VOL. XII. 1898. *PART II.*

TRANSACTIONS

OF THE

Canadian Society of Civil Engineers

OCTOBER TO DECEMBER, 1898.

CONTENTS

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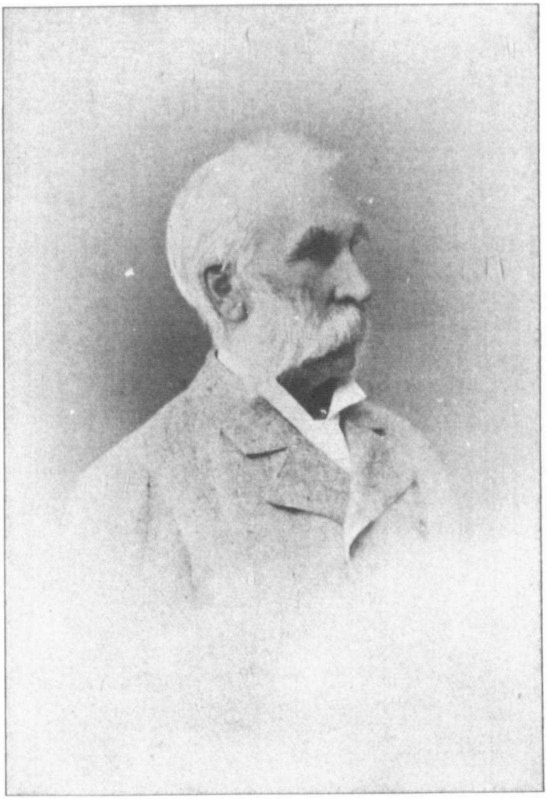

Yours very truly
W. G. Thompson

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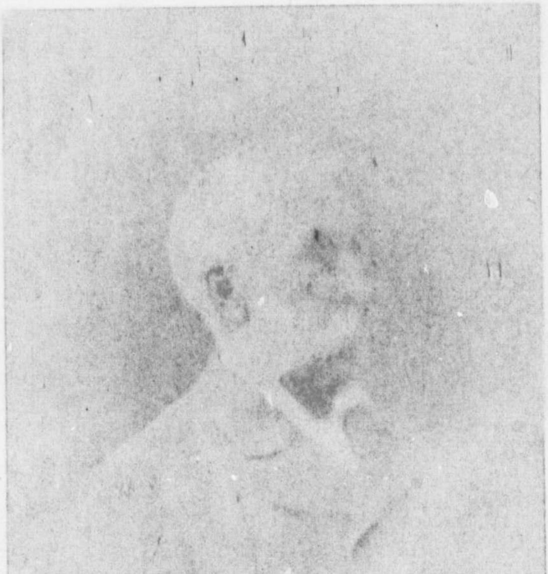

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Thursday, 13th October.

P. W. St. George, Vice-President, in the Chair.

The following donations to the Library were announced :—

Thirty-nine volumes on engineering subjects, from Mr. John Kennedy, Past President ;

"Modern Methods of Sewage Disposal," from Mr. C. A. Bigger, A.M. Can.Soc.C.E.

"Surveying Instruments" and "Mathematical Drawing Instruments," from Mr. Wm. Ford Stanley ;

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Paper No. 133.

THE STAUNCHNESS OF RIVETED JOINTS.

By Prof. J. T. Nicolson, D.Sc., M.Can. Soc. C.E., M.Inst.C.E.

The subject which I venture to bring before you to-night is that of riveted joints.

As you all know, the usual method of designing riveted joints is to proportion the area of the rivets and of the plates, so that the shearing strength of the rivets shall be equal to the tearing strength of the plates measured through the rivet holes, allowance being made for supposed alterations in strength of plates caused by drilling or punching. All experiments on riveted joints have, with few exceptions, been made on their limit of tenacity. The experiments made by the Committee of the Institution of Mechanical Engineers of London, on which Professor Kennedy reported, were almost exclusively on the breaking strength of these joints. These experiments were made in 1881.

From recent experiments it appears, however, that all the work hitherto done is somewhat wide of the mark ; and it seems astonishing when we think of the matter under the new light that these things should not have been found out before. Thus, when a hot rivet is put into a joint on cooling, it endeavours to contract, but being prevented from doing so by the plates, it is subjected to a high tensile strain, and in consequence of this its diameter becomes smaller by reason of the resulting cross strain, which is one-quarter of the longitudinal strain.

On this account, and on account of the contraction in the diameter due to cooling, the rivet when cold no longer fills the hole in the plate, even if the hole were filled perfectly when the rivet was hot. From this it appears that the shearing strength of the rivet never comes into play, even when the original fit of the rivet is a close one.

Many must have thought of this, some may even make use of it in practice; but, so far as known, such is not the case, and all the books with which I am acquainted make no mention of the fact that a rivet does not really fill the hole.

What is it then that makes the resistance of the joint? Obviously, the resistance of the plates to slipping over each other holds the joint staunch. This is certainly the case in boiler plates. In many such joints which were perfectly staunch it was found that the rivets did not touch the sides of the hole at all until the joint had yielded and they were really brought into shear. A little consideration will show that, even if one or two rivets are initially in such a position as to resist by means of shearing, the rest cannot be touching.

The Committee of the Mechanical Engineers in 1881 on Riveted Joints considered the matter of the friction of the plates and came to the conclusion that the resistance due thereto was a negligible quantity, as it did not help to increase the ultimate tenacity. We now see that it could hardly be expected to do so. The plates are then so drawn out by the stretching to which they have been subjected that rivets no longer nip them.

So long, however, as the load on the joint does not exceed the safe strength of the plates, the joint resists entirely by friction.

Especially is this the case when the load changes its direction; it must be friction which is operative and not shearing resistance. One objection raised to this theory is that, if the co-efficient of friction is only at most one-half, then the frictional force required to make the joint operative necessitates so great a tension in the rivet that it would be ruptured.

Now, whilst it must be admitted that no one knows how the co-efficient of friction is affected by pressure, it seems clear that the co-efficient of friction must increase with pressure, and with high mutual pressures may even exceed unity.

In the case of a butt joint with double butt straps, we have two surfaces which offer resistance to slipping; and as the resistance we get on that joint is proportional to the force with which the rivet squeezes the plates together, we have twice the resistance that there would be if the rivet were in single shear.

It is to bring to your notice some results which have been found in connection with this important question, and to show what remains to be done, that I venture to translate to you the following extracts from French and German writers.

The first series of experiments, of which I propose to make a short abstract, is found in a memoir by Dupuy, printed in the "Annales des Ponts et Chaussées" for 1895. The paper is one of considerable length, containing 110 pages, but I propose to give you merely a short summary of his conclusions, as drawn up by himself.

He begins with a summary of some well-known results in elasticity, which it is necessary to know before the conclusions drawn from them can be tested.

"(1) A bar subjected to tensile stress in the direction of its length elongates proportionally to the force brought to bear upon it. The 'limit of elasticity' is the name given to the force per square inch of the section of the bar below which the extensions are proportional to the loads.

"(2) After the loads have passed the elastic limit, the bar elongates for a certain time without its being necessary to increase the force. This period is known as the 'period of yielding,' the point at which it begins to yield being the 'yield point.'

"(3) If we continue extending the bar, a time arrives when the force begins to increase, but the extensions increase more rapidly than the loads or force. Afterwards there follows a second period, during which the bar elongates without sensible increase of the load. This period may be called the second period of yielding, or the 'plastic period.'

"(4) After the 'second period of yielding,' during which there appears a large contraction of the bar, the extensions are produced by forces which generally decrease, and the bar breaks under a force generally much inferior to that to which it was previously subjected.

"(5) A bar subjected to stresses inferior to that corresponding to the elastic limit takes its original length when the stresses are removed. Such extensions are of course named 'elastic extensions,' and elastic extensions are proportional to the stresses producing them.

"(6) A bar subjected to stresses exceeding its elastic limit does not take its initial length when the stress is removed. The length which the bar takes under stress is diminished by the amount of the elastic extension, but the bar retains what is called a 'permanent set.' (See Fig. 1.)"

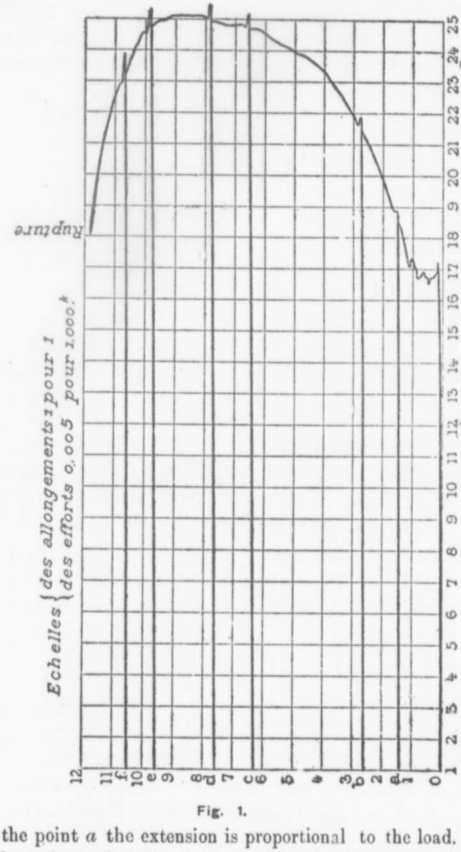


Fig. 1.

Up to the point *a* the extension is proportional to the load. This point is the "elastic limit" and is called by the French and Germans the "limit of extension." From this point the bar is said to go back to its first length, and if this is absolutely true, then "limit of elasticity" is a good name for it, for it means that up to this point the extensions are "elastic extensions." At this point is the greatest elastic extension. After this the extensions are not quite proportional to the loads, and then comes a time when without increase of load we get further extensions. After a time the extensions increase faster than the loads. After passing this point, when the load is taken off, the bar does not go back to its original length, but goes back along a line very nearly parallel to the "proportionality line." A bar strained beyond its elastic limit is said to have taken "a set." In this way the "elastic limit" of the bar may be raised to the rupture stress.

In No. 6 Dupuy says "that a bar subjected to stresses beyond the limit of elasticity does not take its initial length when the force is taken off. The length which the bar obtains during the stress is diminished by "the elastic elongation" only, and the bar takes a permanent set. The bar is then said to be "deformed," or to have taken "a set."

"(7) The limit of elasticity, or, to be correct, the 'limit of proportionality' of a bar which has a set, corresponds very nearly with the force which produces the set.

"(8) The area of the section of the bar which has a set is somewhat less than the initial area. It may be said that the volume of the bar remains constant.

"(9) A bar which has a permanent set almost up to the point of rupture has a 'limit of proportionality' corresponding to the maximum force which the bar has been able to sustain.

"(10) A set increases considerably the limit of proportionality, and even the tenacity before rupture is increased if reckoned on the area of the contracted bar.

"(11) A bar which has a set, if heated to redness, retakes its original elastic limit."

The above conclusions, which are well known by many experiments on wrought iron and steel, have a special application to rivets. We therefore now pass on to the second section of our subject, and come to Dupuy's conclusions respecting the strength of rivets.

"(12) Rivets are bars which have a permanent set, and are subjected to tensile stresses beyond the initial elastic limit of the material. The fibres of the circumference of the rivet appear to have more set than those at the centre.

"(13) The rivets do not exactly fill the holes, but they exert a very high tensile force, which causes a very great resistance to friction between the plates.

"(14) The resistance to slipping of the riveted plates is greater in proportion as the limit of elasticity of the material of the rivets is greater.

"(15) The limit of resistance to slipping is extremely variable. The causes of this slipping appear to be very numerous, and depend upon:—The nature and quality of the material of the rivet; the temperature at which the head was formed; the temperature when the joint was finished; the mode of operation; the kind of rivet, etc.

"(16) The resistance to slipping on which we may count, in practice, in the case of treble riveted members of bridges" (Dupuy is speaking more particularly of bridge constructions) "are the following:—

"(*a*) With iron rivets, with a limit of elasticity of the material of the rivet equal to 25,600 lbs. per square inch, with the rivet bright red-hot, hand riveted, and the hammering stopped when the head turned black; the resistance to sliding equals 5,600 lbs. per square inch of rivet area.

"(*b*) With iron rivets, with an elastic limit of 30,000 lbs. per square inch, with mode of operation as in last section, *i.e.*, rivets bright red, hand riveted and so on, the slipping resistance equals 6,600 lbs. per square inch of rivet area.

"(*c*) With iron rivets of elastic limit 25,600 lbs., but with the rivet white-hot and riveted with presses producing a pressure of at least 85,000 lbs. per square inch of rivet section, the pressure being maintained by the machine until the head of the rivet turned dark, the slipping resistance was 500 lbs. more than in the last, and equalled 7,100 lbs. per square inch of rivet area.

"(*d*) With iron rivets having a limit of elasticity of 30,000 lbs., hand riveted, rivet bright red, and so on, as in article (*c*), the slipping resistance was 800 lbs. more than that in (*b*), or 7,400 lbs. per square inch."

These results go to show that the resistance increases as the elastic limit of the material of the rivet increases.

"(17) When three bars united by rivets are cut through, it is found that the section appears as shown in Fig. 2. If a tensile force is exerted on the centre bar, the position of the rivet in the hole does not change at first. The joint is simply like one continuous piece of metal, the rivets are not all in shear, and the tension of the rivets tends to diminish on account of the thinning of the plates due to their being in tension. If the force goes on increasing, a time arrives when the centre plate slides, and the position of the rivet is as shown in Fig. 3. If the force goes on increasing, the rivet bends and the head tends to slide; when the heads have slipped the form of the joint is as shown in Fig. 4. If the force continually increases, the flexure of the rivet increases, the holes become oval, and the appearance of the joint is that shown in Fig. 5."

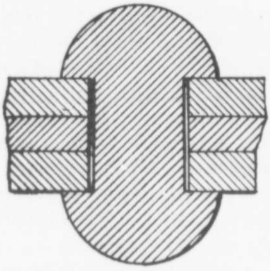


Fig. 2.

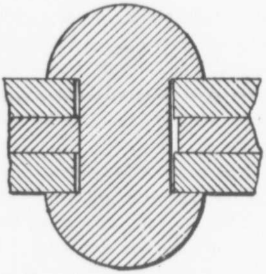
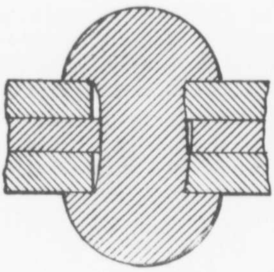


Fig. 3.



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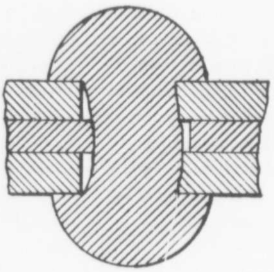


Fig. 5.

This concludes the account of Dupuy's work, and I should add that the way in which he obtains his results is at least as interesting as the results themselves, and I should recommend it to your attention.

The next series of experiments which I shall take up will be illustrated by slides showing the results. These experiments were made in Holland in 1897 by J. Schroeder Van der Kolk. They were written in Dutch, but have been translated into German and published in the "Zeitschrift des Vereins Deutcher Ingenieure" for June 26 and July 3, 1897. I now translate:—

"The apparatus used in these experiments differs considerably from that of Considère and Dupuy. Considère, it should be mentioned, carried out his experiments in 1887. By Considère and Dupuy, only the relative motion on one side of the specimen was determined. The motion of one rivet relatively to another was not examined, nor was the different amount of slipping in different parts of the joint regarded.

"The arrangement adopted by Van der Kolk in the determination of these things is shown by the following figures. In the side surface of the test pieces—which were all of the form shown in Fig. 6, namely, two plates with double butt straps—holes were drilled at *a*, *b*, *c*, *a'*, *b'*, *c'*, and so on, at the centre lines of the rivets. Into these holes three-cornered wedges were screwed, and, by means of a micrometer screw (shown in Fig. 8), the slipping of the pin *b* in the metal plate relatively to the two pins *a* and *c* in the side plates were measured. Figs. 7, 8 and 9 show the apparatus, which was hung by two arms by the milled head *d* against the end surface of the metal pin *b*. In this position the reading of the drum was taken. A fine wire was stretched on the arm *f* for more accurate reading. The pitch of the screw was ½ millimetre. The reading cylinder was divided into 100 parts, so that a motion of one division of the drum corresponded to 1-200 millimetre; and the displacement of *b* relatively to *a* and *c* could thus be read to the 1-10,000 of an inch. A little scale, divided in half-millimetres, gave the total drop of the pin *b*. The left arm of the nut rested on the knife edge (a) by means of two steel caps *g* and *h*. The right hand arm rested at one point, the steel pin *i* on the knife edge *c*. The whole apparatus was pushed along the knife edges up against the test piece, so that it only touched the test piece at one point *l*, and was thus perfectly free to move.

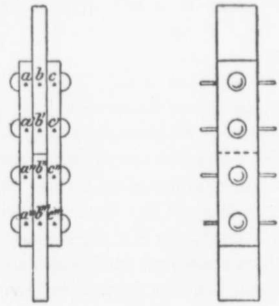


Fig. 6.

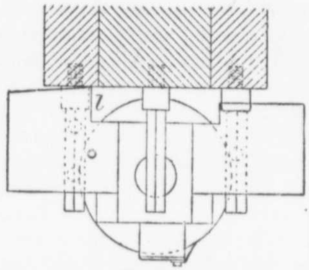


Fig. 7.

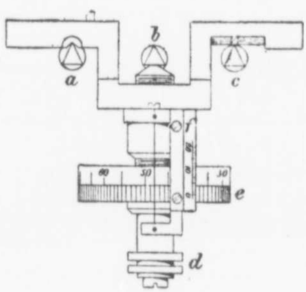


Fig. 8.

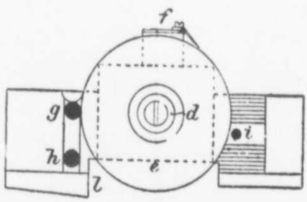


Fig. 9.

"Besides these observations of slip, the extensions of the distances between the knife edge a and the knife edge a', between b and b', c and c', and so on, were measured, for which measurements the apparatus shown in Figs. 10 and 11 was used. The micrometer screw was fixed in the same way as before, and connected to the nut was a small bar *m*, which was hung by means of a hook, provided with a steel cap, from the knife edge *a*. The apparatus was pushed against the specimen by means of the pins *p* and *q*. The apparatus worked, after a little practice, very well."

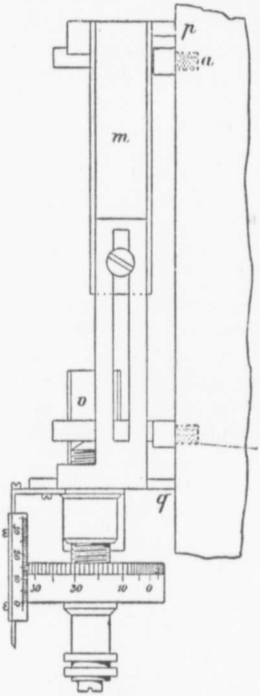


Fig. 10.

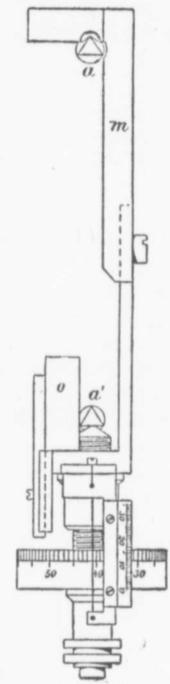


Fig. 11.

The next section treats of the form of the test pieces. The test pieces were butt joints with double butt straps. There were five series of specimens. The first series had butt straps of the same thickness as the plates, and the others had butt straps one-half as thick as the plates. The various divisions of the series will appear better if we show the results, and therefore before going on to the slides showing the experiments I should like to give Van der Kolk's results. His final results are as follows :—

" In this research the breaking strength of the riveted joints was not determined. As a rule, the stresses in riveted joints of bridges are far below the limits at which rupture may be expected, so that the question to be answered is not so much—what joint has the greatest strength, as—what joint has the greatest durability, *i.e.*, in other words, under what circumstances is it least to be feared that the rivets will work slack ? To this question these experiments give the following answer :—Those conditions are most favorable in which the connections have the least relative working, i.e., when the permanent, but especially the elastic slidings, are made to be least."

We have these two kinds of slip to deal with :—" Permanent slip " and " elastic slip." When a load is put on, we get a certain slip ; when the load is taken off, a certain amount of that slip disappears ; the total slip less the amount which disappears is called the " permanent slip."

These two kinds of slip have a great effect upon the durability of the joint. Each of them has a detrimental influence. The permanent slip, however, only happens once, and on a repetition of the load which first caused it, it hardly, if at all, increases. The elastic slip, on the contrary, takes place at every repetition of the loading, and actually has a greater effect in loosening the rivets than the permanent slip.

There are two conditions in which the elastic slip is as small as possible : (1) hand riveting, *with the holes too large for the rivet ;* (2) machine riveting, with a very great pressure on the dies.

In the case of hand riveting, the plates must be twice as thick as the butt straps ; in the case of machine riveting, the influence of the thickness of the butt straps was not investigated.

If the permanent slip is required to be as small as possible, and to begin at high values of the stress, then it is necessary that (1) in the case of hand riveting, the large holes should be in the butt straps, and (2) that the continued duration of the contact and pressure of the dies should be as long as possible.

These conclusions go to show that, with hand riveting, a tight fit of the rivet in the holes is not the best condition for durability. With machine riveting it seems that the large holes are completely filled by the powerful pressure of the dies, and practically the rivets become a good fit. The fit of the rivets in the holes is, in the case of machine riveting, of inferior importance, while the pressure on the dies and the duration of the contact of the dies on the heads is the matter to which most attention should be paid.

These results do not in the least contradict those obtained by Considère, Dupuy and Bach; as these men did not investigate hand riveted specimens, with rivets fitting the holes tightly. It was quite unexpected (by Van der Kolk) that with specimens with tight fitting rivets slipping should commence with such small loads; indeed, these specimens were made with rivets a tight fit, in order to get model joints with which to compare the rest of the experiments. It was adversely observed that these joints actually gave the worst results. The reasons for the fact that the frictional resistance (resistance to slipping) is increased with holes too large is unknown, and must remain to be explained by further experiments.

Thursday, 27th October.

JOHN KENNEDY, Past President, in the Chair.

Continuation of Prof. Nicolson's paper on "The Staunchness of Riveted Joints."

Thursday, 10th November.

D. MACPHERSON, Member of Council, in the Chair.

A short discussion took place as to the hours during which the Rooms of the Society should be kept open. It was moved by Mr. C. de B. Leprohon, seconded by Mr. L. Skaife, and carried: "That the Rooms be kept open every Saturday evening in addition to the evenings they are now open, and that, at the next special general meeting, the Library Committee be called upon to report as to the Rooms being kept open every morning and afternoon."

The following donation to the Library was reported:—

"Railway Engineering," from Mr. J. W. C. Haldane.

Paper No. 134.

MASONRY PIER MOVED BY ICE AND REPLACED.

By R. W. LEONARD, M.CAN.SOC.C.E.

During the winter of 1895-96 the masonry for the four spans of the bridge which carries the St. Lawrence and Adirondack Ry. (since leased to the New York Central and Hudson River Ry.) over the Chateauguay River, Province of Quebec, was constructed.

The river at the crossing is 600 feet wide, and is spanned by 4 through steel spans of 150 feet each. The river is from 8 to 12 feet deep at low water, the bottom being clay with some gravel in places and a few scattered boulders.

The abutments were built on shore. Seventy-five piles were driven through the ice for each pier and cut off by hand with a cross-cut saw carried in a light, stiff hardwood frame, just above mud-line. Field stones were filled in between piles to a level with top. A caisson was framed with double 12 x 12 bottom caulked, and double plank sides with tar paper between the planks, and sunk in place by the masonry as it was built inside. Rip-rap was finally placed round the piers to a height above the timber platform, to prevent scour.

The abutments and two westerly piers were completed and two spans erected and resting on them. The easterly pier was just erected and two men were pointing the masonry on a warm spring day, when the ice shoved in the river and went out very suddenly. The winter had been exceptionally severe, with but little snow-fall, and the ice was strong, especially where it had been worked on all the winter close to the bridge, at which place it was about 3 feet in thickness. A very large field of ice drifted down from the basin, lodged against the west shore and the westerly piers and swung against the unfinished pier, striking it obliquely on the westward side of the ice breaker.

The field of ice was immediately broken in pieces by the piers and passed on, apparently doing no damage. On close inspection and measurement, however, it was found that the easterly pier had moved out of position, as shown on the accompanying plan.

To replace the pier the writer built a crib as shown on the plan, sunk it in place, drove a row of piles behind it, loaded the top of the crib with stones, and set four hydraulic 50 ton jacks between the crib and the pier. These moved the pier 2 inches, and the bottom of the platform then stuck on the head of the corner pile from which it had been pushed. A diver, who had been employed to remove the rip rap around the pier and to examine the foundation, was instructed to cut this pile down half an inch, and a second and successful attempt was made with 3 jacks, 2 of 100 tons and one of 50 tons capacity. The pier was moved back to its proper position without showing the slightest crack in the pointing, or any other damage.

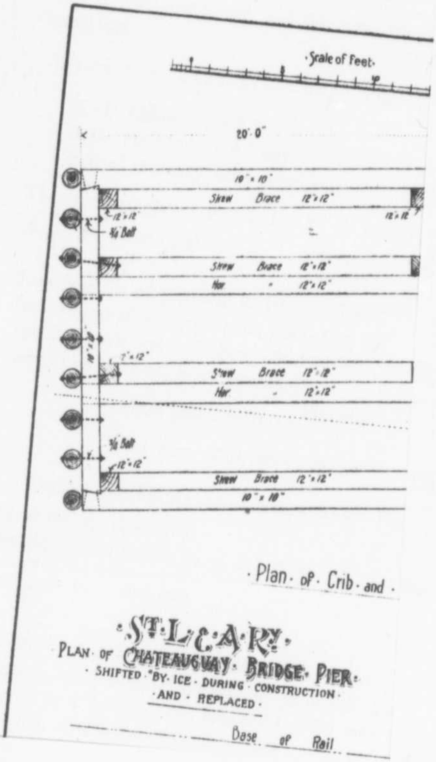
Additional rip-rap was placed around the pier, the crib removed and the piles cut off close at a total cost of about $800.00.

There has been no further difficulty.

The weight of the pier is about	960,000 lbs.	in air
Hemlock platform "	50,000 "	
	1,010,000 "	or 500 tons.

Plan shows level of water when ice moved, and level of water at time when pier was replaced.

The facts may be interesting to Canadian engineers, as they show the dimensions of the masonry and the conditions existing in the case


·Scale of Feet·
20'·0"
10" × 10"
Skew Brace 12" × 12"
12" × 12"
3/4 Bolt
Hor " 12" × 12"
Skew Brace 12" × 12"
Hor " 12" × 12"
3/4 Bolt
10" × 10"
·Plan·of·Crib·and·
·ST·L·&·A·RY·
PLAN·OF CHATEAUGUAY·BRIDGE·PIER·
·SHIFTED·BY·ICE·DURING·CONSTRUCTION·
·AND·REPLACED·
Base of Rail

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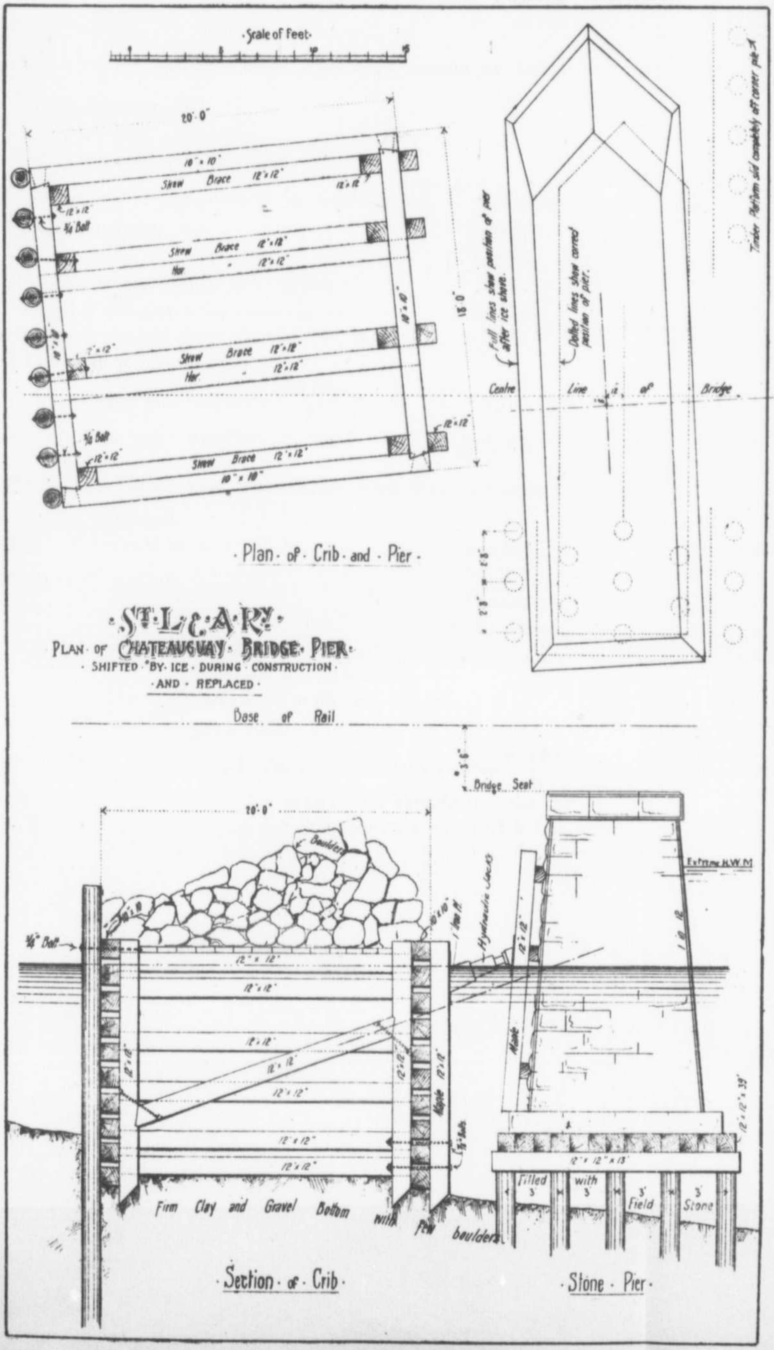
Scale of Feet
20' 0"
10" x 10"
Shew Brace 12"x12"
¾ Bolt
Hor
18' 0"
Full lines show position of pier after ice shove.
Dotted lines show correct position of pier.
Centre Line of Bridge
Timber Platform sits completely off corner pile
Plan of Crib and Pier
ST. L. & A. RY.
PLAN OF CHATEAUGUAY BRIDGE PIER
SHIFTED BY ICE DURING CONSTRUCTION
AND REPLACED
Base of Rail
Bridge Seat
Boulders
Hydraulic Jacks
Extreme H.W.M.
Maple
Firm Clay and Gravel Bottom with few boulders
Filled with 3' Field Stone
Section of Crib
Stone Pier

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of a pier that just moved, and the force necessary to shift it on its foundation.

WEIGHTS ON FOUNDATION WHEN PIER WAS PUSHED BY ICE.

S. G. Limestone = 2.7
S. G. Hemlock = 0.7 say :
5/6 of masonry submerged say,

Therefore weight of pier at H. W. M. would be $\frac{960000}{6}$	160000 lbs.
$+ \frac{17}{27} \times \frac{5}{6} \times 960{,}000$	503700
	663,700
Less flotation of platform 3/10 × 50000.	15,000
Net weight of east pier when pushed by ice	648,700
150 foot span weighed about 350,000 lbs., therefore weight on piers not moved would be	
Centre pier $648{,}700 \times \frac{350{,}000}{2}$	823,700
West pier $648{,}700 \times 350{,}000$	998,700

WEIGHT ON FOUNDATION WHEN EAST PIER WAS REPLACED.

½ masonry submerged.	
weight of pier would be ½ × 960,000	480,000 lbs.
$+ \frac{17}{27} \times \frac{1}{2} \times 960{,}000$	302,222
	782,222
	Say 391 tons.

Moved by 4 jacks of 50 tons, 200 tons.
Approx. co-efficient of friction, say ½ or 0.5 about.
Moved by 2 jacks of 100 tons and 1 of 50 tons, 250 tons.
Approx. co-efficient of friction 0.65.

Taking co-efficient of friction at ½, the thrust of the ice was about $\frac{648{,}000}{2}$ or 166 tons, or about 11 tons per square foot considering the ice three feet thick and striking the pier obliquely on a width of 5 feet.

DISCUSSION.

Mr. H. Irwin.

Mr. Irwin asked as to the means of connection between the caisson and the top of the piles. It appeared there were piles driven through the ice, caps being put on the piles and the caisson sunk on these, the caisson being framed with double 12 by 12 timbers so that the flat surface of the caisson rested directly on the top of the row of piles. He supposed there was nothing but friction holding the caisson timbers on the tops of the piles.

Mr. R. W. Leonard.

Mr. Leonard repiled that the caisson was sunk on the heads of the piles, and there was no special connection between the timber and the piles. Riprap was placed around the pier before the ice went out, but there was no time to complete the work in a thorough manner. Reliance was placed on the friction, and the resistance of the riprap to hold the pier in place. The motion was between the timbers and the heads of the piles, so that the timber platform slid completely off the corner of one pile, and the neighbouring ones along that side were partially uncovered. The down stream end of the pier remained within an inch of its former position, the up stream end being moved, chiefly laterally.

Mr. D. MacPherson.

Mr. MacPherson asked how high up the riprap came on the piers, and if the stone was filled in between the piles by dumping or placed in position by a diver.

Mr. R. W. Leonard.

Mr. Leonard said that the riprap on the average came to about three feet above the timber. The sides of the caisson had been taken down before the pier moved. These sides were only double planked with tar paper between. Soundings were taken between the piles to find the depth of water, and the stones were dumped in carefully, and subsequently examined everywhere to see that none of them stood above the heads of the piles. Small field stones were used in order to avoid trouble in filling the interstices.

Mr. P. W. St. George.

Mr. St. George asked if new timbers were put on the piles that were exposed by the shove.

Mr. R. W. Leonard.

Mr. Leonard said that the whole pier, with the underlying timber, was moved back two or three inches, then met an obstruction, and would not move further until the top of the corner of the pile was cut off by a diver, after which the platform slipped, under pressure, back into the required position.

Mr. H. Irwin.

Mr. Irwin asked who designed the bridge and substructure.

Mr. R. W. Leonard.

Mr. Leonard said that the substructure and superstructure were designed by the company's consulting engineer in New York.

Thursday, 24th November, being Thanksgiving Day, the Ordinary Meeting of the Society was not held.

Thursday, 8th December.

P. W. St. George, Vice-President, in the Chair.

A special general meeting of the Society was held for the purpose of providing for certain expenses in connection with the Annual Meeting.

It was moved by Mr. J. G. Kerry, and seconded by Mr. H. Irwin : "That the sum of seventy-five dollars be granted out of the funds of the Society to provide for the cold lunches to be served in the Rooms during the Annual Meeting."

An amendment was moved by Mr. L. Skaife, seconded by Mr. C. de B. Leprohon, and carried : "That the motion be amended, increasing the amount to $100.00."

Messrs. W. M. Reid, E. A. Rhys-Roberts, and L. Skaife, having been appointed scrutineers of the ballot, declared the following elected .

MEMBERS.

John Donald Maclennan, Alfred Daniel Watson.

ASSOCIATE MEMBERS.

R. Sherwood Elmsley, Thomas Johnson Locke,
Charles Samuel Leech, M. C. J. Beullac.

STUDENTS.

D. L. G. DeSalaberry Beaudry, George R. Ewart,
Samuel Bourgeoin, John Houliston.
William E. Syer.

Transferred from the class of Associate Member to the class of Member :

Robert B. Kenrick.

Transferred from the class of Student to the class of Associate Member :

James A. Burnett, M. L. Williams.

K

Paper No. 135.

CONCRETE RAILWAY STRUCTURES.

By F. G. JONAH, M.CAN.SOC.C.E.

That concrete possesses many great advantages in the construction of railway structures is being more generally appreciated from year to year, and with the increasing interest in this class of work the writer feels warranted in presenting to the members of this Society some designs of concrete culverts and bridge piers.

These structures are particularly well adapted for use in the construction of new lines of railway, owing to the comparative ease with which the material for making concrete can be transported, as against heavy stone-work. The use of derricks for loading and unloading material and specially constructed wagons for heavy hauling are not necessary in concrete work, and, as it can be made with cheap, unskilled labour, a great saving in the wages of the force employed is thus effected.

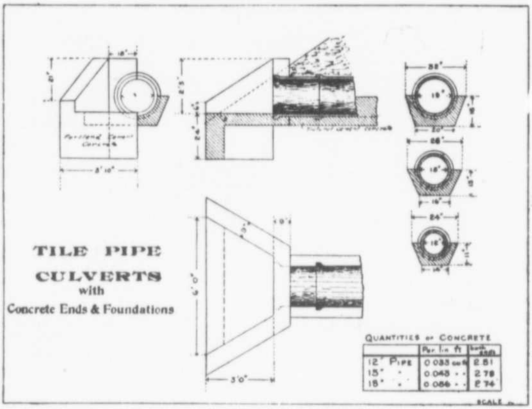
These culverts have a decided advantage over cast iron pipes on new works, owing to the great cost of transporting the pipe, but for renewals on old roads cast iron pipe, up to five feet in diameter, is excellent. They will be much safer from washouts, however, if the ends are protected by wings, for which nothing is better than the concrete ends shown on the culvert plans.

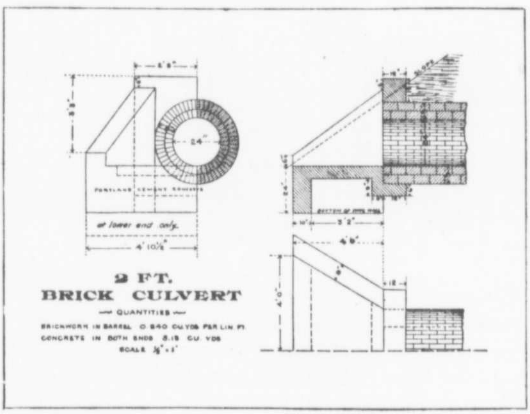
The plans submitted range in size from a 8″ sewer pipe, with concrete ends, up to a five foot arch culvert. In 1894 the writer built upwards of thirty culverts after these plans, and up to the present time there has not been a failure of any kind about them.

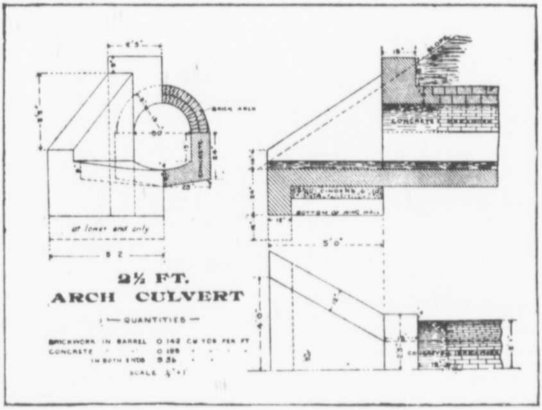
The arches were turned with hard brick; in a larger culvert they could be made entirely of concrete, but for a small semi-circular arch there would be difficulty in holding the fresh concrete in place.

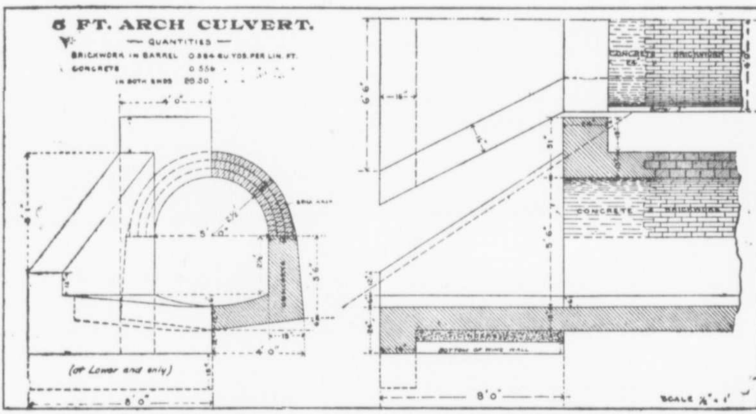
In the construction of these culverts, wooden forms are necessary for the work above the bottom or pavement line. The forms are practically moulds into which the concrete is dumped. They should be made of lumber not less than 1½″ thick, dressed on the side next to the concrete. They should be well made and held together with clamps, to facilitate putting up and taking apart rapidly. If carefully used, one set of forms will serve for a great many culverts.

For that portion of the culvert which is in the ground, including the back of side walls, the earth should be carefully excavated to the


TILE PIPE
CULVERTS
with
Concrete Ends & Foundations
QUANTITIES OF CONCRETE
Per lin ft
both ends
12" Pipe 0.033 cu ft 2.51
15" " 0.043 " " 2.78
18" " 0.086 " " 2.74
SCALE


24"
at lower end only
4' 10½"
2 FT.
BRICK CULVERT
— QUANTITIES —
BRICKWORK IN BARREL 0.840 CU.YDS PER LIN FT
CONCRETE IN BOTH ENDS 5.15 CU. YDS
SCALE

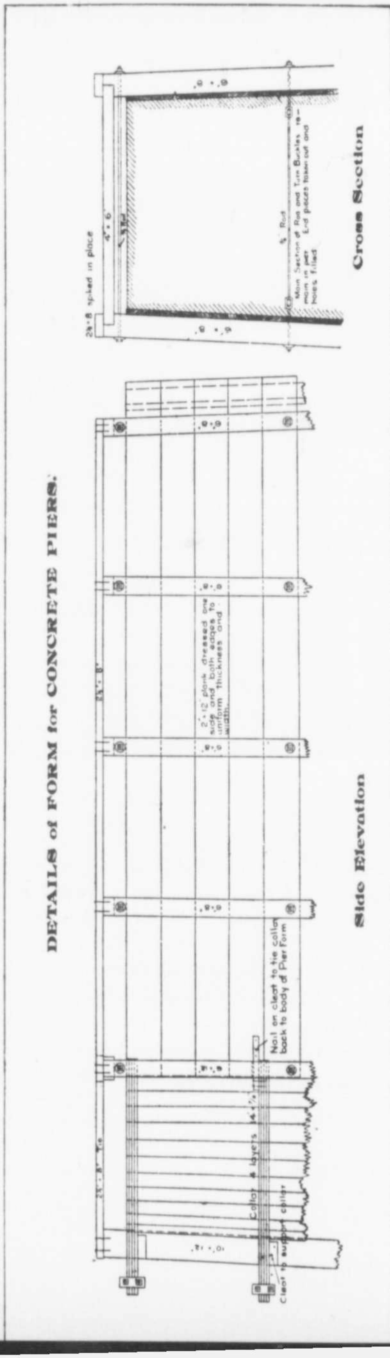




exact form of the culvert, any irregularities or holes beyond the figured dimensions will represent a waste of concrete.

In putting the concrete in place, great care must be exercised in tamping it thoroughly, to insure a close contact with the forms. If this is not done, the work will present a honeycomb appearance when the forms are removed. Forms should be left standing in place until the concrete has partially set.

It was found in this work that to make one cubic yard of concrete required 1.17 bbls. Portland cement, 24.5 cubic feet of broken stone and 9.3 cubic feet of sand.

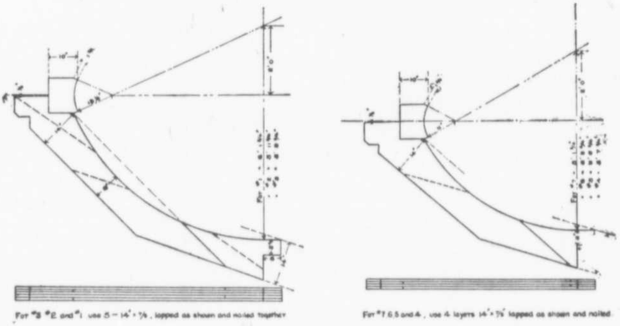


DETAILS of FORM for CONCRETE PIERS.

Side Elevation

Cross Section

DETAILS of FORM for CONCRETE PIERS



Collars

To make a cubic yard of brick work required 400 ordinary size brick and .93 bbl. natural cement.

The material was hauled an average distance of three miles, and cost on cars as follows :—

Portland cement, per bbl	$ 2.90
Louisville cement, per bbl	.90
Machine crushed macadam, per cu. yd	2.10
Sand per cu. yd.	.80
Brick, per m	8.00

The following rate of wages was paid :—

Teamster, man and team	$ 2.50	per day
Bricklayers	2.50	do

Concrete gang :—

Foreman	$ 2.00	per day
One laborer	1.50	do
Six laborers at	1.25	do

The average cost on all culverts was :—

Earth excavation in foundations	$ .35
Concrete, per cu. yd	6.80
Brick-work, per cu. yd	7.70

During the summer of 1897 the St. Louis, Peoria & Northern Railway erected two spans of 175 feet, one of 160 feet on concrete piers, and built a concrete abutment for a 75-foot girder.

Drawings of the piers are shown and of the forms used in their construction. The piers were built rounded on the up stream side and square on the down stream side. This was done to simplify the making of forms, but, as the rounded end was found to be a comparatively simple matter in practice, it would be advisable to round both ends in this class of work. In the Sangamon River and Salt Creek bridges, the concrete below frost and scour line was made with natural cement. All work above this line was made with Portland cement. In the Mackinaw bridge, which rests on piling, Portland cement was used throughout. By thoroughly tamping and working the concrete well against the forms, a perfectly smooth surface was obtained on the piers and no plastering was required.

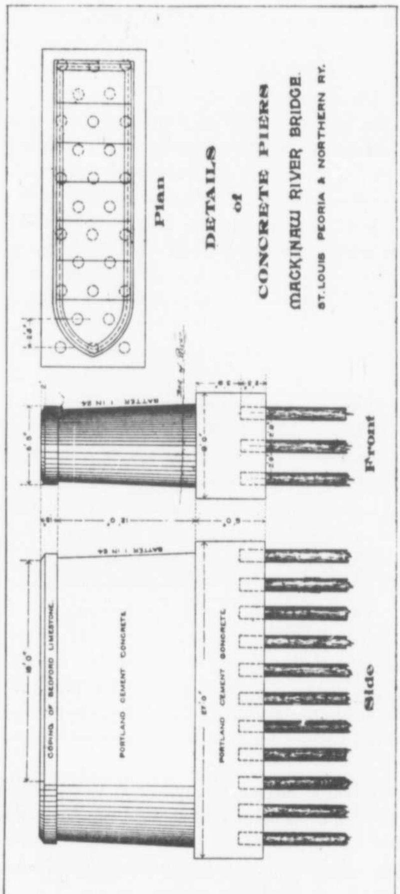
The concrete in all this work was made after the following specifications :—

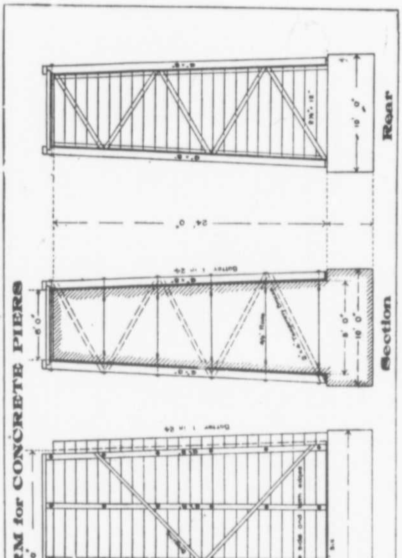
" The mortar will be composed of one part cement and three parts clean, sharp, silicious sand, from which all sticks and gravel have been removed by screening. The portions of cement and sand shall be obtained by measurement and shall be thoroughly mixed. Enough clean mortar shall then be added to make a stiff mortar, care being taken to avoid an excess of water. After the mortar is well mixed on a tight jointed platform, add broken stones, which must be clean, hard and angular, not more than two inches in greatest dimension and not less than one half inch in greatest dimension. After the stone is added, the whole mass shall be turned twice on the platform with shovels and then deposited in place in layers not more than one foot in thickness, and rammed until the mortar flushes to the surface. The amount of mortar used shall be from five to ten per cent. in excess of the volume necessary to fill the void spaces between the stones."

It was found that a mixture composed of one part cement, three parts sand and six parts broken stone filled the requirements of the specifications.

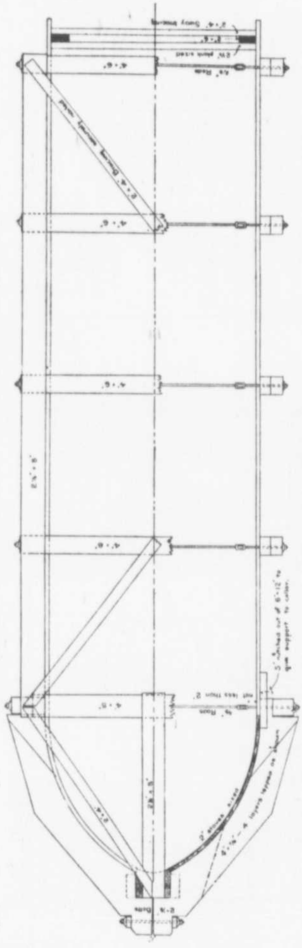
In receiving bids on the work, it was found that concrete was about $2.00 per yard cheaper than first-class masonry.

The culverts and piers were designed under the direction of Mr. Robt. Moore, Civil Engineer, St. Louis, Mo.

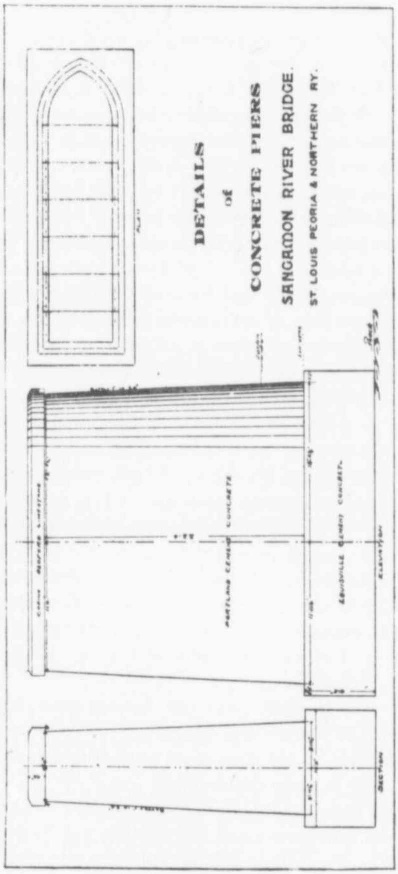

Plan
DETAILS
of
CONCRETE PIERS
MACKINAW RIVER BRIDGE
ST. LOUIS PEORIA & NORTHERN RY.
BATTER 1 IN 24
Front
BATTER 1 IN 24
COPING OF BEDFORD LIMESTONE
PORTLAND CEMENT CONCRETE
PORTLAND CEMENT CONCRETE
Side


DETAILS of FORM for CONCRETE PIERS
Rear
Section
Side
Front

DETAILS of FORM for CONCRETE PIERS



Plan and Section


DETAILS
of
CONCRETE PIERS
SANGAMON RIVER BRIDGE.
ST. LOUIS PEORIA & NORTHERN RY.
PORTLAND CEMENT CONCRETE
LOUISVILLE CEMENT CONCRETE
ELEVATION
SECTION

DISCUSSION.

Mr. J. G. Kerry. Mr. Kerry said that it was surely an error to use natural cement under water. It would, on the other hand, seem that natural cement could have been used with advantage above high water. It is, of course, well known that natural cement will not stand frost.

Mr. H. Irwin. Mr. Irwin thought that possibly the engineer was more afraid of frost than anything else, and may have been able to use natural cement below high water mark owing to the small amount of water in the stream at low stages.

Mr. D. MacPherson. Mr. MacPherson thought that the author should give further information as to the portions of work in which Portland cement was used. That this was necessary in connection with the average cost of concrete which was stated at $6.80. This would seem to be a rather high figure, especially if a great deal of natural cement was used.

Mr. J. G. Kerry. Mr. Kerry remarked that, in regard to the proportion of cement employed in concrete, recent Canadian practice seems to have diminished that quantity very largely, and especially in heavy work where large stones can be used to fill voids.

Mr. P. W. St. George. Mr. St. George said that in the use of natural cement a very much greater proportion had to be employed, and that, in the Soulanges and other canal works referred to, the engineers were wise enough to buy their own cement. Many years ago it was possible to use ordinary lime mortar for work above the water line, but the character of modern mortar was by no means the same as what was employed in this locality thirty or forty years ago.

Mr. Jos. Rielle. Mr. Rielle said he would have some anxiety about concrete being used in positions in which it was subject to great vibration, such as railway piers, and that he had some doubt as to the permanent character of concrete under such circumstances.

Mr. G. Duggan. Mr. Duggan remarked that in the Interprovincial bridge at Ottawa no concrete was used above a point 20 feet below the water surface.

Mr. F. G. Jonah. In answer to Mr. Kerry's remarks about the error of using natural cement under water :—

It certainly would be an error to use natural cement in any place where it could be acted upon either by frost or water, and none was so used in the structures described in paper. The foundation below the "water and scour line," *i e.*, entirely in earth, was of natural cement concrete, in which condition it is just as good as any other, and much cheaper.

The author does not see how natural cement could be used to advantage above high water when it is of course well known that it will not stand frost.

The above will also cover the point noted by Mr. Irwin.

Replying to Mr. MacPherson :—All the concrete in culverts was made of Portland cement, the cost of which ($6.80 per cubic yard) was not excessive when it is remembered that this was on new work with the culverts some distance apart and only a small quantity of concrete in each. Of course, in putting in a large quantity of concrete in one place the cost could be reduced.

In regard to Mr. Kerry's question concerning proportion of cement used in concrete, the author believes 1, 3 and 6 to be the proportion most generally used in this country, and is the proportion required to comply with the specifications under which work was done.

Mr. St. George's observation about engineers buying their own cement is good advice, and such has been the uniform practice on this road.

As to Mr. Rielle's remarks concerning permanent character of concrete piers, the author believes a well built concrete pier will stand the vibration of railway traffic better than an ordinary masonry pier with its numerous joints. Our concrete piers have been subjected to the traffic of 60 ton engines and 40 ton coal cars for over a year, and up to the present time there have been no signs of fracture. The author knows of concrete piers which were built last year on a railway in Illinois to the height of 40 ft., and the practice is by no means rare in this country.

Thursday, 22nd December.

W. McLea Walbank, B.A.Sc., Member of Council, in the Chair.

Messrs. E. A. Rhys-Roberts, J. S. Vindin, T. W. Lesage, C. de B. Leprohon, C. H. Ellacott, and W. I. Bishop, having been appointed scrutineers of the ballot, declared the following elected:

Member.

Robert Bowie Owens.

Associate Members.

Ernest George Coker,
Joseph Armand Hormisdas Gauthier,
John Reid Heddle,
Charles G. Milne,
Phillips Bathurst Motley,
R. Maitland Roy,
John Huth Walters.

Students.

William Albert Sanders,
Bertram Dodd Dean.

Transferred from the class of Student to the class of Associate Member:

Charles H. Mitchell,
Homer M. Jaquays.

Paper No. 136.

DISPUTED POINTS IN CONNECTION WITH THE CONSTRUCTION AND MAINTENANCE OF MACADAMIZED ROADS.

By H. Irwin, M.Can.Soc.C.E.

The present paper was written in October, 1893, and was originally intended to be used as a private record of the opinions expressed by several members of the American Society of Civil Engineers during the course of a discussion on the subject before us, which may be found in the transactions of that Society for December, 1892, and February, 1893.

The author now offers it to the Society on account of the present scarcity of papers, and of the brevity of most of those which have been read this season up to the present. The purpose of the paper is to compare the opinions of the Engineers who took part in the discussion above alluded to, not so much with a view of bringing forward anything new, which would be almost impossible, but in order to ascertain how far the diverse opinions might be reconciled or accounted for by difference in the local conditions.

The principal points discussed are arranged under the following heads, viz. :—

1. Grades.
2. Drainage.
3. Transverse section.
4. The necessity for using the Telford foundation and its construction.
5. The construction of macadamized roads without the Telford foundation.
6. Quality of stone, and the size of the macadam.
7. Binding material and its usefulness.
8. Rolling—Whether by horse or steam rollers.
9. Repairs or maintenance.

The writer proposes to take these up in the order given :—

Firstly, Grades.—Mr. Owen states that any departure from an ideal grade of one per cent. is to a certain extent to be resisted, and that the minimum grade should never be less than one half per cent. in order to secure proper longitudinal drainage ; and that the maximum grade for ordinary country and general travel should be four per cent., which is the limit of an ordinary trotting gait.

Mr. F. Crowell differs from Mr. Owen as to one per cent. being the ideal grade—and states that, in his opinion, if a uniform grade of one per cent. can be secured, without undue expense, it is preferable not to exceed it, but that where the road is undulating, with frequent reversions of grade, the horse will do equally well or even better with grades of two per cent. He also states that it is well known that horses as a rule travel better on a slightly hilly country than on a dead level.

The other members who joined in the discussion do not appear to have touched on this branch of the subject.

The writer would venture to remark that both maximum and minimum grades might be made to suit the class of vehicles most likely to make the greatest use of the road to be constructed, and that the question of cost would have to be considered.

In farming districts, where the large majority of the vehicles carry heavy loads and do not go faster than a walk, the maximum grade might well be raised to five per cent. and the extra cost of four per cent. grades either saved altogether or expended on the road surface.

As to the minimum grade, water will flow so freely along a water-table or gutter with a fall of one-half per cent., that a similar grade might well be taken as minimum for long uniform stretches of road, short pieces of level being permitted to break grades or at summits.

The fact that horses seem to travel better on undulating roads, where the grades are not over two per cent., than they would on the level is probably due to change in the muscles used in ascending and descending ; this would apply, however, more to heavy than to light traffic, as a trotting horse, going at a good pace, would find a two per cent. grade pretty hard, and would probably travel much easier on the level than on an undulating road, especially if allowed to walk a short distance occasionally. The writer would add that he has often heard drivers complain of a long uphill pull, even when the grade was light.

Secondly, Drainage.—Mr. Owen's opinion is that :—

" It is necessary at all times that proper and complete provision be " made for thorough and perfect drainage of the water from the road- " way ; this, as well as the necessity of under-drainage in certain spe- " cified localities, either by pipes or blind drains, admits of no dispute, " when the fact is remembered that one dollar spent judiciously in un- " der drainage will save many dollars as a capitalized fund to meet the " expense of repairing badly drained sections of the road."

Mr. Latham Anderson, referring to the rainy and muddy part of the country east of Central Kansas, says that :—

" Given an earth road skillfully located, properly shaped for surface " drainage, and with the road bed thoroughly under-drained with tile, " say, to the depth of at least two feet, all that is necessary to make " this a fairly good country road is to cover a strip in the middle, " say 14 to 16 feet wide, with six inches of gravel or shale."

Mr. Anderson also recommends the excavation of ample ditches, and using the earth thus obtained to raise the sub-grade above the surrounding ground and the construction of drains under the road surface in all clay or tenacious solid.

Mr. J. E. Cooper states that :

" Telford roads put together with loam and light rolling stand " because the water, that will surely find its way through the metal, is " drained away through the Telford," and that " The Macadam roads " put together in the same way will go to pieces because sub-drainage " is not provided."

Mr. W. C. Oastler on the other hand states that:

"The suggestion that the earth sub-way being flattened instead of "being an arc of a circle causes the drainage to be defective or in-"sufficient is not correct in practice; that the stone road above the "foundation will, if properly rolled, be practically water tight, and "will preserve itself and the foundation against the inroads of water;" and also says: "I do not believe it is worth time or money to make "elaborate schemes for under-drainage of broken stone roads. Lateral "drains, honey-combed foundations and other expenses for so-called "drainage are wasteful excess and generally can be omitted."

Messrs. Owen, Anderson and Cooper would thus seem to differ materially from Mr. Oastler as to drainage. On closer examination, however, the difference of opinion may be considerably reduced. All are agreed, of course, as to the necessity of surface drainage. With regard to under-drainage, Mr. Owen states that its necessity in certain specified localities, either by pipes or blind drains, admits of no dispute. Mr. Anderson's opinion evidently is that an earth road should be thoroughly underdrained with tile in order that it might be put into fairly good order with six inches of gravel or shale.

Mr. Cooper seems to think that the Telford foundation will act as an under-drain, while Mr. Oastler saves himself from being too dogmatic by stating that lateral drains and honey combed foundations can generally be omitted. Surely Mr. Owen's statement last referred to admits of no dispute, since under-drainage is an absolute necessity where there are springs under the road surface and in wet clayey soils where the side ditches will not drain the centre of the road-bed. Mr. Anderson's opinion as to earth roads might be modified by stating that in open gravelly soils the side ditches, when not too far apart, may be counted on to drain the road bed. Mr. Cooper's idea that the Telford foundation will act as an under-drain may hold good for a year or two after the road has been constructed, but the writer does not think that it would hold good for any length of time, as he has never yet seen an old foundation dug up in which the spaces between the stones were not completely filled with earthy material, so that it could not possibly act as a drain. Indeed, even when the foundation was quite new, it is almost certain that the water, on passing through it, would soak into the earth below unless some special provision were made to carry it off at the sides. Mr. Oastler's scheme for avoiding under-drainage altogether by keeping the surface well rolled would also involve constant repairs to prevent water standing in slight hollows, would probably be more expensive in the long run than under-drainage, and could only be carried out in rich districts.

The writer's experience, though rather short so far as actual practice goes, certainly goes to show that less depth of stone is required on a firm, well-drained road bed.

The approximate distance apart at which drains act might here be given :

In open gravelly soils, drains from three to four feet deep will act from twenty-five to thirty feet on each side ; in such soils the side ditches will drain the road-bed perfectly if deep enough.

Where the soil is marly loam drains will act about twelve to fifteen feet on each side. In this case, unless the road surface is kept in good order so as to throw all rain water quickly into the side ditches, and unless the road-bed be originally dry as on a side hill or an embankment, a covered drain would be required along the centre.

In stiff clay soils French drains can only be counted on for about eight or ten feet on each side, in which case, if the sub-soil be wet, V drains running from the centre of the road-bed diagonally to the sides may be needed.

In making drains it is well to remember that water will not flow through soil so nearly on a level as it will in an open channel. Drains therefore will only dry wedge-shaped sections of ground, and the denser the soil the steeper will be the wedge.

The subject of drainage might be closed by quoting Mr. Calvin Tomkins' remarks, viz. :

"It is possible by making the road-bed sufficiently thick to ignore a " wet bottom, but it is cheaper to arrange for a dry base and place a " thinner road on it. Drainage is of the first importance, but the cost " of drains can be greatly modified by making the surface of the road " as nearly water-tight as possible."

Thirdly—The transverse section of the road-bed and of the foundation.

Mr. Owen states that "it is agreed on all sides that the road-bed " should be graded to a surface uniform with the finished roadway," and that his practice is to roll the road-bed when no foundation is used, but not to roll it previous to laying a Telford foundation which he brings to a uniform surface by scooping out the earth below the deeper stones.

Mr. Oastler does not agree with Mr. Owen as to grading the road-bed to a surface uniform with the finished road, and prefers to grade it level across; firstly, because it is cheaper, and, secondly, because it admits of using stones of different thickness, the larger stones being placed in the center.

Mr. Oastler also prefers to compact the road-bed by rolling, and does not agree with Mr. Owen's plan of laying the foundation even by scooping out earth under the stones, as he does not think it necessary that the surface of the foundation should be quite even.

Mr. Callanan stated that his practice was to grade the road-bed to a surface uniform with the finished roadway, securing good lateral drainage.

Mr. Thomas Codrington, formerly General Superintendent of Roads in South Wales, after stating that, since timber hauling and other heavy traffic generally takes the sides of a road, gives it as his opinion that it is usually better to form the road-bed with its surface either nearly or altogether parallel to the finished surface so as to have a uniform or almost uniform thickness of metalling.

Mr. Codrington also states that this method of formation is attended with the advantage that a dry formation surface is prepared for the road materials.

The writer thinks, therefore, that it might be fairly concluded that where there is likely to be heavy traffic extending over the entire width of the road, the road-bed should be graded either exactly, or almost, parallel to the finished surface, and that this method of grading the road-bed will help to keep it dry during construction, but that it cannot be counted on for drainage purposes for any great time after the road has been finished; but that, in the case of roads for lighter traffic, which should of necessity be cheaper, the road-bed might be made flat and the crowning of the finished surface obtained by making both the foundation and the macadam thinner towards the sides.

As for the completed surface, in the district of which the writer had charge in Ireland, the usual rule was to raise the centre above the sides at the rate of one inch per yard of width from the centre to the side, the slope being steeper at the sides than in the centre.

Mr. Owen states that for a sixteen foot roadway, an average crowning of four inches is desirable, which is at the rate of one inch in two feet from the centre to side, or a grade of one in twenty-four.

The other members who took part in the discussion did not question the statement. Mr. Codrington's opinion is that the fall from the centre to the sides need not be more than six inches on a thirty foot road, or one in thirty from centre to side, and should never exceed nine inches or one in twenty; and that for a road eighteen or twenty feet wide three or four inches or from one in thirty-six to one in thirty is enough. He also remarks that, if the surface be neglected and allowed to wear into ruts, no amount of convexity will clear the surface of water.

This latter statement can be fully endorsed by the writer, who saw a gravel road last winter, about fourteen feet wide, in the centre of a sixty-six foot road allowance, and raised about two feet above the level of the water tables at the edges of the side-walks, the water tables being quite dry, and yet the roadway, which was badly rutted, was full of water, and almost impassable.

Had this road been well harrowed and rolled, it might have been kept in good condition.

As there was no discussion on this subject, it might be taken for granted that on the level, or on easy grades, a fall of from one in thirty to one in thirty-six is sufficient, and that on hills the slope from the centre to the sides might be from one in twenty to one in thirty, and that it is useless to try to make higher crowning take the place of an even surface for transverse drainage.

Fourthly—The necessity for using the Telford foundation and its construction.

Mr. Owen states that he "is unqualifiedly in favour of thick pave- "ments with a foundation, and opposed to thin pavements of broken "stone," and, that after three years' experience of thin pavements, he would build no more of them.

He concedes, however, that, on gravelly or sandy soil, thin macadam roads may be used with success and economy, and that he had seen very good thin macadam roads in such districts. He also states that in districts where the frost does not enter the ground more than eight inches, provided the drainage is good, or in mountainous countries, thin macadam roads may be used; and that where the grades are over five per cent. he has adopted six inch macadam roads as a rule.

Mr. Owen also mentions several four inch macadam roads which turned out very badly.

Mr. North mentioned the case of seventy or eighty miles of roads made with only four inches of macadam of which only two short pieces failed, but did not state the nature of the soil in the locality nor how the roads were constructed. He also said that, in his opinion, when a steam roller could not be procured, macadam roads should be made more than four inches thick except on sandy or well drained gravelly soils.

Mr. Grant stated that the exclusive use of macadam stone in mass for road purposes appeared to him "to be both unscientific and poor "economy; and that the more modern road, consisting of a foundation "bed of larger and cheaper stone, which is to remain a permanency, "and a lighter body of surface material to receive the wear and to be "renewed as occasion requires, is far preferable."

Mr. Crowell alluded to his construction of roads with Telford foundation, and did not say anything as to roads made without it.

Mr. Latham Anderson stated that an earth road properly crowned and well drained can be made a fairly good country road by covering a strip from fourteen to sixteen inches wide with gravel or shale. Certainly it appears to the writer that this is what is required in the poorer districts.

Mr. Anderson also referred to the construction of macadam roads on well drained road beds, but did not allude to Telford macadam roads.

Mr. Oastler does not mention roads made without foundation, and states that he prefers a flat road-bed well rolled to receive the Telford foundation, which he lays with the larger stones at the centre, thus utilizing stones of varying size, the surface of the foundation not being necessarily uniform, being covered with macadam.

Mr. Callanan's opinion is that the greater cost of the Telford foundation must be first considered; that it is only required where the soil is wet, unstable and treacherous; that, in such cases, unless the stone is near at hand to supply the Telford foundation, skillful workmanship in laying the macadam would give the most satisfactory results; that superior drainage, the introduction of easily obtainable soil, upon which frost has little effect, and skillful manner of rolling and applying the different courses of broken stone may be substituted for the more costly Telford.

Mr. Callanan also states that six inch macadam roads made in the latitude of Albany, N.Y., and carefully constructed, had turned out well; and that, in most localities, the expensive nature of the Telford foundation places it out of the reach of country districts.

As to Mr. Callanan's statement that Telford foundation should not be used unless the stone is near at hand, it might be remarked that foundation stone does not cost more to transport than does macadam, and that any stone suitable for macadam is also suitable for foundation. It would also seem that laying a Telford foundation might often prove cheaper and more satisfactory than carting good soil to take its place and expending extra time and money in handling the macadam.

Mr. Mitchell mentioned an eight inch macadam road, the lower layer being of stone from three to five inches in diameter and the upper from two to three inches. The stone was thrown down loosely and left to be packed by the traffic. He stated that this was a cheap method of construction, but not to be commended; and the writer would remark with regard to it that, unless the road-bed was good, firm gravel or rock, a good part of the lower layer of stone would get mixed up with the earth below, and that as good a road could probably have been constructed as cheaply with six inches or possibly four inches of stones had the road-bed been well rolled as well as the macadam.

Mr. Bacot discussed the comparative merits of Telford and macadam roads as follows, viz :

" The one advantage I find in the use of the steam roller is that it " produces a macadam road of such superior character that it takes " the place of the more expensive Telford construction. An eight inch " road in which gravel is used, or any good binding material, I find to " be just as good as a Telford road, and whether there could be any " discrimination made in favor of the Telford I have so far failed to dis- " cover. In wet soils it is necessary to have a Telford and particularly " on flat grades. The point I wish to make is that, without the steam " roller, we could not get such good results out of the eight inch roads. " In the Telford roads you have a solid foundation underneath, and " the necessity for the roller is not so apparent, and I can therefore " understand why Mr. Owen is in favour of the Telford roads."

As to Mr. Bacot's remarks about an eight inch macadam road—Mr. Owen in concluding the discussion stated that he considered an eight inch macadam road " anomalous " ; that he built his eight inch roads with Telford foundation, which was evidently better considering the hammering it has to go through ; and that an eight inch macadam road is not as economical as an eight inch Telford.

The writer fully agrees with Mr. Owen on this point—an eight inch road with Telford foundation should not cost any more than an eight inch macadam road, the road-bed for which must be rolled much more than for the Telford foundation, which saves half the cost of crushing the stone and the rolling of the lower layer of macadam, as against the cost of laying the foundation by hand.

The Telford foundation is also much more reliable: since it will stand the effects of frost and wet, either of which may weaken the road-bed so much that the macadam will begin to sink into it, and the writer's experience of this goes to show that once the macadam begins to go down, the only remedy is to tear up the road and lay down a Telford foundation.

These remarks do not apply, of course, to road-beds of hard gravel or rock, in which cases Mr. Owen admits that six inches of macadam are sufficient.

Mr. Cooper's remarks seem to be a good summary of the discussion. It is as follows, viz:

" Mr. Owen advocates Telford roads, and uses light rollers and " some loam as a binder. He makes good roads on this plan at rea- " sonable cost."

" Others, particularly Mr. North, advocate macadam roads, use " steam rollers and no loam. There are plenty of examples of these " roads that are entirely successful."

" Telford roads can be more successfully made with light rollers " than macadam roads."

" The Telford roads, put together with loam and light rolling, stand " because the water, that will surely find its way through the metal, " is drained away through the Telford."

" The macadam roads put together in the same way will go to " pieces because sub-drainage is not provided."

" The successful macadam road builder must omit the loam and " seek the utmost consolidation by steam rolling. He must make " a water-tight road and a more perfect surface to shed the rain. It " would seem to be plain that a Telford road, having a sub-grade rolled " to ultimate resistance, and the metal consolidated by a heavy roller, " without any loam, would be a more durable and perfect road than a " Telford road on Mr. Owen's plan."

" I would prefer an eight inch Telford road made on Mr. Owen's " plan to an eight inch macadam road made on the same plan, namely, " with some loam and light rollers. But I would greatly prefer the " eight inch Telford road made with no loam and a heavy roller. It " will usually be found that the last will cost little or no more, " particularly if a good local stone can be obtained for the Telford. " Personally, I prefer the Telford road made without loam and " with a steam roller used with judgment as the most economical and " perfect road."

There is just one statement in Mr. Cooper's remarks in which the writer ventures to differ from him, viz: that "the water that will "surely find its way through the metal is drained away through the "Telford." The writer believes that if Mr. Cooper will take up a piece of Telford foundation six or eight years old he will find the interstices between the stones completely filled up with earthy material so that it could not act as a drain.

As to the actual construction of the Telford foundation, Mr. Owen states that:

"It should be understood that the idea of a pavement should be "maintained in these roads built with foundations, the stone should "be laid as close as possible by hand, and chips driven in and wedged "on top, this practically, with the crown of the road making an arch, "and immediately distributing any excessive load occurring on one "stone to its neighbour, and completely obviating any settlement.— "After the foundation is laid and wedged, a coating of loam or clay "is placed thereon to a thickness of half or three-quarters of an inch. "This is merely put there to prevent the spawls working up and mix- "ing with the smaller broken stone above, which they will surely do "unless great care is taken in rolling, which costs money, and it is "more economical to use the packing. After placing our packing on "the foundation, let it be rolled to a uniform surface, on which place "and spread the broken stone."

Mr. Owen also stated that he did not think it proper to roll the road-bed before placing the Telford foundation on it.

Mr. Oastler stated that he would expect far better results from rolling the road-bed with a steam roller, thus making the earth foundation uniformly solid to receive the Telford foundation. Mr. Oastler also said that he was strongly opposed to the use of loam or clay as binding material.

Mr. Cooper said that he preferred to use no loam for binding, but does not refer in particular to its use on the surface of the Telford foundation. The other members who took part in the discussion did not mention this branch of the subject.

The writer thinks that the following conclusions may be arrived at from the discussion as to the necessity of using the Telford foundation, viz:

Firstly—That where money cannot be raised to build anything better, very fair roads may be constructed with four inches of macadam on a firm, dry, well-rolled road-bed, but that it is useless to attempt to make so thin a road on a soil that is wet or liable to be heaved by frost, and that a road of this description must be kept in such repair as that water will not lie on the surface.

Secondly—That a similar road six inches thick will wear better, will require less repairs, and will probably prove as cheap in the long run.

Thirdly—That when the necessary funds can be raised, eight inches of stone will make a strong serviceable road, and that, in general, it will be found just as cheap and more satisfactory to have the lower four inches made of Telford foundation.

Fourthly—That where the road-bed is rock or hard gravel, six inches of macadam is sufficient without any foundation.

Fifthly—That it is better to lay the Telford foundation on a well rolled road-bed, as its surface need not be uniform; and

Sixthly—That where there will be heavy traffic over the whole road, it is better to lay the foundation of uniform thickness on a crowned road-bed, but that where the travel will be mostly on the centre of the road it will be cheaper to lay the foundation on a flat road-bed with the deeper stones in the centre.

The writer's opinion is that five inches is little enough for the thickness of the Telford foundation, and that it is better to have it not less than seven inches at the centre and five inches at the sides of the road, except where the strictest economy is necessary.

As to using a thin coating of loam or clay on the surface of the foundation, opinions seemed to be divided, but the matter was not much discussed.

Part of this coating would doubtless find its way down into the foundation and probably do no harm, and it would seem as if the remainder might be useful in keeping the lower layer of the macadam from shifting about on the foundation, and would do no harm as long as it could not work up into the body of the macadam and prevent it from wedging together properly.

Fifthly—The construction of roads without Telford foundation.

The discussion already referred to on the respective merits of roads made with or without the Telford foundation covers all that was said under this head also.

The conclusion seemed to be that a heavy steam-roller should be used where there was to be no Telford foundation, and that the macadam should be more carefully and thoroughly rolled, also that more attention should be paid to draining the road-bed.

Mention was made of seventy or eighty miles of roads which had been made with only four inches of macadam, one of which had been used for seven years, and of which only two short pieces failed. As four inches is about the limit of minimum thickness of macadam, the writer thinks that the fact that these roads were on gravelly soil should not be lost sight of. Mr. Owen stated that he found that four inches was too little except on steep grades, and gave an instance of four inch roads built in a county adjoining a gravelly district where four inch roads had proved a success, and stated that the former roads were satisfactory for about three years, when a hard frost broke them up badly.

The writer thinks that the experience of the next ten or fifteen years will prove that four inch and six inch macadam roads, except in very favorable localities, are neither durable nor economical in the long run, though doubtless the use of heavy rollers will permit of roads being built thinner than was the custom before such rollers were introduced, and where money cannot be raised to build thicker and more permanent roads, it is much better to make them thin than to stick to the old earth road.

Sixthly—Quality of stone and size of the macadam.

Mr. Owen stated that he preferred close-grained trap rock to any other for making macadam, and that, in a general way, "it would "be more economical to haul trap rock 300 miles by rail than to use "granite or limestone found at site; to haul granite 200 miles rather "than to use limestone, and that limestone is only economical or desirable in the locality in which its occurs," also that "the success of "the hard limestone in many localities is due to its comparison, not "with harder and better rocks, but with the aboriginal mud," and that "it makes a dusty road."

Mr. Brush said that "even with trap the dust is almost blinding in dry weather."

Mr. Callanan seemed to admit that trap rock made the best macadam, but thought Mr. Owen's condemnation of limestone was too sweeping, and mentioned the case of a very good road made of six inches of macadam from a quarry of hard limestone.

Mr. Callanan also stated that he knew of a road made of macadam from trap rock which was as dusty in dry and as muddy in hot weather as any road he had seen.

Mr. H. M. Wilson mentioned the excellent roads in India, some of which were macadamized with hydraulic limestone and some with trap.

Mr. Saabye stated that in Denmark granite was used for macadam, and also a very hard limestone which was somewhat sticky possessing a mortar-like detritus, and when rolled down and sprinkled with water soon formed a solid mass.

Mr. C. Tomkins, while not disputing what had been said regarding the strength and durability of trap rock, said that he had found by experience that hard limestone macadam has a capacity for binding compactly in the road surface in such a way as to make it impervious to water, and that trap rock does not consolidate in this way so effectively.

Mr. Tomkins also exhibited a photograph of a piece of limestone roadway with the stones firmly cemented together, and concluded as follows, viz. :

" While I do not wish to controvert the proposition that a heavy " travelled road constructed of clear trap stone and sharp binder, and " thoroughly rolled, is the best road, yet I believe that a road con- " structed of a hard silicious limestone is more expedient and better " adapted to situations where the following conditions or some of them " prevail :

" First—When suitable limestone can be obtained much cheaper " than trap.

" Second—When the heavy and protracted rolling necessary to com- " pact a trap road laid without loam or clay binder cannot be afforded " or is impracticable for other reasons.

" Third—On country and suburban roads not subjected to heavy " travel.

" Fourth—On side hills subjected to heavy wash, and

" Fifth—That limestone screenings are an advantage as a binder in " roads constructed of trap and intended for heavy travel."

Mr. James Hall, New York State Geologist, stated that the idea " that a proper selection of local stone will lead to more road building " than a reliance on trap rock as a sole material is worthy of serious " consideration. While trap rock may be the most durable material for " roads, we find good roads in portions of the country where no trap " rock exists."

Mr. North mentioned the Dunderberg limestone, which is hard, and packs readily under wheel traffic if not laid in too thick layers—and gave the results of an analysis of this rock which showed it to be a hydraulic limestone containing six per cent. of silica and eleven per cent. of alumina.

The writer would add that in his district in Ireland the macadam was of very good local trap rock, but that on steep hills a soft limestone was used, as it was found to bind better, and was not so liable to be washed loose.

In the City of Montreal the macadam is mostly made of a close grained grey syenite, which makes very good road metal, but the roads are too often muddy in wet, and dusty in dry weather, on account of the use of an excessive quantity of soft dirty sand as binding material, which is now to a great extent being replaced by syenite screenings from the stone breakers.

The roads immediately outside Montreal and its closely built up suburbs are almost entirely macadamized with a medium quality of limestone; and where limestone is not used, a poor trap rock is substituted. The limestone roads, where not badly broken up by frost, are very good during average weather, as they dry up quickly after rain, but they get very muddy during continued wet weather, and extremely dusty during dry weather.

These roads were, so far as the writer has seen, never rolled, the foundation being usually of loose stone, the largest being about six inches long by four inches square, thrown down indiscriminately, and covered with macadam from two to three inches cube, earth or very soft dirty sand being generally used for binding. After a season's travel, they get into pretty good order, and are infinitely superior to the earth roads still further from the city.

From the discussion as to the quality of stone to be used, it is evident that good trap or syenite makes the best macadam, but that no one should hestitate to use limestone or any other inferior stone where trap or syenite cannot be obtained at a reasonable cost; and also that many varieties of limestone will make very good roads, while others can be used to advantage on steep hills on account of their capacity for consolidating together.

As to the size of the macadam—Mr. Owen preferred all one and a half to one and three quarter inch stone, but as the stone breakers could not deliver such a uniform size, he adopted a lower layer of two to two and a half inch stone and an upper layer of the smaller size.

Mr. Crowell spoke of using a lower course of three inch stone and an upper course of two inch stone.

Mr. Callanan obtained good results from using stone varying from one inch to two and a half inches, but stated that he preferred to use the largest stone that would bind properly and make a smooth road, following the principle that a large stone is stronger than a smaller one.

Mr. Wilson stated that roads in India were made with stone broken by hand to from one and a half to two inches cubes.

Mr. Saabye said that in Denmark the lower layers of the macadam were of two and a half to two and three quarter inch stones and the upper layers of one to one and a half inch stones, the rock used being granite or very hard limestone. Mr. Saabye stated also that he considered one to one and a half inch stone to be the best for the top layers.

It might be remarked that Mr. Owen and Mr. Saabye, who preferred one to one and a half inch stone for the upper layer, used trap, granite or very hard limestone, while Mr. Callanan, who preferred the largest sized stone that would bind, referred to hard limestone.

The writer thinks, therefore, that these gentlemen would agree with him that smaller stone might be used when very hard and tough rock can be procured than when limestone must be used, and that two inches is small enough for limestone.

In the writer's district, already alluded to, the specification called for trap broken to pass through a two-inch ring, though stone somewhat larger was not always rejected.

It was agreed by all that hand-broken stone was much better than that broken by machines.

Seventhly.—Binding material and its usefulness.

Mr. Owen stated that he spread a thin layer of loam or clay on his foundation and then rolled it; that then the macadam was spread of the required thickness, and rolled till consolidated as thoroughly as possible, after which another layer of packing or binding was spread and well rolled.

Certainly, the writer thinks it is necessary to roll the macadam well before putting on any packing, as the rolling will prevent the packing from mixing with the lower layers of macadam and so preventing them from binding together, the packing being only required to prevent the upper stones from getting loose. Mr. Owen also said that he had for a long time built roads without packing, but found that they broke up in dry weather more easily than roads built with packing, and that it cost ten cents per square yard more to build roads without packing than with it.

Mr. North stated that he considered loam to be necessary for packing where horse-rollers are used, to keep the stones from rolling over each other and wearing off their sharp edges, but that trap screenings are much better when a ten or fifteen ton roller is used, the screenings being well watered before being rolled. He also said that clay was entirely out of place in a trap road intended to be compacted so as to shed water from its surface.

Mr. Prince considered the best material for packing to be clean sharp sand, well worked in with water; and that the next best material was fine road scrapings.

Mr. Howe thought nothing could be better than screenings from a stone crusher for finishing the surface of a road.

Mr. Grant stated that he had found by experiments that it was impossible to compact macadam with a roller without a binding material of some sort. He also said that he did not consider road scrapings to be suitable for binding material. The writer's experience leads him to agree with Mr. Grant on this point, as he had about two miles of road, subject to very heavy traffic, and which had a soft uneven surface, put into first-class order by preventing road scrapings from being spread over the fresh macadam which was put on in patches.

Mr. Crowell stated that he rolled each layer of macadam and then gave the whole a top dressing of screenings.

Mr. Oastler referred to the question of binding material as follows, viz.:—

"I prefer fine gravel or sand as a binding material to anything else, "and no matter what the 'binder' is, the less used the cleaner and "more durable will be the road-way. Screenings and fine broken stone, "particularly when of trap rock, are objectionable because they "do not readily bind, and screenings of any description of stone "soon grind into dust, which is blown away with the first wind, "or washed away with the first shower; moreover the small "stones intermix themselves with the larger stones and keep them "asunder,............it is preferable to use some material such as gravel "or sand that will not interfere with the stones coming close together, "but merely fill up the interstices of the newly rolled road. I would "sweep off the surplus 'binding' and allow the traffic to come into "direct contact with clean broken stone."

The writer agrees with Mr. Oastler that the less "binding" used the better will be the road, providing enough be used to prevent the upper layer of stone from being loosened by the traffic, and also that the surplus "binding" might well be swept off, but thinks that the sweeping should not be such as to let traffic come on the clean broken stone at first, or the top layer would be loosened. After the top layer had settled down under the traffic would seem to be the time to remove all loose "binding."

Mr. Cooper said that the successful macadam road builder must omit the loam and seek the utmost consolidation by steam rolling, and that he preferred the Telford road made without loam and with a steam roller.

Mr. Bacot said that he had used gravel, sand and even clay as a binder; that the surface of a road built of nothing but rock dust as a binder breaks in the first dry spell; that the use of a little clay is not detrimental, but that the depth of half an inch should be the limit, and that he found nothing as good as gravel.

It would appear from the above discussion that some binding material is required to finish a road, according to the modern practice of consolidating the surface with a roller; that the "binding" should be applied only on the final surface, after the macadam has been rolled to prevent the binding from sinking into it; that as little as possible should be used, and that the only suitable materials for the purpose are screenings from stone breakers, fine clean gravel or coarse, clean sharp sand.

Eighthly.—Rolling whether by horse or steam roller.

Mr. Owen said that he was satisfied that no amount of rolling, *per se*, would ever succeed in producing a homogeneous mass of broken stone as well as the wheel itself will do; that a steam roller is cheaper to use than a horse roller, but that the weight of a steam roller will not compress the macadam, and that to accomplish settlement of broken stone motion is necessary; the more continuous and repeated the motion the more decided being the settlement.

The writer thinks that the statement that some motion is necessary for thorough settlement is correct, but considers that a ten or fifteen ton steam roller in passing over the macadam must cause a good deal of motion in the macadam immediately in front of the roller, though no doubt the constant passage of vehicles for a few weeks will help materially to cause the top layer of stone to finally settle into place.

Mr. North said that he considered a heavy steam roller much better than a horse roller.

Mr. Prince stated that he considered a fifteen ton or twenty ton steam roller far superior to a horse roller, even of five tons weight, for sub-grade foundation and top dressing; and that the pressure of the steam roller per inch run is so great that weak spots in the sub-grade are found and consolidated, which would not be found at all with a horse roller.

Mr. Howe said he agreed with Mr. Owen that a better binding can be obtained with a light roller, especially with a sectional grooved roller, but that too much time and money were required. He also said that experience showed him that the steam roller travels faster than the horse roller.

Mr. Grant stated that from his experience he would vote for the heavy roller, but that he would not dispute the evidence of others that light rollers may produce good results by long continued use.

Mr. Crowell's experience was that heavy rollers produce better results.

Mr. Oastler said that the sub-grade should be thoroughly rolled, and that as to rolling the road surface he had sent out a circular to a number of engineers and superintendents of roads asking their opinion as to that point, and that he had received answers from twenty-eight, twenty-seven of whom said that they preferred a steam to a horse roller, and the twenty-eight used a light roller at first and finished with a heavy roller.

Mr. Callanan stated that his practice was to use a fifteen ton steam roller, and that the shrinkage under the rolling had usually been from 40 to 50 per cent., a result which could not be obtained with a horse roller.

The roads Mr. Callanan referred to were made without Telford foundation, and as the total voids in broken stone only amount to about fifty per cent., the writer thinks that a good part of the apparent shrinkages of from forty to fifty per cent. must have been due to the macadam sinking into the sub-grade, as it would be impossible to consolidate the macadam to within ten per cent. of its volume before breaking.

Mr. Wilson mentioned the first-class roads in India, which are rolled with two or three ton rollers.

Mr. Bacot thought that he could not get along without steam rollers, and that without their use they would have a lot of stone mixed up with mud and dirt.

Mr. Bacot also said that the steam roller produces such a superior macadam road that it takes the place of the more expensive Telford construction.

Mr. Saabye stated that he thought Mr. Owen was right in preferring the horse roller, because in some districts the steam roller would crush the surface of the read as the stone was not hard enough. It might be mentioned, however, that Mr. Owen referred to the use of horse rollers where good trap macadam was used; and also that the fact that the macadam was too soft in a few places is not a good argument against the general use of steam rollers.

Mr. Saabye also said that he considered that the use of heavy steam rollers produced an excessive amount of dust through crushing the stone.

Mr. Brush referred to two Telford roads made with trap, one of which was rolled with a steam roller and the other with a horse roller, and said that it was difficult to see any difference in the wear of the two. He also said that he considered that a horse roller will make as good a road as a steam roller, but that it takes more time to do so.

Mr. Cooper pointed out that Mr. Owen, who built Telford roads with loam binding, used a horse roller; while others, who built macadam roads with no loam, used heavy steam rollers; and said that personally he preferred a Telford road without loam and rolled with a steam roller.

The differences in practice pointed out by Mr. Cooper seem to be the principal reasons why a few preferred a light roller while the majority preferred a steam roller, which certainly seems to be much the best for consolidating the road-bed.

The discussion also shows that care should be taken not to use a roller heavy enough to crush the stone.

Ninthly, repairs.—Mr. Owen said that a road properly and uniformly constructed should wear out uniformly; that repairs should be made in large sections as occasion demands, and that new stone should be spread when the surface is rough enough to receive it, no picking of the surface being necessary.

He also said that in repairing roads he put on the one-and-a-half-inch macadam about three inches thick, rolled it, put on packing and again rolled it, as in the case of the construction of a new road; that in dry weather he would put on a coating of screenings or a thin coat of loam; that the practice of isolated patching and repairs is to be condemned; that ruts should be filled up, not with screenings but with one-and-a-half inch stone; that he knew of a four inch road which required repair the year after it was made, and of a twelve inch road which had not been repaired for nineteen years, though its condition was not ideal; that the average duration of a road, under ordinary conditions, would be four or five years, and that a fair estimate for repairs would be three inches of broken stone every four years.

Mr. Owen also stated that he did not scrape off the mud before spreading the new macadam, but put down such a thick coating that the surface below was so far down that its condition was not material.

Mr. North said that constant maintenance and frequent local stores of macadam are not applicable to trap roads, and that the man who built trap roads which required constant maintenance had failed; though roads made with softer materials required continual attention, and that he agreed with Mr. Owen that screenings used for repairs are almost invariably wasted.

Mr. Prince considered that no great length of road ever existed which would wear uniformly; that the efficiency of a considerable length of road was much lessened by a few serious defects; that therefore constant attention is necessary as well as frequent piles of stones along the road wherewith to make repairs.

Mr. Howe did not agree with Mr. Owen as to patching, as no road would wear down quite uniformly. He also said that on the Park roads in Boston, constant repairs were made with coarse screenings from half-inch to three-quarter inch in size; that the roads had been in use for nine years and were in good condition, but that heavy loads were not allowed to pass over them.

At the same time Mr. Howe advocated the use of screenings for repair of roads in cities.

Mr. Grant said that it was idle to make any rule as to the time a road should be left without repairs; that the case of each road must be judged by itself, and that the surface material must be renewed when worn out. Mr. Grant also said that his opinion was that road scrapings should be removed before fresh macadam was spread.

Mr. Oastler stated that he did not think that clay or loam should be used as a binding material, as it would be mud in wet weather and dust in dry weather.

Mr. Cooper believed that, as far as repairs are concerned, Mr. Owen's method would do better on a Telford road than on a macadam road, but that certain defects are sure to appear in most roads, due to the weather and not to faulty construction, which require immediate attention. Mr. Cooper also said that he believed that there was economy in repairing in the spring and fall, and during prolonged spells of drought or wet weather.

Mr. Tratman referred to the English system of continual repairs, cleaning, trimming grass and hedges, breaking stone, etc., and mentioned the hand scraping machines so largely used. The writer has referred to these machines in previous papers, and thinks that similar machines would be found economical on this side of the Atlantic, especially if made to be drawn by one or two horses, as revolving brushes have a tendency to loosen and displace the macadam, and are more suitable for wooden, stone, asphalt or brick roads.

Mr. Wilson alluded to the roads in India, which are kept in good order by constant attention.

Mr. Saabye said that it was not necessary to repair a road constantly if it is only well looked after, which means that men should be constantly employed to fill in ruts, clear out drains, etc.

From this it would appear that the word "repairs" in this discussion refers only to the spreading of fresh macadam, whereas in Europe generally it is applied to all the work performed periodically.

Mr. North said that the superiority of European roadways is due more to continuous maintenance than to excellence of building.

As to the "continuous maintenance" in Great Britain and Ireland, lest there should be any mistake as to its meaning, the writer thinks it well to state that it is not to be supposed that a man is to be seen at work at all times on any short section of road, but that one or two men are given such a length of road to look after as they can keep in proper order by working on it a certain number of days in each week.

In the writer's district in Ireland there were some sections of unimportant roads, one or two miles in length, on which a man would work only one or two days in the week, being assisted by a man with a horse and cart to distribute stone in the fall and winter; while, on other sections of about the same length, two men would be employed every day, the traffic being very heavy.

It should be noted, however, that the district was rather rainy, and that, on that account, a considerable quantity of mud had to be removed.

From the discussion on this branch of the subject it would seem the general opinion was that no road would wear out so uniformly as not to require periodical repairs, which are necessary to keep a road in "good condition."

The writer thinks, however, that the difference of idea as to what "good condition" means has a good deal to do with the difference of opinion as to the necessity for repairs. Certainly the road Mr. Owen alluded to, as having been without repairs for nineteen years, must either have been exceedingly well made, have been subject to very light traffic, or else must have been allowed to get into very bad order.

Mr. Owen's idea that a road would not require macadam till it was so rough that it did not require to be picked to help the macadam to bind, may, to some extent, explain how a road might be allowed to go for nineteen years without repair.

Mr. Owen stated that he spread the macadam for repairs three inches thick, but said that he did not scrape off the mud, which was too far below the surface to make any difference.

The writer cannot agree with this conclusion. Mud below three inches of stones will surely prevent them from binding properly, and will work up again to the surface.

Mr. North's statement that constant repairs are not applicable to trap roads should be modified, since the writer has seen first-class trap roads under very heavy traffic which required constant attention.

The writer thinks that Mr. Owen and Mr. North are right in saying that screenings used for repairs are generally wasted, as they could not last under heavy traffic, which would certainly crush them to dust.

As to repairing by patches, the writer thinks that that is by far the best method of applying macadam on roads where the traffic is light, and has a tendency to follow along one beaten track, for the patches, if properly laid, divert the vehicles from the ruts, and besides, if large patches are spread on such roads, and well rolled, the traffic will again tend to follow the same track, and ruts will again appear. It is necessary, however, to have men who understand this method of repairs.

On roads near large towns, where the traffic is heavy and crowded, so that the tendency is to wear the surface more evenly, it is, no doubt, best to spread the macadam over half the width of the road at once, and to roll it thoroughly, before and after spreading binding material.

The general conclusion would seem to be that there are often two different ways of attaining a given end, both of which give about equally good results.

The writer wishes to add that, since this paper was written, he has noticed some of the municipalities adjoining Montreal using steam rollers; and also that quite a long discussion by the members of the American Society of Civil Engineers is published in the proceedings of that Society for the latter part of this year.

DISCUSSION.

Mr. St. George said that in order to get a good surface for streets or roads, the surface should be put on in thin layers and rolled with an ample supply of water, each layer to be separately and thoroughly rolled; that unless this is done thoroughly, big stones will work up to the top, and that the less binding material employed the better. Mr. P. W. St. George.

Mr. Kerry asked as to what weight of roller was best suited to this work and what was the best proportion between the large sized and the smaller sized stones or metalling. He understood that in some recent good work the stones larger than 7/8 of an inch in greatest dimension did not exceed 50 p.c., that in old roads 20 p.c. of the material might be classed as surface mud. Mr. J.G. Kerry.

Mr. St. George remarked that the stone used on the Turnpike Trust roads in the neighbourhood of Montreal was hand broken stuff that had not been screened; that a good practice was to surface new roads with screenings. The present price for hand broken macadam is 95 cents per ton. Mr. P. W. St. George.

Mr. Kerry asked what description of road could be described as water proof. Mr. J.G. Kerry.

Mr. Irwin stated that it was generally found in any old road, when picked up, that there was a quantity of mud which, mixed with the macadam, made the road practically waterproof. Mr. H. Irwin.

Mr. St. George said that the waterproof quality of road surface depended very much upon the proper cambering; that if water gets through at all, the frost will heave it; if dry, this does not take place. Mr. P. W. St. George.

Mr. MacPherson enquired what was the real use of the Telford foundation. Mr. D. MacPherson.

Mr. St. George replied that it prevented the mud from working upwards into the surface layer. Mr. P. W. St. George.

Mr. Armstrong enquired as to the comparative cost of Telford and macadam, and what size of stone could be used for the former. Mr. J. S. Armstrong

Mr. St. George stated that the Telford material was cheaper because any stones could be used; that the size of the stone employed in the Telford surface depended upon circumstances, but might be from 6 to 9 inches long and from 3 to 4 inches in thickness. A roller, weighing from 15 to 20 tons, should be used directly upon the Telford surface. Mr. P. W. St. George.

Mr. H. Irwin. Mr. Irwin enquired of Mr. Booth, Town Engineer, Westmount, as to the practice in Westmount in handling macadam when used beside the rails of car tracks, and said that it was desirable to make a good junction with the rail, and enquired as to the desirability of the practice of putting a plank on edge against the rail.

Mr. C. S. Booth. Mr. Booth remarked that he had always removed a plank junction when he made repairs, and had replaced it by macadam directly in contact with the rail. Repairs could then be more thoroughly carried out when necessary.

Mr. P. W. St. George. Mr. St. George was of the opinion that planks should not be laid beside rails because they not only "worked" but also rotted. In Montreal he had found that asphalt would not give a good surface when in direct contact with the rail, due, he supposed, to the expansion and contraction of the latter, thus causing a movement and admitting water into the joint and freezing, this lifted the asphalt which was quickly broken and worn away. Where there was no movement of the rail, however, the asphalt stood the wear where the joint was solid and the rails good. The result of an examination of 20 miles of track was that the amount of wear was largely a question of foundation. Twelve inches of concrete are now used as a foundation on street railway tracks.

Mr. L. Skaife. Mr. Skaife remarked that asphalt was now being used generally in contact with the rails.

Mr. J. S. Armstrong. Mr. Armstrong, referring to the agitation for good roads in New Brunswick, in which he had taken part, told of a good roads parliament held in Fredericton and of meetings held throughout the Province in which improvements in country roads were chiefly dealt with.

He had recommended macadam roads where the first cost was not prohibitive, and laid special stress on drainage by means of under drains (when the conditions required it) as well as surface ditches.

The main condition for a good country road was to obtain a dry arched stratum two to three feet thick, and, to obtain this, underdraining was often a necessity. The practice of making a hard surface with gravel or macadam on half the width of the road, leaving the other half for light driving in dry weather, was sometimes recommended, and for a cheap by-road or farm road double furrows may be thrown out (one each way) at each wheel track and filled with stone.

A law had lately been passed by the Provincial Legislature requiring the use of a five-inch tire on loaded wagons. This would come into force in May next.

Mr. St. George asked as to the method of collecting moneys for the construction of roads, and said that in the Province of Quebec, for one piece of road with which he was connected, a small tax had been levied on the farms abutting upon the road, and that the Province had purchased stone crushers which were loaned to any locality desiring to use them. Mr. P. W. St. George.

Mr. Armstrong stated that the question of taxation as distinguished from statute labour for road maintenance had not been definitely dealt with yet in New Brunswick. There was a law permitting the county councils to substitute the cash tax in any districts petitioned for, but the right had only been exercised in a few cases. Mr. J. S. Armstrong.

Mr. Skaife said that it was a mistake to think that a steam roller is necessary to build a macadam road properly. Horse rollers are now very largely used. In fact, he knew of one firm which had more horse rollers in operation in the United States than all the steam rollers in use there. The makers of horse rollers claim that the steam roller, being small in proportion to the weight carried, gets stalled in soft places, thus causing great inconvenience. It is a fact that many improvements have been made in horse rollers of late years with a view to adapting them to the use of road building. Mr. L. Skaife.

The following proportions have been found to give good results:—

5 ton roller............	5 ft. diameter............	4 ft. 8 in. wide
6 " "	$5\frac{1}{2}$ ft. diameter..........	do do
7 " "	6 ft. diameter............	do do
8 " "	$6\frac{1}{2}$ ft. diameter..........	do do
9 " "	7 ft. diameter............	do do
10 " "	$7\frac{1}{2}$ ft. diameter..........	do do

A 5 ton roller is easily operated with two horses, while an 8 ton roller can be operated on sub-grade with four horses. A swinging carriage below the shafts prevents the capsizing of the roller and permits the reduction of the "tread" to compete with a 12 ton steam roller. An 8 ton horse roller costs less than $700, and a 12 ton steam roller costs about $3,500. Horse rollers are now made with a reversible carriage so that the horses can come round without turning the roller.

Mr. Irwin remarked that there were eight members in favour of steam rollers and five in favour of horse rollers. This discussion, however, took place in 1893, and he knew that a good many engineers had changed their minds since that time. Mr. H. Irwin

Mr. J. G. Kerry.

Mr. Kerry said that the matter of this paper was not one that could be discussed closely in this Province, as we do not know very much about macadam roads, and that it would be desirable if Mr. Irwin, whose knowledge of the methods of road building is very accurate, would give some suggestions as to any method that would in any way improve the value of farm property.

Mr. H. Irwin.

Mr. Irwin said that, in places where they cannot afford to macadamize the roads, a good deal might be done in the matter of draining the roads. Where the soil is sandy they should, if possible, procure clay to mix with it, and *vice versa*, and if the local farmers would attend to the roads occasionally so as to prevent the roads from going from bad to worse it would be a good thing. But one often notices in this country, in the case of dirt roads, that the farmers start in vigourously for a day or two and throw on a mixture of roots, grass and large, round boulders and then leave it. The more homogeneous the surface, the better for the road. If a road is made entirely of earth, it will be better than earth with a few boulders. The greatest improvement, however, could be made by drainage, but until the people can be made to take an interest in the matter it is hopeless to try to do anything. Farmers cannot see that if they can save $10 it is better than putting $1 into their pockets. They will not listen to any proposal for taxation to keep up the roads, and it is useless to attempt to drain ordinary roads and keep them in repair without money.

CORRESPONDENCE.

The conclusions arrived at by the author of the paper on "Macadamized Roads" appear to be correct in every particular; and, although peculiar local conditions may necessitate some modifications, yet any methods radically at variance with those indicated by the author would inevitably result in failure. Mr. J. A. Duff.

A case where the firmness and solidity of the foundation was neglected has come under the observation of the writer, and may be of interest to the Society.

The pavement was on a residential street, 24 feet wide between the curbstones, and constructed in the following manner:—Upon a good dry sub-grade, excavated and rolled in the usual way, there was laid a foundation composed of stones of various kinds, shapes and sizes, sometimes two, sometimes three stones being used to make up the required thickness of 10 inches. These foundation stones were laid with reasonable care, and fitted each other as closely as could be expected, considering that there was no chipping or wedging or filling of the voids in any way. The surface was fairly level, but the man in charge of the steam road roller thought it was too rough for his machine, so the ceremony of rolling the foundation was dispensed with. Upon this foundation a layer of limestone and hard shale, broken to the usual size, was laid so as to have a thickness, when rolled, of 4 inches at the centre of the street and 3 inches at the curb. It was rolled with a 15 ton road roller, and after being compacted was covered with a layer of broken granite of the same thickness. After the layer of granite had been thoroughly rolled, granite screenings were spread over the surface to a depth of $\frac{1}{2}$ an inch, and flushed and rolled into the macadam in the usual manner.

The surface was quite smooth when completed, and was observed to dry up quickly after rain. It soon became evident, however, that settlement was in progress, and about six months after the pavement was completed an examination was made and the settlement found to be nearly two inches. The bond of the macadam was very imperfect, and openings could easily be made with a pick, and in many places with the fingers. The layer of macadam overlying the foundation stones was practically destroyed. Most of the pieces which still held together were so badly crushed as to crumble in the hand, and about half the material which had composed the layer had fallen into the spaces between the foundation stones, and in this way the settlement of the surface was accounted for.

It is probable that any vacant spaces left in a Telford foundation would become filled in a similar manner, and would be of no permanent value as drainage channels. In order to have a firm subsoil it is frequently necessary to provide drainage channels, but this should be done in some other way than at the expense of a solid foundation.

In the case of the road above described the settlement was so general as to be quite uniform, and the surface did not become very rough, but the macadam was not bonded, and at the time of examination the road would yield visibly to the passing of an empty coal cart.

The loosening of the bond of the broken granite and the crushing of the intermediate layer of limestone and shale may be attributed to the holes in the foundation, to its uneven surface and unequal pressure, and to the rocking of the foundation stones under the concentrated loads on waggon wheels.

A much better foundation might have been constructed at half the cost by using a single layer of stones, 5 to 6 inches thick, carefully laid and properly wedged.

The essential requisites of a macadamized road are strength and solidity of subsoil and foundation, combined with firmness and hardness of wearing surface. It should be the object of the engineer to employ those methods and materials by which the solidity and durability may be obtained at the least cost. The best methods of construction are those by which the strongest and hardest materials may be properly consolidated.

Limestone is objectionable for the wearing surface, because it wears away rapidly and produces quantities of dust and mud; but good strong limestone is suitable for the bottom layers of macadam, provided always that it is placed upon a properly constructed foundation or firm subsoil. If the granite is not too brittle it makes a good wearing surface, though it is difficult to consolidate on account of being deficient in cementing properties. Granite screenings are of little value as a building material, and when the wearing surface is composed of broken granite the binder should be of limestone or some other cementing stone which, by cementing the pieces of granite together, would consolidate the whole roadway.

Thursday, 12th January, 10.00 a.m., 1899.

Annual Meeting.

G. H. DUGGAN, Member of Council, in the Chair.

Paper No. 137.

THE SOULANGES CANAL.

By THOMAS MONRO, M.CAN.SOC.C.E.

At the close of 1888 the writer was transferred from the Welland Canal, and assigned the duty of determining the best location for a canal, having a navigable depth of fourteen feet, between Lakes St. Louis and St. Francis.

After extensive surveys and examinations, he submitted a report, dated 15th June, 1889, addressed to the late John Page, M. Can. Soc. C. E., Chief Engineer of Canals, in which reasons were given why the new canal should be constructed on the north side of the St. Lawrence. Mr. Page died in 1890, and in June of that year a second report was addressed to the Secretary of the Department, confirming the views previously expressed. In that document the projected work was for the first time named the "Soulanges Canal."

In a memorandum dated 25th January, 1891, prepared for the Right Hon. Sir John Macdonald, by Toussaint Trudeau, M. Can. Soc. C. E., Deputy-Minister and Chief Engineer of Canals, the scheme submitted by the writer was approved of in general terms. This view was subsequently confirmed by the Government, and, in August, 1891, a sum of $300,000 was voted by Parliament towards the construction of the Soulanges Canal, which was then estimated to cost $4,750,000.

Plans and specifications of the work were subsequently prepared; and in May, 1893, all the thirteen sections between Cascades Point and Coteau Landing were under contract.

It is not intended to discuss in this paper the fitness or otherwise of the dimensions adopted for the Welland and St. Lawrence Canals. The writer's views on this important subject are fully set forth in his address on retiring from the office of President of this Society on the

15th January, 1896. The object now proposed is to briefly describe the Soulanges Canal as it is, and to draw attention to the fact that in many essential features it differs in design from the other links of the St. Lawrence system.

It may be stated, at the outset, that more extended study of the question of the fluctuations of the St. Lawrence River led to the conclusion that it would be unsafe to accept previous records as a guide in fixing the heights of the mitre sills at each end of the canal. The lowest water at Valleyfield (1849-90) was in October, 1872; when it fell for part of one day to 10′ 8″ on the mitre sill of the guard lock at the head of the Beauharnois Canal. But the mean for that month was 11′.3″. Practically, 11 feet would therefore represent extreme low water during the navigation season. Adopting this view, the sills of the guard lock at the head of the Soulanges Canal should have been placed 3½ feet lower to secure a fourteen feet draught. As a matter of fact, the sills of the Soulanges are *five feet* lower than those at Valleyfield; and it is due to this that, in November, 1895, when the lowest water occurred of which there is any reliable record, there was a depth of 14.55 feet at the upper entrance, and 14.83 at the lower end of the Soulanges Canal. In the same month there was only 13.50 feet at the lower entrance of the Cornwall Canal, and 13.08 at the head of the Lachine Canal.

Attention is drawn to these facts, because between the time when the estimate attached to the writer's report of June 18, 1890, was made, and the letting of the works, the bottom plane of the summit level (10½ miles long) and the foundations of the structures on it were lowered about 1½ feet, largely increasing the quantities, and add, ing, at a fair valuation, about $500,000 to the estimated cost of construction, which, instead of $4,750,000, should be placed at $5,-250,000.

It may also be stated that in previous canal surveys along the St. Lawrence, various datums were employed, making the results somewhat confusing, or only intelligible after a good deal of trouble. An attempt has been made to avoid this by referring the levels of the Soulanges Canal to mean tide at New York. To do this, lines were run from a bench mark established by the U. S. Coast and Geodetic Survey at Rouse's Point, N. Y., to the head of the Beauharnois Canal. In this way the mean level of Lake St. Francis was found to be 154.80; and directly connected with the records at the Valleyfield lock since 1849. The U. S. Army Engineers have determined the mean height of Lake Ontario (1860-75) at 246.61 above the same datum, so that the difference between Lakes St. Francis and Ontario should be (to close the circuit) say 91.81 feet. Lines run under the writer's direction between Coteau Landing and Kingston confirmed these figures. But the previously accepted distribution of fall was found to be quite erroneous. The descent from Kingston to Prescott was supposed to be three or four feet. It is now approximated at about one-third of a foot, pending the completion of the precision levels begun some years ago under the able direction of Mr. René Steckel, M. Can. Soc. C. E., of the Public Works Department. This work has not yet been continued along the St. Lawrence above Lachine. It may be stated, however, that levels recently taken by the Engineers of the U. S. Deep Waterways' Commission only differ 0.12 from the figures given above as representing the relative levels at Rouse's Point and Valleyfield—about 47½ miles apart.

Attention is drawn to the accompanying lithographic profile of the St. Lawrence, prepared for the Canadian Deep Waterways' Commission of 1895, as explanatory of the foregoing remarks. This profile shows the position and length of the various canals between Kingston and Montreal. The fall in the river is about 220 feet. That overcome by locks is about 204 feet.

It will be seen that Lake St. Francis is 33 miles long. It is merely an expansion of the river—a pool above the rapids between it and Lake St. Louis. The fall between these lakes is 82½ feet at mean water. In this distance of about sixteen miles there are the Coteau, Cedars, Split Rock and Cascades Rapids. At some points on the river there is a depth of not more than six feet in the channel at extreme low water. It is to surmount these rapids that the Soulanges Canal has been constructed. Its position is shown on the small sketch map which accompanies this paper.

The canal is 14 miles long, and leaves the foot of Lake St. Francis at Macdonald's Point, just below the village of Coteau Landing. Thence it runs straight 1½ miles, touching the margin of the river about a mile from the upper entrance. From the end of this tangent the line sweeps round to the north-east behind the village of Coteau du Lac for about three miles on a curve of 14,324 radius. It is then continued by a second tangent of some 8½ miles long, passing about a mile inland from the Cedar's Village. At the termination of this, the line bends slightly to the north, and is led straight into the Ottawa River, about two miles from its junction with the St. Lawrence at Cascades Point. The canal is, for all practical purposes of navigation, a straight line throughout, and is two miles shorter than the route by the river.

The fall of 82½ feet is overcome by four locks :— 70.50 feet of this is at the Cascades end, where the bluff forming the right bank of the Vaudreuil branch of the Ottawa gives an opportunity of locating three of these in the first mile ; each having a rise of 23½ feet. The original design was for five locks. This was subsequently made four, and, after extended examination, the writer, in January, 1895, proposed a further reduction to three. In this view he was sustained by Messrs. Shanly and Keefer, who were retained by the Government to advise in the matter. The height of these lifts constitutes a peculiar feature in the Soulanges Canal.

There is an interval of over two miles between the third and fourth locks. The latter is about 3 miles from the lower entrance. Here the lift is variable. It is about 12½ feet at mean water of Lake St. Francis —but at extreme high periods it would (if this water were permitted to enter the canal) be about 15 feet.

At the upper entrance there is a guard lock by which the surface level of the summit can be regulated without interruption or danger to navigation. At periods of high water, this will be used as a lift lock, but, at ordinary stages of the lake, its surface level will be that of the canal. It is needless to point out to this audience the necessity of this arrangement. Canal Engineers of experience will admit that such a safeguard is indispensable.

About 1,000 feet above Lock No. 4 there are a pair of guard gates placed for safety to the lower locks in case of accident.

The distribution of lockage as above described is supplemented by a series of weirs for the passage of the necessary supply. That at the head of the canal has four openings 9′ x 10′ furnished with gates of the "Stoney" pattern. The tops of these gates will be submerged when hoisted. This structure is connected with a raceway of large dimensions formed to the south of and parallel to the guard lock. This channel is about 650 feet long, and is pitched on both sides. It passes into the canal through a series of masonry arches, and will amply fulfil the intended purpose without creating objectionable currents. About five miles from the upper entrance, at the crossing of the River à la Graisse, a large weir has been constructed having six arched openings 6′ x 6′. It will regulate the summit level of the canal, which can be either lowered or entirely emptied at this point. The channel from the weir connects directly with the River à la Graisse a short distance from its junction with the St. Lawrence. In connection with this weir, a power-house is being erected which will be alluded to further on.

The supply is passed by the guard gates above lock No. 4 through two 20′ x 22′ Stoney sluices; and at locks 4, 3, 2 and 1 the regulating weirs consist of twin culverts through the dividing embankments between the various reaches, having submerged gates controlled from the top bank level through shafts of concrete and masonry.

It will be observed that the water for supply is not in any case passed over breast walls, the writer's experience being that such an arrangement is objectionable in this climate.

There are seven road bridges and one railway bridge across the canal. The latter traverses the lower wings of the guard lock, and carries the Canada Atlantic Railway. It swings over the lock and raceway, and is about 180 feet long. The superstructure of this bridge was manufactured and erected by the Dominion Bridge Company, of Lachine, Que. At the head of this lock there is another swing to pass the main road between Coteau Landing and Cascades Point. A similar structure will be erected at lock 3 in connection with the Quinze Chiens Road. The superstructure of these two small bridges is from the shops of the Weddell Company, at Trenton, Ont.

The remaining five road bridges cross the full prism of the canal, and have been designed to permit a full and free flow for the water and so as not to impede rapid navigation. This is effected by building the pivot pier in a line with the toe of the south slope, between which and the foot of the north slope there is an opening of 100 feet. The bridges are 246 feet long, and the south half swings partly over the land and partly over a channel formed in rear of the pivot pier to give additional water section. It is believed that this is a considerable improvement on the old method of placing the pivot in the middle of the canal with a narrow channel on each side of it where vessels have to slow up, and often find it difficult to get safely past. The piers, abutments, etc., of these bridges are of concrete coped with cut stone The superstructure was manufactured and erected by the Dominion Bridge Company in a quite satisfactory manner.

To pass the drainage of the country, lying to the north, across the line of the canal, has necessitated a very large outlay. The first stream met with in descending is the River Delisle. This has its sources some 60 miles inland. Its catchment basin has an area of about 180 square miles, and during spring floods the flow is sometimes over 200,000 cubic feet per minute. The river is passed under the canal through four lines of cast iron tubes 10 feet in diameter laid in a trench fifty feet wide, excavated in the rock to the depth required. The tops of these tubes are two feet below canal bottom. At each end there are masonry wells, and at the north end the macadam road is carried over by arches of masonry and concrete. This structure has been found to answer the required purposes satisfactorily. At no time has there been, so far, a greater head than from 18 inches to 2 feet on it, whilst the position is such that no just claims for backwater can arise. In connection with this culvert there has been excavated a channel of diversion of considerable length and dimensions, which secured a good foundation for the structure and diminished the interruption from water which would have been inevitable had it been placed in the old bed of the river. It is believed that this plan should be followed where at all practicable.

The next stream is called the Rouge River. Its flow during floods is about half that of the Delisle, and it is carried under the canal by two lines of tubes of the same diameter as those previously mentioned. The excavation for the foundation of this structure was carried down to boulder clay through a stratum of soft blue material, which gave a good deal of trouble through sliding during the progress of the work. A diversion channel has been formed here also, the sides of which are pitched with masonry laid in cement.

At the River à la Graisse the water is carried by a single line of tubes 10 feet in diameter. The foundations of this structure are on piles driven some 25 or 30 feet to hard material.

There are also two pipe culverts of small dimensions towards the lower end of the canal which do not merit particular description.

Now as to the dimensions of the canal itself.

Ordinary prism is throughout about 100 feet wide at bottom with side slopes of 2 to 1. The banks or cuts are first formed to these and then a notch is cut to receive the stone protection lining. This reaches from four feet below to four feet above mean level in the summit.

It is about 3 feet wide at the base, tapering up to about one foot on top, where it is finished by a rough coping. Between this coping (158.0) and the top of the bank (161.0) the surface of the slope is sodded the sodding being returned about five feet on the level. On the north side of the canal a macadam road, 15 feet in width, will be formed throughout its entire length, the centre of which is 33 feet from the edge of the cut or bank on that side. This road was designed, not only for the service of the canal, but also to provide a means of intercommunication between the various farms cut across by the canal and the side roads where bridges are built, and so, if possible, reduce damages—a result which has not, however, been realized, as the sums paid for right of way are very much greater than was anticipated. The total quantity of land taken is about 950 acres, ample width having been secured throughout.

Wherever practicable, material arising from the excavation has been used to widen out the embankments to give additional safety. The north side of the canal where in filling is fifty feet wide on top. On the south side it is generally thirty feet at least. The large amount of surplus material was spoiled either on land adjacent to the canal taken for that purpose, or wasted into the St. Lawrence river at several points.

The small profile will show the various kinds of soil traversed by the canal. At the Cascades' end the excavation is in rock of the Potsdam formation, which affords a solid foundation for locks Nos. 1, 2 and 3. The upper extension walls of the latter lock are, however, of piles and concrete. The reach between locks Nos. 3 and 4 is in clay upon which the piers and abutments of the St. Antoine Road bridge are founded.

At lock No. 4 solid material is from 30 to 35 feet below the floor line. The lock walls are therefore placed upon a foundation of piles and concrete. They are 36½ feet high, and, from careful levels taken before and after building, they have not perceptibly subsided. The structures immediately to the west of lock No. 4, namely the guard gates sluice abutments, retaining walls, etc., are all founded on the clay, which affords a sufficiently solid bearing. The road bridges at St. Feréol and St. Dominique are also built upon similar material.

It will be observed that the surface of the blue clay along the summit reach gradually rises towards the west and culminates at the crossing of the St. Emmanuel Road, where it is almost level with top bank, being only covered with a thin layer of sandy soil. Where-ever this clay was cut into by the prism, there was danger of slides roughly in proportion to the depth of the cutting. This danger was greater on the north side, which intercepted the natural drainage towards the river, so that in time the slope became so saturated as to break loose and slip into the canal. In other words, by the excavation of a deep trench of such dimensions, a similar condition of things was set up as that existing along the bank of the St. Lawrence between Coteau and Cascades, where, from time immemorial, *déboulements* have occurred, causing in many places a wearing away, which in some cases is measured by hundreds of feet.

One of these slides took place on the 25th October, 1897; when, without any previous perceptible warning, the north bank of the canal, for over a quarter of a mile in length, slid into the prism, taking with it the abutment of the St. Emmanuel bridge, which was thrown bodily forward about fifty feet into the centre of the canal. This occurrence is considered to be of so much interest as to warrant its being made the subject of a separate paper. To discuss it in detail at present would take up too much time.

Slides have also occurred more or less for a mile or so to the west of the St. Emmanuel Road, but a plan of repairs has been adopted which will enable the north slope to be satisfactorily restored in time for the opening of navigation through the canal.

Towards the crossing of the River Delisle, the surface of the blue clay lowers rapidly. At the river itself rock of the "calciferous" is encountered, and this alternates with the clays and sands of the drift formation for some two miles to the west. At the upper entrance the guard lock and surrounding structures are all founded upon solid rocks.

There are about 6¾ million cubic yards of clay of all sorts, and 300,000 cubic yards of rock of various kinds in the excavations for the canal.

The level of the bottom of the summit reach at the foot of the guard lock is 137.00 above datum. Ordinary surface of Lake St. Francis may be taken at 155.50, at which time there will be 18½ feet of water in the canal, equal to a cross sectional area of 2534 square feet. Propellers of the type now being built on the upper lakes to navigate these canals will have a submerged midships section of say $42 \times 14 = 588$ square feet, or less than one-fourth of that of the water area at mean level. This will permit of a fairly high speed through the summit reach, which it will be observed forms 75 per cent. of the whole length of the canal. The bottom of this reach has an inclination of 0.10 per mile. Top bank is level and 161.0 above datum. The cross section of the canal has, as before stated, been kept as nearly as possible uniform throughout. This will avoid the creation of cross currents, and facilitate the rapid navigation of the canal.

The relation of the area of the vessel to that of the canal is a matter of much importance. Full depth under the keel is of great value, both for speed and safety. The whole question of the gain in time in relation to the cost of construction affords ample scope for further investigation. It does not appear as if a slight increase in speed where the canals are short in comparison with the length of natural navigation would warrant a largely increased outlay even where ample means are at hand. As to locks, it is believed that, as has been stated, "The "single individual lock is better than the fleet lock, and can be operated "more quickly—and the maximum facilities may be provided by "duplicate locks. The lift of locks should be made as great as possible "where conditions permit, as time is consumed by the number of "locks rather than by the lift."

To return to a description of the locks. It was the writer's intention that these should be constructed entirely of concrete up to the level of the surface of the lower reach. In this particular the design was almost wholly frustrated, lock No. 4 only having been built on this plan. The nature of the foundations of all the locks having been previously indicated, it will perhaps be as well to describe the general features of lock No. 2, and thus avoid tedious repetition.

It will be observed that the lock is filled and emptied through culverts in the side walls, from which cast iron pipes 30 inches in diameter—ten on each side—lead into the bottom of the chamber. These pipes have about 40 per cent. greater discharging capacity than the culverts themselves. The lock will be filled in about five or six minutes, and this will be effected without subjecting the vessel to much surging or strain. At the head and foot of each culvert there is placed in a shaft (8′ x 4′) operated from the coping a 6′ x 6 sluice of the "Stoney" pattern. These are for the first time introduced into a Canadian canal. Their operation is, as will be seen by the drawings, exceedingly simple. They are in extensive use in Europe, and have given the best satisfaction in controlling large bodies of water. They are used for that purpose on the Manchester ship canal. It may here be stated that the details for these gates on the Soulanges Canal have been worked out and modified by Mr. Geo. H. Duggan, M. Can. Soc. C. E. This has been skilfully done; and it is believed that their operation throughout will prove quite satisfactory. The method of emptying and filling locks through tunnels in the side walls is considered to be entirely the best, and manifestly better than any system of filling from below the floor.

The main object in adopting this plan was, however, to avoid that in vogue on the Welland Canal, where the filling and emptying is done through valves in the gates. This is objectionable from every point of view. It weakens the gates just where most strength is required, and weighs them down with cumbrous valve gear. Besides, it introduces the water for filling so as to strike the stem of the vessel heavily, creating an unnecessary disturbance in the chamber and a tendency to surge it on the upper gates. All this is now well known to practical men, and need not be dilated upon here.

It will be observed that each lift lock is provided with a heavy breast wall at its upper end, corresponding in height to that of the lift. These walls have been re-introduced for the purpose of removing the cause of about nine-tenths of the accidents which have occurred on the enlarged canals; namely, vessels carrying away the upper gates of the locks by striking them whilst entering from the lower reach. It is difficult to understand why all the four gates of each lock on the Welland and other canals were made the same height—but there is no doubt that the plan is defective. If a vessel goes ahead too far in a Soulanges canal lift lock, she will strike against the breast wall, and damage herself instead of the gates.

The filling and emptying of the lock having, it is believed, been secured in a reasonable time in the way above described, it may now be stated that an attempt has been made to simplify the manner of working the gates by the use of struts operated in the manner shown in the accompanying drawings. An inspection of these will render further description unnecessary. It may, however, be noted here that the writer made a series of experiments in 1894 at Lock No. 9 of the Beauharnois Canal, which convinced him that this method would prove entirely practicable. Since then machinery of a similar kind, but on a greatly larger scale, has been and is now in operation on the North Sea Canal.

The gates are built on what is called the "solid" plan, which consists of a number of superimposed timbers shaped to the required horizontal pattern and fastened together. The method is simple, and in this case the strength is superabundant. One leaf of the lower gates of the high lift locks at the Cascades' end of the canal weighs over 90 tons in the air. The drawings were made by Mr. J. B. Spence, M. Can. Soc. C. E., and the gates have been constructed in a thoroughly workmanlike manner by the firm of Messrs. J. & R. Miller, of Ingersoll, Ont., who have had very extensive experience in connection with the Welland and St. Lawrence canals. The timber used is principally Douglas fir, which was hauled across the continent for that purpose. A number of spare gates are also on hand in case of accident.

It is proposed to work a lock from one point on the south side and about 20 feet back from the coping, where a switch cabin will be placed as shown. This will be connected with the motors actuating the sluices and operating bars previously described. Suppose a vessel to enter the lock from the lower level. When her stem is up to the breast wall she signals, and the lower gates are closed. The machinery will effect this in a perfect manner. The gates will shut precisely and synchronously, and avoid any trouble from over lapping, which often occurs now. This should be done in one minute. The lower sluices are then dropped and the upper ones hoisted, the lock being filled as indicated. When the water has risen to the full height, the upper gates are opened and the vessel passes out. The lockages should be easily made in from 12 to 15 minutes. But the saving of time at a lock, although of much importance, has been unduly magnified. The capacity of the canal at four lockages per hour on the basis of one-third westbound freight would be about 20 millions of tons in an ordinary season. Of course, this estimate is merely theoretical. But, even if one-half of it is realized, it will require a good many ports like Montreal to handle such tonnage economically.

In the construction of the Welland Canal locks, nearly every mitre sill on the line was forced up, causing great delay to navigation, annoyance, and much expense. The plan of mitre sill and bottom designed for the Soulanges Canal will, it is believed, fully obviate these difficulties. It will not be possible under any imaginable circumstances to disarrange sills held down as shown on the plan of lock No. 2; which is a type of all the rest. It will also be seen that the mitre sills themselves are the only pieces of timber in or connected with the lock bottom, and these can easily be renewed when this becomes necessary.

The extension walls above and below the locks and in immediate connection with their masonry should not be built on a twisting batter. Where these walls cease to be self-sustaining and become slope walls, they are sure to crack—and besides, the bases of those at the lower ends of the locks are liable to be washed out by the strong currents created when they are emptied; and have a tendency to slide into the canal. All the walls connected with the upper and lower entrances to the locks of the Soulanges Canal stand upon their own bottoms, and are therefore not liable to failure in the way alluded to.

The macadam road which runs along the north side of the canal is carried past the locks by a series of ramps, the inclination of which does not exceed 1 in 8. To enable foot passengers to surmount the rise between the different levels, a flight of steps is provided on each side of the lower ends of all the locks.

Concrete has been introduced into the construction of these locks to an extent greater than heretofore in Canada Since the plans for them were made, the use of this material has rapidly spread. But a few years ago experienced hydraulic engineers looked upon concrete construction with suspicion, at least in this climate. This is not to be wondered at, because the cement supplied (which is the life of concrete) was of very inferior quality and manufacture. Now, however, excellent Portland is obtained at moderate rates. On the Soulanges Canal the writer specified that cement of a certain quality should be supplied by the Government to the several contractors—and should not be purchased by them at all. The benefits of such a course are obvious. There is no inducement to supply an inferior article or to stint its use; both of which may happen with the ordinary type of canal contractor. It is better to remove the temptation than to depend upon the virtue of the individual. The specifications for the preparation of concrete do not offer any feature out of the common. Some 70,000 briquettes have been made for testing purposes in a quantity of about 200,000 barrels. Good clean sand and properly broken stone have been insisted upon; and so it is believed that this work is excellent throughout. Mixing has been done both by hand and machine, but in either case the product when carefully laid and rammed makes an unexceptionable hydraulic wall, whilst its cost per cubic yard is here less than half that of masonry. Of course this varies with circumstances, but on the Soulanges Canal its use is clearly suggested by the fact that in the excavation for the prism about 300,000 cubic yards of rock had to be taken out, which is excellent for concrete, but unfit for masonry. This supplied the 150,000 cubic yards required for concrete—also about 120,000 cubic yards for stone protection lining, together with over 50,000 cubic yards for macadam, repairs etc.,—leaving a large surplus to be thrown to spoil.

It will be seen on reference to the plan of road bridges that these structures are almost entirely of concrete, the copings only being of cu stone. This remark will also apply to the retaining walls, regulating weirs, etc. A large amount of concrete was also used in connection with the culverts under the canal and in other positions too numerous to mention.

Time will not permit of more than a passing reference to the style of supply weir or regulating culverts designed for the canal. The plans will show details of construction. They can be made to control the levels automatically if so required. It will be seen that the weir at Lock No. 4 is connected with its south wall, and differs in construction from those at the lower locks.

It is believed that the drawings and photographs will show with sufficient clearness the main features of the culverts under the canal to pass the Rivers Delisle, Rouge and à la Graisse. The casting of the ten foot tubes was done by Messrs. H. R. Ives & Co., Montreal.

The site chosen for a power house to generate electricity for the operating of the locks, bridges, etc., and the lighting of the canal throughout has many advantages, and will perhaps merit a brief description, which must close this paper. At this place the River à la Graisse crosses under the canal, and joins the St. Lawrence about 400 feet to the south of it. The surface of the canal is, as before stated, at ordinary stage about 155.50 above datum. At such time the à la Graisse is about 135.00, or 20.5 feet lower. It is obvious that by drawing a sufficient volume from the summit reach and passing it through wheels, power can be readily obtained here; and from this site a free discharge can be had into a wide tail race connecting directly with the St. Lawrence on Government property where no claims for damages can arise. Of course the above height of 20.5 feet represents the fall on the River St. Lawrence between Lake St. Francis and the mouth of the à la Graisse.

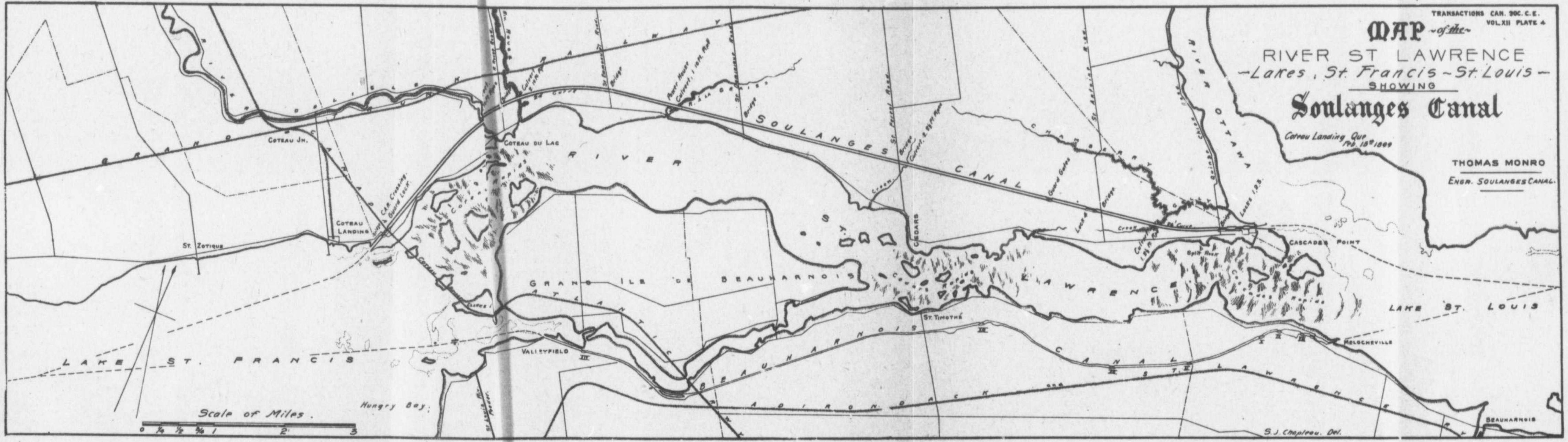
The amount of electrical power required to operate the locks, bridges and other structures and to light the canal satisfactorily throughout its entire length of fourteen miles was carefully determined by the officers of the Royal Electric Company, who also worked out the details of the distribution and application of this power. They also provided designs and drawings for the power house proper, and the switch cabins at the various locks, together with the necessary specifications. The hydraulic development was entrusted to Mr. A. M. Rice, of Dayton, O., a gentleman of acknowledged skill and experience in such matters. He prepared plans showing the number and position of the wheels, tail races, etc. These have been partly carried out; and work will be resumed in the spring. The power house is connected with a regulating weir previously referred to, and which is intended to control the summit level of the canal without discharging a great volume of water through the Cascades Locks. The works for electrical power plant have been recently let, and the whole system will be in operation next season. The canal will be efficiently lighted throughout, and, considering its position in the St. Lawrence system, this will be of great importance in securing safe navigation through it by night.

The entrances at each end of the canal are wide, of full depth, and sufficiently commodious. It will be observed that there are concrete walls heavily coped with cut stone on the top of the cribs, forming a permanent face work, instead of the timber generally used in such positions.

There are a number of other matters of interest to canal engineers which cannot even be touched upon in this sketch. It will, however, be seen that an attempt has been made to provide an unobstructed channel of full dimensions for a fourteen foot navigation at lowest water, with a much less number of locks than has hitherto been deemed advisable to overcome a similar fall on the other canals of the St. Lawrence system. In construction, materials of a practically imperishable kind have been almost wholly used, and this fact, taken in conjunction with the improved methods of operating the locks and bridges, will, it is believed, largely decrease the annual expenditure for maintenance and operation.

The writer sincerely hopes that the beneficial results which must follow the completion of the St. Lawrence Canals to dimensions capable of passing vessels of 2,000 tons will be realized to the fullest extent; and that the immense expenditure so pluckily incurred by

CANAL
Guard Gates
Lock & Bridge
CEDARS
LAWRENCE
ST. TIMOTHÉ
CANAL


TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE 4
MAP of the
RIVER ST LAWRENCE
Lakes, St. Francis ~ St. Louis
SHOWING
Soulanges Canal
Coteau Landing Que
Feb. 15th 1899
THOMAS MONRO
ENGR. SOULANGES CANAL.
SOULANGES CANAL
RIVER
COTEAU JN.
COTEAU DU LAC
COTEAU LANDING
ST. ZOTIQUE
CEDARS
CASCADES POINT
LAKE ST. LOUIS
GRAND ILE DE BEAUHARNOIS
ST. TIMOTHE
VALLEYFIELD
MELOCHEVILLE
BEAUHARNOIS
BEAUHARNOIS CANAL
LAKE ST. FRANCIS
Hungry Bay
RIVER OTTAWA
Scale of Miles
0 1/4 1/2 3/4 1 2 3
S. J. Chapleau. Del.

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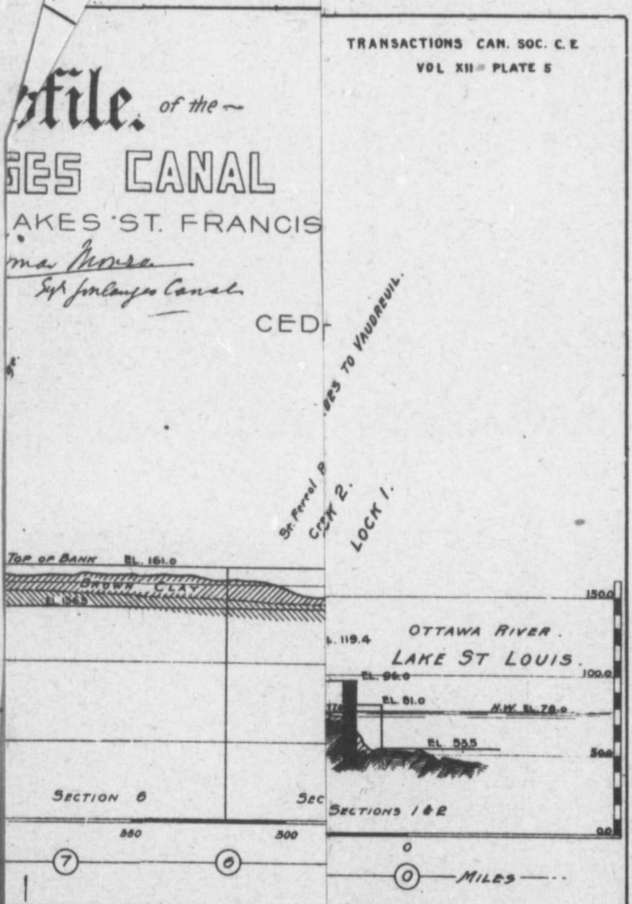
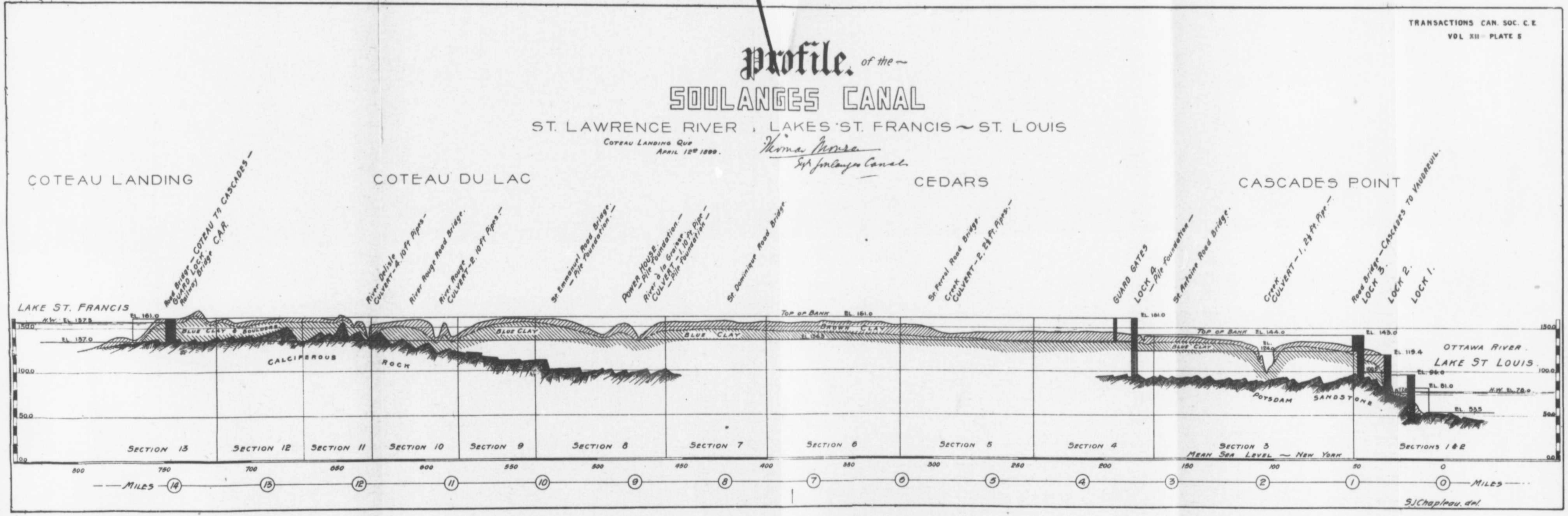
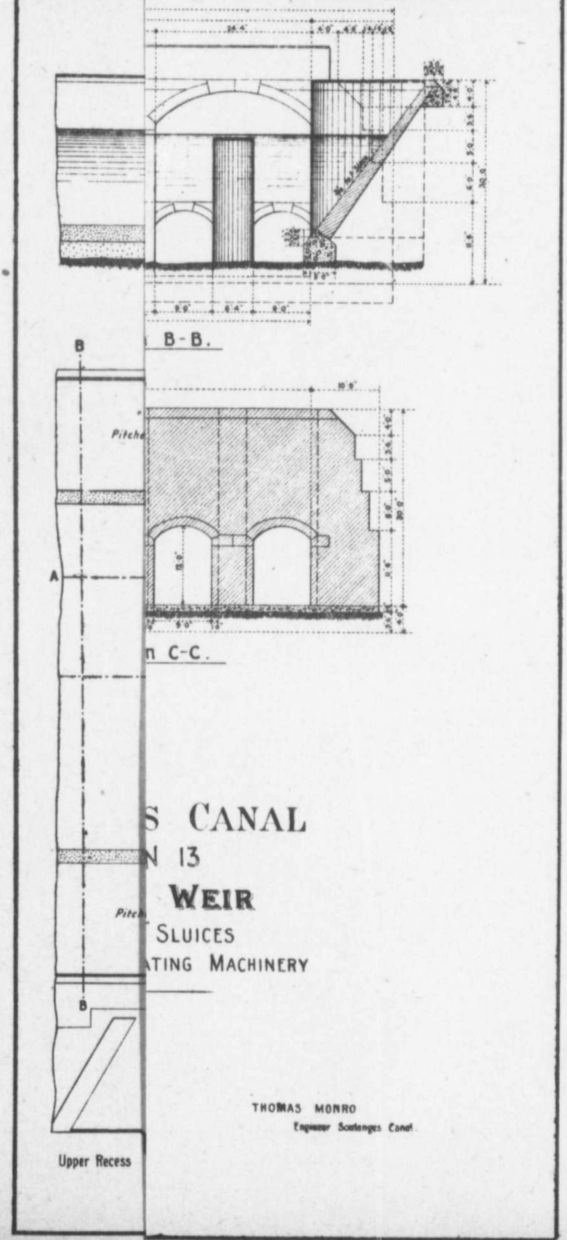
TRANSACTIONS CAN. SOC. C.E
VOL XII PLATE 5

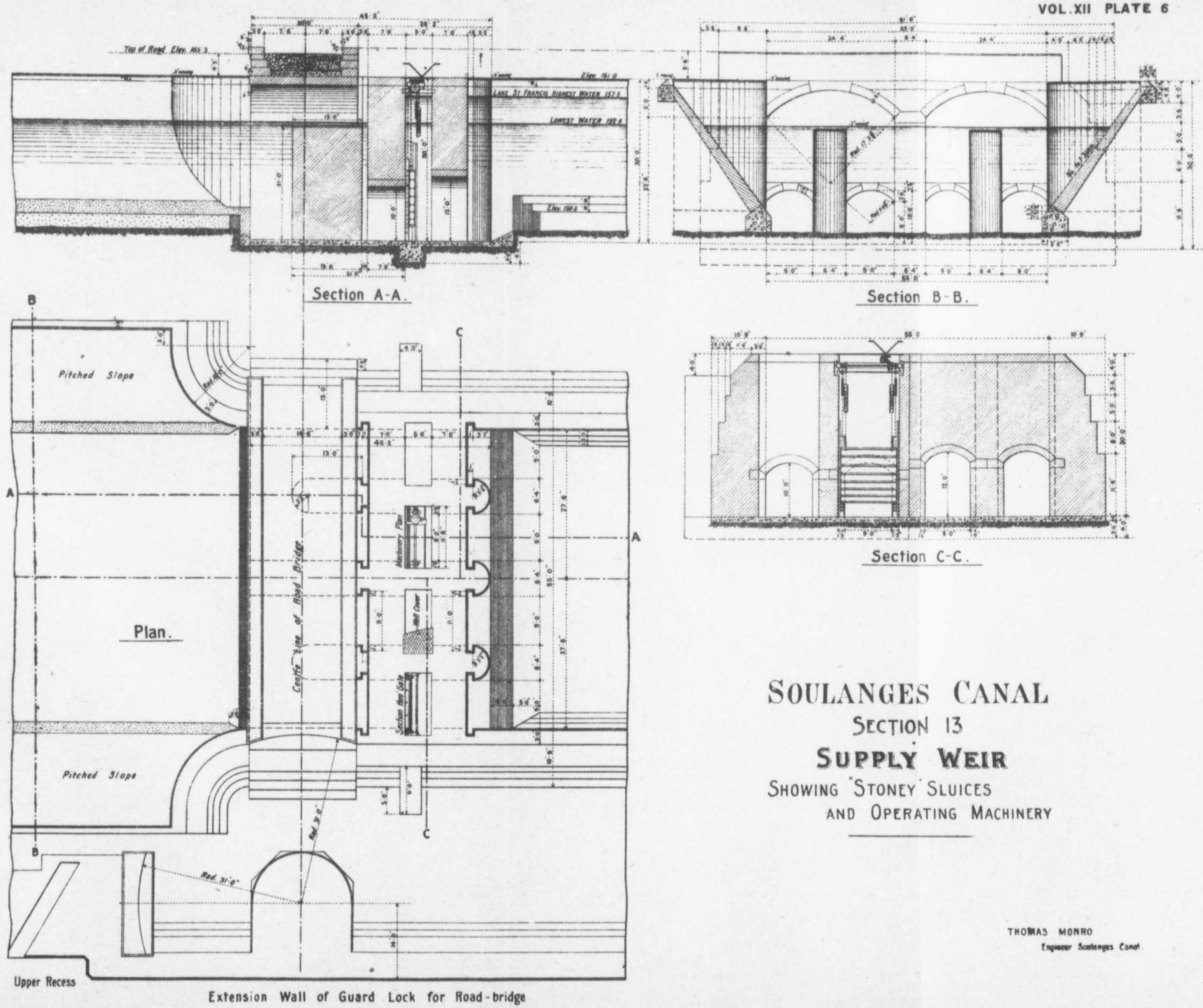



TRANSACTIONS CAN. SOC. C.E.
VOL XII PLATE 5
Profile. of the
SOULANGES CANAL
ST. LAWRENCE RIVER , LAKES ST. FRANCIS ~ ST. LOUIS
COTEAU LANDING QUE
APRIL 12th 1899.
COTEAU LANDING
COTEAU DU LAC
CEDARS
CASCADES POINT
Road Bridge — COTEAU TO CASCADES —
GUARD LOCK.
Railway Bridge C.A.R.
River Delisle
CULVERT - 4, 10 ft Pipes -
River Rouge Road Bridge.
River Rouge
CULVERT - 2, 10 ft Pipes -
St. Emmanuel Road Bridge.
— Pile Foundation —
POWER HOUSE.
— Pile Foundation —
River à la Graisse —
CULVERT - 1, 10 ft. Pipe —
— Pile Foundation —
St. Dominique Road Bridge
St. Ferreol Road Bridge.
Creek
CULVERT - 2, 2½ ft. Pipes —
GUARD GATES
LOCK 4.
— Pile Foundation —
St. Antoine Road Bridge.
Creek
CULVERT - 1, 2½ ft. Pipe —
Road Bridge — CASCADES TO VAUDREUIL.
LOCK 3.
LOCK 2.
LOCK 1.
LAKE ST. FRANCIS
H.W. EL. 157.5
EL. 161.0
EL. 137.0
BLUE CLAY & BOULDERS
CALCIFEROUS
ROCK
BLUE CLAY
BLUE CLAY
TOP OF BANK EL. 161.0
BROWN CLAY
EL. 136.5
EL. 161.0
TOP OF BANK EL. 144.0
BLUE CLAY
EL. 124.0
EL. 143.0
EL. 119.4
EL. 96.0
EL. 81.0
H.W. EL. 78.0
EL. 55.5
POTSDAM SANDSTONE
OTTAWA RIVER.
LAKE ST LOUIS.
150.0
100.0
50.0
0.0
SECTION 13
SECTION 12
SECTION 11
SECTION 10
SECTION 9
SECTION 8
SECTION 7
SECTION 6
SECTION 5
SECTION 4
SECTION 3
SECTIONS 1 & 2
MEAN SEA LEVEL ~ NEW YORK
800 750 700 650 600 550 500 450 400 350 300 250 200 150 100 50 0
MILES 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 MILES
S.J.Chapleau. del.

TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE 6



TRANSACTIONS CAN. SOC. C.E.
VOL. XII PLATE 6



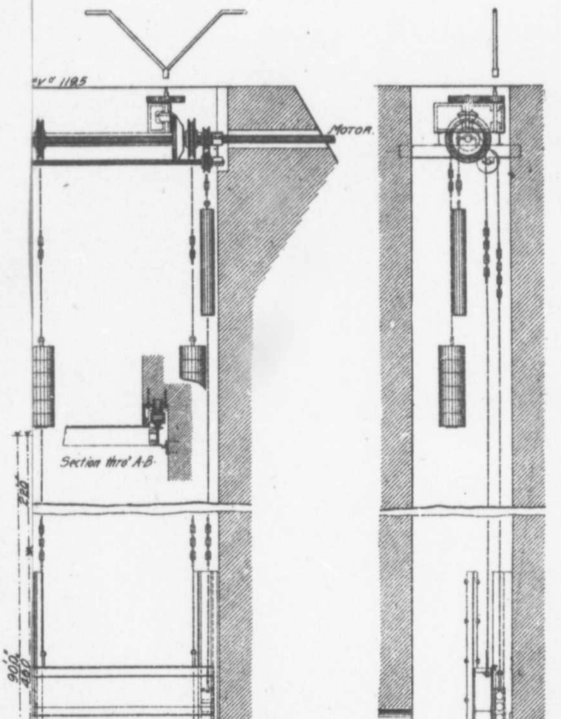
SOULANGES CANAL

SECTION 13

SUPPLY WEIR

SHOWING "STONEY" SLUICES
AND OPERATING MACHINERY

THOMAS MONRO
Engineer Soulanges Canal


Elevn 119.5
Motor.
Section thro' A-B
Elevn 78.0
Section. B-B
Section A-A

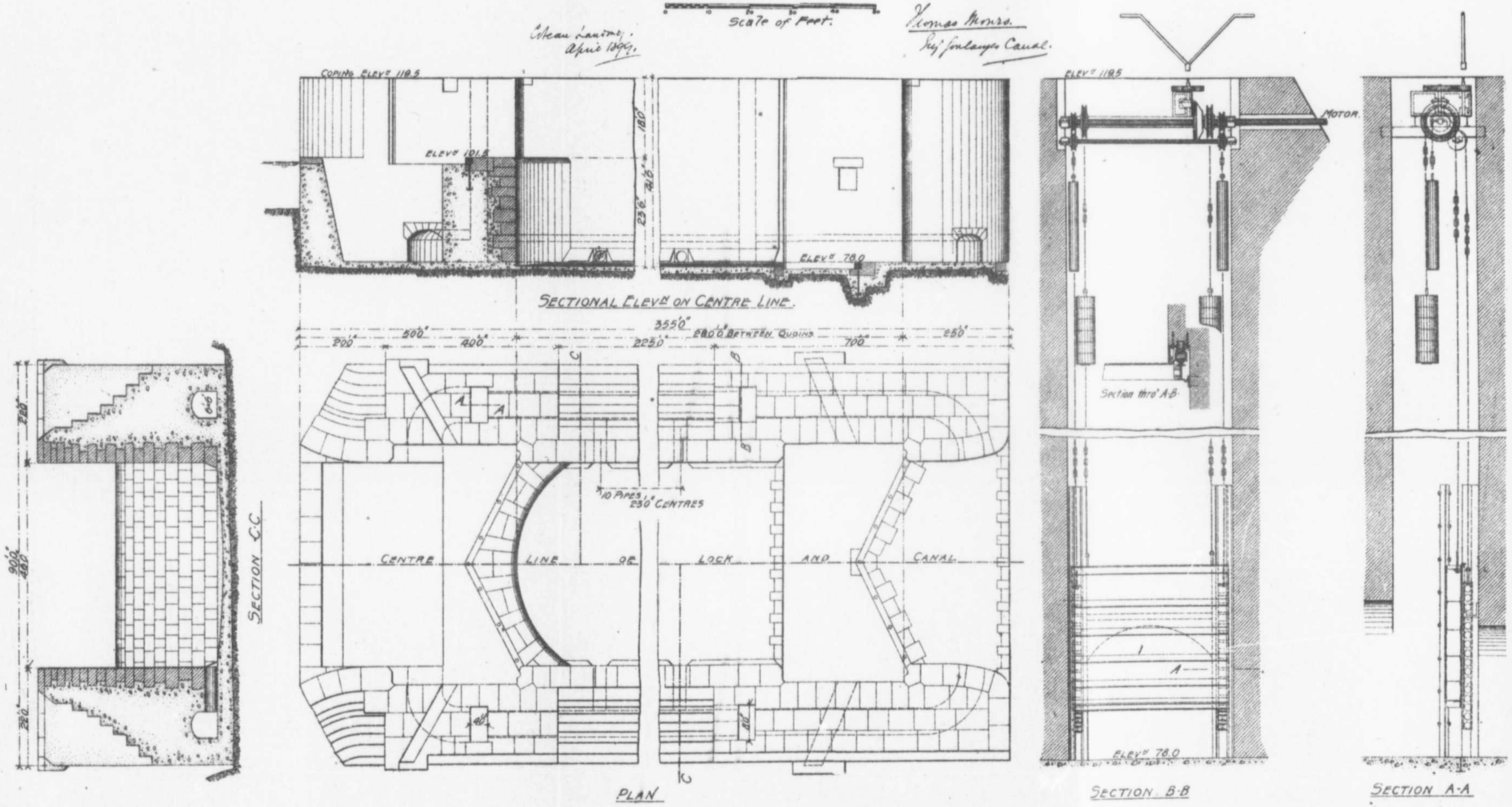
TRANSACTIONS CAN. SOC. C.E.
VOL. XII PLATE 7

SOULANGES CANAL

SECTION 1

Lock 2

SHOWING "STONEY" SLUICES & their OPERATING MACHINERY



Canada with her comparatively small population and limited resources may at last draw to our national route the current of European trade for which we have waited so long.

The writer may be permitted to state, in conclusion, that in his humble opinion, if such a large volume of traffic as may be reasonably expected on the completion of the St. Lawrence Canals has to be economically and quickly handled at Montreal, a very different condition of things to that existing there must at once be established and maintained. If not, the expected benefits to Canada will be largely neutralized or the point of trans-shipment for grain in bulk and whole cargoes will be transferred to Quebec.

The thanks of the writer are due to Mr. John L. Allison, M. Can. Soc. C. E., by whom he was materially aided in the preparation of the general designs for the Canal and its structures. He also desires to acknowledge the zeal and intelligence of Messrs. C. R. Coutlée and A. J. Grant, A. M. Can. Soc. C. E., to whom, together with a staff of juniors, inspectors, etc., the superintendence of the principal works has been entrusted.

Thursday, 12th January, 2.00 p.m., 1899.

Annual Meeting.

K. W. BLACKWELL, Vice-President, in the Chair.

Paper No. 138.

TRENT CANAL.

By RICHARD B. ROGERS, B.A.SC., M.CAN.SOC.C.E.

In this present day of doing things on such a large scale, it almost calls for an apology to come before such a critical body with the solution of the problem of cheap transportation by such simple and comparatively inexpensive methods as those that are the subject of this paper. When the air is full of schemes for ship canals, deep waterways and big vessels, it is with a feeling of diffidence that one refers to competition with such by means of barge navigation. However, it may be argued that the natural features of this scheme are such that the Trent route when completed will more than hold its own with any existing or proposed lines of transportation for many years to come. Owing to the comparatively insignificant cost of the completed work compared with the other projected lines of transportation, and that it would successfully accomplish the object in view, viz., the cheapening of transportation, it might be advocated that it should at least be completed before any of the schemes requiring such vast expenditures of money be taken in hand.

HISTORY.

The history of the Trent Canal means going back to what might almost be called ancient history. About the year 1820, or before, the Imperial Government undertook the task of opening up this country, and they decided upon doing it by improving and utilizing the natural waterways. In consequence, the Rideau Canal was built, and a considerable amount of money was expended upon the Trent. On the Trent, navigable stretches of from 25 to 50 miles were created by the construction of locks, dams and other means. The money for the completion of the Canal for the whole distance between Trenton and

Balsam Lake was actually voted by the Imperial Government. But about this time the McKenzie rebellion broke out, and the money voted for the completion of the route to Balsam Lake was taken to subdue the outbreak. When peace was restored new conditions were created. In the meantime, strong political influence was brought to bear on the Canadian Government (which had now taken up the transportation question) from the Niagara District, and as the Trent District at that time was very sparsely settled, and had very little political influence, the Canadian Government was induced to start the Welland Canal, and work on the Trent was abandoned for the time. The work on the Trent again started in the year 1880, and continued till about 1888, when the locks, dams and canals were built at Fenelon Falls, Buckhorn, Lovesick, Burleigh, Young's Point and Lakefield. No further contracts for new work were let till 1894, when the contract for section No. 1, Simcoe-Balsam Lake Division, was let, and in 1895 the contract for section No. 1, Peterboro-Lakefield Division, and in 1896 the contract for section No. 2, Peterboro-Lakefield Division, were awarded. The work on these contracts is about completed, with the exception of that on section 2, Peterboro-Lakefield Division. This briefly is the history of the Trent Canal. The route of the Trent Canal runs through the different lakes and rivers, which will form a continuous line of navigation between Lake Ontario at Trenton and Georgian Bay near Midland.

To complete the Trent Canal from Georgian Bay to Lake Ontario, exclusive of the divisions at present under construction, will take from three to three and one-half millions of dollars. This is a comparatively small sum to provide another through and satisfactory waterway between Lake Ontario and Lake Huron. When the divisions at present under construction are completed, there will be an unbroken navigable stretch from Washago or Barrie to Heeley's Falls, a distance of about 160 miles.

In the first place, it is a misnomer to call the Trent route a canal, as almost the whole distance from Lake Huron to Lake Ontario is through beautiful lakes and rivers, or on flooded reaches. The distance between Lake Ontario and Georgian Bay by the Trent route is about 200 miles. When completed, it is expected that not more than 20 miles of this distance will be actual canal.

DIMENSIONS OF CANAL.

Where canal is necessary, the prism has a width of 50 feet on the bottom, with side slopes in earth of 2 to 1, and in rock of 1-4 to 1

The slopes in the earth are protected by broken stone placed in a notch cut into the slope. This notch is about three feet on the base, has a vertical height of six feet, and is coped with flat limestone twelve inches wide, five inches thick and about thirty inches long. The part of the slope above the protection lining is sodded in order to protect the top of the slope.

The standard size of the locks is 134 feet long, 33 feet wide, with 6 feet of water on the sills—though all the lands bought so far for canal purposes have been surveyed and laid out to allow of eight feet of water being on the sills of the locks. To make all the works so far constructed to allow of eight feet of water would only mean holding the water two feet higher on the sills of the locks—the locks being constructed to allow of this—by means of extra stop logs placed in the dams, and a slight extra expenditure for the purpose of adapting the present works to the increased depth of water.

DESCRIPTION OF ROUTE.

A description of the route is as follows :—The southern outlet of the canal is at the Town of Trenton, which stands at the head of the Bay of Quinte, and also at the eastern outlet of the Murray Canal, which gives access to Lake Ontario to the West. There are two routes surveyed from Trenton to Frankford, a distance of about seven miles. One route is all in cutting on the west bank of the river, while by the other it is proposed to utilize the present course of the river for navigation purposes. If the latter route is adopted, it is proposed to canalize the river, as has been done between Nassau and Lakefield by a system of locks and dams as far as Frankford, a distance of about seven miles. The river will form a beautiful channel, and is between 300 and 400 feet wide between the banks, and the banks are high. No more favorable opportunity to apply such a system could exist—with its rock bottom and high banks.

The rise in this section is 118 feet. Above Frankford a flooded reach of the river is entered for a distance of 5½ miles to Chisholm's Rapids. At Chisholm's there is a masonry lock and canal about half a mile in length excavated out of the solid rock. These works are in as good a state of repair as when they were built nearly 60 years ago by the Imperial Government. The route again enters a flooded reach of the river for a distance of 3½ miles to Hoard's Creek. From Hoard's Creek a cut across the country will be made for a distance of 11 miles to Crow Bay. There is a rise on this section of 166 feet. The route then enters Crow Bay as far as Heeley's Falls, a distance of 2 miles. Here a rise of about 77 feet is to be overcome, where it is proposed to place a mechanical lift lock, the lay of the land being most favourable for such a structure. From Heeley's Falls to Hastings, a distance of about 11 miles, is at present navigable. The river on this reach is about 600 feet wide, and forms a beautiful stretch of navigation. At Hastings there is a lock and dam all in good repair and in daily use. From Hastings to Peterborough the route lies along the river for 6 miles, then enters Rice Lake for 12 miles, and again follows the river for 21 miles to the south end of the town of Peterborough. Here there is a dam and lock in good repair. From above the lock the route enters Little Lake for a distance of about a mile to the entrance of the town of Peterborough. From Peterborough to Hastings seven steamers regularly ply during the navigation season. From Little Lake the route cuts across country for about 4 miles to Nassau, and has a rise of 78 feet. This is comprised in Section No. 2, Peterboro-Lakefield Division, and is under construction—Messrs. Corry & Laverdure being the contractors. A short description of this Section is as follows:—

At the Outlet at Little Lake a lock with 13 feet lift is being constructed. The ground in which this lock stands is fine sand with some layers of blue clay in it. There is a pile foundation with transverse rows of sheet piling, on which rests the mass of concrete of the lock. There is no timber in the lock, excepting the mitre and stop log sills. The floor of the lock is concrete 3½ feet thick at the bottom of the invert—the walls are 10 feet thick at the base and 4 feet at the coping, and 25 feet high. About 500 feet above this lock a highway crosses, and about 500 feet beyond this the Canadian Pacific Railway crosses the canal on swing bridges. The reach from Little Lake for about three-quarters of a mile northerly is mostly through sand interspersed with layers of blue clay. At about 2,000 feet north of the C. P. Ry. crossing, it is proposed to transfer vessels from one reach to the other—a difference in level of 65 feet—by means of an hydraulic balance lock, the contract for the superstructure of which has been awarded to the Dominion Bridge Co. of Lachine.

HYDRAULIC LOCK.

A short description of this lock may be interesting. There are two water-tight steel boxes, or chambers, 33 feet in width by 140 feet in length, with 8 feet of water in the clear, and closed at the ends by means of gates hung on the lower edge. Similar gates also close the ends of the reaches. These chambers are carried by means of heavy trusses supported on top of two rams 7 feet 6 inches in diameter, which work in two steel water-tight presses, one under each chamber. The presses are connected with each other by a pipe 12 inches in diameter, in the centre of which a valve is placed for the purpose of regulating the motion of the chambers.

The weight of each chamber full of water is 1,800 tons, and each ram 120 tons. The gauge pressure produced in the presses by this weight is about 600 lbs. per square inch. The estimated weight of metal in both chambers is 720 tons; in the rams and presses 550 tons, and in sundry other parts 230 tons, making a total weight of metal in the whole structure of about 1,500 tons. The total load on the foundation of the presses is about 6 million pounds, which is taken by a foundation of granite in large blocks. The granite will be subjected to a pressure of about 650 lbs. per square inch on top, which, by the footings, is reduced to 230 lbs. per square inch on the bottom, resting on a limestone formation.

It was first proposed to make the presses of cast iron banded with steel hoops— the same as those used at La Louviere in Belgium. However, with the recent developments in the art of making steel castings, it has now been decided that a more satisfactory as well as a cheaper press can be made by using steel castings. An offer to construct the main presses of steel castings was made by the Dominion Bridge Company, and was accepted.

For the purpose of making up for the small quantity of water lost in the working of the main presses, an accumulator is installed in one of the side towers. This accumulator has a ram 20 inches in diameter, with a stroke of 30 feet 6 inches, working at a pressure slightly greater than that of the main presses. Its pressure is also utilized to operate the gates, capstans and small pumps.

The junction between the ends of the moveable superstructure and the ends of the reaches is made watertight by means of a continous rubber hose, placed on the outer side of the ends and bottom of the gate of the reach. This hose is inflated with compressed air from a Taylor air compressor installed in the main wall.

The mode of operating the lock is as follows:—Supposing both chambers are at a standstill—one up and the other down—both gates towards the reach open ready for a vessel to enter. When the chambers are thus, the bottom of the upper chamber will be about 10 inches lower than the bottom of the canal above, and has say 8 feet 10 inches of water on the sill. The bottom of the lower chamber will be just level with the bottom of the canal below, and will have 8 feet of water on the sill. Thus the upper chamber has 10 inches more water in it than the lower chamber, and consequently is so much heavier than the lower one (approximately 100 tons).

The valve in the connecting pipe between the two presses is closed. When it is desired to operate the lock, the gates at the end of each chamber and the gates at the ends of the reaches are closed, the air is allowed to escape from the air hose, making the watertight seal between the lock and the end of the reach—and the operator, who stands in his cabin on the top of the central tower, opens the valve in the connecting pipe between the presses. The upper chamber then commences to descend, and the lower chamber to ascend till both chambers reach their new positions, the upper chamber being now level with the lower reach, and the former lower chamber being opposite the upper reach. The operator now closes the main valve in the connecting pipe, and inflates the air hose forming the water-tight seal at the end of the lock. When the chambers are in their new positions, the surface of the water in the lower chamber is 10 inches above the surface of the water in the reach below and the surface of the water in the reach above. Communication between the water in the upper chamber 10 inches below the surface of the chambers and the reaches is now made by opening the valves in the gates nearest the reaches, and the water in each chamber is allowed to find its own level. The gates are then opened. When this is done the chambers are then in the condition they were on starting. Vessels are hauled in and out of the chambers by means of hydraulic capstans. The time required to lock and pass one or two vessels in and out of the lock will be from 12 to 15 minutes. The time required to raise or lower the lock chambers will be about 3 minutes. On the upstream side of the lock a guard gate is placed, which is operated by hydraulic power, and which is closed when a vessel enters the lock.

The substructure of the Hydraulic Lock will be of concrete. A general idea of the masonry can be formed from the drawings annexed. The natural surface of the limestone is at such an elevation that very little expense is necessary for the finishing of the floors at the lower reach level. The main retaining wall, 126 feet long by 40 feet thick, rests upon the limestone formation. Its height will be about 83 feet. The sides are to be carried up plumb for their whole height, the bearing pressure upon the rock being only about 6 tons per square foot.

The wing walls rest upon the hard-pan found just below the natural surface of the hill, and, in order to be subject to as little settlement as possible, are designed with wide footings. At the junction of the wing walls with the main wall a vertical slip joint is formed to provide against injury from possible uneven settlement, owing to the two different kinds of foundations.

The side towers have, at the level of the top of the walls of the lower reach, a base of 30 feet by 25 feet. The vertical shaft above the splayed base is 16 feet by 18 feet.

Within the main wall provision is made for a power-house as well as a roadway connecting the two sides of the canal. Voids are made in different parts of the walls for the purpose of containing the different pipes leading to the pumps and accumulator for the operations of the gates, etc., and for a means of communication between the different levels. The plans in connection with the superstructure have been prepared by Mr. W. J. Francis, and those for the substructure by Mr. T. A. Hay.

The only other locks constructed on this principle are those at Les Fontinettes in France, La Louviere in Belgium, and at Anderton in England, but these are not much more than half the size of the one being constructed at Peterborough. The lock at Anderton is very small, being only 70 feet long and 14 feet wide.

Passing along the line, the work consists of earth cutting and embankment in about equal proportions for about one mile. The Norwood Road is carried across the canal on a high level bridge, and the Warsaw Road by means of a swing. A small creek at the Warsaw Road is carried below the canal by means of a cast iron pipe 5 feet in diameter. From about the Warsaw Road the Canal is formed by means of a flooded reach to almost the end of the section at Nassau. At Nassau a light rock cutting was required to be made before entering the river. There are no structures from the Warsaw Road to Nassau, except a waste weir for emptying the reach. A seven sluice way timber dam is constructed at Nassau to raise the water in the river. At Nassau the highway and the G. T. Ry. are carried across the canal on swing bridges. Section No. 2 extends from Nassau to Lakefield, a distance of about 5½ miles, and is under construction with Messrs. Brown, Love & Aylmer as contractors. On this section the river has been canalized by means of dams and locks. There are five locks and four dams. All the structures rest on rock foundations. The dams are the ordinary timber dams, with stop log openings. A wall of concrete runs along the upper face of the foundations of the dams for their entire length. The locks as before stated are entirely of concrete. The gates are of solid timber, with the valves for filling and emptying the lock in them. They are hung from a cast iron cap bolted to the top bar of the gate, and from which the anchor and suspension bars are fastened. The gates rest on a cast iron shoe and a loose pintle, which sets on a cast iron plate at the bottom of the heel. The gates are opened and closed by means of a stiff built up girder, which is fastened to the top of the gate. A wire cable is fastened to each end of this girder, and passes around a corrugated drum, which is attached to a capstan placed in a recess below the coping of the lock. The capstans at present are worked by hand power with bars, which are attached to a vertical shaft on the coping, and have a horizontal motion. It is proposed to operate the gates by electricity when the canal is completed. The lifts of the locks on this section are 16, 14, two of 12 feet and one 10 feet. At Lakefield the highway is carried across the canal on a high level bridge.

After leaving section No. 1, there is a navigable stretch from Lakefield to Balsam Lake, a distance of about 65 miles, and on which there are at present about 24 steamers.

From Lakefield the route is through Katchawannoe Lake to Young's Point, a distance of 6 miles. At Young's Point is a lock and dam with a seven-foot lift. From Young's Point the route passes through Clear and Stony Lakes to Burleigh, a distance of about 10 miles. At Burleigh there is a double lift lock of about 25 feet rise, and three dams. Passing through Lovesick Lake, a distance of about 1½ miles, the lock at Lovesick, with a rise of 3 feet, is reached. There are five small dams here to retain the water on the reach above. The route then passes through Deer Bay for a distance of 6 miles to Buckhorn. Here there is a lock with 9 feet of a lift, and one dam. The three last mentioned locks are comparatively new, being only built about 12 years ago. They are all of splendid stone masonry. From Buckhorn the line passes through Buckhorn and Pigeon Lakes for a distance of 17 miles to Bobcaygeon. At Bobcaygeon there is a lock with 7 feet of a lift, and one dam. The route then passes through Sturgeon Lake to Fenelon Falls, a distance of 15 miles, where there is a double lift lock of 26 feet rise, and one dam. This lock is of stone masonry of the finest quality, and was built about 12 years ago.

Cameron Lake is the next lake passed through to Rosedale, a distance of 4 miles. At Rosedale there is a lock with three feet of a lift and one dam. The route then passes through Balsam Lake, which is the summit level. From this level the lockage is downwards in both directions. From Rosedale across Balsam Lake is 6 miles to the east end of section No. 1, Simcoe-Balsam Lake Division, which is at present under construction, with Mr. Andrew Onderdonk as contractor. There are no locks on section No. 1, Simcoe-Balsam Lake Division, which is about 5½ miles in length. About the first mile of this section is a light rock cutting. For the next three miles the material is for the most part swamp bog. The swamp will be flooded when the water will be at its normal level. For the next mile and a half there is a rock cutting running up to 25 feet in height and again running to nothing. The highway at Victoria Road is carried across the canal on a swing bridge, and at the Portage Road by a high level bridge. The G. T. Ry. is carried over the canal by a high level bridge.

At the end of this section it is proposed to construct another Hydraulic Lock, with a 50 foot lift. We then enter section No. 2, Simcoe-Balsam Lake Division. The next mile is through a rock cutting for a distance of about three-quarters of a mile. We then have a flooded reach for about 7 miles, on which very little work is required to be done. The valley of the Talbot Creek, which is 200 to 300 feet wide, and about 25 feet deep, is then made use of. It is flooded by throwing two dams across the lower end, and raising the water nearly up to the top of the banks. The route then passes across the country for 2½ miles, when Lake Simcoe is reached. There are five locks on this last reach. The route then passes through Lakes Simcoe and Couchiching. From Lake Couchiching to Georgian Bay two routes have been surveyed, but it has not yet been decided whether to take the cross country route, which is 13½ miles in length, or to canalize the Severn and utilize it. There is a fall of 131 feet from the level of Lake Couchiching to Georgian Bay. The Severn River is a beautiful river about 600 to 800 feet in width, and very deep. It would make a most desirable route, but will somewhat increase the total length of the canal. Opposite the outlet of the canal into the Georgian Bay is the Harbour of Midland—one of the finest harbours on Lake Huron, and into which any of the largest steamers can enter.

WATER SUPPLY.

One of the most important questions in connection with a canal is the question of water supply. With regard to the question of the sufficiency of the water supply for the Trent Canal there is no doubt. A glance at the map of the water supply will show this at once. In fact, a great part of the country about the source of the Trent is water, or can be made so by the building of a few more cheaply constructed dams. A large part of the land in this northern section of country is very rough, and of little use for anything else than to form reservoirs. The reservoirs are at present controlled by 51 dams, and have a capacity of 68,000 acres, which will store 12 billion cubic feet of water. The quantity of water required for lockage if the canal is working to its full capacity night and day would be 12 million cubic feet, so that making allowance of 50 per cent. for evaporation, percolation, etc., we still have left enough water to supply many such canals as the Trent.

As most of you know, all the structures on the recent contracts on the Trent Canal, such as locks, piers, culverts, etc., are built of concrete. The concrete is composed of Portland cement, sand, gravel and broken stone. Though several foreign brands of cement have been used, most of the cement employed has been of Canadian make, and none better could be desired. All cement used is furnished to the contractors by the Government. There is abundance of sand and gravel of the finest quality in the immediate vicinity. The concrete is mixed either by hand or machine. The machine-mixed will be found to be the more uniformly mixed, unless a very conscientious inspector and gang of men are employed. The mixture called for in the specification is one yard broken-stone, one-half yard screened gravel, one-quarter yard sand, and one barrel of cement. In practice it was found necessary to vary to some extent these several proportions. It was found that it required about one-tenth of a barrel more of cement to the yard than was called for in the specification.

Tests of the fineness of the sand and gravel and broken stone are occasionally made, in order to know what proportions of materials are going into the concrete, and the quantities of the different materials are varied accordingly. The gravel and broken stone are not sifted after the proportion of fine to coarse material is found out by test sifting. Every car load of cement is thoroughly tested, and none but the very best goes into the work. Enough water is added so that when thoroughly rammed the water rises to the surface. The concrete is put in layers of about 8 to 10 inches, and thoroughly rammed. A finishing coat of about 3 inches in thickness of mortar in the proportion of 2 of sand to 1 of cement is put on all exposed surfaces. If the different ingredients of the concrete are first class, and the mixing and putting in place are faithfully performed, there need be no apprehensions that concrete will not satisfactorily do all that can be expected of it, but if any one of these features is lacking, failure is sure to follow. For the same reason, stone will go to pieces if there is one bad ingredient in its composition. In the first lock constructed, which was the first built of concrete in Canada, no allowance was made for the contraction and expansion of the concrete, and the consequence was that it made provision for itself, and two cracks were found in each lock at the greatest line of weakness of each wall. These cracks are very slight, and are not more than 1-32 or 1-64 of an inch. No further cracks have since developed in this lock—the contraction and expansion always taking place in the same points. In the new locks, provision has been made for the contraction and expansion by building the walls up in sections of about 40 feet in length. This was accomplished by merely carrying one section up 4 or 5 feet ahead of the adjoining section by placing a bulkhead of plank at the end, and filling in the intermediate section against the dry surface of the adjoining section after the plank-forming had been removed. The exposed face-forming is 3 inch plank, planed and jointed with a ship joint, and spiked to 6 x 6 inch posts placed every five feet, and braced as shown on the slide. A small triangular piece of moulding is tacked on to the forming at the intersection of the sections, so that a regular V-joint is made which prevents the surface cracking in irregular lines where contraction and expansion takes place. Since the walls have been regularly divided into sections, no other cracks have developed during the past two years. All the walls are protected by lines of heavy oak waling pieces, except the lock walls, which are left exposed. Concrete appears to be an ideal material for lock construction, there being no joints or cracks to leak, as in masonry construction. It has also the advantage that its cost is not much over half that of stone masonry.

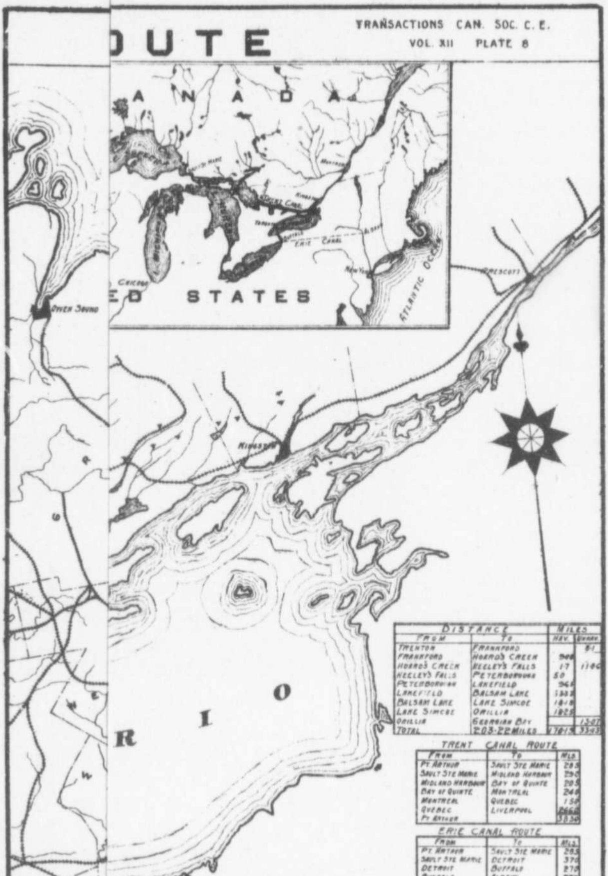
Of course a very noticeable feature of the scheme is the great amount of lockage. This at first sight appears a great detriment in the working of the route. However, with the assistance of mechanical lift locks, the high lifts at present made by the ordinary lock, and the many advantages of electricity and compressed air, which can be developed by water power, this feature is not so formidable as at its first appearance. When we realize that vessels are elevated or locked by these mechanical lifts for a height of 60 to 70 feet in the same time that it takes to lock through an ordinary lock of 6 or 7 ft., the amount of lockage is not then so great a bugbear, and if not too extensive will become a very favourable feature of the project. For, with the advances in the application of electricity and compressed air to motive power, a fleet of barges will be taken at one end of the canal and towed to the other by means of the power developed on the canal itselt. In consequence, what once appeared a great drawback to the success of the scheme has become, if not a most favourable one, certainly not one that militates to a very great extent against the success of the scheme.

There is on the Trent Canal about 850 feet of lockage—600 feet up from Lake Ontario to Balsam Lake, which is the summit level, and 250 feet down from Balsam Lake to Lake Huron on Georgian Bay. This lockage is distributed as is shown on the profile of the route.

BARGE NAVIGATION.

Though great improvements have been made in railroad transportation, and also in big vessels on the upper lakes, very little time and attention have been given to the development of barge navigation. This may have been partly for want of a favourable route on which to operate. It is safe to say that if the same favourable facility for barge navigation existed on the Erie Canal as exists on the Trent Canal, one would have seen the highest state of perfection reached in barge navigation, and very little would have been heard of the needs or requirements of additional navigation facilities to New York. It is no criterion to say that because barge navigation on the Erie Canal under the present conditions, or in fact any conditions, is not the great success that one could wish for, that therefore barge navigation under all circumstances will be a failure. Let us look at the conditions that exist on the Erie. In the first place there is a law on the Statute books of the State of New York that forbids any Company operating boats on the Erie Canal that has a capital of over $50,000. Imagine such a law being in existence respecting railroads or canals in this country. What kind of a business would be done were such a law applied to the C. P. Ry. or the G. T. Ry.? When we consider the number of extra officials, employees, and the many other requirements that such a law would entail, is there any one who will say that under such circumstances it could compete with a large capitalized railroad company under one management. Still, this is precisely the state of things that exists on the Erie Canal to-day. Is it any wonder then that with four of the best managed and equipped lines of railway paralleling the canal, that the traffic on the Erie Canal has somewhat diminished? The great proportion of the traffic on the Erie Canal is still carried by the same method as it was when the canal was first constructed, namely, by a team of mules with one or two barges in tow. The Cleveland Steel Barge Company of Cleveland tried to improve the system of barge navigation. They went to the expense of building a fleet of steel barges and propellers to run from Cleveland across Lake Erie to Buffalo, and through the Erie Canal to New York without breaking bulk. The experiment proved a great success, but they were compelled to discontinue it on account of the law limiting the capital stock of companies to $50,000. Would space permit, it might be argued that, under the favourable conditions that will exist when the Trent Canal is completed, that heavy freights can be carried from the upper lakes to the seaboard at less cost by the cheaply constructed and cheaply propelled barges that are proposed for this canal than by any other proposed route. It is proposed to tranship grain from the large vessels at Midland Harbour to the barges, which will be towed by steam or electricity in fleets of from five to ten in number to Montreal or Quebec, and there to load into ocean vessels. Navigation is opened for about 7 months of the year, and with barges drawing 8 feet of water, the capacity of the canal for the season would be about two hundred million bushels of grain. Barges drawing 8 feet of water, and of the full size of the locks, will have a capacity of about 25,000 bushels of wheat.

The staff in connection with the construction of the Trent Canal is as follows:—Mr. H. S. Greenwood, Resident Engineer of the Peterboro-Lakefield Division, assisted by Mr. H. A. Morrow and Mr. A. W. Spence, and on the Simcoe-Balsam Lake Division, Mr. Geo. E. Robertson is Resident Engineer, and who was assisted by Mr. F. B. Fripp. Mr. W. J. Francis and Mr. T. H. Hay have charge of the draughting department.



DISTANCE		MILES	
FROM	TO	NAV.	UNNAV.
TRENTON	FRANKFORD		8·1
FRANKFORD	HOARDS CREEK	[illegible]	
HOARDS CREEK	HEALEYS FALLS	17	[illegible]
HEALEYS FALLS	PETERBOROUGH	50	
PETERBOROUGH	LAKEFIELD	[illegible]	
LAKEFIELD	BALSAM LAKE	[illegible]	
BALSAM LAKE	LAKE SIMCOE	[illegible]	
LAKE SIMCOE	ORILLIA	[illegible]	
ORILLIA	GEORGIAN BAY		13·07
TOTAL	203·22 MILES	[illegible]	[illegible]

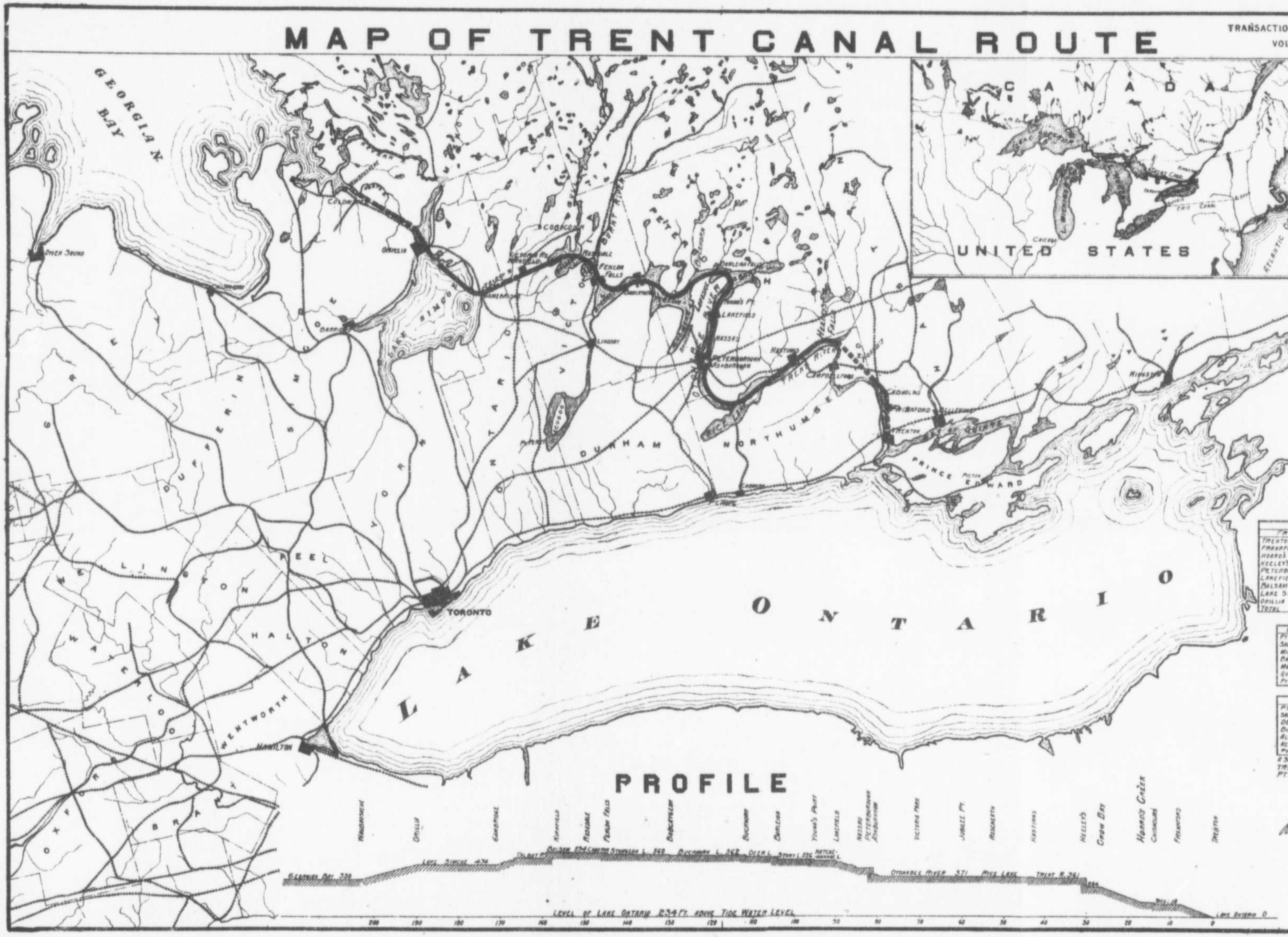
TRENT CANAL ROUTE

FROM	TO	MLS.
PT. ARTHUR	SAULT STE MARIE	285
SAULT STE MARIE	MIDLAND HARBOUR	[illegible]
MIDLAND HARBOUR	BAY OF QUINTE	205
BAY OF QUINTE	MONTREAL	[illegible]
MONTREAL	QUEBEC	[illegible]
QUEBEC	LIVERPOOL	[illegible]
PT. ARTHUR		[illegible]

ERIE CANAL ROUTE

FROM	TO	MLS.
PT. ARTHUR	SAULT STE MARIE	285
SAULT STE MARIE	DETROIT	370
DETROIT	BUFFALO	[illegible]
BUFFALO	ALBANY	[illegible]
ALBANY	NEW YORK	145
NEW YORK	LIVERPOOL	[illegible]
PT. ARTHUR		[illegible]

A SAVING IN DISTANCE IN FAVOR OF THE TRENT ROUTE OF 650 MILES BETWEEN PT. ARTHUR AND LIVERPOOL



DISTANCE FROM	TO	MILES NAV.	MILES UNNAV.
TRENTON	FRANKFORD		[illegible]
FRANKFORD	HOARD'S CREEK	[illegible]	
HOARD'S CREEK	HEELEY'S FALLS	1.7	[illegible]
HEELEY'S FALLS	PETERBOROUGH	50	
PETERBOROUGH	LAKEFIELD	[illegible]	
LAKEFIELD	BALSAM LAKE	[illegible]	
BALSAM LAKE	LAKE SIMCOE	[illegible]	
LAKE SIMCOE	ORILLIA	18.25	
ORILLIA	GEORGIAN BAY		13.07
TOTAL	203.22 MILES	[illegible]	[illegible]

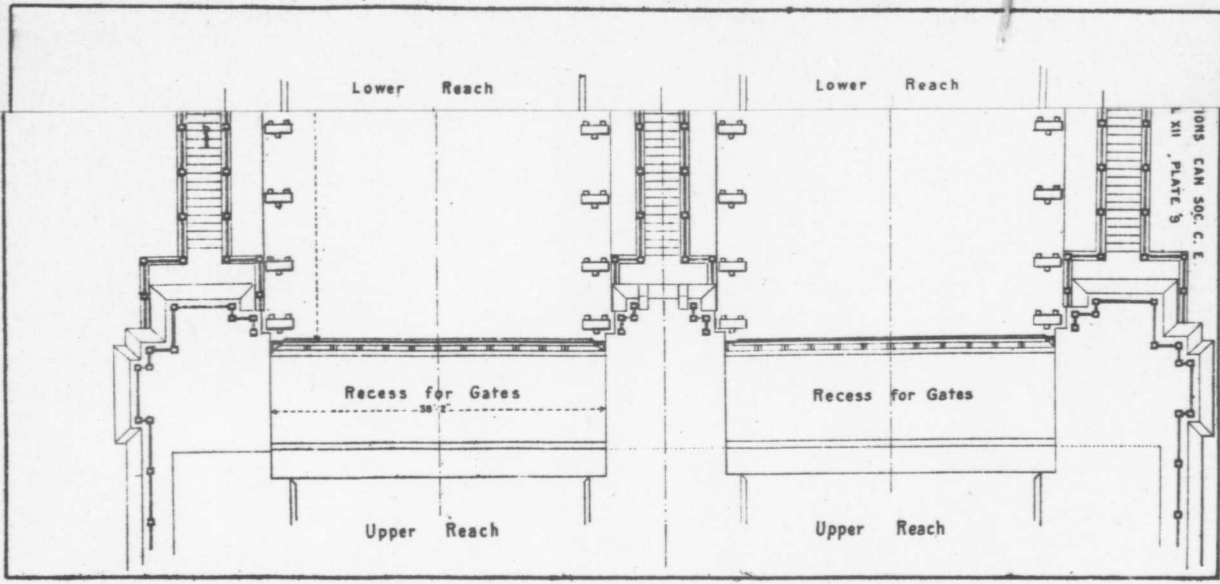
TRENT CANAL ROUTE

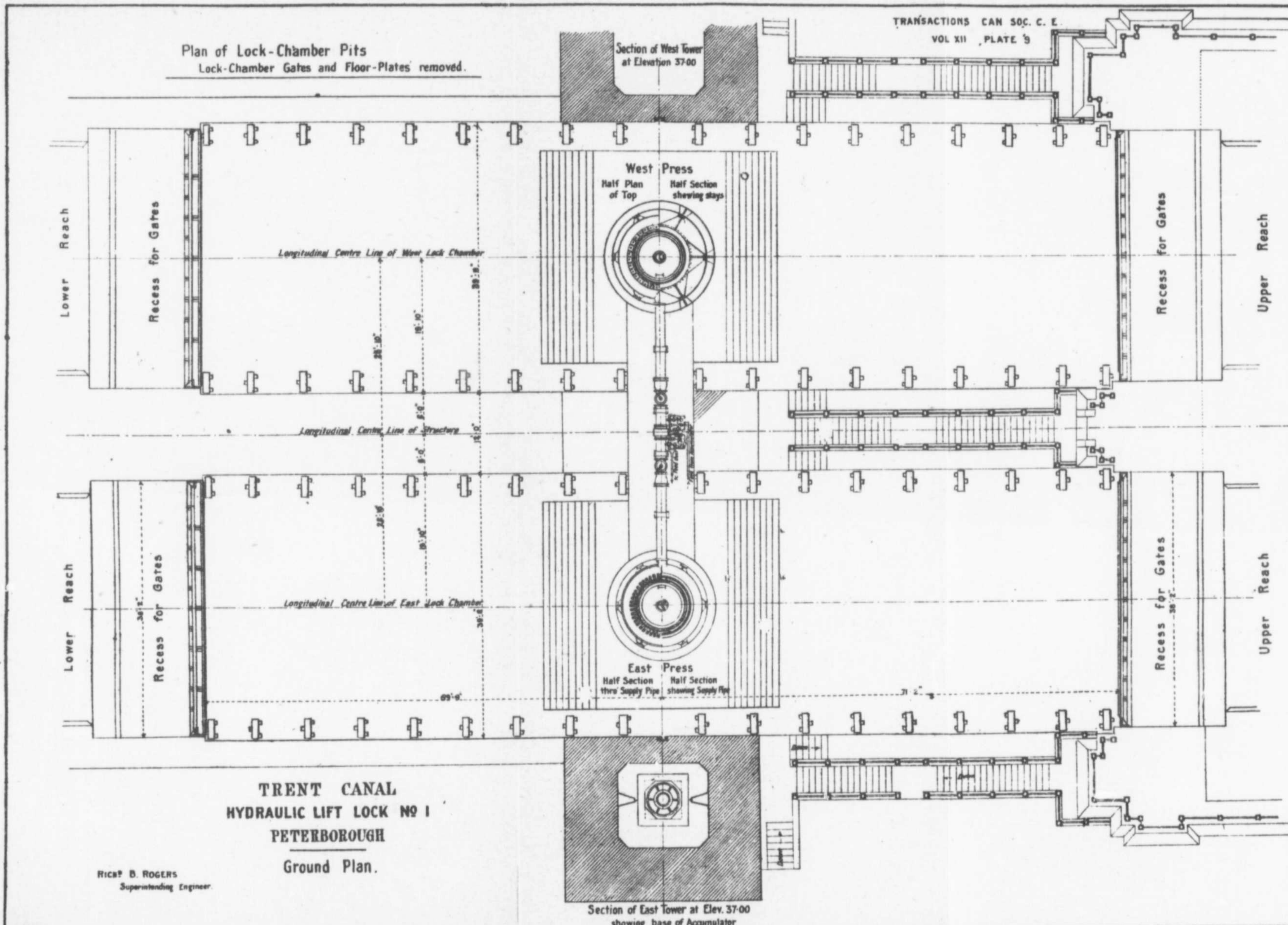
FROM	TO	MLS.
PT. ARTHUR	SAULT STE MARIE	285
SAULT STE MARIE	MIDLAND HARBOUR	290
MIDLAND HARBOUR	BAY OF QUINTE	205
BAY OF QUINTE	MONTREAL	240
MONTREAL	QUEBEC	150
QUEBEC	LIVERPOOL	2660
PT. ARTHUR		3830

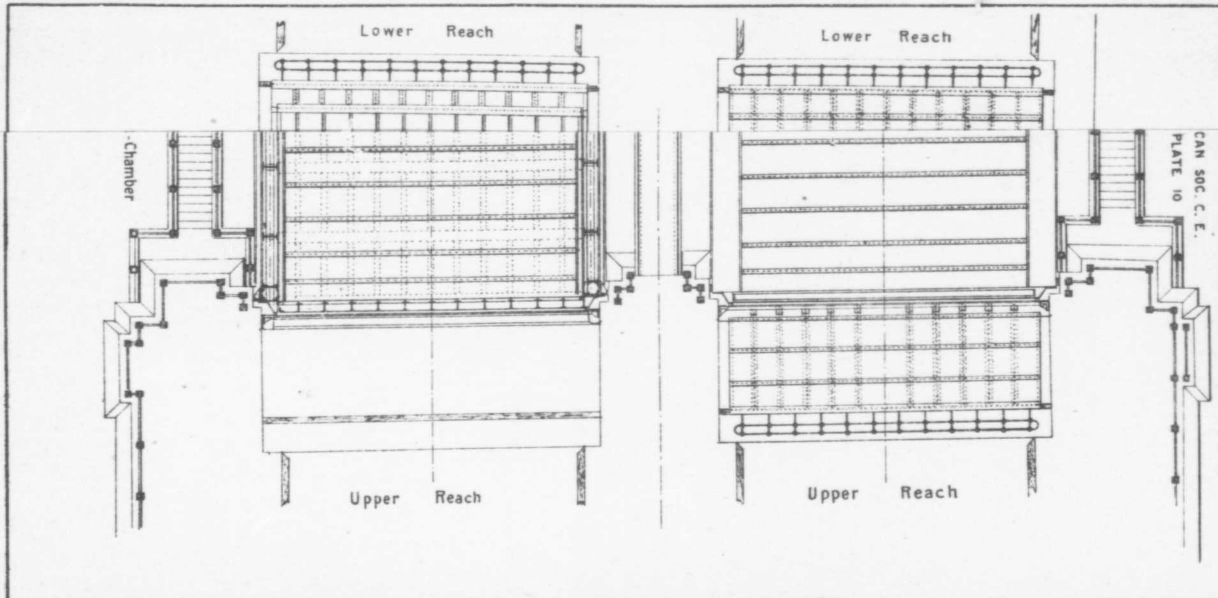
ERIE CANAL ROUTE

FROM	TO	MLS.
PT. ARTHUR	SAULT STE MARIE	285
SAULT STE MARIE	DETROIT	370
DETROIT	BUFFALO	270
BUFFALO	ALBANY	280
ALBANY	NEW YORK	145
NEW YORK	LIVERPOOL	3130
PT. ARTHUR		4480

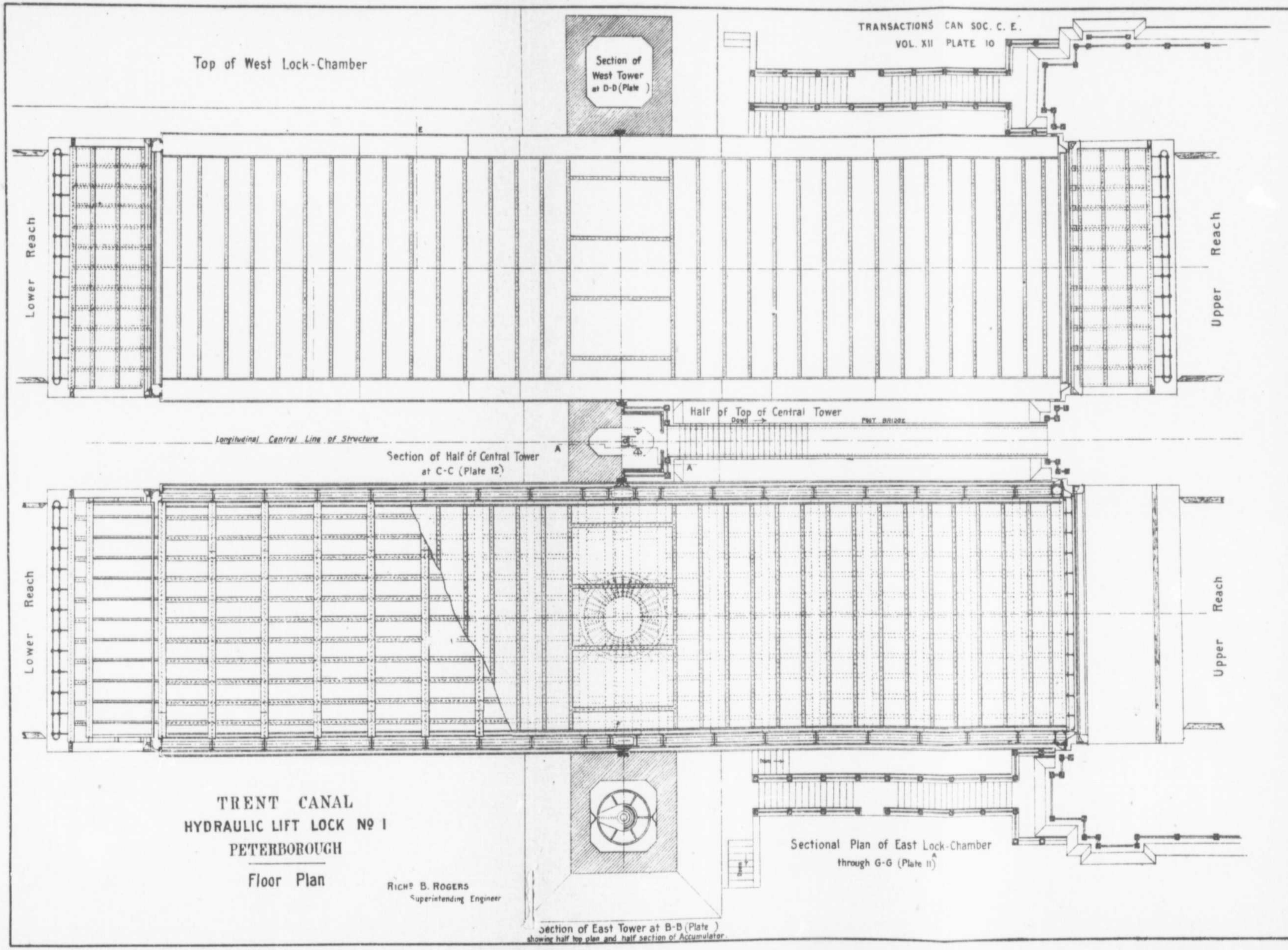
A SAVING IN DISTANCE IN FAVOR OF THE TRENT ROUTE OF 650 MILES BETWEEN PT. ARTHUR AND LIVERPOOL

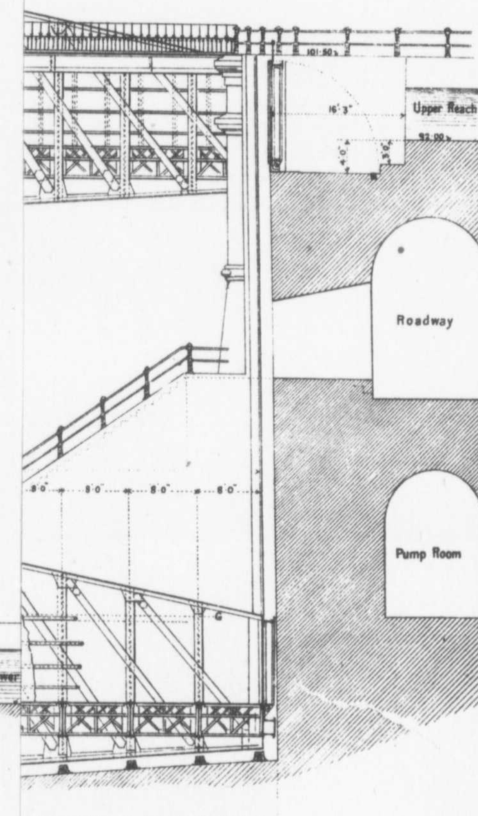

Lower Reach
Lower Reach
Recess for Gates
38' 2"
Recess for Gates
Upper Reach
Upper Reach
IONS CAN SOC. C. E.
L XII , PLATE 9


TRANSACTIONS CAN SOC. C. E.
VOL XII PLATE 9
Plan of Lock-Chamber Pits
Lock-Chamber Gates and Floor-Plates removed.
Section of West Tower at Elevation 37·00
West Press
Half Plan of Top
Half Section shewing stays
Lower Reach
Recess for Gates
Upper Reach
Longitudinal Centre Line of West Lock Chamber
Longitudinal Centre Line of Structure
Longitudinal Centre Line of East Lock Chamber
East Press
Half Section thro' Supply Pipe
Half Section showing Supply Pipe
TRENT CANAL
HYDRAULIC LIFT LOCK No I
PETERBOROUGH
Ground Plan.
Richd B. Rogers
Superintending Engineer
Section of East Tower at Elev. 37·00
showing base of Accumulator

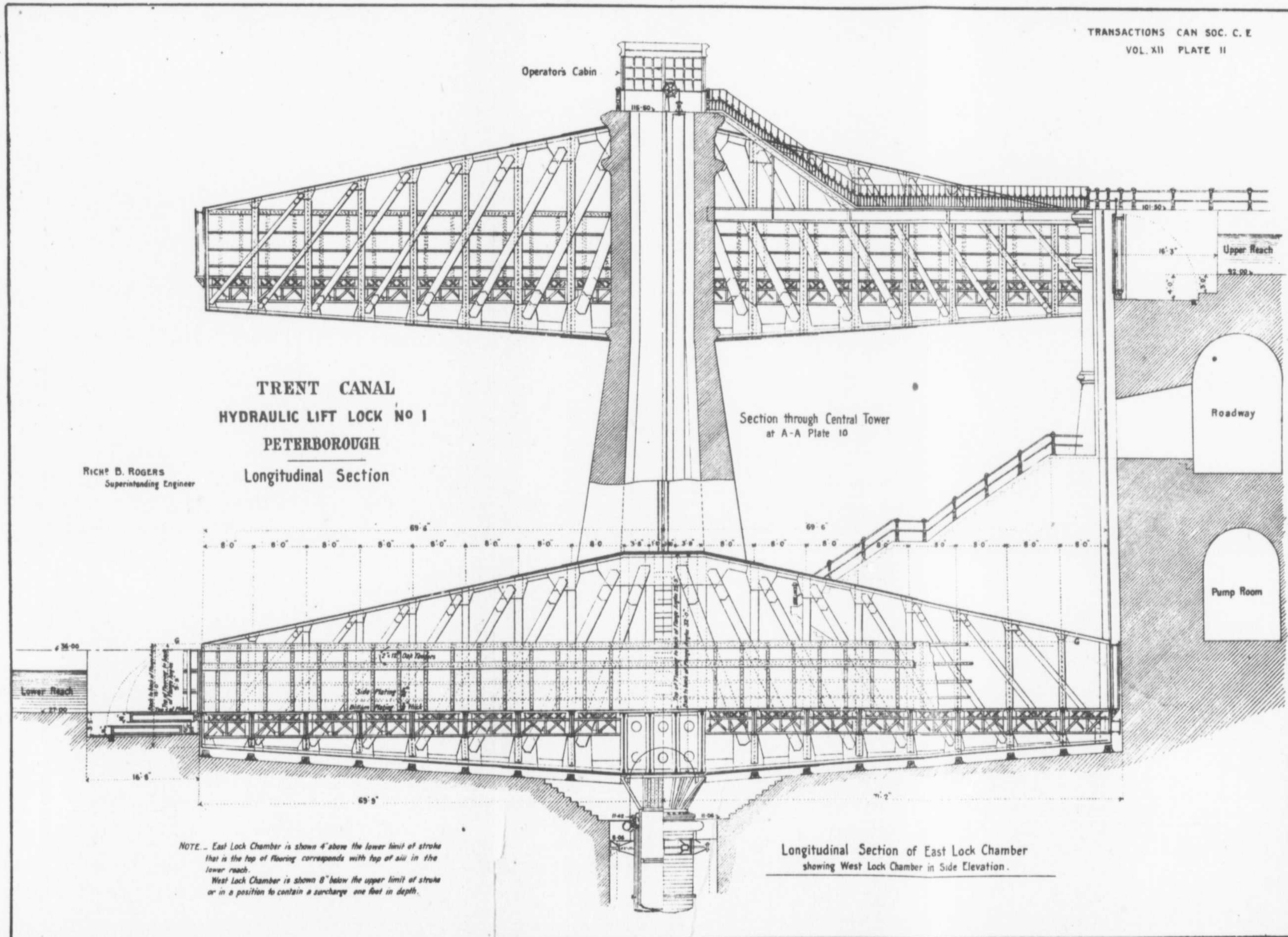


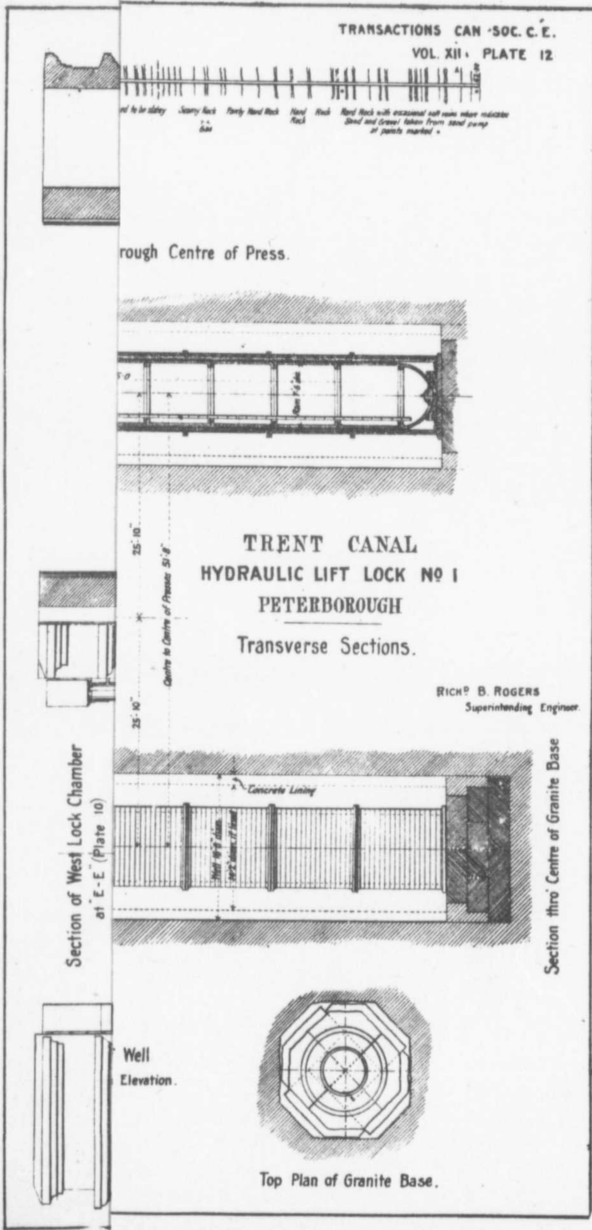
CAN SOC. C. E.
PLATE 10

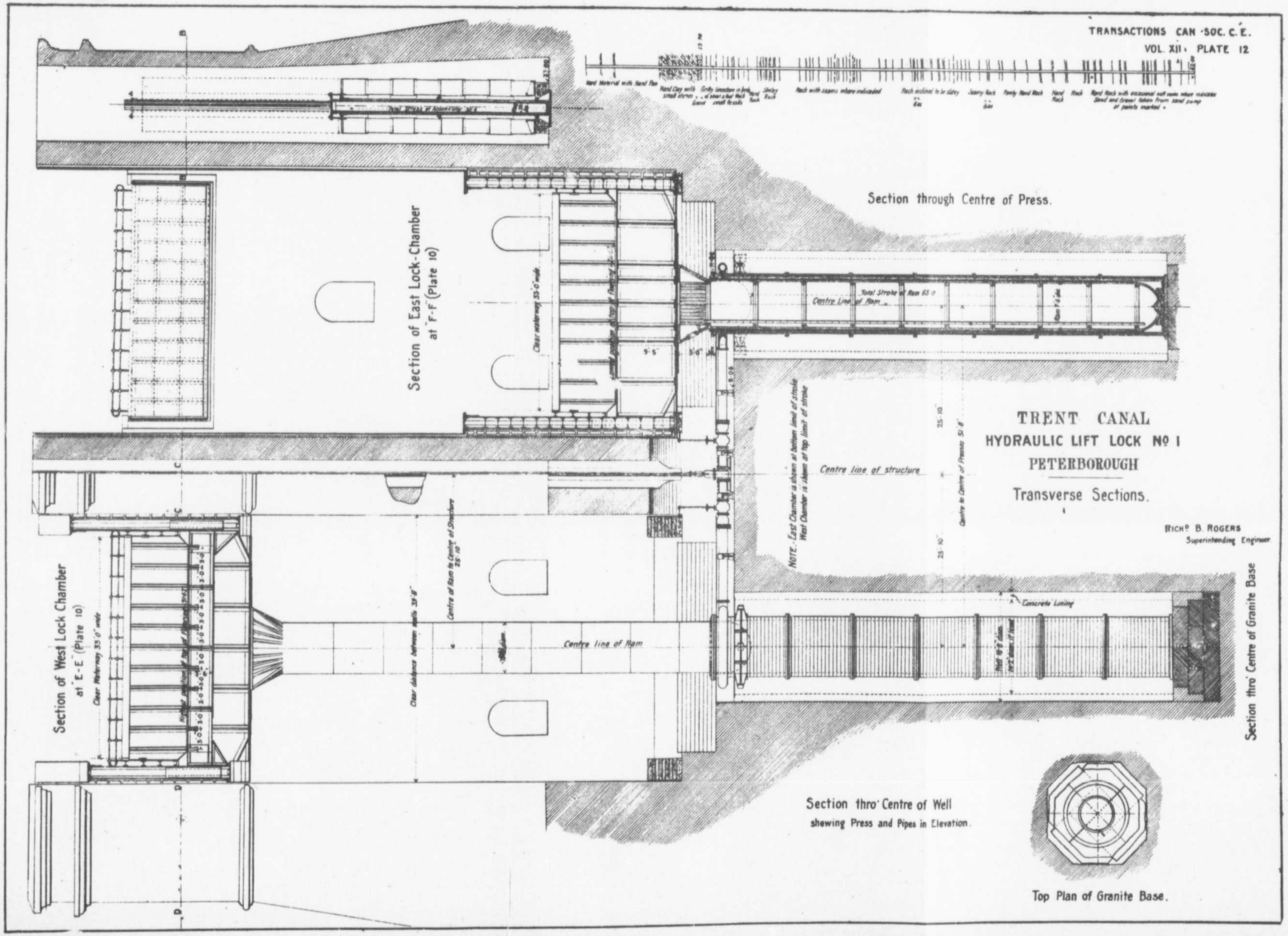

TRANSACTIONS CAN SOC. C. E.
VOL. XII PLATE 10
Top of West Lock-Chamber
Section of West Tower at D-D (Plate)
Lower Reach
Upper Reach
Half of Top of Central Tower
Longitudinal Central Line of Structure
Section of Half of Central Tower at C-C (Plate 12)
Lower Reach
Upper Reach
TRENT CANAL
HYDRAULIC LIFT LOCK Nº I
PETERBOROUGH
Floor Plan
RICHD B. ROGERS
Superintending Engineer
Sectional Plan of East Lock-Chamber through G-G (Plate 11)
Section of East Tower at B-B (Plate)
showing half top plan and half section of Accumulator.



East Lock Chamber
in Side Elevation.


TRANSACTIONS CAN SOC. C. E
VOL. XII PLATE 11
Operator's Cabin
Upper Reach
Roadway
Pump Room
Lower Reach
TRENT CANAL
HYDRAULIC LIFT LOCK No 1
PETERBOROUGH
Longitudinal Section
RICHD B. ROGERS
Superintending Engineer
Section through Central Tower
at A-A Plate 10
NOTE. – East Lock Chamber is shown 4" above the lower limit of stroke
that is the top of flooring corresponds with top of sill in the
lower reach.
West Lock Chamber is shown 8" below the upper limit of stroke
or in a position to contain a surcharge one foot in depth.
Longitudinal Section of East Lock Chamber
showing West Lock Chamber in Side Elevation.

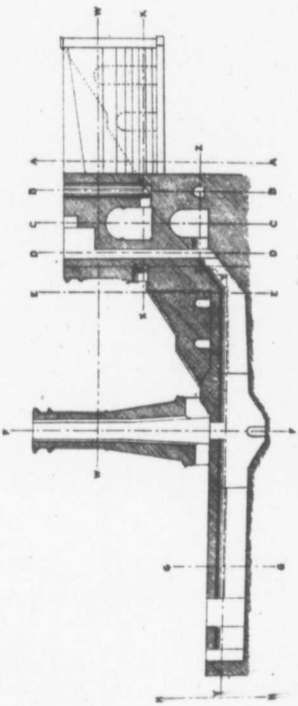

TRANSACTIONS CAN. SOC. C. E.
VOL. XII. PLATE 12
rough Centre of Press.
TRENT CANAL
HYDRAULIC LIFT LOCK Nº 1
PETERBOROUGH
Transverse Sections.
RICHᴰ B. ROGERS
Superintending Engineer.
Centre to Centre of Presses 51'8"
25'-10"
25'-10"
Concrete Lining
Section of West Lock Chamber
at "E-E" (Plate 10)
Section thro' Centre of Granite Base
Well
Elevation.
Top Plan of Granite Base.


TRANSACTIONS CAN. SOC. C.E.
VOL. XII. PLATE 12
Section through Centre of Press.
Section of East Lock-Chamber at "F-F" (Plate 10)
Section of West Lock Chamber at "E-E" (Plate 10)
Centre Line of Ram
Total Stroke of Ram 65.0
Centre line of structure
Centre line of Ram
Concrete Lining
NOTE.–East Chamber is shown at bottom limit of stroke
West Chamber is shown at top limit of stroke
TRENT CANAL
HYDRAULIC LIFT LOCK No. 1
PETERBOROUGH
Transverse Sections.
RICHD. B. ROGERS
Superintending Engineer
Section thro' Centre of Granite Base
Section thro' Centre of Well
shewing Press and Pipes in Elevation.
Top Plan of Granite Base.

TRANSACTIONS CAN. SOC. C. E.
VOL XII PLATE 13

West Side

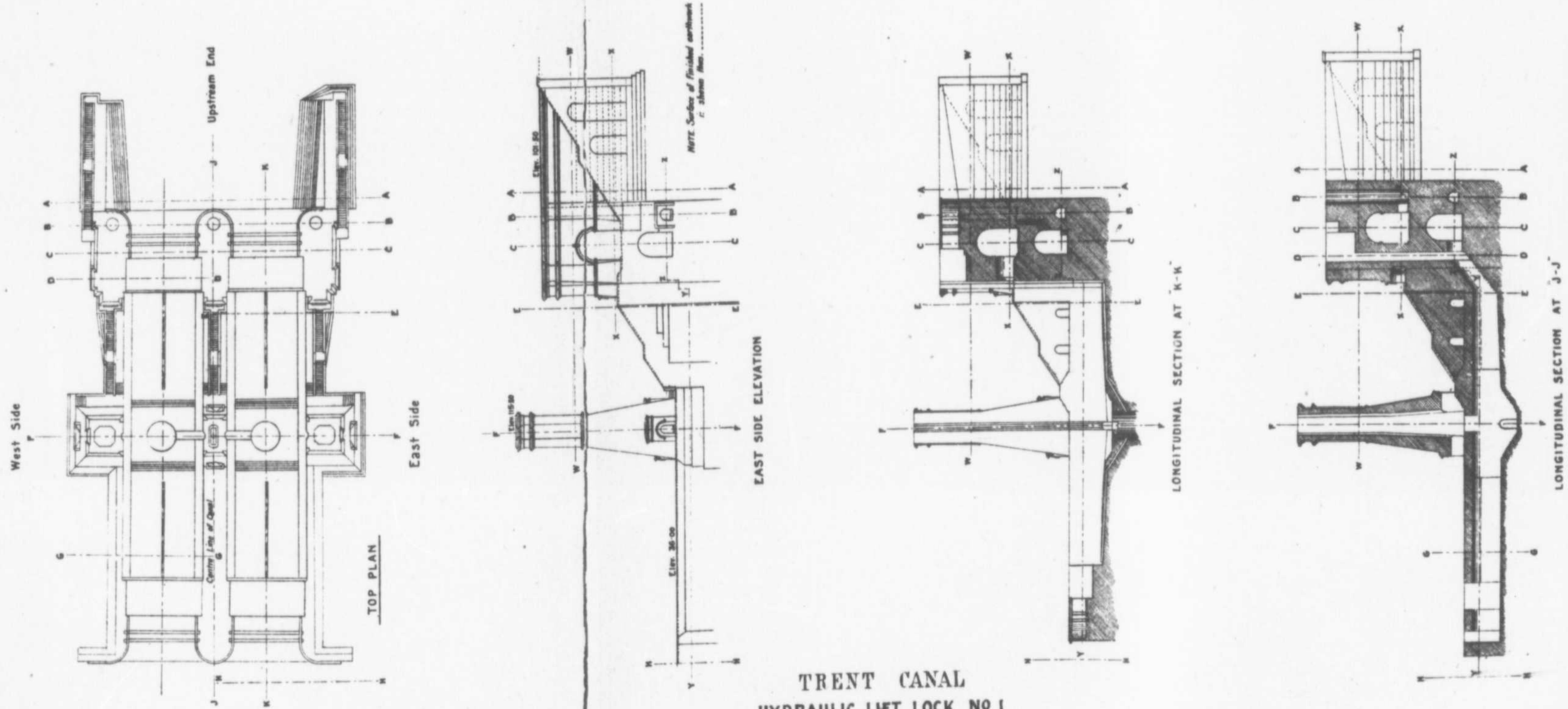
LONGITUDINAL SECTION AT "K-K"



LONGITUDINAL SECTION AT "J-J"

ROGERS
...rintending Engineer.

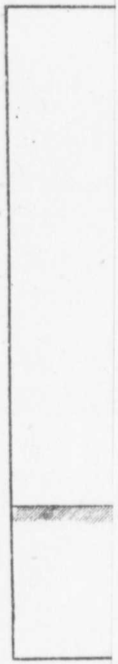
TRANSACTIONS CAN. SOC. C. E.
VOL XII PLATE 13



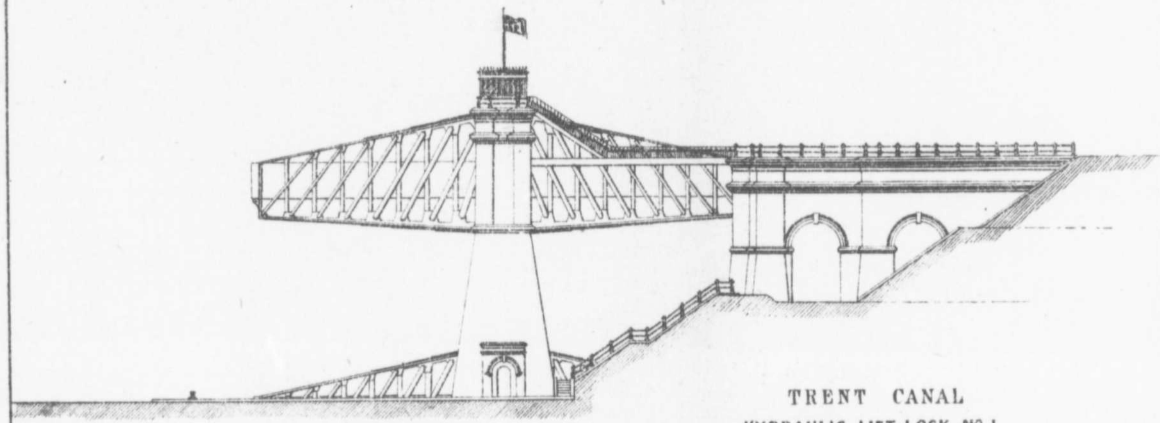
TRENT CANAL
HYDRAULIC LIFT LOCK No I
PETERBOROUGH

Masonry

RICHD B. ROGERS
Superintending Engineer.



TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE 14



Side Elevation.

TRENT CANAL

HYDRAULIC LIFT LOCK No 1

PETERBOROUGH

RICHT. B. ROGERS
Superintending Engineer

Paper No. 139.

MONTREAL, OTTAWA AND GEORGIAN BAY CANAL NAVIGATION.

By H. K. Wicksteed, M.Can.Soc.C.E.

HISTORY.

The history of the water communication between the great lakes and the ocean really dates back some tens of thousands of years to the period when the upper lakes discharged their surplus volume via Lake Nipissing and the Mattawa and Ottawa rivers. The evidence that such a condition of things once existed is indubitable, and is strongly set forth in an able essay of two very well known geologists, Messrs. Ells and Barlow. The signs are very eloquent, even to a careful non-scientific observer coming up the Ottawa to Mattawa, who will notice the great mountain gorge through which he has been ascending all the way from Fort William still stretching onward to the westward, but, instead of being occupied by the great volume of the Ottawa, it is drained by a comparatively insignificant stream, the Mattawa, and partially filled in by enormous accumulations of drift or glacial deposit, while the Ottawa itself comes in around a sharp corner from the North. Mr. Walter Brown, of Montebello, has pointed out that the original drainage of Quebec and Ontario was mainly from North to South, and that the glacial drift followed pretty much the same lines, the result being a still further erosion and cleaning out of the North and South drainage valleys and a more or less complete filling in of the east and west members of the system with detritus. This theory is especially well borne out in this instance, the Ottawa Valley coming from the North through a channel so clean and bare of soil for one hundred miles or more that only in the lateral valleys and eddies is there sufficient soil to make a potato patch, while up the Mattawa, as before noticed, are immense accumulations of sand, gravel and boulders, extending away around the Northern Shore of Lake Nipissing and partially filling even its great basin. Mr. Brown attributes the change of outlet of Lake Huron to an upheaval relative or absolute of the country about Lake Nipissing, but it may be partially accounted for by this very filling up, just as the old outlet of the Niagara river at the whirlpool has been filled up and the still greater gorge up which the Great Western runs in leaving Hamilton for the west, and in the bottom of which lies the town of Dundas. These speculations are interesting, and to a certain extent instructive, but it is with present conditions that we now have to do, and their only practical value is the strong reasons which they afford for the belief that the proposed summit cutting between Lake Nipissing and Trout Lake will show little or no rock, but that it will consist almost wholly of glacial drift comparatively free of boulders.

Coming forward in time to historical periods, we find some two and a half centuries ago the Indians telling Champlain of the great waterway leading to the West and to the still greater inland Sea of Lake Huron, and so exciting his adventurous spirit that he undertook the journey under their guidance—eventually paddled out onto its broad bosom. French fur traders following in his track almost immediately pushed along the sheltered north channel of the Lake to Sault Ste. Marie, and discovered Lake Superior a full decade or more before Hennepin reached Niagara and the shores of Lake Erie. Even when the St. Lawrence route was opened up, it was as a route to the Ohio via Presqu'ile and to Lake Michigan and the Mississippi via Toledo and the Miami River. To the far West and Northwest, the regions which form the heart of Canada to-day, the highway has ever been and is mainly still the same as that opened up by Champlain. When the writer was a boy, brigades of Northwest canoes still started from Lachine, ascended the Ottawa, skirted the North Shore of Lakes Huron and Superior, and then made their way through the labyrinth of lakes and rivers between the latter and Lake Winnipeg. Coming down to modern times, the Ottawa Valley was accepted without question as the route for the Canadian Pacific Railway. But the settlement and rapidly growing wealth of the southern portion of Ontario fronting on the two lower lakes, the comparative non-progress of the central plains west of the Red River and the demands of local trade led to the construction of the Welland and the Rideau canals, and later of those on the St. Lawrence itself. And although, in 1858, the Ottawa river was examined with a view to further extension of canal navigation and favourably reported upon, it was deemed, and perhaps wisely, that the times were not ripe, and the ancient highway and its advantages dropped out of view and almost out of recollection for thirty years, until the writer in 1890, attracted by the agitation in Manitoba for the Hudson's Bay Railway and a shorter route to the markets of the old world, took occasion, in a series of letters to the Toronto *Empire* and Ottawa *Citizen*, and later in the *Engineering News* in comment upon Mr. Corthell's paper upon the Georgian Bay Ship Railway, to call attention to the superior attractions offered by the old half-forgotten canal route to all and any of the more recent schemes. The letters attracted attention and comment, and probably more in consequence of the obvious merits of the project than as a result of the author's eloquence the rival schemes were dropped and the Ottawa navigation taken up again, and I think it may fairly be said that in the seven or eight years which have since elapsed it has been steadily growing in favour. One powerful argument against it for a long time, and one most difficult to controvert, was that, if the Ottawa route were taken hold of and sanctioned by the Government, it would at once become a competitor with the St. Lawrence canals, and render them comparatively useless, placing the Government in the position of having needlessly expended some millions of the peoples' money. The writer thinks this a false view, and that, as will presently appear, the enlarged St. Lawrence canals have and will have an abundant *raison d'être.* They would still offer the shortest route to the sea for the exports of all the ports on Lake Erie, Lake Ontario, and as far north as Detroit, and this means an enormous output and traffic, but of this more in its proper place. To bring history up to the present date, a number of other navigation schemes have been promulgated within the last few years, and seriously and earnestly considered, and all bearing more or less directly upon the subject under discussion, and so greatly did some of these appeal to the interests of the public, that a commission was appointed by the United States Government empowered to collect statistics and to report, the result of which is a great volume of statistics and information now before the writer.

Still later, and bearing directly upon the question at issue, is the completion of the Ottawa, Arnprior and Parry Sound Railway and the enormous traffic developed by it. Showing that, in spite of "vested interests" and "established trade routes," trade is eager to avoid the long circuit of the St. Clair River and flats and the dangers and difficulties of navigating them and of the Detroit River and its mouth, and is eager also to take the short railway haul in connection with a water route, the only limitations on which in the matter of draught are the Chicago River and the Hay Lake channel below Sault Ste. Marie.

Within the present year we have the appointment of a committee of the Senate to enquire into and report upon the merits of the project. Their report has within the last few days been printed, and almost simultaneously there is evident an awakening of interest among the business men of Montreal and its trade bodies, and the intimation that an exposition of the subject would be acceptable to the Society.

I should perhaps have said before that some two or three years since, when the relations between Great Britain and the United States became somewhat strained, and the defence of the Empire was under discussion, the writer took occasion to call attention to the importance of the project from that point of view, and said over again at a very opportune time things which had been better said by Lord Dufferin, Sir John Michel and others.

These utterances carried forward and expanded by energetic individuals attracted attention in the Mother Country, and two of the leading papers sent out representatives to enquire more closely into the subject in all its bearings. And, as a result of all these things, one of the leading contracting firms of the world sent a representative to Ottawa to make a definite offer of construction on very advantageous terms.

TOPOGRAPHY.

The Ottawa River is, as every one knows, a great river, the second largest in Eastern Canada, and one of the largest on the continent. The ordinary traveller knows little about it further up than Ottawa, and generally associates it with low alluvial banks, a broad placid stream, expanding near its mouth into a considerable lake, and interrupted by one or two rapids running over flat limestone rock belonging to the Lower Silurian group. Almost immediately above Ottawa, however, it loses this character, and becomes, in common with the other tributaries of the St. Lawrence, a Laurentian river having the almost invariable characteristic of Laurentian rivers, of being very unriver-like, and consisting of a number of deep, almost currentless pools, separated or connected by short abrupt falls and rapids tumbling over the hardest and firmest of solid rock. The same applies to the Mattawan, and, in an even greater degree, to the French River. The navigable reaches now existing are almost ideal ones, with scarcely any improvement, deep and broad enough to admit of high rates of speed with vessels of considerable draft and magnitude. Almost without exception, the improvements necessary are in the direction of locks and short stretches of canal between each pair of navigable pools. It is in this respect that it is so much superior to any route hitherto built or proposed, and notably to the St. Lawrence. The St. Clair flats, Lime-kiln's Crossing, Lake St. Francis flats and the lower portion of Lake St. Louis have all been the occasion of large expenditure, altogether distinct from the canals themselves. I think Mr. Monro will bear me out in saying that it is these outside considerations which have, to a very great extent, dictated the abandonment of the Beauharnois Canal in favour of the magnificent work on the north side of the river now nearing completion.

In this connection we are considering only the portion between the Georgian Bay and the City of Ottawa; below that point the conditions are tolerably well understood, the water-way is already complete for navigation on a limited scale of draught, and seems to demand improvement on its own account. Aside from any question of connection with the Great Lakes, Ottawa is fast becoming a railway centre, and its manufacturing interests are growing almost daily, and vast deposits of iron ore, phosphate, etc., etc., in the immediate neighbourhood are merely awaiting cheap transport to be developed on a very large scale indeed.

In the case of the St. Lawrence, the end is not yet. From Prescott to Dickinson's Landing between the rapids are a series of tortuous channels and swirling currents, which troublesome now will become much more so with the large vessels which it is proposed to use in the enlarged canals. Taking all in all, from Port Huron to Montreal, we shall have an expenditure of about 75 millions of dollars, most of which has been borne by Canada for a satisfactory 14 ft. navigation. And we have still to consider the proposed regulating dam at the outlet of Lake Erie, and the possibility of a similar one being needed below Prescott for the regulation of Lake Ontario and the river below. In the case of the Ottawa, we have the estimate of Mr. Marcus Smith for the completion of a waterway on the same scale, and between the same points, but with greatly reduced distance, of 25 millions, and this to include wharves, elevators, etc., which have been, in the case of the St. Lawrence, constructed by private enterprise.

Still the writer does not wish to be understood as indicting the various governments for an unnecessary or ill-judged expenditure. He believes that the growth and prosperity of Canada are largely due to its canals, and would not have been possible without them; that they have still an important part to play, but that the time has come when something more is needed, and that something is indubitably the improvement of the Ottawa. In this connection the report of a committee appointed by the city of Pittsburgh to enquire into the practicability of a 14 ft. navigation between that point and Lake Erie is interesting. Among other points brought up is an estimate that this canal in connection with the St. Lawrence system would enable coal to be laid down in Montreal for $1.50 per ton. What possibilities this opens up for the gas-producer, the iron-smelter and the steam-user!

To return to our topography. The one important exception to the prevalence of hard granitic or syenitic rocks at the salient points is that of the summit or divide between Trout Lake on the Mattawan and Lake Nipissing, which is largely, if not wholly, composed of drift, the summit being only 3 ft. above Trout Lake and 27 ft. above Lake Nipissing. In view of the moderate depth, this is probably the one point at which we should prefer sand cutting to solid rock, as the two lakes would be brought to the same level, and this somewhere near the present high-water level of Nipissing. Assuming this at 5 ft., we should have a maximum cutting of 27—5 x 14, or 36 feet, and an average of about 20 ft. for a total distance of some 4 miles. This can very possibly be done by floating dredges, and is by far the most formidable individual piece of work upon the whole system, and aggregates in length over 20 per cent. of the total excavation between Ottawa and Lake Huron. To any one familiar with the enormous excavations on the Galops and Soulanges Canal, such a piece of work will appear insignificant in comparison. Some minor excavations in the bed and outlet of Trout Lake can be easily dealt with by diverting the upper Mattawan temporarily into Lake Nipissing, and working upon a dry bed. The raising of Lake Talon some 10 ft. gives a magnificent summit level of nearly 60 miles, of which only some 5 miles would be an artificial channel. The writer can think of nothing at all comparable with this sketch in any inland navigation aside from the great lakes, with the exception of Lake Champlain and the proposed summit level of the Nicaragua Canal.

In connection with the water supply, about which some doubt has been expressed, owing probably to a misapprehension of the meaning of a clause in Mr. Shanly's report of 1858, I may say that Mr. Shanly and Mr. Clarke both describe the supply of Lake Nipissing as being inexhaustible, and Mr. Clarke goes into more details, and says—"The quantity of water flowing from Lake Nipissing at a low stage was found by careful guaging to be 9,500 cub. ft. per second," or 820,-800,000 cub. ft. per 24 hours, to which must be added the volume of the Mattawan. And he further remarks that this is equivalent to 5,472 lockages of 250x50x12 in each 24 hours. And, finally, "this sets at once at rest any idea of the necessity for a storage reservoir."

Mr. Clarke did not know, as we do now, that on the principal feeder of Lake Nipissing is a natural reservoir of some 500 square miles in extent, and that a portion of the waters of this lake is running through a secondary outlet into the Montreal River and thence into the Ottawa, but he knew quite enough to satisfy himself that the supply was and is ample without artificial storage or reinforcement, which could easily be had if required.

The character of French River has been referred to before as markedly Laurentian in its features of long dead water pools separated by short rapids. Another characteristic which it has, and which is almost peculiar to itself, is that it has for almost its entire length two and sometimes more distinct channels. This is a feature of great value as well as interest, allowing one channel to be used as canal and another as wasteweir.

For instance, Mr. Shanly speaks of the first rapid he meets on entering from Lake Huron, and of the possibility of placing a lock upon the portage alongside, and goes on to say that other rapids and falls are of similar character. It will be quite possible, and the writer believes in a majority of instances much cheaper, to use the bed of the river itself for the lock chamber and allow the surplus flow to find its way through the other channels. Similarly, the surplus water of the Mattawan as far as the summit level extends to the foot of Lake Talon can be discharged by these same side channels of the French River into Lake Huron, leaving the bed of the river available for the locks. Further examination may or may not show this to be desirable, but it is undoubtedly practicable, and removes one of the difficulties found by Mr. Shanly. From this point downwards through the Mattawa and its Lakes and the Ottawa and its expansions to the foot of Deep River the topography is almost constant in its character, and the methods of dealing with obstructions the same throughout. Controlling dams to retain the levels as nearly as may be the same at all stages of the water and short canals with locks at various points. The narrowness of the channel permits us to drown out minor differences of level and to concentrate the fall within a short distance. Below the Deep River the Ottawa expands into the Allumette Lake, the improveable channel lying to the North of the Allumette Islands by the Culbute channel. Descending still further, we come to the Coulonge Lake, and below this the Portage du Fort, embracing a series of rapids and falls extending to the town of that name, giving an aggregate fall of 98 ft. in a distance of 10 miles, the most rapid pitch found on any part of the river below Mattawa. The methods of dealing with these falls is the same as for the others, drowning out the smaller ones by means of dams, and connecting the pools so formed by short canals and locks. As in the case of the French River, the existence of parallel channels renders the improvements easier of accomplishment than they would otherwise be. Below Portage du Fort comes Chats Lake, eighteen miles in length, and with the exception of a couple of minor obstructions of good depth (not less than 25 ft.) throughout.

At the foot of Chats Lake are the Chats Falls, 50 feet fall in 3 miles. Here again the river is divided by islands into many channels, and the same methods of construction are available with a total length of canal only $\frac{6}{10}$ of a mile. We then enter Lac des Chenes, 26½ miles long, with a general depth of from 20 to 30 ft., with some few short bars covered by less water. We are now clear of the Laurentian rocks, and the river enters a limestone country which continues to its mouth. Below Lac des Chenes the river drops 60 ft. in a distance of 6½ miles.

Mr. Clarke's proposal follows the river as before, but the enormous growth of Ottawa since 1860 has placed obstacles in the way, and it may be found preferable to follow one of the minor side channels on the Hull side of the river. Here, as elsewhere, nature has provided a number of different natural channels, and on them the work of excavation has been more or less commenced.

Below the basin at Ottawa for some 8 or 9 miles the channel is more or less filled with accumulations of sand and sawdust until the green shoal of bed rock is met. The banks being low, it is impracticable to raise the river ; it will be necessary to excavate shale rock under water for a distance of 500 or 600 feet. The sand and sawdust accumulations are a matter of dredging. With these exceptions the channel is wide and deep, and the current gentle for the entire distance of 56 miles to Grenville. Here we have a canal already built to overcome the Long Sault Rapids with a descent of 45 feet in a distance of 8 miles.

Below this again is a stretch of slackwater created by the building of a dam at Carillon—around the end of which is a short canal. Descending from Carillon there is a generally clear and deep channel to the head of the Lake of the Two Mountains, and, with the exception of one or two bars of morainic character, to within one mile of Ste. Anne lock. Whether the best route from this point to the St. Lawrence would be by the Ste. Anne's or Vaudreuil channels, or with a view to enlarging the harbour facilities of Montreal via the Rivière des Prairies behind the city, is a point on which it is difficult to decide with existing information The Rivière des Prairies scheme is certainly feasible, and a couple of dams would create an equal number of magnificent slack-water basins and two fine water powers altogether free from interruption by frazil, which, owing to their proximity to the city (4 miles), would probably yield revenue enough in themselves to pay interest charges on the cost of improvements and land damages. They would be basins too altogether removed from any danger from ice shoves and extreme variations in water level, and in which vessels might lie all winter with impunity.

The question of water power alone was so attractive that parties spent a considerable amount of money a few years ago in making surveys and estimates for this purpose alone, and came within measurable distance of floating the enterprise. The character of the Rivière des Prairies or Back River is, in descending, first a short rapid between Isle Bizarre and the Island of Montreal, and again between Bizarre and Jésus, and then a stretch of comparatively shallow water running swiftly over flat limestone; then a deep stretch with alluvial banks extending to the C. P. R. bridge at the head of the Grand Sault; then some 3 miles of swift water between fairly high banks to the Sault-aux-Recollets, falling 13 ft. over flat limestone in 1½ miles, and then a shallow stretch between high banks to the navigable channel below St. Vincent de Paul. The improvements would consist of a high dam near the latter point drowning out the Sault-aux-Recollets and the swift water above and forming a slack-water basin some 6 miles in length; then a short sharp lift through a canal already partly excavated to a basin formed by a second dam at the head of the Grand Sault and extending to the Lake of Two Mountains. As in nearly every case above, nature has provided overflow channels for surplus water at Ste. Anne's, Vaudreuil and by the Rivière des Isles or Terrebonne channel, enabling us to take full possession of the Riviere des Prairies channel for our navigation and hydraulic works.

One more point in connection with the Laurentian topography of the upper portion of the river and the almost universal presence of hard solid rock, which in his report of 1858 Mr. Shanly so much deplores.

The rock undoubtedly increases the cost of excavation of the canal prism, in moderate depths of section at any rate, though not to anything like the extent that it would have done in those early days, when dynamite, nitro-glycerine and other high explosives were unknown, but it has been shown that the actual amount of canal is extremely small, only some 21 miles of new and 8 or 9 miles of enlargement, or about 7 per cent. of the total distance between Montreal and Lake Huron—and, on the other hand, the solid rock is an immense advantage in the building of permanent dams, and also in the creation of locks. These in a majority of instances would necessarily be little more than excavations lined with masonry or concrete, or even and perhaps preferably for the underwater portions with timber.

TRAFFIC AND COST OF CARRIAGE.

We now come to a portion of our subject on which such a vast amount has been written and so great a quantity of information collected that the mere contemplation of it is bewildering. All the writer can hope to do within the limits of such a paper as this is to set forward the main facts and his inferences, and to mention his authorities and sources of information and so put the engineering members in a position to judge for themselves.

Among these pamphlets and reports will be found also a much more detailed description of the works to be executed than as given above, the writer having confined himself to bringing into due prominence the facts and figures which seem to him most to deserve it. Not only are the figures in connection with the traffic of great Lakes bewildering in their magnitude, but on account of the way in which they increase from year to year by leaps and bounds. Writing in 1858 for instance, a distinguished engineer makes the remark that in view of the depths obtainable in the harbours of the great lakes, 10 feet of water was as much as it was desirable to seek. The draught of the heavier and larger vessels has nearly doubled since then, and the able manager of the Ottawa and Parry Sound, in selecting a terminal harbour on the

Georgian Bay, has with great foresight been content only with a spot which he can approach with 25 to 30 feet of water throughout. Again, as to freight rates, only 7 or 8 years ago the writer raised rather a smile when he mentioned the possibility of carrying freight between Duluth and Montreal on a liberal scale of navigation at the rate of 1 mill per ton mile. In the report on the Ohio and Lake Erie Canal, dated a year ago, I find these words: "The average rate of freight on tonnage passing through Detroit River in 1896 is estimated at $\frac{85}{100}$ of a mill per ton per mile. Ore is now being carried by lake from Duluth to Ashtabula at a rate of $\frac{6}{10}$ of a mill per ton per mile. Coal is being carried by lake from Ashtabula and Buffalo to Duluth at a rate of $\frac{1}{4}$ mill per ton per mile. Coal is being carried from Pittsburgh to New Orleans by the Ohio and Mississippi river at a rate of about $\frac{1}{3}$ of a mill per ton per mile. On the same page of the report will be found the statement that the average Trunk line long distance haul on the railways was 5 to 6 mills per ton mile, or from 6 to 10 times that of the lake navigation. Enormous as have been the strides made in economy of railway carriage, the progress in water carriage has completely outstripped it, as the following table by Mr. Thompson, of Duluth, will show:

Cost of carriage of wheat between Chicago and New York at different periods per bushel:

Year.	Lake and Canal.	Lake and Rail.	All Rail.
1868	25. 3 cts.	29.0	42.6
1873	19. 2 "	26.9	33.2
1878	10. 1 "	11.4	17.7
1883	8. 4 "	11.5	16.5
1885	4.55 "	9.6	14.0

It will be seen that, while the carriage by rail has diminished to $\frac{1}{3}$ of what it originally was, the water transport has been reduced to less than $\frac{1}{5}$, and this in connection with a canal navigation of very limited capacity; indeed, a mere barge canal of 300 miles in length. In a paper by Mr. T. C. Clarke, written in the present year, he estimates the cost of carriage between the same points via the Ottawa and an extension through Lake Champlain at present rates at 2.07 cents, as compared with 5.51 cents via the Lakes and the Erie Canal. It may be further remarked that the Erie Canal among American waterways is among those of least capacity, and the New York Central and its western connections among railways is probably, without exception that of greatest capacity for cheap carriage, so that the comparison between a modern navigation and an ordinary railway would be still more striking.

The expansion in the volume of the trade of the Great Lakes is a point very much better understood by the public. The aggregate net tonnage of freight through the Sault Ste. Marie Canal increased from 3 million tons in 1885 to 16¼ millions in 1896. In 1894 it was 13¼ millions during 234 days of navigation, while the Suez Canal open all the year round carried in the same year 8 millions. And this 13 millions in 234 days was equal to 13½ per cent. of all the freight carried by all the 150,000 miles of the United States railway system in the whole year; but let it be borne in mind that the Sault Ste. Marie traffic does not include that of Lake Michigan. In 1889 Mr. George Ely estimated the traffic carried through the Detroit River as being three times greater than the foreign trade of New York, and that it exceeded the aggregate foreign trade of all the seaports of the United States by 10 millions of tons, and was 3,000 tons more than the foreign and coastwise trade of London and Liverpool combined. At the annual meeting of the Lake Carriers' Association at Detroit in 1896, the statement was made that in 1895 the traffic of the river was estimated at nearly 22½ billions of ton miles, and that the net freight carried was within a trifle of 30 millions of tons.

It is difficult to grasp these enormous figures except by comparison, but any one who has stood on the banks of the river and watched the stately procession go by, or who has even been becalmed, as the writer has been off Long Point on Lake Erie, and has watched the Buffalo section of the fleet file past, will have got some idea of its magnitude.

The total receipts of grain at the port of Buffalo nearly equal the total exports of grain from all the ports of the United States, and were for 1893 to 1895 from 161 millions to 187 millions of bushels annually. This does not include the surplus production for export of Canada, which grew from an average of 3 millions of bushels in the years 1881 to 1885 to over 10 millions of bushels from 1891 to 1895. In the current return of the Department of Trade and Commerce for Canada, I find the exports of grain classed among "agricultural products," and stated in money value as totalling 33 millions of dollars. It is difficult to separate this into bushels of grain as distinguished from other agricultural products, but there is evidently an enormous increase.

So much for the volume and growth of the trade of the Great

Lakes. Now as to its character, and especially that coming through Sault Ste. Marie.

Out of 15 millions of tons coming through the canal in 1895, 8 millions or over half were iron ore.

The writer wishes to make the remark that not only is this quantity enormous, and not only has its carriage been greatly cheapened by the existence of the waterways, enabling the United States to take a leading place among the iron producers and steel makers of the world, but it has been actually created by the waterways, and that with only railway carriage to depend on it could not exist at all.

To carry the ore to the coal, 1,000 miles by rail would in itself cost \$5 to \$6 per ton, nearly $\frac{1}{3}$ of the total cost of the finished steel rail in Pittsburg to-day. We can readily understand how large a factor the Sault Ste. Marie Canal, scarcely thought of in the early 50's, has become in the manufacturing trade of the United States.

The total export of grain from the North American Continent for 1898 will be in the neighbourhood of 200 millions of bushels, or 6,000,000 tons. Is it not fair to assume that the greater portion of this would immediately take the cheapest route, which, as will be readily seen from a glance at the accompanying map, is for every part of the wheat growing lands of the United States and Canada via Montreal, and for 95 per cent. of it via the Ottawa. But aside from and in excess of the wheat grown for export is that consumed in the New England States and the seaboard and manufacturing cities and districts of the East. And to these also the Ottawa route, even without the proposed extension of the waterway to Lake Champlain and the Hudson, offers the cheapest route. Wheat growing for export in Manitoba and the Territories is still in its infancy, and its growth is seriously cramped and hindered by competition with the production of Argentina and Uruguay, as well as of India, which, growing close to the sea, pays a relatively small tax for transportation. Is it too much to expect that, in view of all these considerations, the grain traffic alone of the proposed route would reach within a year or two 6,000,000 tons? The writer thinks not.

Another large item of export is live stock, cattle and hogs, which are at the present time exclusively carried over the railways from Chicago to Montreal or New England ports. In this connection it may be remarked that not only is the Ottawa route itself land-locked, but the approach to it from the west, if the inside or north channel of Lake Huron is taken, is sheltered for 200 miles from Mackinac or Sault Ste. Marie.

Comparatively light draft and swift steamers could make the entire run, including lockages from Chicago to Montreal, at an average rate of 10 miles per hour or 100 hours in all, or not much longer than that consumed by a cattle train between the same points. And to quote Mr. Edward Devlin, a well-known cattle shipper:—" With fast boats built specially for carrying live stock, making the distance between Chicago and Montreal in less than 100 hours, the Ottawa River would compete strongly for the traffic. These boats could be thoroughly ventilated and easily kept clean. Cattle could be given more space than on the cars, the facilities for feeding and attending them would be better, they could be kept cooler in hot weather and always have better air, with the result of their reaching Montreal healthier and in much better condition to stand an ocean voyage. The Ottawa is the only waterway on which that business could be successfully done, and its success would make Montreal the most important cattle shipping point upon the continent."

But this is not all. The interior of the continent is essentially an agricultural district, and needs the products of the mine, the forest and the factory in exchange for its agricultural products, and these now come and will in the future come largely from the east, giving return freights.

The Ottawa Valley in itself possesses immense stores of natural wealth in the forms of lumber, pulp wood, iron ore, phosphates, etc. It is notable that all these commodities are dependent upon cheap transportation for their development, and that with the Ottawa navigable only as far as Ottawa City, and only for a limited scale of navigation even to that point, the river carried nearly 600,000 tons in 1896, which is greater than the local traffic of the Erie Canal and double that of the St. Lawrence system. A pamphlet published by Mr. A. J. Forward, of Ottawa, goes very exhaustively into this question of local traffic.

Just as the opening of the Sault Ste. Marie Canal has created an enormous traffic in iron ore and coal, which could not have existed on the basis of railway traffic alone, so it would seem by no means unreasonable to expect that water communication between the ore deposits of the Ottawa Valley and the coal of Nova Scotia and Ohio and Pennsylvania would develop these dormant resources to an incalculable extent. Even allowing that we have a population only $\frac{1}{10}$ of that of the United States, and that we could not expect to produce at more than the same ratio, we should have a traffic from this source alone on the basis of the figures of 1895 of nearly 1,000,000 tons. Wood pulp is one of the newest industries, and in the raw material for this the Ottawa Valley and those of its tributary streams are particularly rich. Not only this, but the enormous power of the river itself made available by the same dams which create the navigation, would assist to render this the most favourably situated manufacturing district on the continent not only for pulp but for many other commodities.

The low water flow of the Ottawa at Mattawa is 25,000 cub. ft. per sec.; its elevation at that point is 500 ft. above the sea. Without counting on tributaries and increase of volume, this represents a total horsepower of 1 1-3 millions, or, reckoning on a 10 hour instead of a 24 hour day, of over 3 millions. If even one-tenth part of this, or 300,-000 H. P., could be usefully developed and used, it represents an enormous source of wealth, and, at even the very low rate of $5.00 per H. P., an income of 1½ millions annually, or 4 per cent. on a capitalization of $37,500,000.00.

We all know how Ottawa's water supply, light and internal communication are supplied by the power of the river, besides which it keeps many of the local industries running, and there is still nearly as much running to waste as is used. It may be that in the future we shall see a dozen such cities in the Ottawa Valley, and the district the busiest on the continent.

A distinguished English writer, Mr. Ernest Williams, whom the writer had the pleasure of accompanying on a somewhat extended tour through the region of the Upper Ottawa, expressed this thought in somewhat striking language of the following tenor :—

The 19th century now closing may be called the steam age of the world's history, during which the nations having the most abundant coal supply have necessarily come to the front in the world's commerce. The 20th, just dawning, may come to be called the "electric age," in which the countries having the greatest and most readily available water power will take the lead in the world's manufactures. If this be true, and it seems probable, there are few countries more favoured than Canada, and few portions of Canada more favoured than the Ottawa Valley; and if we add to the water power and the natural supply of raw materials the (in some senses) most remarkable line of inland water communication extant, there seems no reason why the Ottawa Valley should not hold its own at least with the basin of Lake Erie, for instance, which with a length of less than 250 miles, or less than 2-3 of the distance between Montreal and Lake Huron, supports 8 cities upon its southern borders, aggregating in population many times that of Montreal and Ottawa combined, and all dependent upon either the proximity of one natural product, coal, or the cheap carriage afforded by the Great Lakes, or both combined.

In the case of the Ottawa Valley, we would have the cheap transportation, the contiguity with several natural products of great value and the additional advantage of unlimited power, which would largely take the place of coal, with the further advantage of greater proximity to the ocean.

In all the foregoing, it should be noticed that we have been takin- into account only the figures of to-day, and of the last few years, but a glance at the general map submitted will show that the project under discussion concerns the output of some 2¼ millions of square miles, of which the Canadian portion of ½ to ¾ million has only begun to be settled, and of the remainder in the United States, probably one half has never been farmed to its full capacity, owing to its great distance from the world's markets, and the cost of transportation thereto. A difference of a couple of cents in cost of transport means so much more into the pocket of the producer, and is enough to vastly stimulate, not only the settlement of our own territory, but the production of the Central and Western States.

MILITARY AND POLITICAL CONSIDERATIONS.

The writer does not claim to be either a military authority or a statesman, but there are a few points in connection with matters political and military which will be suggested to almost anyone who cares to think on them, and who is fairly well posted in the history of the world during his own lifetime. Canada is peculiarly situated with regard to her powerful neighbour on the South, and natural conditions must inevitably connect the destinies of the two great divisions of North America. We, in Canada, possess a strip of territory 3,000 miles in length from east to west, but although on the map it shows a vast breadth from north to south, its available breadth for settlement and development does not average much more than 1-10 of this, or 300 miles. In order to unite this territory politically, we have been obliged to build a railway which for hundreds of miles is close to its southern boundary, and, owing to the peculiar formation of the Great Lakes, or rather of Lake Superior, it lies for some 200 miles on the very edge of our territory, at points almost overhanging it. This railway has come to be regarded as of enormous importance, not only to the Dominion, but to the empire at large. A second line of communication exists in the St. Lawrence and Welland canals ; also for its entire distance upon the extreme southern verge of British territory. In case of trouble with the big Republic, therefore, our line of water navigation comes within reach of American guns at Cornwall, and our railway communication at Peninsula Harbor, on Lake Superior. There may be no reason to apprehend trouble—the writer hopes there never will be—but we shall presently see a possible, if not probable, reason for trouble, and it is an axiom in other than political matters that the best means of avoiding trouble is to be prepared for it. The opening of a waterway between the Great Lakes and the Atlantic wholly through Canadian territory, giving access to ships-of-war to Lake Superior, is, the writer believes, the only adequate means of defending the Canadian Pacific Railway from destruction at a half dozen different points on its northern shore. It is also a remarkable means of offence and attack on the Lake Marine and the great commercial lake ports.

In reference to causes of disagreement, let us again look at our map of the continent, and we shall find that, as before mentioned in considering trade and commerce, Canada possesses in the St. Lawrence and its estuary the shortest route between the food-producing districts of the New World and the food-consuming countries of the Old. Shanly, writing in 1858, says: "The natural outlet of all that fertile region east of the Mississippi which drains into the Great Lakes is, of course, their outlet, the St. Lawrence, and the preponderance of the trade of that immense area will settle into that channel as a matter of destiny." And again: "Canada lies directly across the leading route from the far west to the Atlantic seaboard, and over some portion of our territory the great tide of Western commerce must forever roll." If Mr. Shanly had been writing at the present day, he would not have confined his predictions to the region east of the Mississippi, nor have spoken of that as the "far west."

Mr. A. M. Wellington, writing only a year or two before his death on this same topic, speaks of it as "a route provided by nature through Canadian territory for the carriage of American commerce."

And again, a distinguished citizen of Toledo in correspondence with the writer makes use of this expression: "If Canada is to continue to hold the gateway of continental commerce, the gates must, at least, be made wide enough for the caravan to pass."

These remarks, although written in every case in comment of the scheme of rendering the Ottawa navigable, apply equally well to the enlarged St. Lawrence, as far as the political aspect is concerned, and the report of the Deep Waterways Commission shows to what enormous expenditure the United States would become reconciled in order to become independent of Canadian waterways. We have seen within the last year or two 9 millions spent by the State of New York alone in the futile attempt to secure only 9 ft. of water in the Erie Canal. And within a month or two we have seen the seizure of Porto Rico and Cuba, less the writer believes on account of their intrinsic value than because they command the approach to another great projected waterway, the Nicaragua Canal, which the United States are anxious to build, but will not until they can control and defend it. The writer has introduced these considerations with some diffidence as being somewhat outside of his "ken" and that of his audience. His excuse is that the same considerations have affected the location of the Intercolonial Railway, and have built the Rideau and Ottawa Canals, although commercial considerations alone dictated the enlargement of the latter. Sir John Michel and General Gascoigne both testified to the military value of the proposed work, and Lord Dufferin and the late Sir John Macdonald have spoken enthusiastically of its political aspect. Better endorsement could hardly be asked for. The considerations are of value to us here as affecting the scale of navigation and the depth of water.

DEPTH OF WATER.

When the writer first took up the question he was immensely impressed, as must be every one who first glances at the subject, that it would be a magnificent thing to take sea-going vessels through to the very heart of the continent without breaking bulk. Considerations of economy in first cost led him to abandon this idea, and he has since come to regard it not only as impracticable at the present time but undesirable.

The vessels which can perform best on a 3,000 mile ocean run are not those which are best adapted to entering narrow approaches to locks and lake harbours, and navigating sheltered inland channels.

Enormous vessels are now navigating the lakes, and still greater ones are being built, but these are intended for one definite purpose and only one, the carriage of iron ore between two deep water terminals with only one lift lock at Sault Ste. Marie. The writer has himself seen a cargo of 5,000 tons of ore floated into the harbour of Erie, and a vessel now building is to carry 7,500 tons net on a total displacement of 10,000 tons.

The grain trade seems to be largely if not wholly carried on by vessels of rather smaller tonnage and on a draft of about 16 ft. Whalebacks are coming largely into use for general freighting. The writer had the pleasure within the last day or two of examining at close quarters two of the largest of these in Buffalo harbour, the "Alexander McDougall" and the "Colby." He was not impressed with the desirability of the type in some of its features, and the largest and latest of them, the "McDougall," shows a tendency to revert to the older models, but, in regard to cardinal dimensions and proportions, these boats teach some valuable lessons, which are rather at variance with the conclusions arrived at in connection with the St. Lawrence Canals and more in accordance with ocean practice. The big liners on the latter take for draft, beam and length, pretty nearly the proportions 1 : 2 : 20. The more recent whalebacks with smaller outside dimensions, more compact midship section, and restricted as to draft, have developed a greater proportion of beam and length, and the proportions approximate 1 : 2½ : 25. None of these boats have developed undue weakness even in long voyages at sea, so the writer thinks that these proportions may fairly be accepted as easily practicable from a structural point of view, and structural or spinal weakness seems to be almost the only argument against increased ratio of length in fairly straight and open channels, while there are many reasons in favour of it, the principal among which is that the longer boat can be driven with the same power almost as fast as the shorter one, while the net carrying power is increased in a slightly greater ratio than the increase in length. Taking the draft at 14 ft, the displacement of such a boat would be between 3,500 and 4,000 tons, and the net carrying capacity nearly 3,000 tons. The beam would be 35 ft. well within the capacity of the Welland Canal, but the length would reach 350 ft., or 80 ft. longer than the Welland locks. Turning to the report of the Committee on the Lake Erie and Ohio River Canal, we find that the size of locks recommended is 340 feet long, 45 feet wide, by 15 ft. deep on the mitre sills. The only change the writer should feel inclined to make would be to increase the length to 370 ft. for the reason given above, that the increased length is clearly practicable, and adds very little to the cost of the locks, while it adds in a very much greater ratio to the carrying power of the vessel and as a corollary to the cheapness of carriage.

The writer has accepted the ruling draft of 14 feet in the above argument partly because it is the draft upon which hundreds of existing vessels are being profitably worked, partly because it is the draft of the St. Lawrence Canals for which many vessels have been and will be designed, partly because 16 ft. is the standard depth of the principal lake harbours, and partly because he believes with Major Symonds that the very cheapest form of carriage for grain, coal or iron ore is the steel barge handled by 3 or 4 men and towed in flotillas by powerful tugs. Such barges should have at least 14 feet draft in order to be knocked about as little as possible in the open lake, and, on the other hand, a barge of 350 ft. in length and carrying 2,500 to 3,000 tons of cargo seems to be about as large as can be conveniently handled in locks and crowded harbours, etc., by outside motive power transmitted through a hawser. It is perhaps unnecessary to remark that the economy of the barge and tow system consists in its motive power being never idle, in the quantity of the latter being relatively small, and in the vessel's having a clear hold from end to end unimpeded by engine space and shaft tunnel, or, as an alternative, having her engines crowded into a few feet of length in her stern, with the result that the vessel when carrying no cargo must ship hundreds of tons of water ballast or go to sea with her bows so light that she becomes dangerous and unmanageable in a heavy head wind, and in either case draws nearly as much water and takes almost as much power to drive her when light as when loaded.

Lastly, the Ottawa River admits of being improved to a depth of 15 or 16 ft. with a very moderate expenditure outside of the actual canalling, and while much of its natural channel (aside from the great lake expansions, some of which are of enormous depth) is from 20 to 25 feet, even this last depth is by no means too great for the best and most economical results in vessels of 14 ft. draft.

They can, it is true, float over bars and locksills having only a few inches more of water over them, but only at low speeds, and they cannot be economically and steadily driven, and still less steered with precision and certainty, without plenty of water both underneath them and alongside. And this is especially the case with the flat-floored, square-bilged vessels forced into use by moderate draught. Some writers on nautical subjects estimate that the great ocean liners "feel the bottom," and cannot perform at their best with less than 500 feet of water under them, but this seems not only speculative and excessive, but is made in consideration of a speed of 20 to 25 knots, nearly 3 times or more than that at which our lake carriers can be economically driven.

In determining the dimensions of locks, I think we should also take into account the probable use of steamers intended exclusively for passenger and fast freight service—which may reasonably be expected to be built with longer and finer models than those intended exclusively for freight traffic.

LOCKAGE—RISE AND FALL.

The strongest objection, perhaps, which has been urged against the Ottawa navigation is the extra amount of rise and fall as compared with the St. Lawrence, in which, of course, the change in elevation is uniformly descending, and calculations have been made on the basis of so many minutes per foot of lockage to show how much time would be lost in locking up to the surface of Lake Nipissing, some 70 ft., and down again to that of the Georgian Bay. This basis of so much per foot of rise and fall is scarcely a fair one. So much of a vessel's time is taken up in entering the lock, closing the gates, and opening them again, and in getting headway on, that the actual time lost in filling the lock is small in comparison, so that it will take but little more time to get through a lock with 10 ft. lift than one with 4 feet, and not more than 50 per cent. longer to get through a 20 ft. lock than a 10 ft. To put the matter in another form, the time consumed depends as much or more upon the number of locks as the total lift. By actual experiment, the time consumed in passing through the Welland canal locks by a small boat is 26 minutes, or, as nearly as may be, 2 minutes per foot of lift, but fully one-half of this is consumed in moving the vessel, and tending lines.

The gates and the guard locks at Pt. Colborne, with only a foot or two of lift, consume at least 15 minutes. I think, therefore, that, if we allow one minute per ft. of lockage, or rise and fall, and add 15 minutes for each lock, we shall have a fairer basis of comparison. We need a little more information than I have to speak positively, but there is no reason to doubt that nearly all the differences of level on the Ottawa chain can be overcome by lifts of 20 ft., and we can control the levels everywhere so that guardlocks will be unnecessary.

In the case of the St. Lawrence canals, we have an elevation of 560 ft. from Lake Huron to Montreal overcome by 47 locks. In the case of the Ottawa, we have this same 560 ft., plus 70 ft., up to Lake Nipissing, and as much more down again, or 700 ft. in all. At an average lift of 20 ft., this could be overcome by 35 locks. The writer thinks that 40 will be amply sufficient, say 30 of the full 20 ft. and 10 more with an average of 10 ft. Now, applying our time calculation, we have:—

COMPARATIVE TIME OF LOCKAGE.

St. Lawrence and Welland, 47 locks @ 15 min.	=	705 m.
" " " 560 ft. lift @ 1 min.	=	560 m.
		1265
		or, 21 hrs., 5 min.

OTTAWA NAVIGATION.

40 locks @ 15 min each	600 min.
700 ft. lift @ 1 min. per ft	700 min.
	1300
	or, 21 hrs., 40 min.

The writer thinks that on this score the two systems may be assumed to be practically equal.

DISTANCES RUNNING TIME.

It is in the matter of distances, and especially in length of canal proper, that the Ottawa route shows up to greatest advantage as compared with others. The comparison is thus made by Mr. Marcus Smith:—

DISTANCES CHICAGO TO MONTREAL.

	Lake.	River.	Canal.	Total.
St. Lawrence Canals	1145	132	71	1348
Ottawa River	575	372	33	980
Difference				368

Assuming 4 miles for canal, and 10 miles for open water, we have St. Lawrence route—

1,277 miles @ 10 miles	127 hrs., 7
71 " " 4 "	17.75 hrs.
	144.45 hrs.

OTTAWA ROUTE.

947 miles @ 10 miles	94.7 hrs.
33 " " 4 "	8.25
	102.95 hrs.

Writing of the towage system, Mr. T. C. Clarke assumes a much faster rate on sheltered waters than on the open lake; 10 miles and 4½ miles per hour, respectively, and by working over the inside channel between the mouth of the St. Mary's River and that of the French makes a still more favourable showing, but he does not state his reasons for assuming so great a difference, and in the writer's opinion it is too great, and should be more nearly 9 miles and 7 miles respectively. At these rates the comparison would be about as follows:—

ST. LAWRENCE ROUTE.

1145 miles	Lake	@ 7	miles	164.17	hrs.
132 "	River	" 9	"	14.66	"
71 "	Canal	" 3	"	23.67	"
				262.50	hrs.

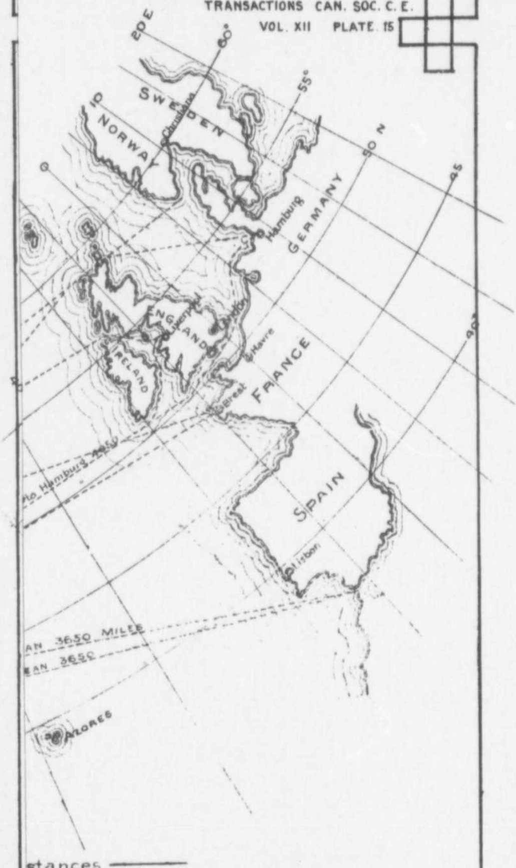
OTTAWA ROUTE.

380 miles	Lake	@ 7	miles	54.28	hrs.
561 "	River	" 9	"	62.33	"
33 "	Canal	" 3	"	11.00	"
				127.61	
Difference				74.89	

There is much more that might be said on any and all of these topics, but the writer feels that he has already taken a great deal of time and space. He will conclude by again calling attention to the breadth and scope of the project, and that it is not a matter of local development or even of the advancement of the Dominion of Canada; it concerns the Empire and the neighbouring republic, and will affect rates and prices over at least one-half of the North American continent. It is not a competitor in any sense with the railways, for it will, as Sir William Van Horne has said, bring them more traffic than it will take away. As we have seen in the case of the Sault Ste. Marie lock, a large portion, if not the major portion, of its traffic will be of its own creation, and of such a nature as could not exist without it. One might as well speak of the railways entering into injurious competition with the turnpike roads. The railways have killed forever long distance travel on common roads, but while doing so they have rendered possible such communication and interchange with distant localities as was altogether out of the question in the days of stage coaches, and, as a result, have stimulated trade and production to an incalculable extent, with the result that there is to-day more demand and agitation for good roads than ever before. The two systems of transportation are complementary, one acting as a feeder to the other, and we are probably on the eve of a great development of an intermediate system, the light electric branch railway. Similarly, the navigation schemes are supplementary to the ocean routes, and act as a link between them and the railways, carrying at rates which the latter cannot dream of, building up and creating thereby industries and centres of industry and population which could not otherwise exist, and so creating for the railways traffic in passengers and light and perishable freights far more profitable to them than that which properly belongs to the steamboat and the barge. Statistics tend to show that this is the case, and that the most profitable railways in the world are those through countries well supplied with waterways, and the busiest of all are those which parallel the latter.

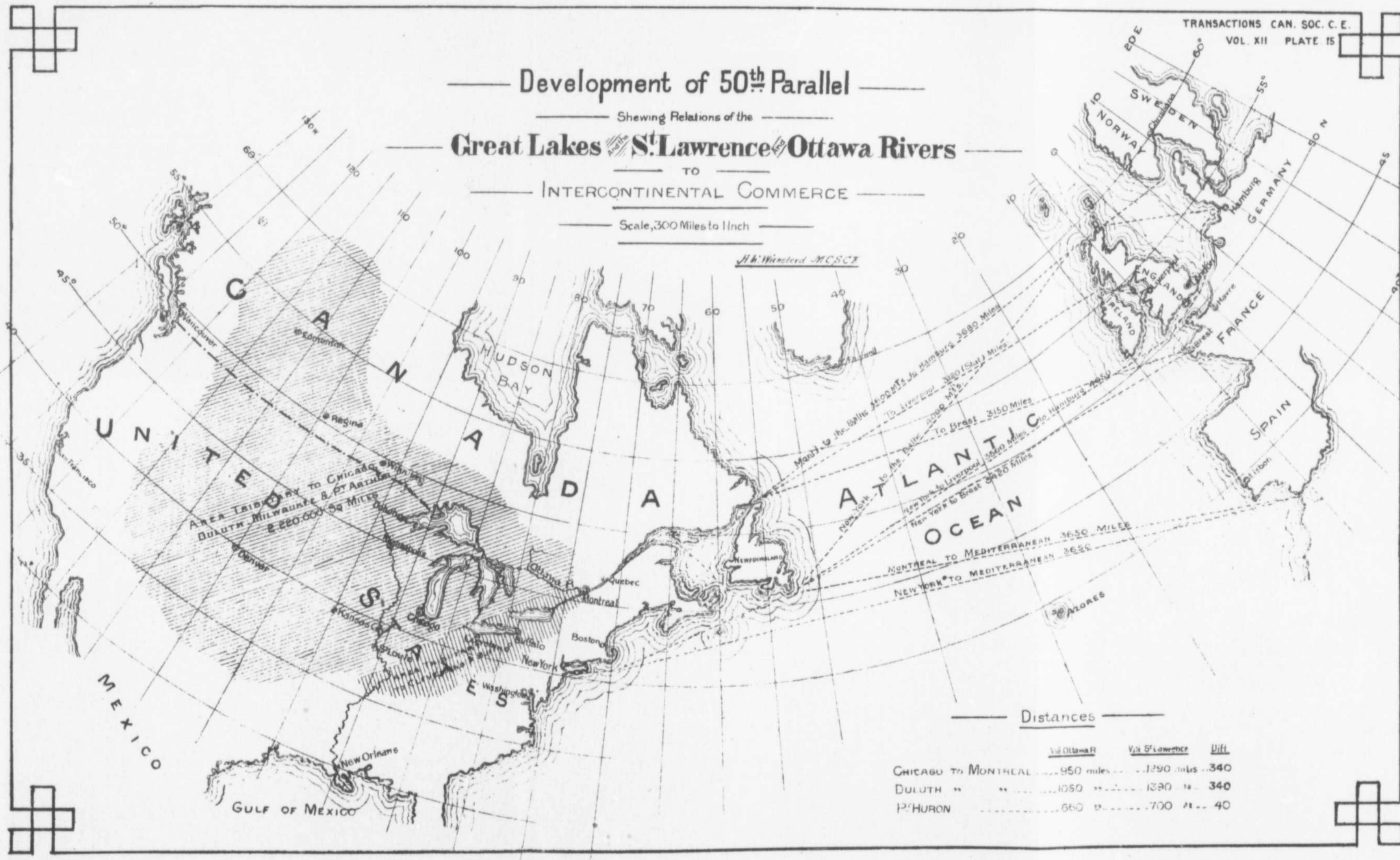
The New York Central is a case in point, and its development has now reached such a point that it is competing successfully with the Erie Canal, and we shall soon see the latter either greatly enlarged or fallen almost into disuse, but, in contravention of the plea that this is an argument against the building of canals, let me call the attention of my readers to two or three points :—1st. The Erie Canal built up the State of New York, and the cities and towns along its banks and through them, and their trade made traffic which alone made a 4 track road possible, and it is now struggling for existence with the giant it called into being. 2nd. The New York Central is competing with only a portion of the waterway, and is still dependent for a large portion of its traffic on the remainder. With Lake Erie filled up or drained, and the Lake trade of Buffalo and Cleveland killed, how much traffic would there be for it, and would the Empire State Express be a possibility? 3rd. The navigation which has failed after 50 years of use is one on an extremely limited scale indeed, and the vessels using it too small to navigate the lakes above and too slow to carry anything but the bulkiest and cheapest of commodities. Between the Erie canal barge carrying 240 tons at a speed of 3 miles per hour, and the whaleback barge carrying 2,500 to 3,000 at 8 miles, there is as great a step in efficiency and economy as between the tallow candle and the electric light, and we have already seen that the water-borne traffic has pro-

TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE 15

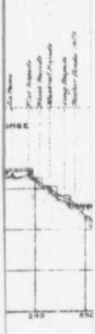


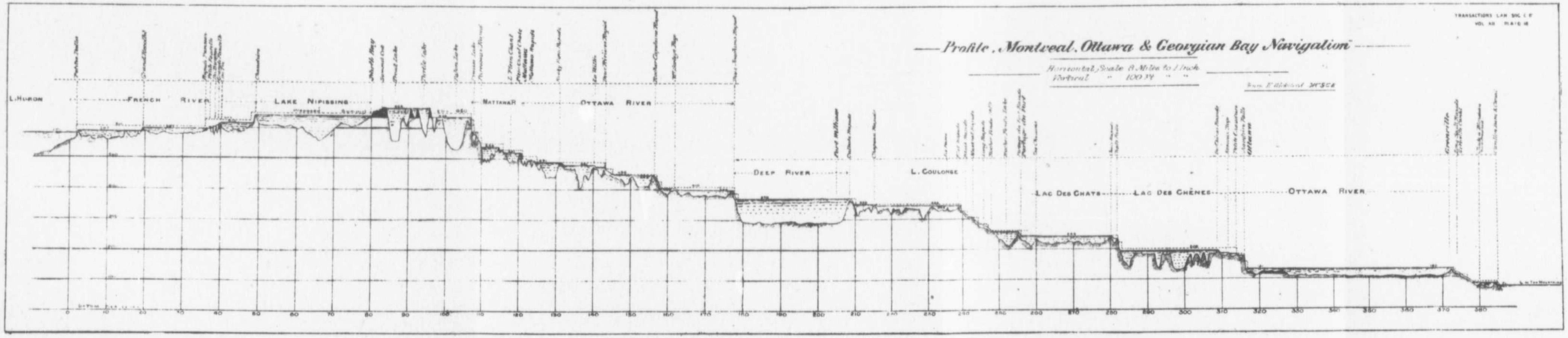
stances

Via Ottawa R	Via St Lawrence	Dift.
....950 miles	....1290 miles	..340
....1050 "	....1390 "	340
....660 "	....700 "	..40


TRANSACTIONS CAN. SOC. C. E.
VOL. XII PLATE 15
Development of 50th Parallel
Shewing Relations of the
Great Lakes and the St. Lawrence and Ottawa Rivers
TO
INTERCONTINENTAL COMMERCE
Scale, 300 Miles to 1 Inch
CANADA
UNITED STATES
MEXICO
GULF OF MEXICO
HUDSON BAY
ATLANTIC OCEAN
NORWAY
SWEDEN
GERMANY
ENGLAND
IRELAND
FRANCE
SPAIN
AZORES
Edmonton
Regina
Denver
Kansas
Chicago
Buffalo
New York
Boston
Montreal
Quebec
Ottawa R.
Washington
New Orleans
Hamburg
Brest
Havre
AREA TRIBUTARY TO CHICAGO, DULUTH, MILWAUKEE & PT ARTHUR
2,220,000 Sq. Miles
Montreal to Brest 3150 Miles
Montreal to Mediterranean 3650 Miles
New York to Mediterranean 3650
Distances
Via Ottawa R. | Via St Lawrence | Diff.
Chicago to Montreal 950 miles 1290 miles 340
Duluth " " 1050 " 1390 " 340
Pt Huron 660 " 700 " 40

Profile .




Profile, Montreal, Ottawa & Georgian Bay Navigation
Horizontal, Scale 8 Miles to 1 Inch
Vertical " 100 Ft " "
L. Huron
French River
Lake Nipissing
Mattawa R.
Ottawa River
Deep River
L. Coulonge
Lac des Chats
Lac des Chênes
Ottawa River

gressed faster in the matter of cheapness of haul than has land carriage. Imperfect and obsolete as it has come to be considered, the Erie Canal is estimated to have saved in transportation of grain alone through the State of New York, during the last thirty years, at least $200,000,000. This, however, does not represent the full gain to the community, for, with this amount added to its value, a large portion of the grain in question would probably never have been grown at all, as being incapable of competing with that of other territories, and thousands upon thousands of acres of wheat lands would never have been broken with the plough.

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