ON THE WISCONSIN RIVER IMPROVEMENT.

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Before speaking of the physical features of the Wisconsin river, we will offer some general remarks applicable to the whole of North America. Recent surveys show that Lake Winnebago formerly had its outlet southward to the Wisconsin river, and since changed to the north through the lower Fox river into Green Bay. It has long been known that Lake Michigan once had its outlet southward through the Illinois river, and that Chicago stands in the old bed of the lake, the southern shore of which is twelve miles south of the city. All the small lakes examined show the same condition, an elevation south of a line drawn from Cape Hatteras on the Atlantic to Cape Mendocino on the Pacific, and a depression north of that line. If this supposition be correct, going back in time, the lake outlets would all be southward, and not northward as at present. Hence we would infer that the Niagara and probably the St. Lawrence rivers (though there are signs of greater antiquity connected with the last), are of comparatively modern origin, which is confirmed by the fact of their abounding in waterfalls and rapids. There is no doubt that Lake Winnipeg was once continuous southward, covering the central portion of the valley of the Red River of the North, and having its outlet down the Minnesota River, and not as now, down the Nelson river to Hudson's bay. The river bank near the old out-
let show that this change took place since the glacial period. The ancient Lake Winnipeg was larger than the present Lakes Superior and Michigan combined. The northern depression is known to be going on along the Atlantic coast from New Jersey to Greenland. Any one can test the matter of northern depression and southern elevation for himself by examining the published maps, and remembering that the effect of bodies of water on the shore is to abrade it and spread the material smoothly over the bottom, while the effect of the atmosphere is to cut the land up in ridges and to wash the soil from the rocks; so that the land rising from the water will have comparatively smooth outlines, and successive lagoons parallel to the shore, while the land going under the water will show jagged and sharp outlines, with deep indentations and numerous islands. We know that during the cretaceous period, an ocean extended from the present Gulf of Mexico to the Arctic Ocean, covering a large portion of the space between the Missouri River and the Rocky Mountains. At that time the country through which the Upper Mississippi now flows was dry land, and its slopes must have sent its water westward to that cretaceous ocean. As the continent rose this ocean disappeared, and the tertiary period began with great fresh water lakes along the Rocky Mountains. Into these lakes the waters of the upper Mississippi region continued to drain westward. The gradual southwestern elevation of the continent throughout the tertiary period, is distinctly proved by the deposits of the tertiary lakes. The earliest deposits were of the least area, and as they become more recent they expand northeastward, and this action continued apparently to the time preceding the glacial epoch. Preceding the glacial period, then all the water-courses westward of the upper Mississippi region were westward and not southward, as now. Not only the slope of the land but the great folds of the Silurian strata compelled the water to this course. Over a great deal of the region thus drained, no rocks more recent than the Silurian are found, so
that it must have been dry land since the Silurian period. In the immense ages succeeding the time of the Silurian oceans, the rocks being exposed to the destructive atmospheric influences must have been cut up by the ravines and valleys encroaching on each other in endless confusion. The pre-glacial erosions of even the hard Azoic rocks which formed the dry land of the Silurian period can still be distinguished from those made since. When the glaciers came they planed down the whole region of the upper Mississippi river, removing silurian strata 500 feet in thickness over hundreds of miles. The south-western limit of the glacial drift action is the Missouri river from the 48th down to the 43d parallel of latitude. From the Missouri river to the Rocky Mountains, over a space varying from 300 to 500 miles in width, there is no drift. The motion of the glacial mass must have been along the line of least resistance; and towards this limiting line, the glacial scratchings in the northwest show that the glacial motion was southwest. There, then, on that limit, a river must have been formed to carry away the melting water from the glacier, and this limit was the Missouri river, and that was the river so formed. As the glaciers began to retire to the northeast, as long as the general slope of the plain was towards the glacial mass, successive rivers were marked out by it along the western face; and all have a parallax and are close to each other, and have short tributaries or parallel branches, if any. There are, besides minor streams, the James, Big Sioux, Des Moines, Iowa and Cedar rivers; and finally the Minnesota and Mississippi the last of the parallel rivers. After the lowest line of the continental valley was passed, the glacier would retire, so that the melting water would run directly from it, and thus we see the origin of the tributaries of the Mississippi on the east side.

This direction corresponds with that of the pre-glacial rivers, and it is probable that many of them were washed out and regained their old beds; such as the St. Croix, Chippewa and
Wisconsin rivers, and is confirmed by their appearance. From the foregoing we infer that the Wisconsin River was in the trough of what was formerly a far mightier stream; that the ancient river was not only greater in volume, but cut deeper into the bed through which it flowed; that this ancient bed is composed of the silurian or older rocks and is silted up many feet deep. Such are a few of the facts which geology lays before the scientific engineer to guide him in making his plans for water improvements. A knowledge of the old channels of our rivers would have prevented the folly of making a canal through the solid rock in order to avoid the falls of the Ohio at Louisville, instead of digging through the drift of the old channel of the river. Instead of probing with an iron rod every inch of the bed of the Mississippi before we can determine the practical depth at which firm rock may be reached, geology steps in and tells us it will be found at a depth of at least 60 to 100 feet through the sand, with two remarkable exceptions at the rapids, one at Keokuk, the other at Rock Island. These exceptions are readily accounted for, when we know that the whole valley of the Mississippi was covered with an extension of the Gulf since the glacial period as high up as Savannah or Dubuque. That the silt brought in by the Des Moines river in the one case, and the Iowa and Rock rivers in the other, during this period, filled up entirely the valley cut out by the great glacial river, and that when the land rose again the Mississippi could not at these points regain its old bed, so it had to cut a new one, which is not yet completed. There is no doubt that Lake Erie had formerly an outlet past Fort Wayne, Indiana, and down the Wabash valley, which indicates the natural course for water communication between the lake and the Ohio river.

From these general remarks which will be recognized as germane to my subject, I will now turn to its special consideration. The main features of the Wisconsin river are common to northwestern rivers. First, there is a high bluff on
each side of the river valley, from one to ten miles apart, and from 100 to 400 feet high, composed mainly of horizontally stratified rocks; and in the case of the Wisconsin, of Magnesian Limestone of the Silurian formation. The slopes, however, are often covered with earth and green grass. The sand feature is a level or nearly level terrace mainly composed of sand, though occasionally having a rich surface soil. This terrace is from 20 to 60 feet above the level of the water. It is never continuous throughout the valley on either side, and rarely of much extent but on one side at a time. It is probably the shallow part of an ancient water-course which once occupied the valley from bluff to bluff. It is now generally above overflow. The third feature is the bottom land of the river, generally overflowed at highest stages, and having the high bluff or terrace for its margin. This bottom contains many lakes and marshes, and is cut up by sloughs forming islands. These islands sometimes divide the main stream into nearly equal parts. The margins of these bottom lands are, in the natural state, generally wooded, and form the banks of the streams at moderate stages when the sand bars are covered. The fourth feature is the bed of the stream, which includes the part covered at medium stages, but large portions of which become dry sand or gravel bars at very low ones. There are thus four different prominent branches or levels in the river valley: 1. The level forming the main bluff. 2. The sand terrace generally above overflow. 3. The bottom land generally overflowed at highest water. 4. The bed of the stream. In 1867, a careful survey under direction of Gen. Warren was made of the Wisconsin river from Kilbourn City to its junction with the Mississippi river. A continuous transit line was carefully measured and staked off on one bank or the other of the main river, as was found most easy and all the topography sketched along it. The opposite shore was located by triangulation across. A careful line of levels was run, noting frequently the height of the bottom lands, or sand terrace when
near, the height of the water at the time, that of the last high water, and the most noted high or low water mark ascertained. Besides the parties who ran these main lines there were two subordinate compass parties who surveyed the minor channels making connections with the main line as often as possible, a cross section level party and a sounding party. The object of this survey was to determine the practicability of improving the river so as to form part of a line of communication by steamer from the Mississippi River by way of the Wisconsin River, Upper Fox, Lake Winnebago and Lower Fox River to Green Bay, and thence with the lakes. For this improvement Gen. Warren submitted three plans. 1. By means of a series of wing dams, etc., and the use of Long’s scraper, so as to make it navigable for boats drawing three feet water. Estimate $428,000. 2. By use of natural channels in connection with side-canals of sufficient width and depth for steamboats drawing four feet water. Estimate, $3,207,000. 3. By means of a canal designed for steamboats drawing five feet water, built along the valley, alternating from one side of the river to the other, as circumstances demand, and using the natural bed of the river for crossings. Estimate, $4,164,000.

In 1871, Col. Houston, U. S. Engineer, was directed in accordance with these plans to improve the navigation of the river at those points where the proposed canal was to cross the river, and in doing so to determine the practicability of improving the river itself. The proposed canal starts from a point on the canal now connecting the Wisconsin and Fox rivers, near Portage City, where it connects by a lock with the river. The canal then commences on the opposite bank of the river and proceeds on the right bank to a point about 56½ miles below Portage, when it again connects with the river by a lock. Commencing again on the left bank opposite it proceeds to a point 88½ miles below Portage, when a similar crossing becomes necessary, and then proceeds on the right bank to Prairie du Chien, when it connects with the Missis-
sippi river. The depth of the proposed canal is for vessels
drawing five feet, and the lengths of the river to be improved
to enable boats navigating the canal to cross the river, are, at
the upper crossing, 2,800 feet; at the middle crossing, 7,000
feet; and at the lower crossing, two and a half miles. There
are two classes of obstructions. Those arising from causes
not now operating and which once removed will not return,
and those arising from causes now operating and which must
be constantly recurring until the cause is removed. In this
latter class we find sand the chief obstruction to the improve-
ment of the Wisconsin river. What shall be done with it?
This problem, John Nader, Assistant U. S. Engineer, under di-
rection of the U. S. officer above named, has been endeavoring to
solve, since July, 1871. He finds the sandbanks of the upper
river the cause of the sandbars below Portage. That where-
ever the river is contracted between narrow banks, the sand-
bars will form only behind projections or obstructions, and in
this case tend to improve rather than obstruct the channel;
also occasionally, where the river is moderately wide, sand-
bars are found to have lodged on one side or the other (prob-
ably caused by some obstruction) and preserve a good chan-
nel; but where the stream is straight for some distance, and
of considerable width, there will be formed a middle ground,
with but little water over the same, and sometimes a dry bar;
in either case the channel is on one side or the other, never on
both. Where the middle ground is flattened out, and extends
across the whole width of the river, one side of the bar ad-
vances more rapidly than the other, and the crest of the bar
is formed obliquely across the river; the current generally
flows at right angles with the line of the crest, and the width
of the river is virtually nearly doubled in some cases; in
nearly every case, deep water is found along the crest of the
bar. The motion of the sandbars is quite regular, and de-
pends not so much on the stage of the water as upon the ra-
pidity of change from high to low, and upon the velocity of
the current. During a continuous stage of water, the movement is slow and regular, and the bars are moved along as an obstruction by the pressure rather than by the velocity of the water, rolling slowly and steadily along the bottom with no floating sand, until the equilibrium is disturbed. When moved by the velocity of the water, they move quite rapidly, and the sand is found floating in the water in quantities. He gives an instance of a bar above Steamboat Slough, containing a uniform depth of water of twenty-two inches at a certain stage of water. After the water had fallen twelve inches, the same amount was found; also subsequently when the river had risen again a little above its former stage, still the same amount of water covered the bar, clearly indicating the existence of equilibrium between the current and weight of sand.

In order to determine the most favorable condition of equilibrium to preserve a good channel, a section was measured near Lone Rock, where the channel is quite uniform for several hundred feet, and the stream at low water is confined to one channel of 325 feet between banks; the greatest depth was 7.4 feet, and the mean depth six feet, giving the cross-section of 1,950 square feet; a series of floats gave a mean velocity of 1.95 miles per hour; the channel in question always preserves a uniform depth, and is free from sand-bars. As there are many similar places on the river, it will be safe to assume from these the necessary section for any required depth of water.

Aside from the sand bars, the only other obstruction to navigation are the railroad bridges and the principal difficulty with these is that they are built obliquely across the stream; the water is thereby inclined to flow to the bank at the downstream end; whereas the draws of both the Spring Green and Lone Rock bridges are at the opposite or up-stream end; in addition to this the draw spans are very narrow; and still more contracted by the piles and protection of the pier-foundations, making the entire available width at low water about
36 feet only. The experimental improvement was made by building wing-dams at suitable points along the line to be improved. The plan adopted required only the use of brush, with sufficient stone to retain the same in places and the addition of gravel to prevent leaks under the brush. The brush was made in fascines of 11 feet long and 13 to 15 inches in diameter, securely bound. The fascines were then formed into mats of about 9 feet wide, by placing a number of fascines side by side, and placing light poles on top and bottom, and tying the ends of the poles with twine. Having determined the position of the dam with stakes driven into the sand, a sufficient number of mats were prepared as above stated, and a quantity of stone and sand bags being in readiness, the work was commenced. The mates were floated into position and sunk by placing stone and sand bags upon them. They were placed side by side in the line of the draw, and the bottom row carried to the entire required distance; the brush ends or tops were placed upstream, and after the first course was laid the tops were covered with a layer of gravel, to prevent undermining; and the remaining courses were carried up in the same manner; each course was brought forward from 2 to 4 feet in order to break the fall of the water. After the dam rose a little above low water, a substantial layer of loose brush was placed along the entire face of the dam, and covered with a layer of stone, and then with sufficient gravel to stop all leaks. The general effect of these dams was the usual effect of contractions; the water was elevated above the contracted part in some cases as much as six inches, but subsided again as the channel accommodated itself to the change. In the case of cross-dams, a general movement of sand took place for some distance above, and to a considerable distance below the work; and as soon as the current was checked there was a deposit of sand in front of the dam in its whole length. As soon as the dams were brought to the surface, there was a rapid deposit of sand and below the same; that above was concave, and that
below convex to the axis of the stream. In connection with the work, observations were made of the movements of sand bars, and the effect of the work upon them. The movement at Portage was from 3 to 5 feet per day which seemed to be the average upon the river unless disturbances occurred. At Dekorra the effect of dams caused a movement of from 7 to 14 feet in twenty-four hours, and at Lone Rock from 6 to 20 feet in twenty-fours hours. The bars moved along at this rate until reaching the dams, and then receded as rapidly and disappeared, the sand being deposited behind the dams. From the result of the work it would appear that it is only necessary to contract the stream proportionate to the required depth, everything else depending upon the stability of the dams, of which he has not the slightest doubt, as he considers the test which they withstood, when in an early stage of progress, the water poured over the same in an entire sheet, as much severer than any resulting from high water. Concerning the stability of the channel produced, the question arose as to whether high water with increased pressure and velocity would not continue excavating the same until banks and dams would slide in, and the channel become useless; this gave rise to an examination of the river where the same is confined to a narrow channel, so that its depth is from 6 to 8 feet at low water; at such places the bottom is found to be composed of coarser material and gives considerable resistance to the thrust of a pike; the bottom always remains the same excepting during the passage of a sand bar during a freshet.

For my own part I think the canal project by far the most preferable. As the work will be principally excavation in sand and loam it can be done with proper machinery at a comparative small cost. When once completed it can be maintained at small cost. The banks as proposed will be above high-water mark in the river and consequently not be liable to damage from floods. No estimate need be made for feeders. The Wisconsin river will constitute a natural
feeder. The daily discharge of water in the Wisconsin at Portage City is 259,000,000 cubic feet; not less than 8,000 cubic feet per second. The total daily supply of water for the Erie canal of Pennsylvania, enlarged with a prism greater in area than the one here proposed, is less than 20,000,000 cubic feet—about 231 cubic feet per second—not one-twelfth of the amount available in the Wisconsin, and yet the Erie canal, which is 136 1-2 miles in length, and has a lockage of 926 feet, has sufficient water to pass through the locks 144 boats per day, or to carry through the boating season 5,400,000 tons of freight. The Dalles, which is a gorge in the rock about 23 miles above Portage, reduces the river at one place 54 feet, so that the extreme of fluctuations from low to high water below the Dalles does not exceed 10 feet, and arrangements could be made, besides supplying the proposed canal, to turn only the desired quantity into the Portage canal and Fox river. Freight could be carried by this line for about one-fourth of what they can by railroad. In view of the great and increasing amount of grain annually shipped to the east from the west of the Mississippi, it should be constructed at the earliest practicable day.