills. They are set in the upper half of the height of the wall, and have a segmental arched roof. At the back, rising 8 feet against the wall, is a filling of gravel or earth. The coping stones, etc., were brought from the limestone quarries at Great Kaukauna or Duck creek, but are only a superior quality of the rock found right at hand. The work is very handsomely and substantially executed.

DAM AT UPPER LEVEL, APPLETON.—This is by far the finest dam on the stream and in that part of the country. It is built of the limestone quarried from the bed of the river at the spot, except the coping stones, which which were brought from the government quarry at Kaukauna. The masonry is dressed rubble; the coping stones ashler work. The drawing on page 46 (made from description and dimensions given) explains the structure. Each coping stone is fastened by a band of 1-inch round iron to a hook set into the masonry at the toe of the dam. Adjoining coping stones are also fastened to each other by iron straps 1¼ inches wide, doweled into the stone. The lower courses of the masonry are bolted to the rock-bed, and the irons are fastened into the stone with an alloy of lead and antimony. In building, a coffer-dam was first erected, so as to confine the river to the north side of the channel; then the bed was cut smooth to receive the masonry, and the dam completed up to the coffer-dam. Afterward the coffer-dam was removed, and the process repeated for the remainder of the way across the stream. The coffer-dam was principally made of triangular sets, with string-pieces, on which planking was spiked.

DAMS AT LOWER LEVEL, APPLETON, AND AT NEENAH.—These are each spar-dams, and one description will serve for both.

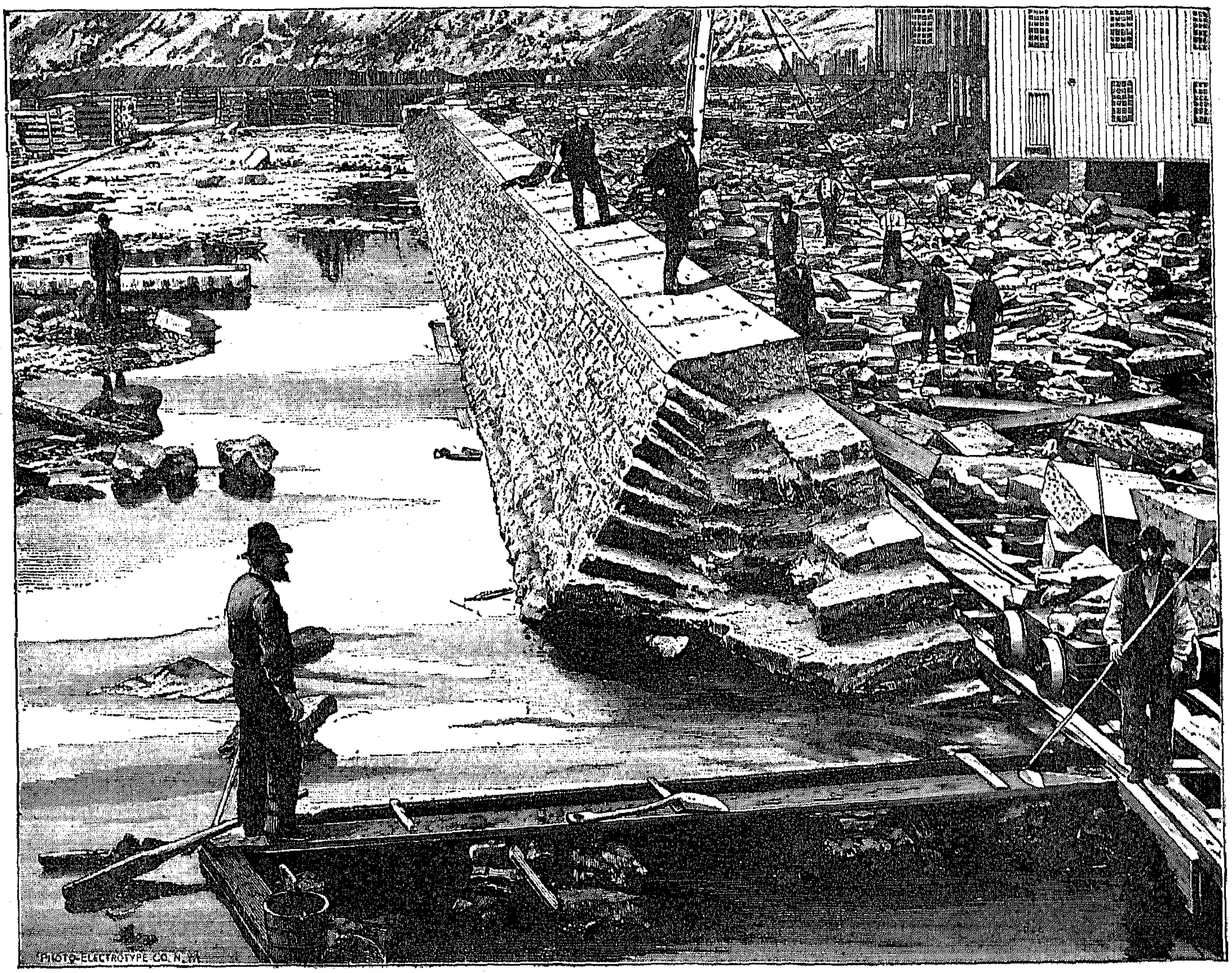
The lower dam at Appleton is built of spars or tree trunks 40 feet long, resting on log cribs. These cribs are 16 feet long by 8 feet wide and 8 feet apart, with their length in the direction of the current. Along these cribs rests a string-piece, and on this are laid the butts of the spars, which run back until they strike the river bed. Upon these spars is a layer of earth and gravel, and the space is open below. This form of dam is found to be tight, and works satisfactorily.

DAMS AT CEDARS, LITTLE CHUTE, AND RAPID CROCHE.—These dams are all built on the plan shown in the drawing on page 47, a continuous crib-work extending across the river. The lower and upper courses of stringers are 12 by 12 inches; the others 10 by 10 inches.

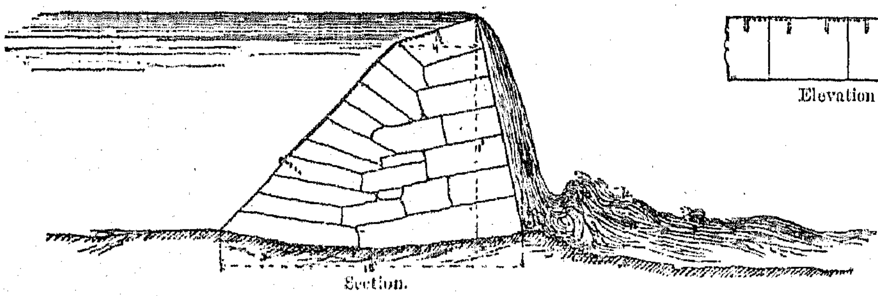
This crib is filled with stone, and is also bolted to the bed-rock by 1½-inch bolts. The timbers also are bolted together. The back of the dam, instead of sloping to the bed of the river, is cut off by a vertical back, sheeted with plank. Against the back is a filling of clay and gravel, with a slope of one to one to the river bed. The face is not protected by planking. The timbers, 6 by 10 inches, are 2 feet apart, and the spaces are filled in with stone. There is no apron at the face of the dam. The abutment consists of a crib-work core, into which the main crib-work of the dam is securely built. This crib-work core is surrounded and filled with packed clay and gravel, and the surface, sloping to the water, is faced with dry-laid stonework. At the lower side of the dam the abutment terminates in dressed rubble masonry, laid dry, and this rubble masonry is also extended as a retaining-wall for that portion of the clay and gravel of the abutment above the crest of the dam.

DAM AT GRAND KAUKAUNA.—This is of similar construction to that at Cedars, except that an additional crib 12 feet wide has been built on the lower side, continuing the face of the dam, with the same slope as in the preceding case, and is merely the Cedars dam with another crib added on the lower side. The crib is formed of 12 by 12 and 10 by 12 stringers, with 8 by 10 cross-pieces. This is filled with stone and planked over to the crest of the dam with 3 or 4 inch plank.

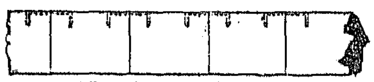
DAM AT DEPÈRE.—This dam (see drawing on page 48), for the reason already given, was built in the deep water back of the old one. Cribs 50 feet long by 28 feet wide at the base were built and sunk by stone, adjoining each other, and when built to their full height they were 12 feet high and 16 feet wide on the top. Three-inch iron drift-bolts were let into the rock-bed 12 to 18 inches at spaces of 8 feet apart in front of the dam. These project 1 foot above the bed through timbers extended from the cribs, tending to hold the dam in place. They are used as a precaution, rather than as a necessity. The front of the dam is vertical and not sheeted. The back is inclined from the crest at a little less than 45 degrees to the river bed, and is sheeted with 4-inch planks 12 inches wide. The upper surface is slightly inclined down stream, and is covered with the same-sized plank. The abutment consists of a timber crib 48 feet long by 9 feet wide of 12 by 12 inch timbers, with a flooring of 12 by 12 timber. On this is laid a trapezoidal-shaped wall of masonry, 47½ feet long by 6¼ feet high, and 5 feet 8 inches wide on top. The old dam still standing, the new one is often entirely hidden from view, and is, of course, under no hydrostatic pressure as yet.



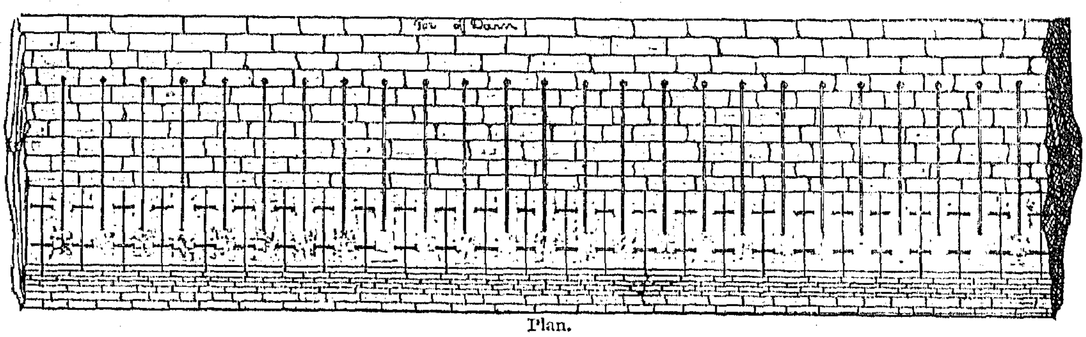
Appleton, Wisconsin: View of upper dam, in process of construction.



Section.

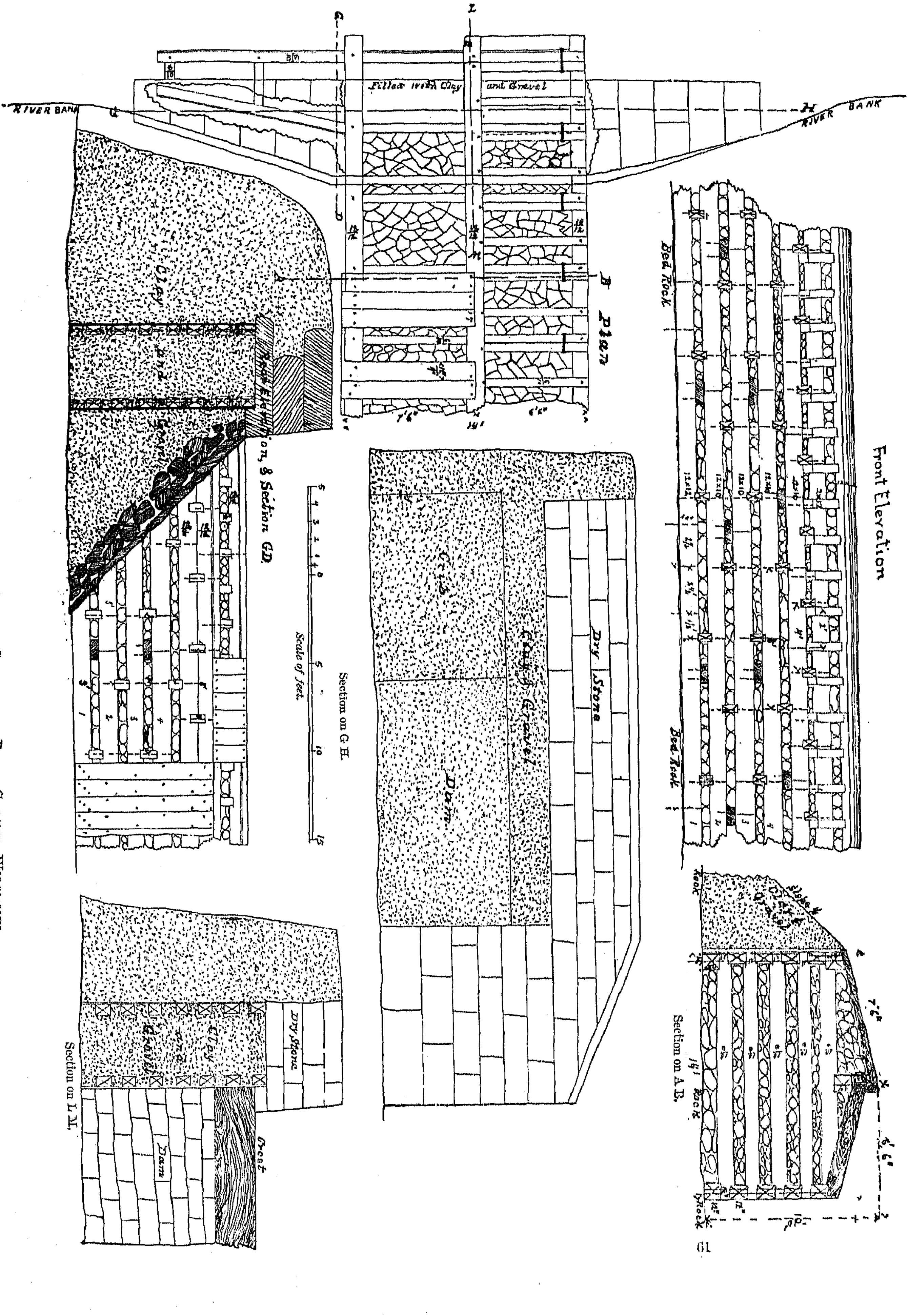


Elevation of coping stones.

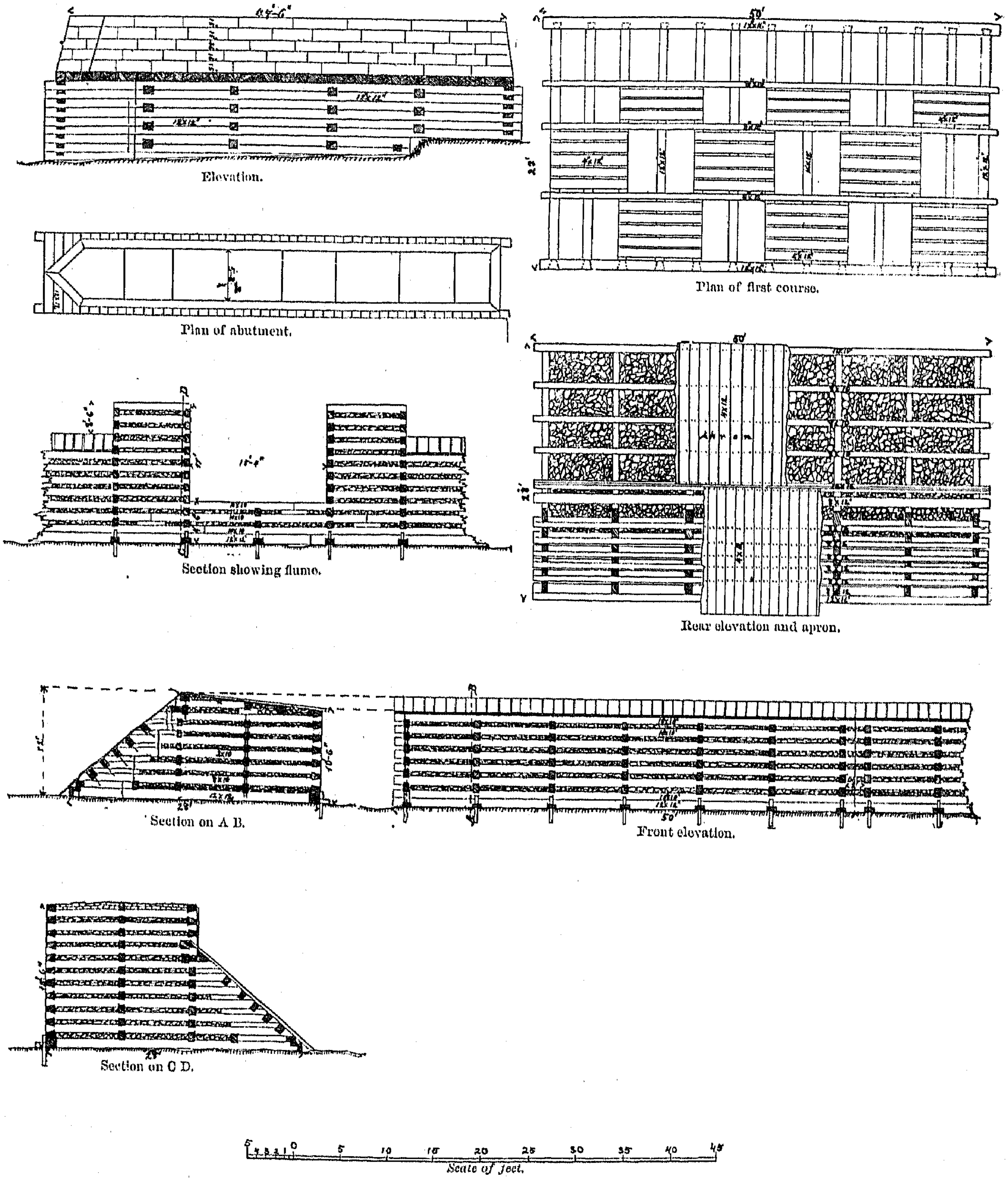


Plan.

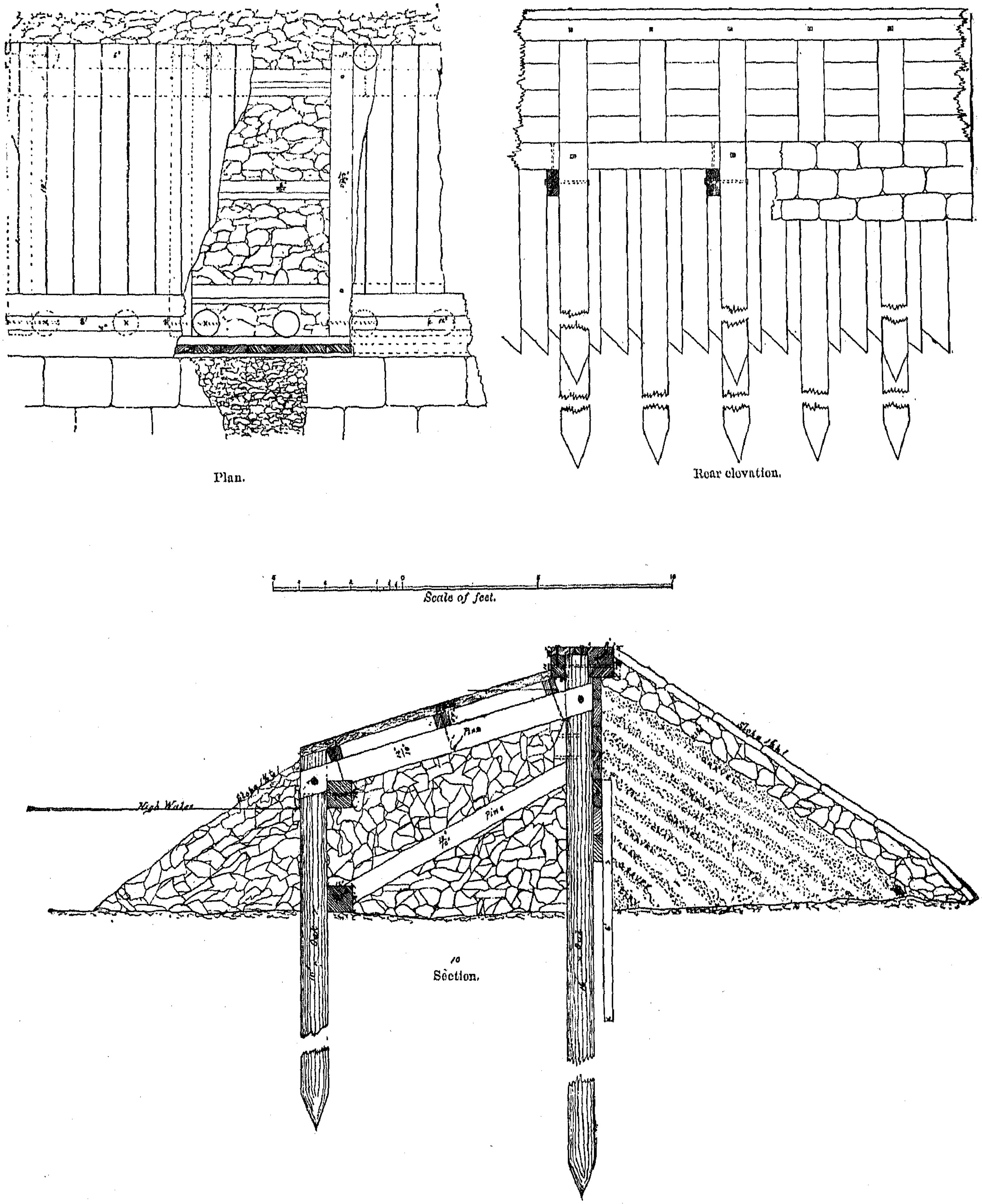
Dam at upper level, Appleton, Wisconsin (drawn from description and dimensions given by the United States engineer corps).



PLAN OF CRIB-DAM AT CEDARS, LITTLE CHUTE, AND RAPID CROCHE, WISCONSIN.

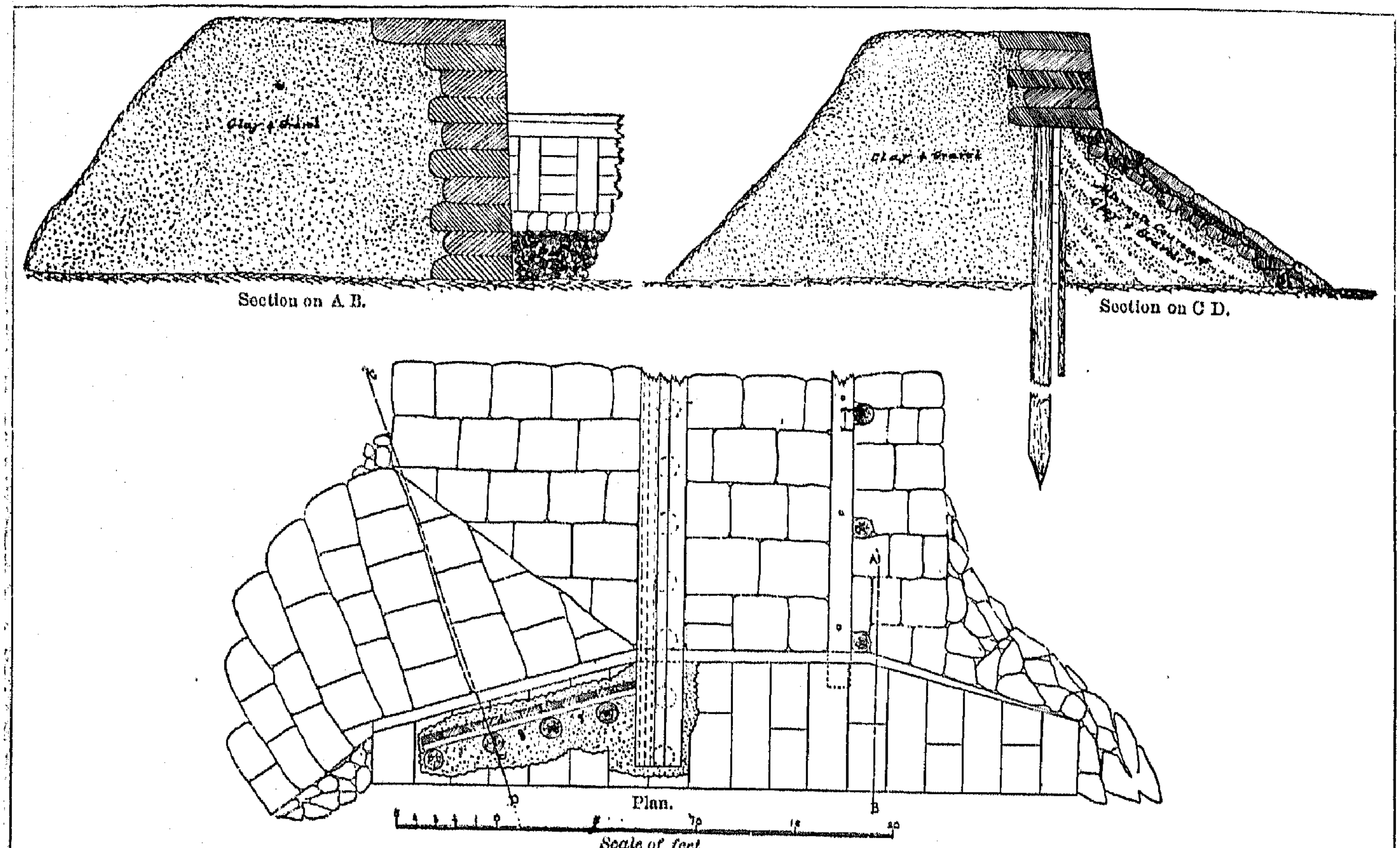


CRIB-DAM AT DEPÈRE, WISCONSIN.



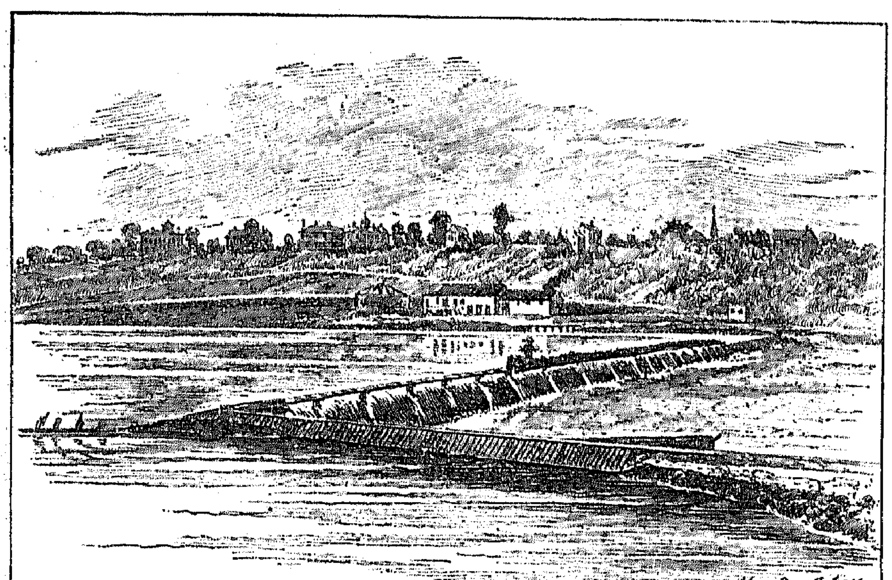
PILE-DAM AT LITTLE KAUKAUNA, WISCONSIN.

DAM AT LITTLE KAUKAUNA.—This is the only government dam on the river without a solid rock foundation (see the table on page 44); hence its construction is peculiar. The dam, of pile construction, was built below the old one. Two parallel rows of oak piles, 10 feet apart, were driven 14 feet into the gravel and bowlder bed. Difficulty was experienced in driving the larger ones, of 15 inches diameter especially. The two rows were braced together by 10 by 12 and 10 by 10 inch timbers, as shown, and the intervening space filled with stone. On the upper



ABUTMENT OF DAM AT LITTLE KAUKAUNA, WISCONSIN.

sides of the upper row 4-inch planking was spiked to within 2 feet of the bed of the river; then sheet-piling was driven down against this planking 4 feet into the gravel bed. Against the planking and sheet-piling alternate layers of clay and gravel were packed, with a slope of 1½ to 1; then a layer of 1½ feet of loose stone, and on this a course of carefully laid flat stones, 4 inches thick, coming flush with the crest of the dam. The top surface was planked with 4-inch oak, and at the face stones were filled in, with a slope of 1½ to 1. The abutment is formed of clay and gravel, faced with stone and a line of sheet-piling above the dam, and connecting with the piling of the dam proper, to prevent any possible leakage.



MIDDLE DAM AT APPLETON, WISCONSIN, FROM GRAND CHUTE ISLAND.

DAM AT MENASHA.—This dam is old, and has been patched at various times, until it consists of a conglomeration of cribs, spars, brush, gravel, etc., difficult to describe.

DAM AT MIDDLE LEVEL, APPLETON.—This is the only dam across the river that is not owned by the United States, and was constructed by Captain N. M. Edwards, of Appleton. Like the Little Kaukauna dam, it is on a gravel foundation, which the rapids have not succeeded in washing away, but it is a frame instead of a pile-dam.

The frame proper is a continuous crib-work, triangular cross-section, with a 16-foot base and 9 feet high. The face is vertical, and the back slopes to the river bed. The timbers are 10 by 12 inches, except at the toe, where they are 12 by 14 inches, to withstand better the greater pressure of the water. The crib-work is filled in with stone, and the back is covered with 4-inch planking, projecting at the toe over the ends of a line of sheet-piling driven 4 feet into the bed of the stream. The face is not covered, but is left open to the stone filling, which was allowed to take its natural slope when thrown in. Below the dam an apron 16 feet wide was built out on the bed of the river. Its timbers are set back into the lower courses of the crib-work, and are covered by a 4-inch thickness of planking. The tendency of the falling water is to work out a cavity under the apron for several feet back, but this action ceases soon, and the construction of the apron holds it in position to the dam.

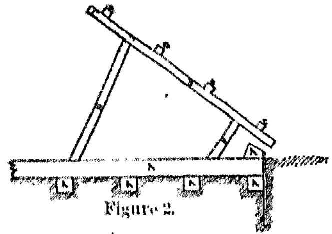


Figure 2.

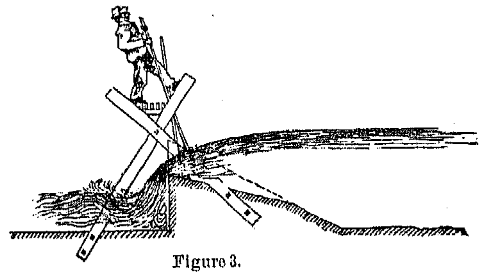


Figure 3.

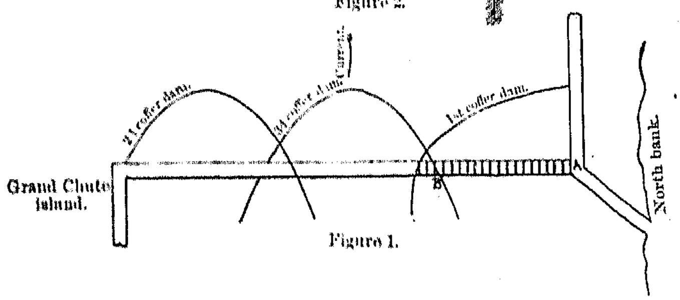
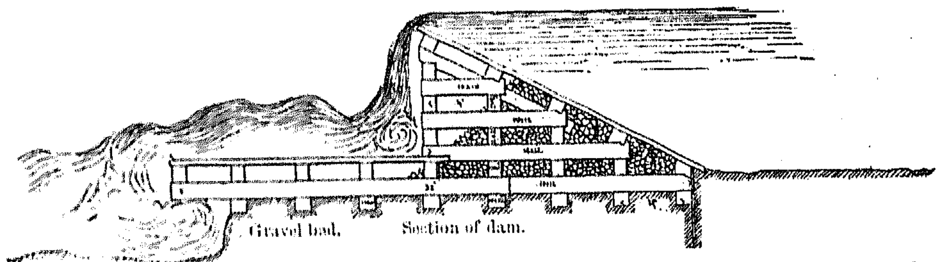


Figure 1.



DAM AT MIDDLE LEVEL, APPLETON, WISCONSIN (drawn from description and dimensions given by the engineer of the work, Captain N. M. Edwards).

METHOD OF BUILDING.

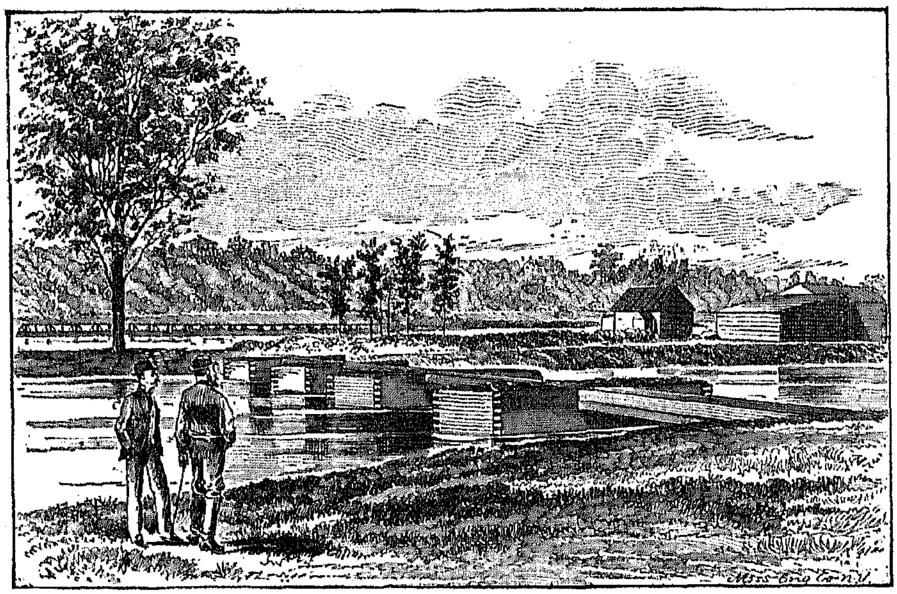
METHOD OF BUILDING.—To avoid expensive coffer-dams Captain Edwards used an ingenious method, which deserves description. He estimated that $2,000 were thereby saved in the cost of construction.

Starting from the old wing-dam, at the north bank, a light coffer-dam was built out, as shown in Figure 1, about 150 feet into the stream, turning the flow against the south bank. In the space thus left dry he built the parts marked A in Figure 2. Then, at distances of a few feet apart, the sets marked B B B were set up, leaving a space at the toe sufficient to shove in a plank between A and B. These sets are shown in plan in Figure 1. Then the sill-pieces, marked A in Figure 2, were boarded over. The first coffer-dam was then removed and replaced as the second coffer-dam, starting from the other side of the channel at Grand Chute island. Back of this the dam was built complete. Coffer-dam No. 3 was then built. The whole flow of the river was now passing through the space A B in Figure 1, between the timber sets marked B B B in Figure 2. Behind the third coffer-dam the dam was completed out to B, Figure 1, with a waste-weir. The third coffer-dam was then removed. String-pieces, C C C, Figure 2, were pushed down against the sets B and held in place by the force of the current. Then over these planks were shoved down. This made a dam, and caused the water to flow over the waste-weir constructed back of the third coffer-dam. A clear, dry place was now left in the section A B, Figure 1, and the dam was then completed without removing the sets B B B. When all was completed these were cleared away.

The waste-weir is 3 feet lower than the crest. At the north end a length of 75 feet is left permanently open, but for the rest of the length there is a system of needles, whose object has been already described in treating of the water-power. These needles are 5 by 3 inch scantling, which are let down close together over the waste-weir, and so close it when required. A platform, shown in Figure 3, extends along the dam, on which the operator stands. He shoves a needle down into the water, and the force of the current carries the lower end snug against a cleat on the floor of the weir, while the platform supports the upper end. These needles and the platform are shown in the view of the dam.

MISCELLANEOUS CONSTRUCTIONS.

CHEAP FORM OF COFFER-DAM.—A very cheap and yet effective form of coffer-dam is much used on the Lower Fox, where the stream is so steady and shallow as not to require expensive structures. This consists of sets formed of logs 6 or 10 feet long, with two legs at one end, string-pieces, and boards. The sets are first put in position, and the lower end is held down by stones; string-pieces are then spiked across these, and on them thin boards are nailed.



BULKHEADS OF THE HYDE & HARRIMAN CANAL, LOWER LEVEL, APPLETON, WISCONSIN.

WOODEN BULKHEADS.—The bulkhead at the upper part of the Hyde & Harriman canal, at the lower level at Appleton, is illustrated here. The object is to shut off the water from the canal in case repairs are necessary. Three timber cribs, filled with stone, are placed in a row across the channel at equal distances apart, and connecting them is a frame and plank roadway. Directly below, on the bed of the canal, is a timber sill-piece, extending from crib to crib. When necessary, planks can be shoved down into the water, with their lower ends resting against the sill-piece, and the water can thus be effectually shut off from the canal. The roadway can be employed as a bridge. This form of bulkhead is much used.

TRIBUTARIES OF THE LOWER FOX RIVER.

The only tributaries of any importance in a consideration of the water-power are the two streams which unite to flow into lake Winnebago at Oshkosh, on its western shore. These are the Upper Fox, from the southward, and the Wolf, from the north. They are the feeders of the great reservoir which make the Lower Fox so valuable, and on this account are of importance. The tributary branches extend so as to drain almost the whole lake Winnebago basin. All the other streams emptying into lake Winnebago are of small size.

WOLF RIVER.

This river rises about 30 miles south of the line between Wisconsin and Michigan, and flows in a general southerly direction 145 miles, measured along its general course, to the Upper Fox, which it enters about 10 miles from lake Winnebago. It is called a tributary of the Upper Fox, but, as in the case of the Missouri and the Mississippi, the tributary is the master stream. For this reason it is thought best to discuss it alone, and not as a branch of the Upper Fox.

On the map it will be noticed that the tributaries are almost entirely from the west—a fact due to its wedge-shaped valley, with a long gradual western slope, and a sharper slope on the eastern side. The cause of this peculiar formation of valley has already been given, and the statement has been made that at one time the Wolf river ran to the Mississippi through the lower portion of the Wisconsin River valley.

SURROUNDING COUNTRY.—The country about the Wolf has lain undisturbed until late years. It is true that the pine woods which covered the country have been largely cut away along the lower part of the rivers, but above Shawano, which is 40 miles from the foot of lake Winnebago in a straight line and 70 miles from the mouth of the river (map measurement), the pine woods still remain, although the lumbermen are hard at work there. It is said that there are over two billion feet left upon the upper Wolf and its tributaries. The country, then, except at the lower portion of the river, is still a wilderness. The business of the region has been lumbering, but the products of the farm are beginning to take a prominent place. The principal town is Shawano, the county-seat of Shawano county. Its population is about 1,000.

THE RIVER BELOW SHAWANO.—Shawano seems to mark the dividing point between two portions of the river, differing to some extent in their characteristics. Here the river leaves the metamorphic base rock, already described as forming the foundation for the other rock layers, and runs along the stratified rock. In this vicinity also it crosses the old coast-line of lake Michigan and enters the region of red clay, the lacustrine deposit. Below

Shawano the stream is sluggish, falling only about 50 feet to lake Winnebago in a distance of at least 70 miles. The banks are low, and in high water the surrounding flats are all covered. In heavy freshets the river becomes several miles wide. This characteristic has been already mentioned as of some importance in aiding lake Winnebago in its action as a reservoir. In freshets the river takes some time in finding its way among the swamps and adjoining lowlands, and after these are filled an equally long time is consumed by the water in running out; so that a freshet which in many streams would be spent in a few days is thus distributed through a much longer period.

Shawano is considered the head of practical navigation, and the United States engineers have been engaged in making surveys of the river up to that point for the purpose of improvement. Colonel D. C. Houston, major of engineers, stated in his report that the present or the prospective business of the region does not warrant any large outlay. The plan of improvement appears to be the removal of snags and leaning trees and the excavation of sand-bars. Near Shawano the width averages 80 feet, with a mean low-water depth of about 2.8 feet, and the course is very winding. It will be evident, from what has been given, that there is no available water-power on the river below Shawano.

THE RIVER ABOVE SHAWANO.—Above Shawano the stream is more rapid. Lac Vieux desert, the head of the Wisconsin river, is about 30 miles north-northwest of the source of the Wolf, and is 951 feet above lake Michigan. From the east and west directions of the intervening streams it does not seem probable that the upper waters of the Wolf are many feet below those of the Wisconsin. But suppose there is a descent of 200 feet in the space between them; this would make the head of the Wolf river 751 feet above lake Michigan. Shawano is about 221 feet above the datum plain; hence the river falls, according to this estimate, 530 feet from its source to Shawano. The distance is about 75 miles, and the average fall per mile is a little over 7 feet. It is thought that this estimate is slightly below the true figures.

The upper section of this river appears more promising for power, and it is in this portion that the water-power is located. The country there is as yet so undeveloped that these powers are of small value, but when it becomes more settled and the land is cleared for farms the conditions will be changed. For many years, however, the upper Wolf will probably be left unimproved. The lumber companies have upon the main stream and its upper tributaries at least twenty flood-dams, which are used for ponding the water, and then, when the stream is full of logs, the gates are opened and these logs flushed down on the high water thus produced.

FLOW OF THE RIVER.—The low-water discharge at the mouth of the Wolf river, as estimated on August 9, 1878, was 1,608 cubic feet per second. The low-water volume below the outlet of Shawano lake, at Shawano, was estimated on August 30, 1879, to be 633.7 cubic feet per second. The discharge at Shawano would give, with 10 feet head, a low-water power of 719 theoretical horse-power, or, with an efficiency in application of 75 per cent., 539 available horse-power.

MILLS ON THE WOLF RIVER.—The only utilized power on the entire river is at Keshena, about 7 miles above Shawano. At this place is an Indian reservation, and the government has a grist- and saw-mill, run by water-power, to supply the wants of the Indians.

TRIBUTARIES OF THE WOLF RIVER.

The principal tributaries of this river are on the west side, and of these the farthest north is Red river. Flowing about 40 miles (map measurement) southeast, it enters the main stream 3 miles above Shawano. Then the Embarrass river, the longest tributary of the Wolf, enters at New London, after flowing about 60 miles in a general southeast direction. The Little Wolf, the third large tributary, enters from the west about 4 miles below the mouth of the Embarrass river, and is about 45 miles long. The tributaries on the east are a small stream, the Shiocton, about 20 miles long, which enters some 10 miles above New London, and the outlet of Shawano lake, entering at Shawano. This lake is 5 miles long, and averages about 2 miles wide, and the outlet is not over 3 miles from the Wolf river. The tributaries on the west have considerable fall, and the northern ones especially are described in the geological reports as being frequently broken by rocky rapids. They run through the same character of country as does the upper Wolf itself. Upon these tributaries are many water-powers of moderate size, and several of them are in use upon the more southern of the streams. On the Embarrass the lowest mill is at the village of Embarrass, and there are one or two above that place. The fall on this river is mostly situated above the town of that name, which is 20 miles from its mouth. Below, the descent is slight. The water-power of the Little Wolf is not so great as that of the Embarrass, but it is more improved, and there are beside a mill at Manawa, two above that place, and two below it; also a mill on the outlet of Shawano lake.

These mills on the Wolf river and tributaries are grist- and saw-mills of a small capacity, as might be expected in a newly-developed portion of the country, and average about 50 horse-power under an average head of 8 to 10 feet

UPPER FOX RIVER.

It has been seen that the Upper Fox forms a part of the navigation route from the great lakes to the Mississippi, and its course lies most conveniently for such a purpose. The river rises in Columbia county and flows west-southwest about 20 miles to within 1½ miles of the Wisconsin at Portage. There, as already described under the title of "Physical conditions of the basin", it is separated from the Wisconsin only by a low, sandy plain. At this point it turns at right angles and flows north for about 16 miles, and then northeast to lake Winnebago.

ANCIENT COURSE OF THE UPPER FOX.—It is the opinion of those best capable to judge that at one time the current of the Upper Fox was reversed; that the Wolf river occupied this valley to Portage, where it entered the present Wisconsin valley, and that the original of the Upper Fox river was that portion above Portage, merely a small tributary of the ancient Wolf river. The peculiar bend in the river at Portage is entirely in accord with this view, which has been previously discussed.

Unlike the Lower Fox, the river flows with a gentle current, and the aim of the United States engineers in the improvement has not been so much to overcome the fall of the stream as to obtain a channel of sufficient dimensions for the passage of boats. From lake Winnebago to Portage, where the route changes to the Wisconsin river, the navigation is by slack water, produced by several dams with locks. The following table shows the distances and elevation along the Upper Fox from the mouth to near Portage:

Place.	Intermediate distance.	Fall of water between places.	Total distance.	Elevation above lake Winnebago.
	Miles.	*Feet.*	*Miles.*	*Feet.*
Oshkosh	0.00	0.00	0.00	0.00
Eureka	22.50	5.20	22.50	5.20
Fiddler's Bend	16.50	5.98	39.00	11.18
Princeton	12.25	4.92	51.25	16.10
Mechan river	5.75	2.57	57.00	18.67
Head of lake Puckaway	6.25	0.95	63.25	19.62
Montello	15.25	4.93	78.50	24.55
Governor's Bend lock	21.00	5.95	99.50	30.50
Fort Winnebago	5.50	2.60	105.00	33.10

The Wisconsin river at Portage is 9.51 feet above the Upper Fox at fort Winnebago, 2¼ miles distant by canal, and the river falls only 33 feet in a distance of 105 miles between fort Winnebago and lake Winnebago. The average fall per mile is 0.31 feet, and there are no special concentrations of the descent. The river expands in Buffalo lake to half a mile wide, a quiet sheet of water, largely filled with reeds and wild rice, and at the foot of this lake is the village of Montello. Fifteen and one-quarter miles below Montello the stream enters lake Puckaway, which is 8¼ miles long and from 1 to 2 miles wide; but below lake Puckaway its course is more like a river, the banks being higher and the channel deeper. Ten miles from the mouth the Wolf river enters, and below the mouth of the Wolf the river passes through lake Butte des Morts, finally reaching lake Winnebago at Oshkosh.

CUT-OFFS.—There are many bends in this river, some of which have been cut off by the improvements for navigation, and others have been changed in a very accidental method. In one place the Indians were in the habit of dragging their canoes across the neck, until finally, in high water, a current passed along the channel which they wore, and the bend was cut off; in another place the building of a post fence across a neck of land has been the cause of a cut-off.

It may be readily imagined that there is little water-power upon the Upper Fox, and the conclusion is a correct one.

MILLS ON THE UPPER FOX.—There are two mills only, and one is at the dam and lock at Montello; this is a small grist-mill, with two run of stones, and when there is a good stage of water the head is 3 feet, but sometimes it is as low as 10 inches. The wheel is a large turbine, and as there is plenty of water for this one mill it can run under such a small head. The second mill is at Pardeeville, 8 miles above Portage, and has three run of stones. In June, 1881, the dam, which had been carried away by high water, was being rebuilt.

DISCHARGE FROM THE WISCONSIN RIVER.—There is an available power at Winnebago lock, 1½ miles below Portage, where the canal from the Wisconsin enters the Upper Fox. In low water the Wisconsin is 5 feet above the Upper Fox at Portage, and this is the available head at the lock; but in high water there is from 9 to 11 feet difference in the levels. The larger portion of the flow of the Upper Fox at Winnebago lock comes from the Wisconsin through this canal, and it is the surplus after navigation is supplied which could be utilized for power. This surplus is stated to be 208 cubic feet per second, and it is probable that the government would allow the use of this power, subject to proper restrictions. The theoretical power is 118 horse-power, sufficient to supply a fair-sized flouring-mill.

The Wisconsin river, overflowing into the Upper Fox in high water, produces an element of unsteadiness in the flow of the latter stream rather difficult to estimate. The main overflow is through the channel of Big slough or Neenah creek. The low-water volume of the Upper Fox just above the junction with the Wolf was estimated on August 9, 1878, to be 1,043 cubic feet per second.

TRIBUTARIES OF THE UPPER FOX RIVER.

The principal branches of this river are on the northern side. Three in number, they start as clear, steady springs, running from the sand-ridges of the drift covering that portion of the basin. They are each about 20 miles long, and would be considered unimportant streams except for the fact that their fall, combined with their steadiness of flow, makes them of real value for small water-powers. Their sources are 200 to 300 feet above their mouths. The Montello river, entering the Upper Fox at the foot of lake Buffalo, where Montello is situated; the Mechan river, about six miles below lake Puckaway, and the White river, emptying into the main stream about 12 miles below the Mechan river, are the streams referred to. The Montello river at the mouth formerly ran around a spur of syenite, which there projects above the soil. A dam was thrown across the channel, and the water deflected so as to run down over the rock, and a flour-mill and woolen-mill now use the power. The head is 11 feet. The flouring-mill uses about 75 horse-power, and the woolen-mill about 50. They do not use over one-half the power of the stream at that head; hence the total horse-power on this estimate, at 10 feet head, is not less than 225. The flow of this stream is very uniform, and as the head can easily be increased to 16 feet there is every facility for utilizing its full power. The rise above the dam does not exceed 3 feet in high water.

Above this power are three more mills of about three run each. It is probable that there is more available water-power upon the Montello river than on the whole Upper Fox. The Mechan and White rivers are similar in their characteristics to the Montello, which has been given as an example. At Princeton a small stream enters the Upper Fox, and under a head of 30 feet it supplied a mill of two or three run, using about 20 horse-power.

The region of the Upper Fox is under a much better state of cultivation than the valley of the Wolf, as it has been settled much longer.

The syenite referred to at Montello is a very compact red variety. Quarries have been lately opened there, and the prospects are that the stone will be of value. It has been used to some extent in Chicago for paving blocks, into which it readily splits.

RIVERS OF THE REGION NORTH OF THE LOWER FOX RIVER SYSTEM.

The rivers of importance emptying into lake Michigan north of the lake Winnebago basin are the Oconto, Peshtigo, Menominee, and several streams in the upper peninsula of Michigan. The instructions in pursuing the field-work were to omit the area lying in Michigan, and, as the time at disposal was limited, a personal visit was made to the Menominee river only. The Oconto and Peshtigo rivers have drainage areas of 1,017 and 1,123 square miles, respectively, and as their headwaters are elevated several hundred feet above lake Michigan, there is considerable fall in their beds. On the upper waters especially are many rapids. At the falls of the Oconto, by including the rapids, 60 feet fall is available, and on both streams are many available powers. By comparison with the Menominee, the power of each at the mouth, under 10 feet head, is estimated to be about 560 theoretical horse-power in ordinary low water. The country lying west of Green bay, along the Oconto, Peshtigo, and Menominee rivers, is still a wilderness, with the exception of the advances of civilization along the shore line of Green bay, the villages started by the iron interest of the Menominee range, and a small amount of land cleared for farming.

The great industry of this region in the past has been lumbering, and a pine forest covered the surface about as far south as the southern extremity of Green bay. Owing to extensive fires which occurred in recent years, this is largely burned off along the Oconto and Peshtigo rivers, but on the Menominee and its branches the woods still exist in their primitive state over large areas. It is along the Menominee that the most active lumbering is now done, and logging-camps are located each winter far up toward the headwaters. The famous Menominee iron mines are likely to lead among the industries of the section, but lumbering has been the main source of wealth in the past, and will be a prominent business for many years to come.

Description of the lumber business.—The system of operations employed on the Menominee is the same general plan pursued throughout the lumber regions of the Northwest.

Lumber companies obtain from the state lands containing valuable pine timber, as near as possible to the streams, and when the lumber is cut off the land is of little value to them, and rather than pay the taxes they allow it to revert to the state. In the early winter men are engaged (in the Northwest largely Scandinavians and Germans, who form a great part of the population), and these are sent off into the woods belonging to the company, where log huts are built, and the men settle down to a winter's work. Supplies are taken to them, usually from the companies' own supply stores, and, contrary to what might be supposed, the men live unusually well, canned vegetables, meats, and fruits, along with many other necessaries and luxuries, being furnished to them; and if the food is not the best, or the cook is not liked, the company is sure to hear of "grumbling in the camp". Some of the men are choppers, and others are engaged in hauling the logs with either horses or oxen. A depth of from 18 inches to 2 feet of snow is considered best for hauling; but sometimes there is too little or too much, and then the work is very much impeded. The logs are usually cut in lengths of from 14 to 16 feet, and are hauled to the banks of the nearest stream of sufficient size to carry them. It is on this account that the timber away from the streams is left until the last. Each company has its distinctive mark upon its logs. When the winter breaks up and the streams are swollen by the melted ice and snow, and, later, by the spring rains, the work of the drivers begins. They start the logs on their journey down the rivers and follow along with them, breaking up jams where the logs are piled up in masses by some obstruction, and sort the logs, guiding those of each company into the pocket belonging to it when the destination is reached. On the Menominee there is what is called the Menominee River Manufacturing Company, incorporated in 1866, which is simply an organization for effecting this driving and delivery in a systematic manner. This company builds dams for holding the logs, blasts out the rapids, etc., to make driving better, and drive the logs, charging from fifty to sixty cents per thousand board feet for driving, sorting, and delivering the logs in the pockets of the several steam saw-mills at the mouth of the river. The owners of the timber lands upon the upper portion of the river pay something toward the improvement of the stream, as it makes their property more valuable.

The logs are sawed into boards, and the waste is worked into lath and shingles in the mills at the mouth of the river. The lumber is largely rafted across Green bay into Sturgeon bay, on the peninsula opposite, where there is a ship-canal about 5 miles long, connecting with lake Michigan. Boats are there loaded with it, and carry it to different ports, Chicago receiving a large portion.

In 1875 there were 602,285 logs passed down the Menominee river, yielding 112,056,280 board feet, and in 1872 142,917,228 board feet passed down the river. During the season of 1880 240,660,524 feet of pine passed through the booms of the Menominee River Manufacturing Company.

Iron mining.—The ore beds of the Menominee region are explored from a little below the Sturgeon river, in Michigan, west, all along the Menominee and its tributaries, and to some extent in Wisconsin also. For over thirty years it has been known that there was iron there. In the winter of 1873-'74 the first shipment of ore was made; but in 1877 the Chicago and Northwestern railroad built a branch up to Quinnesec, on the Menominee, and since that time the advance has been rapid. The rock of the region belongs to the metamorphic base, already described as forming the foundation for the rock layers of the eastern part of Wisconsin, and consists chiefly of granite and schists of various kinds. The ores are hematites, specular ores, and magnetites principally, and, as they contain scarcely any sulphur and a small amount of phosphorus in the average specimen, they are especially valuable for the manufacture of Bessemer steel. This region is becoming very prominent, and many new mines are proposed.

When the lumber and the mining interests of this region are described there remains little else to consider, for the country is almost entirely undeveloped except in these respects. It is true, however, that in sections along the Oconto and Peshtigo active farming is beginning.

Field for manufacturing.—It may readily be imagined that the amount of utilized water-power is small, and this is the case, but not because of any absence of the power unimproved. The industries using power have not yet started to any extent, with the exception of saw-mills. These are located at the line of navigable waters, and principally use steam-power. There are great quantities of the crude material for the manufacture of wood-pulp, and already there has been talk of erecting mills on the Menominee, using water-power for this purpose. This and the making of paper are forms of industry well adapted to lead among the manufactures of a new district, and they will very likely lead upon the Menominee. As the country is settled flouring-mills and other kinds of manufactories may be built; but at present the only two mills upon the Menominee are near the mouth, a paper-mill and a flouring-mill, to be afterward described. At the mouth of the Menominee are two towns: Menominee, in Michigan, with a population of 3,288, and Marinette, in Wisconsin, with 5,412 inhabitants. Peshtigo, on the Peshtigo river, has 3,517 inhabitants, and Oconto, on the Oconto river, 4,171 inhabitants. These towns are on the line of the Chicago and Northwestern railroad, and are the centers of trade for their respective regions. Oconto and the two towns on the Menominee have lake ports, more or less satisfactory, and improvements are being made in their harbors.

MENOMINEE RIVER.

This stream through its entire length is the boundary between Michigan on the north and Wisconsin on the south. Formed by the junction of the Bois Brulé, or Burnt Woods, river and the Michigamme, it flows southeast 104 miles by map measurement into Green bay at about the middle of its western shore.

DIMENSIONS OF THE DRAINAGE BASIN.—The drainage basin of 4,113 square miles is very irregular in outline. Narrow at the mouth, it widens out to an average of about 40 miles across, and sends an arm away north, so that the extreme sources are within 10 miles of the waters of lake Superior in Keweenaw bay. Thus, it nearly extends clear across the center of the upper peninsula of Michigan. At the nominal head of the river it already has a drainage area of 1,769 square miles, for the Bois Brulé and Michigamme are each large streams. Farther down it receives the Pine and Pike rivers from Wisconsin, and the Sturgeon and Little Cedar from Michigan, beside numerous smaller streams (see the table of drainage areas of the Menominee and its tributaries, given further on). The Bois Brulé continues westward, the boundary line between the two states.

The region drained by the Menominee river is yet a wilderness, except where the mining villages have sprung up within late years. The lumbermen have not yet made serious inroads upon the upper waters, and the stillness of the stately pine forests holds its sway. The deer, which are disappearing so rapidly in other sections, there find a safe retreat, and the sportsman can yet see trout as plentiful.

Although no industries yet cluster about the numerous falls on the Menominee, it is only a question of time before the resources of the country will be developed. A personal visit was made to the mining village of Quinnesec. At Marinette Mr. Burleigh Perkins, a gentleman who has explored every mile of the region under the employ of the Menominee River Manufacturing Company, kindly gave much information for this report.

GEOLOGICAL CHARACTER OF THE MENOMINEE BASIN.

The main geological features described among the first pages devoted to the Lower Fox river also rule here The Archæan base, with the succeeding outcropping layers of unmetamorphic rock, which characterize eastern Wisconsin extend almost unchanged along the areas of the Oconto and Peshtigo rivers, the Menominee river, and through the upper peninsula of Michigan. Farther south these layers have an inclination to the east and southeast, and the lines of outcrop of the harder rocks, such as the lower magnesian and Trenton limestones, form a succession of steps, as shown in the east and west section through lake Winnebago, although not so prominent as is the case there. The surface is very largely covered with the drift left by the ice-cap of the glacial period, and the Menominee and all its tributaries, down to about the mouth of the Pike river, flow over the metamorphic base rock, consisting of granite, gneisses, schists, etc. It is in this region that the iron mines are located. Below the mouth of Pike river it flows across the Potsdam sandstone for about 10 miles, then it flows on the next higher layer, the lower magnesian limestone, for about 18 miles, and finally leaving that, it crosses the Trenton group of limestones for about 8 miles to its mouth.

INFLUENCE OF THE ROCK STRATA.—Attention has already been given to the very marked influence of the geological structure upon the Wolf river of the lake Winnebago basin, and as the same structure holds farther north it has had an effect similar in a general way upon the streams there, the Oconto, the Peshtigo, and the Menominee. Because of the general slope to the southeast the tendency of the streams is to flow in that direction, but the terraces of rock along the line of outcrop have forced them to flow northeast or southwest along these outcrops until they could find a passage. To this cause are due the bending and the wide sweeps of the rivers under discussion. It will be noticed that in their upper portions the Wolf, Oconto, Peshtigo, and Menominee have more or less parallel courses southeast. There they flow upon the Archæan base. So soon, however, as they strike the region of stratified and unmetamorphic rock their courses vary.

The Wolf, as it existed previous to the glacial period, traversed the Potsdam belt, and, striking the terrace of lower magnesian, had to run across the state of Wisconsin before it could find a passage through this obstruction by the present Wisconsin River valley. The cause of its change to the modern course has been already mentioned. The Oconto, Peshtigo, and Menominee were more fortunate, and succeeded in keeping their general southeast course across the successive belts of rock; but they, too, found some difficulty, and have to run long stretches along a line of rock before a point is reached where they boldly break across the belt of outcrop.

The Menominee river flows in a general southeast direction to about the mouth of Sturgeon river; from there it gradually bends to the south, and appears to follow the line of outcrop of the Potsdams sandstone down to the mouth of the Lowland river. This is apparently due to the Potsdams opposing a barrier in its course, but we cannot assert it positively, as the courses of the Wolf, Oconto, and Peshtigo are unaffected by the sand rock, passing unchanged across it. These barriers are usually where a hard rock is underlaid by a soft variety. At the mouth of the Lowland river the course changes through more than 90 degrees, and passing directly across the belt of Potsdam sandstone the river encounters the projecting ridge of the hard lower magnesian limestone. Along this it flows northeast for 4 miles, when it suddenly succeeds in forcing a passage, and, breaking across at right angles,

runs southeast 4 miles further, when it strikes the terrace of Trenton limestone at the mouth of the Little Cedar river. This barrier of Trenton limestone causes the river to bend again and flow southwest for about 12 miles, when the stream finds a passage across the limestone, and flows about 8 miles southeast to Green bay.

It must not be supposed that these different layers of rock stand out in bold cliffs along the stream; on the contrary, the river flows in many places entirely in the drift accumulation. The rock formation has nevertheless had the influence just described.

The Peshtigo river, in endeavoring to cross the Trenton limestone barrier, runs northeast and comes within 3 miles of the Menominee at its lower bend. The idea is advanced by Professor Chamberlain, merely as a conjecture, that these two rivers formerly united at this point and crossed the limestone barrier in company by an old channel now filled with drift. There is evidence that they have not always had their present places of passage, and at this region is the lowest apparent point of the barrier in their basins.

MAIN TOPOGRAPHICAL FEATURES.

The country through which the Menominee flows is not mountainous, but many ridges give diversity to the surface. These are ranges or continuous ridges, a few hundred feet high perhaps. The bulk of the timber which covers the land is pine, but in places the light sand soil congenial to a pine growth is replaced by clay, and there the growth is hard wood. The transitions from one kind of timber to another are in many places very distinct, and sometimes a ridge covered with hard-wood timber will run far into a body of pine woods. About Chicagon lake there is a large body of hard timber, and when the land is cleared there will undoubtedly be localities where fertile farms can be wrought out of the wild surface left by nature.

VOLUME OF THE MENOMINEE RIVER AND ITS POWER.

ESTIMATE OF FLOW FROM THE RAINFALL.—No estimates of the flow of the river were obtainable, and no attention has been given to calculating this factor from the annual precipitation and from comparison with adjoining streams on which gaugings have been made. The results, which only claim to be mere approximations, are given in the accompanying table.

The upper Wisconsin and the Wolf flow through somewhat similar sections of country, except that the upper Wisconsin has more swamps and lakes than the latter. The area drained by the Wisconsin above Portage is stated by the United States engineers to be 8,200 square miles, and the extreme low-water discharge at that point 2,800 cubic feet per second, or about 0.34 cubic feet per second per square mile of drainage area. The discharge of the Wolf river at the outlet of Shawano lake has been gauged in about ordinary low water at 633.7 cubic feet per second. The area tributary is 887 square miles. This would make the ordinary low-water flow per second per square mile of drainage basin on the upper waters 0.71 cubic foot per second, which is probably excessive.

For the entire basin of the Wolf river the ordinary low-water discharge per square mile of drainage area is 0.43 cubic foot per second, and for the entire lake Winnebago basin, with a rainfall averaging 30 to 32 inches, it is 0.413 cubic foot per second. The average precipitation upon the Menominee basin is, as near as can be estimated from the meager records in that region, 35 inches, while along the neighboring rivers south it averages about 32 inches.

In view of all these facts, it has been concluded to assume the ordinary low-water discharge of the Menominee basin as 0.46 cubic feet per second per square mile of drainage area; that is, the ordinary low-water flow is at the rate of 17.8 per cent. of the average precipitation. This gives a power, under 10 feet head, of 2,140 theoretical horse-power at the mouth and 921 theoretical horse-power at the head of the river.

TABLE OF DISTANCES, DRAINAGE AREAS, LOW-WATER VOLUME, AND POWER AT DIFFERENT PLACES ON THE MENOMINEE RIVER.

Place.	Distance from preceding station.	Drainage area tributary to it.	Amount of yearly precipitation.	Estimated total volume of precipitation per second.	Ratio of low-water discharge of stream to total volume of precipitation.	Estimated ordinary low-water discharge of stream per second.	Theoretical horse-power under 10 feet head.
	Miles.	*Sq. miles.*	*Inches.*	*Cubic feet.*	*Per cent.*	*Cubic feet.*	
Head of river	0	1,760	35	4,561	17.8	812	921
Mouth of Pine river	14	2,410	35	6,237	17.8	1,110	1,259
Mouth of Sturgeon river	18	2,934	35	7,565	17.8	1,347	1,528
Mouth of Pembinebemon river	10	3,156	35	8,137	17.8	1,448	1,643
Mouth of Pike river	18	3,566	35	9,194	17.8	1,637	1,856
Mouth of Little Cedar river	22	3,941	35	10,161	17.8	1,809	2,052
Mouth of river	22	4,113	35	10,595	17.8	1,886	2,140

In high water the power is immensely increased. The river is not especially uniform in its flow, although running in a timbered country; but it cannot be considered an unsteady stream, its character being medium in this respect. The superintendent of the paper-mill at the mouth said that after a heavy rain the river would rise to a maximum in about four days, stay at that stage about the same length of time, and then fall to the usual level in about four days more.

There are only three or four lakes of any size in the basin, and these mostly have limited drainage areas. The most important one is lake Michigamme, far up on the river of that name. This lake is shaped like a letter A, with arms about 6 miles long by half a mile broad. It is altogether probable that suitable sites for reservoirs could be found in the basin, and when the river is improved for power this matter may receive attention. Some of the tributaries are so uniformly rapid, as the Bois Brulé, that a high dam would only flood a very limited area. The clearing away of the timber and brush will undoubtedly have an injurious effect upon the stability of the river in the future, as has been the case in so many instances elsewhere.

Fall of the river.—The extreme sources on the west are within 2 miles of Lac Vieux desert, the source of the Wisconsin, which is 951 feet above lake Michigan, and on the north they are at least 990 feet above lake Michigan, as lake Michigamme is 952 feet above the level of lake Superior. Thus the river may be considered to fall about 975 feet from its sources to its mouth in a distance by water of about 160 miles. This descent is scattered in local concentrations all along its course, and rapids characterize the river from the source to the mouth

Through the kindness of Mr. E. H. Johnson, chief engineer of the Chicago and Northwestern railroad, the approximate elevation of the river at the railroad crossing, 3 miles above the mouth of Pine river, is ascertained to be 475 feet above lake Michigan, and of the Sturgeon river, at the crossing, 2½ miles above its mouth, 253 feet above the lake. Hence, in the 56 miles (map measurement) from the extreme western sources in the Mequacumecum to the railroad crossing above Pine river the Menominee falls approximately 475 feet, an average of 8½ feet per mile, and from the railroad crossing to the mouth of Sturgeon river, a distance of 18 miles, it falls approximately 225 feet, an average of 12½ feet per mile. In this distance occur the two Quinnesec falls. In the 72 miles from the mouth of Sturgeon river to the lake it falls approximately 250 feet, an average of 3½ feet per mile.

To the consideration of the chief rapids on the main river we will now turn our attention.

THE RAPIDS OF THE MENOMINEE RIVER.

The information contained under this head was almost entirely obtained from Mr. Burleigh Perkins, of Marinette, to whom allusion has already been made.

It will be evident, on reading the following account, that there is an immense amount of water-power on the Menominee awaiting development, the concentration of the descent in numerous rapids and falls supplying remarkably fine opportunities for improvement. All that is wanting is the greater development of the whole region, and this is bound to occur in due time. Any works for the utilization of the power would have to be so constructed as not to interfere with the manufacturing company in the driving of logs; but dams, etc., could be built so as to be no hinderance to the passage of logs.

It must be remembered that only the heavy rapids are described, and that undoubtedly many water-powers, available so far as the river is concerned, exist in the intermediate distances.

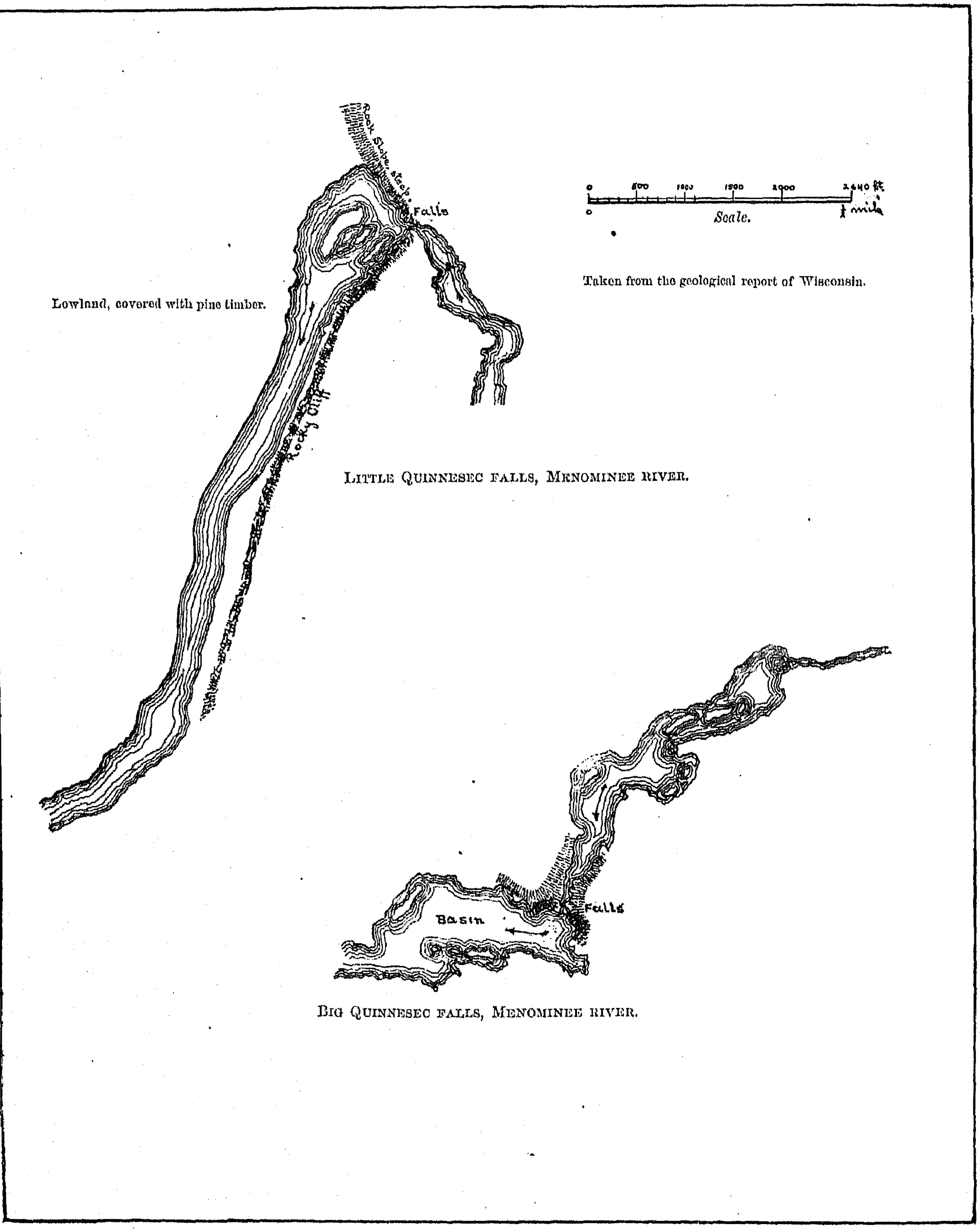
The Menominee river varies from 200 to 600 or 700 feet wide far up toward the headwaters. For the first 7 miles from the junction of the Bois Brulé and the Michigamme there are no heavy rapids, but in the language of the lumbermen, there is "strong water" all the way, and probably many good water-power sites.

Bad Water rapids.—The first important rapids are the Bad Water rapids, 7 miles below the head of the river. A small stream enters here from Spread Eagle lake, in Wisconsin, called the Bad Water by the Indians, on account of its quality. The direct descent at the locality is about 5 feet. The river, which is 180 feet wide, runs over a ledge of rock, probably a schist or a granite. As to the availability for water-power, information is wanting; but in all probability a dam could be reasonably built which would back the water up so that much more than 5 feet head could be obtained. The ordinary low-water power there under 5 feet head would be 455 theoretical horse-power. The Menominee River branch of the Chicago and Northwestern railroad passes about 3 miles south on its way to the young mining town of Florence, in Wisconsin.

Twin falls.—Just below Bad Water rapids 3 or 4 miles are the Twin falls. These consist of two vertical falls of 12 feet each, about half a mile apart. With 12 feet head the ordinary low-water power would be 1,130 theoretical horse-power, making a total for the two falls of 2,260 horse-power. Both falls are said to be well adapted to improvement for water-power, and they are near where the railroad crosses the river into Wisconsin.

Pine River rapids.—Next in course are the Pine River rapids, near the mouth of Pine river, which are half a mile long and have 6 feet fall. An island divides the river into two channels with rocky beds. Above the mouth of the Pine river the ordinary low-water power for 6 feet head is 566 theoretical horse-power; below the Pine river, 730 theoretical horse-power.

Big Quinnesec falls.—Seven miles below the Pine river, and 4 miles from Quinnesec, the most prominent of the villages in that section, are the Big Quinnesec falls, they and Little Quinnesec falls, 4 miles below, being the two heaviest falls on the river.



Little Quinnesec falls, Menominee river.

Big Quinnesec falls, Menominee river.

At Big Quinnesec falls the river narrows to hardly more than 50 feet wide (map measurement) between rocky banks of greenstone, a variety of igneous rock. Immediately at the foot of the falls the river widens out, and

about 800 feet down is 700 feet across. Above the falls it has been running east of north, and there it turns directly east. The banks are 80 to 100 feet high on the Wisconsin side and 30 to 40 feet high on the Michigan side, and the fall proper is a vertical pitch of 60 feet. There is 40 feet of rapid descent above the fall, and 20 feet in the first 900 feet below, the total fall being 120 feet. The total theoretical power with this 120 feet head in ordinary low water is 14,905 horse-power. It seems probable, from the description given of the locality, that it would be very costly to improve the full fall of 120 feet.

Little Quinnesec falls.—Four miles below are the Little Quinnesec falls. For the greater portion of this distance there is quiet water, and the shore deposits are considered by Major T. B. Brooks, who reported on the geology of the district, to indicate the presence of a lake there at a comparatively recent date. Above Little Quinnesec falls the river runs southwest, but at the foot it suddenly turns at right angles and runs southeast, the water surging down an incline of about 45 degrees, and then taking a plunge into the comparatively still water of the basin below. The total fall is about 80 feet. Above the fall a short distance the river is 250 feet wide but narrows down at the pitch to about 50 feet. Immediately below the fall the basin spreads out on the south to 900 feet wide, but 1,500 feet below the channel contracts to 400 feet in width, and in this basin are three or four parallel islands, the largest being 700 feet long by about 150 feet wide. The falls are hemmed in by heavy masses of greenstone and schist rock. Along the Michigan side a massive steep cliff of greenstone, at least 100 feet high, forms the bank of the river for a long distance, and on the Wisconsin side a somewhat similar rib of rock forms the bank of the basin for 600 or 700 feet from the fall, and then slopes away into ridges of more gradual inclination. The rest of the Wisconsin shore of this basin is low. There is a considerable area of level land covered with timber; then the hills rise gradually behind this, and the valley, probably of some small brook, trends away to the west. From the description given it will be seen that the banks adjoining the falls are steep and rocky.

There is not any apparent means of an extensive improvement of this water-power without great outlay of money, and even if only one or two industries were clustered close at the falls the expense would be great. Still, with the head of 80 feet, and an ordinary low-water power of 9,936 theoretical horse-power, the situation will be worth improving when the country becomes older and the value of water-power is increased. A deep snow and limited time prevented a very extensive exploration along the rocky cliffs, but from what was observed it seems probable that the only feasible way of improving this power on an extensive scale is to blast a race out of the rock, or else build flumes along the cliffs and supply manufactories from them. It is possible thus to carry the water along the Wisconsin bank and supply the power to mills upon the flats below. On the Michigan bank there is not much available space, but mills could be built out over the river, provided the high water is not there excessive.

On account of the great width of the river for a long distance down it does not seem probable that the rise is very heavy. A wagon-road could be constructed from the flats below the falls to Vulcan, a station on the railroad, about 6 miles east of Quinnesec. The latter town is about 3 miles north of the falls, and could not be so readily reached from below as Vulcan. The Menominee River Manufacturing Company would, of course, object to having the flow over the falls diminished to a great extent in logging times by side races. It has built cribs on each bank at the crest of the falls, to make the body of water deeper, and has done some work at the foot in blasting out a rock which splits many of the logs as they strike their ends upon it. The company has been considering the plan of damming the river some distance below and backing the water up over this rock.

Sand Portage rapids.—These rapids lie between Little Quinnesec falls and the mouth of Sturgeon river, and received this name because the Indians, in making their "carry" around a part of them, passed over a large amount of sand. The rapids are scattered along a distance of 6 miles, and in this space is 40 feet fall. The ordinary low-water power under this head would be 5,078 theoretical horse-power.

Sturgeon falls.—The next sharp pitch below the Sand Portage rapids is Sturgeon falls, half a mile below the mouth of the Sturgeon river. This fall is in two pitches of 6 feet each. Above the falls the river is 200 feet wide, and below them it spreads out into a broad basin. The banks are rocky ledges, about 30 feet high. From the description which was given it may be conjectured that in order to utilize the power it would be necessary to blast out a race in the rock or to build a flume, and it was stated to be feasible to blast out a place in the bank below and build a mill right at the foot of the fall, carrying the water in a short flume. The ordinary low-water power with 12 feet head would be 1,831 theoretical horse-power.

Nose Peak rapids.—In the next 15 miles are several small rapids, among them Nose Peak, about 1,000 feet long, with 4 feet fall. This would give, at an ordinary low stage, 605 theoretical horse-power, but undoubtedly a greater head than 4 feet could be obtained.

Pemena falls.—One and a half miles below the mouth of the Pembinebemon river begin the Pemena falls and rapids. For a distance of 2 miles there are rapids, with a total descent of 60 feet, and then a vertical fall of 10 feet, where there are two islands, giving two principal channels. The rock is the metamorphic rock of the upper waters, in this case a slaty variety, probably a schist, with quartz veins. Pemena falls and rapids are considered good for the erection of dams. The location is about 12 miles west of the Chicago and Northwestern railroad. Under the total head of 70 feet the power at ordinary low water is 11,115 theoretical horse-power.

Chalk Hill rapids.—About 8 miles below Pemena falls are Chalk Hill rapids. They are nearly 1,300 feet long, with 8 feet fall over a ledge of rock of slaty variety, and there is a good place for a dam. The ordinary low-stage power under 8 feet head would be 1,302 theoretical horse-power.

WHITE RAPIDS.—Four miles below, and about the same distance above the mouth of the Pike river, are the White rapids, with a fall of 20 feet in 3 miles. Two big islands lie in the center of the rapids. The bed is of gravel and bowlders (the drift), and the banks are good. There is a good location here for a dam, and the power could be well utilized. Under a head of 20 feet the ordinary low-stage power is 3,275 theoretical horse-power.

All the rapids down to this point are over the Archæan rocks. From the mouth of the Lowland river, while the stream is crossing the Potsdam sandstone, there are no heavy rapids; but while crossing the belt of lower magnesian limestone the course is southeast, and there are two rapids of note.

SIXTY-ISLAND RAPIDS.—Sixty-Island rapids, about 2 miles above the mouth of the Little Cedar, have only a slight descent, and the situation could not very well be made available for water-power.

GRAND RAPIDS.—One mile below occur the Grand rapids. These are 3 miles long, situated partly above and partly below the mouth of the Little Cedar, and have a fall of 25 feet. The bed is, of course, limestone. These rapids occur just where the river strikes the barrier of the Trenton limestone and turns southwest, and, like the Oconto falls, which are on the same geological horizon, they are caused by the river wearing down into softer strata of the rock, the hard cap not eroding so readily. There are good banks at the foot of these rapids for building a dam, and probably the power could be utilized. The ordinary low-water power under 25 feet head at this point is 4,954 theoretical horse-power, and the railroad passes one mile east of the rapids.

While following along the barrier of the Trenton limestone for about 12 miles to the last bend the river runs south-southwest, and the inclination of the bed is less, as might be expected, because the slope of the strata is toward the southeast.

TWIN ISLANDS RAPIDS.—These rapids are situated about 7 miles below the Grand rapids and 16 miles from the mouth of the river, with a length of three-fourths of a mile, and a descent in that distance of about 10 feet. The two islands lie one below the other, and divide the river into east and west channels. The bed is limestone, the banks steep, and there could be a dam built across each channel to the islands. The total length of this dam, it is said, would have to be about 700 feet. For a long way the old state road passes near the river, and by it access could be had to the towns at its mouth; but this road is not much used now. There was once a saw-mill, called Dr. Hall's mill, on the east channel, with 6 feet head, but this was removed when the lumbering interests began. The ordinary low-stage power under 10 feet head would be 1,995 theoretical horse-power.

At the lower bend the Menominee turns, and, running across the Trenton group of limestones in a southeast direction, finally reaches the lake level. As in passing the lower magnesian limestone, so here there are two sets of rapids.

SCHAPPEE'S RIFTS.—The first is Schappee's rifts, 5 miles above Marinette. These are half a mile in length, with a descent of 7 feet, and have an available head of 10 feet. There are good banks and a limestone bottom. The power at an ordinary low stage of the river would be 2,024 theoretical horse-power under this head.

RAPIDS AT MARINETTE.—The last series of rapids on the river are situated at Marinette, near the mouth. In their natural state there was probably about 10 feet fall, but the Menominee River Manufacturing Company has built three dams, one above the other, the upper one backing the water to the foot of Schappee's rifts. The total head from these dams is 19 feet. The head at the upper dam, about 1 mile above Marinette, is 7 feet, at the middle dam 5 feet, and at the lower dam 7 feet. At each of these there is available water-power. The theoretical power at an ordinary low stage would be as follows:

	Horse-power.
Upper dam	1,448
Middle dam	1,034
Lower dam	1,448
Total	3,930

This, with an efficiency of 75 per cent., would give 2,948 available or effective horse-power. The superintendent of the paper-mill stated that the ordinary low-water power available under 7 feet head was 1,000 horse-power. These calculations, based on the rainfall, make it 1,146 horse-power.

PRINCIPAL RAPIDS ON THE MENOMINEE FALL, AND ESTIMATED THEORETICAL POWER.

Name.	Fall, in feet.	Horse-power.	Name.	Fall, in feet.	Horse-power.
Bad Water rapids	5	455	Pemena falls and rapids	70	11,115
First Twin falls	12	1,130	Chalk Hill rapids	8	1,302
Second Twin falls	12	1,130	White rapids	20	3,275
Pine River rapids	6	566	Grand rapids	25	4,954
Big Quinnesec falls	120	14,905	Twin Islands rapids	10	1,995
Little Quinnesec falls	80	9,936	Schappee's rifts	7	2,024
Sand Portage rapids	40	5,078	Rapids at Marinette	19	3,930
Sturgeon falls	12	1,831	Total	450	64,231
Nose Peak rapids	4	605			

Of course, this table does not represent the total theoretical power of the river, as only a portion of the total fall is taken. It must not be forgotten that many of the amounts of fall given are only estimates made by an informant perfectly familiar with the stream; still, the figures given are moderate, and will serve to give some idea of the water-power lying idle.

UTILIZED POWER UPON THE MENOMINEE.

The only power used is from the lower dam at the mouth.

In 1831 permission was obtained from the Menominee Indians, upon the payment of certain supplies, to build a grist-mill on the river. This was built in 1832 on the Wisconsin bank, a short distance above the present crossing of the Chicago and Northwestern railroad. The next mill, a saw-mill, already mentioned as owned by Dr. Hall, was erected in 1841 at Twin Islands rapids. This ran for five years, when the lumbering interests became paramount, and as the dam interfered with the passage of logs it was removed. In 1845 another mill was built. The two mills now remaining are a pulp-mill at the Michigan abutment of the lower dam and a flouring-mill at its Wisconsin abutment. The head averages 7 feet, but sometimes the water of Green bay rises from 6 inches to 1 foot on their wheels. The pulp-mill belongs to the Marinette Paper Company, which, when visited in December, 1880, was expecting to erect an extensive addition in the succeeding summer for a paper-mill. There is much spruce and poplar along the river for wood-pulp, and the company also was thinking of logging the wood down the river as the lumbermen do. The good quality of wood costs $6 per cord, delivered in Marinette; but by logging they can probably obtain it much cheaper. The better quality of wood is used for the manufacture of fine paper. For common paper they use sawdust, ends, etc., sawed into pieces. The pulp-mill uses 670 horse-power, but they expected to use a total of 1,000 horse-power when the paper-mill was built. The flouring-mill, upon the south bank, has wheels for about 150 horse-power. It will be seen that with the improvements contemplated the low-water power at the lower dam is already taken up.

TRIBUTARIES OF THE MENOMINEE.

TABLE OF LENGTHS, DRAINAGE, AREAS, LOW-WATER DISCHARGES, AND POWER OF THE TRIBUTARIES OF THE MENOMINEE RIVER.

Name.	Length.	Drainage area.	Amount of yearly precipitation.	Estimated total volume of precipitation per second.	Ratio of low-water discharge of stream to total volume of precipitation.	Estimated ordinary low-water discharge of stream per second.	Theoretical horse-power under 10 feet head.
	Miles.	*Sq. miles.*	*Inches.*	*Cubic feet.*	*Per cent.*	*Cubic feet.*	
Bois Brulé river, including the Mequacumecum	42	1,013	35	2,012	17.8	465	528
Michigamme river	72	756	35	1,940	17.8	347	391
Pine river	53	586	35	1,511	17.8	269	305
Sturgeon river	50	400	35	1,055	17.8	188	214
Pembinebemon river	23	163	35	420	17.8	75	85
Pike river	43	292	35	755	17.8	134	152
Little Cedar river	32	149	35	384	17.8	68	77

It will be noticed that, in mentioning these streams in the order of their occurrence in passing down the Menominee, we have also given the order of their drainage areas, the largest being farthest up. There is only one exception, viz: in the case of the Pike and the Pembinebemon rivers. Of course there is no significance in this, as many small streams have been entirely omitted from the table; but one important deduction arises, which is that the tendency is to make the volume of the Menominee at its upper waters more nearly equal to that at its mouth. The total power of the stream would be very different from what it now is if the Bois Brulé, Michigamme, etc., entered near its mouth.

The Bois Brulé and the Michigamme rivers, by their junction, are considered to form the Menominee. The Mequacumecum river is called a tributary of the Bois Brulé, although its drainage area is nearly double that of the latter stream.

BOIS BRULÉ RIVER.—This is equivalent in English to Burnt Wood river, but by the Indians it was called Wisacodé. It runs between Wisconsin and Michigan. The extreme length, measured on the map, is 42 miles; the drainage area, including the 635 square miles tributary to the Mequacumecum, is 1,013 square miles. Its ordinary low-water power at the mouth under a head of 10 feet is estimated to be 528 theoretical horse-power. The extreme headwaters of the river cannot be very far from 900 feet above lake Michigan. At the mouth the Bois Brulé averages 180 to 200 feet wide. The bed of the river is mostly gravel and bowlders of the drift, and on this account the descent of the river, which is large, is not concentrated in vertical falls and sharp pitches, but is very uniformly distributed along the whole course, in either rapids or "strong water". It is said that there are scarcely 50 rods of slack water on the whole length of the stream. At the mouth is a vertical fall of 10 feet past an island. The banks of the river are usually steep, and in many places there are fine water-power sites. The

slope of the river is so uniform and so great that it is almost impossible to make a reservoir upon the stream sufficient in size for flushing down logs. The Menominee River Manufacturing Company has built one dam upon the river for that purpose.

THE MEQUACUMECUM RIVER.—This is the Indian way of saying Paint river. Although a nominal tributary of the Bois Brulé, it deserves separate mention. The length by map measurement is 54 miles; the drainage area is 635 square miles; and the estimated ordinary low-water power at the mouth, under 10 feet head, is 331 theoretical horse-power. The extreme headwaters are about 950 feet above the level of lake Michigan. The river is not so rapid as the Bois Brulé, but there are more vertical falls. The bed is largely gravel, as is the case with the Bois Brulé; but in places the ledge rock takes its place, and to this are due the falls. Three miles above the mouth is a descent of 20 feet in half a mile, divided between three pitches; above this for 4 miles is strong water. At this point is a dam, built by the manufacturing company, which backs the water up for 5 miles. At this point is Crystal falls, with 10 feet of nearly vertical descent. For the succeeding 13 miles up to Hemlock rapids there is strong water. Hemlock rapids are half a mile below the mouth of a river of that name, entering from the east. There is a fall of 16 feet in half a mile. The river flows in three channels, and the manufacturing company has blasted out the rocks from the main channel and turned all the water into that. A short distance above the mouth of Hemlock river there is a vertical fall of 8 feet.

It will be noticed that the river divides into three parts: one branch, the Hemlock river, springing from the northeast, another from the north, and a third draining the county west. These three branches cut through a series of ridges, and the result is on each stream a succession of broad basins and slow currents, with intervening rapids where it passes the ridges. At these places the streams are not over 100 feet wide, and this condition continues up to the sources of the river.

MICHIGAMME RIVER.—This stream is the largest tributary of the Menominee, properly speaking, for if we consider the Mequacumecum separate from the Bois Brulé the drainage area of the latter is less than one-half that of the Michigamme, whose basin is 756 square miles in extent. It is this stream which carries the drainage basin nearly across the upper peninsula of Michigan, the extreme sources being within 10 miles of the waters of lake Superior. The head of the river, however, is considered to be lake Michigamme, already mentioned as being the largest lake of the Menominee basin. The area is 6½ square miles, and the drainage area tributary to it 193 square miles, and if it is feasible to increase the reservoir capacity of this lake by a dam across the outlet it would exert an appreciable effect upon the steadiness of the stream below. The length of the river to the extreme sources is 72 miles (map measurement); to lake Michigamme, 51 miles. The ordinary low-stage power at the mouth, under 10 feet head, is estimated to be 391 theoretical horse-power, and the average width at the mouth is 250 feet and at the head 80 feet. Lake Michigamme is 980 feet above lake Michigan. There are several prominent falls and rapids on the river, and all the falls are over rock ledges, with rocky banks. About 1,300 feet from the mouth is a perpendicular fall of 30 feet, with steep, rocky banks. Four miles from the mouth is another vertical fall of 6 feet. Fifteen miles from the mouth, and about 3 miles below the mouth of Deer river, is a vertical fall of 10 feet over a rocky ledge. Three miles above the mouth of Deer river Fence or Michigan river enters, and between these is a flood-wood jam, caused by an island. This jam backs the water up somewhat. There is as yet no lumbering done so far up in the Menominee basin. Six miles above Fence river is Long Carry rapids, 1¾ miles long, with about 40 feet fall. Next there is a fall and rapid 3 miles below Republic mine, three-quarters of a mile long, with about 20 feet fall. Lake Michigamme is 8 miles above this place.

PINE RIVER.—This is the largest tributary of the Menominee lying wholly in Wisconsin, its length, measured along the general course, being 53 miles to the extreme sources. The drainage area is 586 square miles, and the estimated ordinary low-water power at the mouth, under 10 feet head, is 305 theoretical horse-power. For the first half a mile from the mouth the current is very rapid; in the next 12 or 13 miles the fall is comparatively slight, and the current moderate; and in the next 3 miles there are two falls of 8 feet each, 1,000 feet apart, half a mile of "strong water", succeeded by another fall of 12 feet; then, half a mile above, a fall of 40 feet. Sixty feet above this is a dam belonging to the Menominee River Manufacturing Company, used now for flushing down logs, and two miles up is the mouth of Poplar river. The lumbering only extends 6 miles above that.

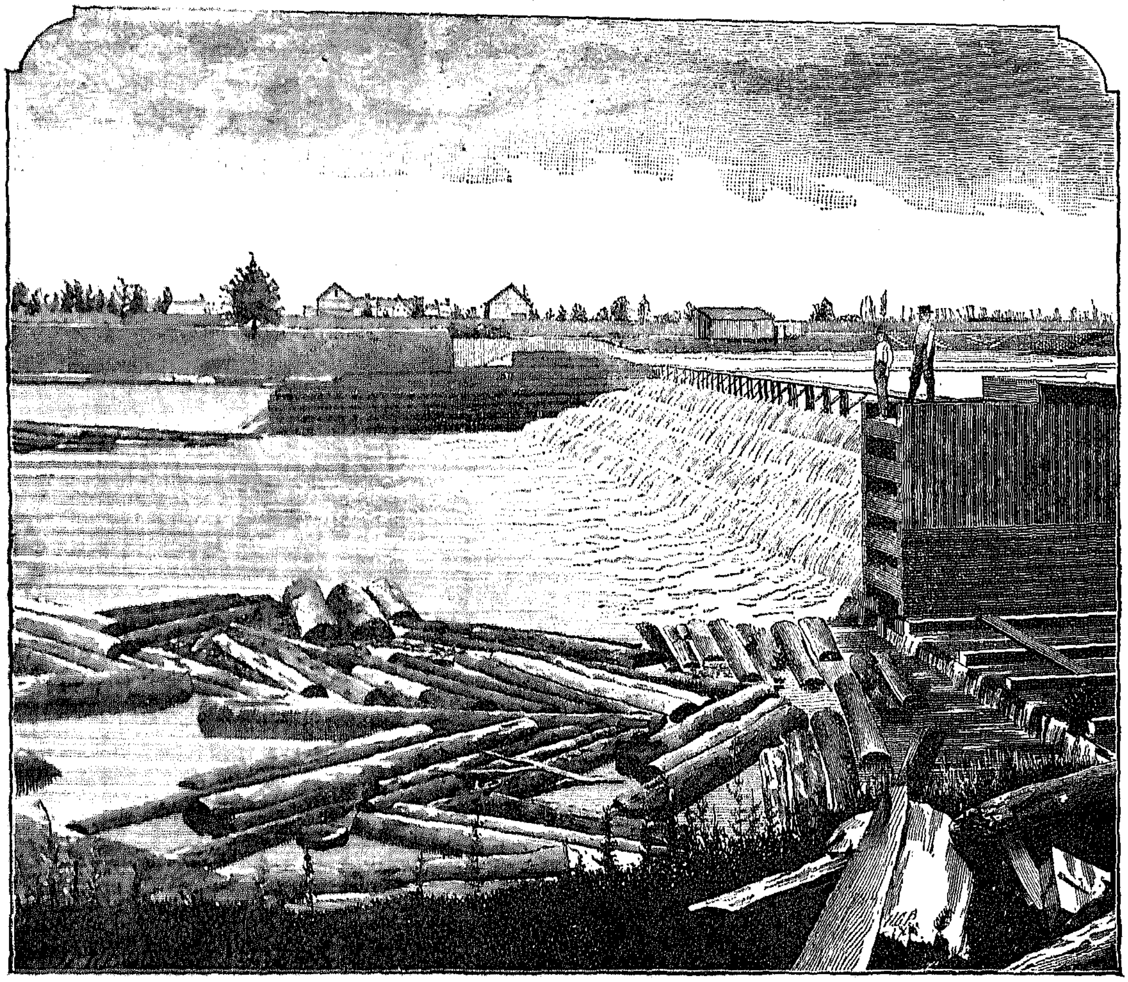
STURGEON RIVER.—The basin of this river is in Michigan, and its length (map measurement) to the extreme sources is 50 miles. The area drained is 409 square miles, and the power, under 10 feet head, at an ordinary low stage of the water is 188 theoretical horse-power. The average width at the mouth is 100 feet. The general course is south-southwest, nearly at right angles with the general slope of the country, and hence the fall of the river is comparatively slight. Ten miles above the mouth is a descent of 16 feet in three pitches.

As is the case with most of the streams flowing southward on the west side of lake Michigan, the river flows near the eastern limit of its drainage basin. This is, in all probability, due to the general southeast inclination of the country. Three-quarters of a mile above the falls is a dam belonging to the Menominee River Manufacturing Company.

All the lower tributaries are small and of less importance than the ones described. The largest is Pike river, in Wisconsin. The length to its sources is 43 miles, and the ordinary low-water power, under 10 feet head, at the mouth is 152 theoretical horse-power.

DAMS UPON THE MENOMINEE RIVER.

All dams on the river and its branches are owned by the Menominee River Manufacturing Company, which uses them for the lumber interests. Those upon the upper waters are for the purpose of making reservoirs, wherewith



LOWER DAM ON THE MENOMINEE RIVER AT ITS MOUTH.

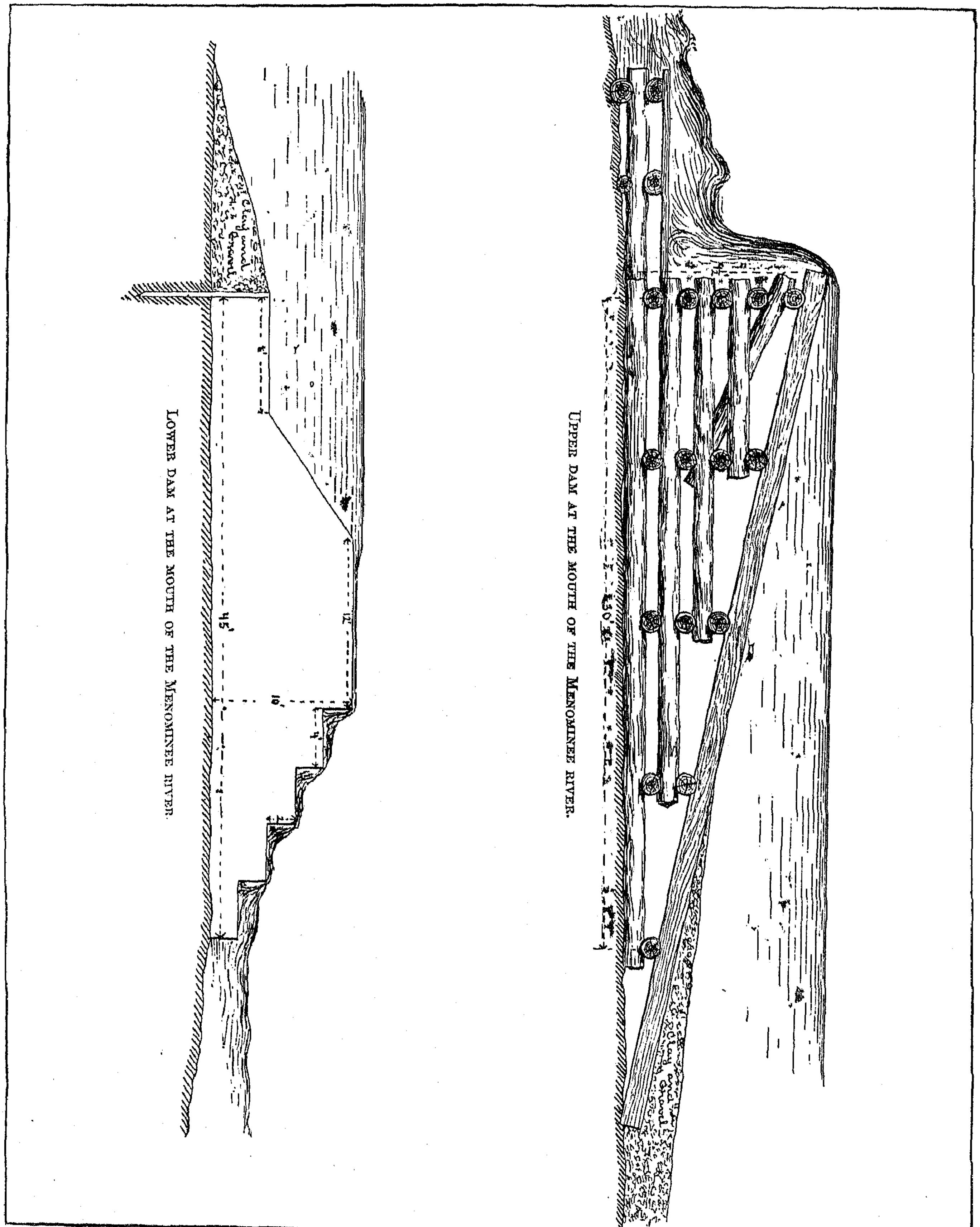
to flush logs down stream. The three dams at the foot are used for collecting and sorting the logs. The upper dam of those three forms a reservoir 5 miles long, and is capable of storing 300,000,000 board feet of lumber. The other two are chiefly as a security, to hold the logs in case the first dam gives way.

UPPER DAM.—The upper dam, called the Bently dam, is 1 mile above Marinette. It is a timber-crib dam, with a covering of spars. The length is 557 feet, the height 9 feet, and the average head 7 feet. The dam is arched up stream with a total rise of 10 feet, and cost $10,000. The bed is smooth limestone rock, and the structure is a continuous crib-work of round timbers, with a vertical face, and a back sloping to the toe of the dam. The base is about 30 feet broad. On the crib-work are hewed spars, laid close together, and running down to the river bed. The lower timbers are all bolted to the bed-rock by 1¼-inch iron drift-bolts, let into drilled holes, and fastened by wedges previously placed in their split ends. Upon the back of the dam is laid clay and gravel. At the face is a kind of apron, built of a low crib-work, planked over. There is a runway in the dam 75 feet wide and 1½ feet above the bed of the pond for the passage of logs. This is faced with hewed timbers. The logs glide over the apron just described.

MIDDLE DAM.—The middle dam is similar in construction to the upper dam, but has a head of only 5 feet. The length is 644 feet, with about 10 feet rise of arch, and the cost was $8,000. An island in the center of the river divides the dam into two parts. The bed is limestone rock.

LOWER DAM.—The lower dam is the finest one on the river. It was built by Mr. H. A. Dow, of Minneapolis, in the year 1880, at a cost of $16,500. The construction is a timber crib-work. The dam is straight, 700 feet long and 9½ feet high. There is a runway near the center, extending below the dam about 120 feet, for the passage of logs, and there are eight sluice-gates. The bed of the river at that point is loose rock, clay, and gravel. Mr. Dow

had no drawings of the dam, and the description, dimensions of the cross-section, etc., were entirely obtained from an interview with him. The timber used is pine. The lower course is of logs, and the others of sawed timbers 12



LOWER DAM AT THE MOUTH OF THE MENOMINEE RIVER.

UPPER DAM AT THE MOUTH OF THE MENOMINEE RIVER.

by 12 inches in size. The planks are 3 inches thick. The cross-section is given. The front consists of a series of four steps, with 2 feet rise and 4 feet tread. The crest of the dam is horizontal for a width of 12 feet. The

back slopes down to 2 or 4 feet above the bed, where there is a horizontal bench, 8 feet broad. This is terminated by a vertical back to the river bed. The base is 45 feet wide. The whole dam is planked over, and at the back are sheeting piles, 3 inches thick, which were driven down into the bed and spiked against the outer timbers. Behind these clay and gravel were filled in. The water runs over the crest of the dam and falls down over the succession of steps. There is no apron below the dam. The runway is a crib-work of squared timbers, faced with the same kind of timbers, close laid. The rush of the current sends the logs through this with tremendous force. The abutments are built of timber cribs. No coffer-dam was used in the construction of this dam.

METHOD OF BUILDING.—The method employed was to build the cribs over their proper positions and sink them. Starting from the Wisconsin bank, four logs were floated down into position and held there, parallel with each other and 8 feet apart, with their lengths in the direction of the current. These covered an area 45 feet long and 32 feet wide. Across these was placed a course of sawed timbers. Another section, entirely similar, was floated down adjoining the first toward the center of the river, but leaving a space of 8 feet between them, and across these the crib-work was built, locking one with the other. This process of floating in the sections and building up the crib-work was continued until the position of the runway was reached, which was then built. In sinking the cribs enough of the sections in the crib-work would be floored, so that when filled with stone the weight would suffice to carry the structure down to the bed, and the other sections were left open. When the cribs were sunk in position the open sections were filled with stone, which filled up the inequalities in the bed under the crib and gave a uniform bearing to the lower course of timbers. After completing the runway a crib 32 feet long was built next to it on the Michigan side, and then a space of 32 feet was left for the passage of the water. The process of building the sections and crib-work above them was then continued to the Michigan shore. The heavy body of water which now passed through the space of 32 feet left open scoured the bed out to a considerable extent before it was closed. The method of closing was to make an immense trap-door, with a very strong frame, hung on a horizontal axis, and at the proper time this was let down. The force of the current immediately forced it shut against the crib-work on each side, and loads of gravel, hay, etc., held in readiness, were thrown in, and in two hours from the time of starting the opening was closed. Back of this trap-door the crib-work was built up and the dam completed.

There are several dams upon the upper tributaries of the Menominee, all of spar construction: and one on the Bois Brulé, 390 feet long, with two gates, each 9 feet wide: and one on the Mequacumecum, 375 feet long, with five gates, one 9 feet wide and four 7 feet wide. The Sturgeon and the Pine rivers have each a spar dam also.

MILWAUKEE, SHEBOYGAN, AND MANITOWOC RIVERS.

NATURE OF THE DRAINAGE AREA.—The water-shed separating the lake Winnebago basin from the streams flowing direct into lake Michigan is almost at the verge of the line of cliffs overlooking the Green bay and lake Winnebago valley. The Kettle range, a medial moraine of the glaciers already alluded to, does not act as a divide, but the larger streams find their way through it. The water-shed averages 300 feet above lake Michigan, and all this fall in the land takes place in a distance of about 30 miles. Toward the north the water-shed narrows to 10 or 15 miles wide, and at the southern end of the lake it is hardly more than 5 miles across. In the section about lake Winnebago, then, the drainage basins of the streams must be the largest, and it is there that the chief streams of the division are located. These are the Milwaukee, Sheboygan, and Manitowoc rivers. The lengths of these, measured along their general courses on a map of large scale, are, respectively, 66, 45, and 42 miles. The headwaters of the Milwaukee are about 500 feet, of the Sheboygan 360 feet, and of the Manitowoc 350 feet above lake Michigan; hence the average fall per mile of each stream is approximately as follows: Milwaukee, 7.6 feet; Sheboygan, 7.9 feet; and Manitowoc, 8.3 feet. These results are probably greater than the truth, because in estimating the lengths of the streams their general courses only were taken. This fall, of course, gives rise to many water-powers, and, as the country is already settled to a large extent, these water-powers are improved in part, but the greater portion is yet lying idle. From the statistical returns for the census of 1880 these data are obtained for the main streams. The returns from special agents on woolen-mills, cotton factories, and other special industries were not yet received at Washington at the writing of this report, and hence the accounts may be slightly too small for these streams; but the error cannot be great, as the bulk of the power is used in flouring- and grist-mills. It must be borne in mind, then, that the data given cannot be considered exact.

MILWAUKEE RIVER.

Number of flouring- and grist-mills		13
Total power used by these	horse-power	775
Number of saw-mills		6
Total power used by these	horse-power	122
Miscellaneous industries		5
Total power used by these	horse-power	75
Total power used on the river	do	972
Average power to each industry	do	40.5
Average head to each industry	feet	10.2
Maximum power used in one industry (flouring)	horse-power	145
Maximum head employed on the river	feet	24

SHEBOYGAN RIVER.

Number of flouring- and grist-mills	7
Total power used by these ... horse-power	260
Miscellaneous	3
Total power used by these ... horse-power	150
Total power used on the river ... do	419
Average power to each industry ... do	41.9
Average head to each industry ... feet	12.4
Maximum power used in one industry (wooden packing-boxes) ... horse-power	90
Maximum head employed on the river ... feet	17

MANITOWOC RIVER.

Number of flouring- and grist-mills	6
Total power used by these ... horse-power	174
Number of saw-mills	5
Total power used by these ... horse-power	108
Total power used on the river ... do	282
Average power to each industry ... do	25.6
Average head to each industry ... feet	9.8
Maximum power used by one industry (flouring) ... horse-power	54
Maximum head employed on the river ... feet	27

ESTIMATED POWER.—As near as can be estimated from data given and the comparison of the drainage basins, the ordinary low-water power under 10 feet head along the lower portions of the river is, approximately: Milwaukee river, 250 theoretical horse-power; Sheboygan river, 220 theoretical horse-power; Manitowoc river, 165 theoretical horse-power. These figures can only be considered as approximate results.

PECULIARITY OF THE MILWAUKEE RIVER.—It will be noticed that the course of the Milwaukee river is east in northern Ozaukee county until within 9 miles of lake Michigan, when it suddenly turns south and flows parallel with the lake above 30 miles to Milwaukee. Professor Chamberlain, in the geological report of this region, states that the river emptied into the lake at northern Ozaukee county, when the lake level was higher than now, at the time of the deposit of the lower red clay. The action of the waves threw up a beach line in front of the river mouth, and caused this to travel south in the endeavor of the water to force an outlet. Thus the river for the last 30 miles of its course flows behind an old lake beach. A similar case has been pointed out in the report on the Red River of the North, as occurring where the Otter Tail river empties into Otter Tail lake. Pike river and East Twin river, which empty at the west shore of lake Michigan, are also considered to have experienced similar conditions.

GENERAL REMARKS UPON RIVERS OF THE WESTERN PORTION OF LAKE SUPERIOR.

The streams tributary to western lake Superior are not of large size. The Saint Louis river, with a basin of 3,000 square miles, may perhaps be considered an exception, but it far exceeds any of its neighbors, and is claimed to be the second river of the entire lake in size.

What the rivers of the western part of lake Superior lose in volume they make up, however, in fall, and to a certain extent this is an equivalent in water-power. The water-shed is near the lake on both sides, but it is also elevated 1,000 feet or more above the lake level, and, as a consequence, the streams are very rapid. This characteristic feature of the lake Superior streams is most strongly exemplified on the north shore, where for a long distance the water-shed is at an average distance of 8 or 9 miles from the lake, and the streams go rushing down a descent that must be nearly 1,000 feet. The rock of the north shore is largely igneous and very hard. Many falls and rapids crowd the water-courses, and often right at its mouth a stream will take a final leap. This is the case with the Pigeon river, which forms part of the boundary between Minnesota and the British possessions, and is one of the largest of these north-shore streams. It is a portion of the water system connecting the Lake of the Woods, Rainy lake, and innumerable smaller bodies of water with lake Superior. The outlets of these lakes are so undecided that it is extremely difficult to determine just what are the boundaries of its drainage basin.

Although there is an annual precipitation of 30 to 34 inches upon this region, and an enormous aggregate of water-power, yet the country is so inaccessible and little improved that the power is of little value except in particular localities. With the Saint Louis river, at the extreme western end of the lake, the case is different, and as peculiar circumstances surround that stream special attention will now be given to it. Succeeding the report on the Saint Louis river are some remarks on the south shore of lake Superior and its water-powers.