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The Canadian Society of Civil Engineers.

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FORT WILLIAM WATER SUPPLY.

By H. SYDNEY HANCOCK, JR., A. M. Can. Soc. C.-E.

The experienced engineer will find little of interest in the following pages, but the writer is hopeful that the younger members of the Society may derive some profit from a description of the various difficulties encountered. With this object in view, special prominence will be given to the more "unfortunate" features, rather than to the successful, but ordinary, incidents of the work.

Fort William occupies the site of the ancient fur-trading post established by the celebrated explorer, D. G. DuLhut, in 1669. In 1782 it became the principal fur-trading post of the Northwest Fur Trading Company, under whose regime it received its present name in 1805, in honour of the Hon. Wm. Gillivray, who was then a prominent officer of that Company. Its importance as a fur-trading post began to wane with the absorption of the Northwest Fur Trading Co. by the even more famous Hudson's Bay Co. in 1821.

The present city lies on the north bank of the Kaministiquia River, which flows into Lake Superior at the extreme northeast boundary of the city, and occupies nearly four miles of the river bank. The river serves as an excellent harbour, providing a channel 300 feet in width and 22 feet in depth. Dredging operations are in progress that will increase the width to 500 feet throughout, with a depth of 25 feet. The work is being carried on by the Dominion Government, and it is anticipated that five years will be required to complete the whole scheme.

Fort William first attained prominence within modern times when in 1874 it became an important base of operations during the construction of a portion of the first Canadian transcontinental railway by the Dominion Government. Shortly afterwards, this portion of the line was handed over to the Canadian Pacific Railway, and only a small settlement survived the activity of the construction period.

The Lake terminals and elevators of the Canadian Pacific Railway were consolidated at this point in 1890, and formed the nucleus of the present city. In 1896 the population had reached 2,500, and the first waterworks system was installed. The supply was taken from the Kaministiquia River and delivered to the mains, unfiltered, by two Northey duplex compound pumps, each of a rated capacity of 750,000 imperial gallons per 24 hours.

In 1905 the Grand Trunk Pacific Railway selected Fort William as the terminus of its Lake Superior branch, over which it expects to handle the major portion of its grain and freight traffic during the season of navigation. This fact, combined with an immediate increase of population, foreshadowed the necessity of increased pumping capacity, or the utilization of some other source of water supply.

Six miles south of the city, beyond the Kaministiquia River, set in the midst of high basaltic hills, is a lake of 10 square miles in area, with a watershed of 30 square miles, named by the Chippewas, Kazazeekeegewaigamag, "The high lake that is always overflowing," but a patriotic Scotsman of the Northwest Company thought it sufficiently like the original Loch Lomond, and so it is named to-day.

Loch Lomond is 332 feet above the level of Lake Superior, and is surrounded by bold, rocky hills, varying from two to nine hundred feet above the level of the Loch, forming a portion of the northwest coast range of Lake Superior. Its shore line is, for the most part, steep and rugged, with occasional sheer cliffs of from one to five hundred feet in height.

The Loch probably averages about 75 feet in depth. Some soundings exceeding 350 feet have, however, been made.

The water is soft, of a good white colour, and the analysis of many samples by Dr. John A. Amyot, the Provincial Government bacteriologist and chemist, has failed to reveal any sign of chemical pollution or the presence of harmful bacteria. It contains one part of chlorine per million.

The Loch has one natural outlet on the east side, about two miles from its northern extremity, through which the overflow is discharged into Lake Superior by the Carp River, one and a half miles in length.

The valley of the Carp lies in a southeasterly direction, and is shut off from the north by some of the highest hills in the range, which end abruptly at the shore line of Lake Superior with almost precipitous cliffs, 800 feet high.

There are undoubtedly many springs that feed the Loch, but the main source of supply is from the natural precipitation within the drainage area.

The watershed consists largely of exposed rock, but the valleys formerly produced large and excellent white pine and cedar. The ravages of the lumberman and forest fires have, however, left little of the original forest, which is now replaced by small birch and poplar.

The character of the watershed leads one to believe that the normal loss from seepage and evaporation should not exceed 50 per cent. of the average rainfall, which for the last 20 years, as recorded by the Meteorological Station in the adjoining city of Port Arthur, is approximately 30 inches per annum, and, consequently, 15 inches of precipitation should be available for use. On a drainage area of 30 square miles this rainfall will produce practically 6,500,000,000 imperial gallons annually, or, say, 17½ million gallons per 24 hours. Gaugings taken at the Carp River during the past three years have produced an average of just over 11,000,000 gallons per 24 hours, but as this period has been the driest at the head of the Lakes since the years 1883 to 1885, it cannot be considered normal. The difficulty of gaining access to the weir during the spring thaw prevented sufficiently numerous readings at the time of greatest flow, amounting for a considerable period to over 70,000,000 gallons per 24 hours. It is therefore safe to assume that the average for any one year will not be less than 9,000,000 gallons per 24 hours, sufficient, at 60 imperial gallons per head, for a population of 150,000 people. In fact, it is quite within the bounds of probability that a population of 250,000 would be well served from this source of supply.

In proportion to the size of the drainage area, the storage capacity of the Loch is immense, the top 3½ feet alone holding more than one year's supply for 250,000 people. This feature not only makes the whole year's effective precipitation available, but would even carry the system over one or two very dry years, when the consumption might exceed the available annual precipitation.

The citizens of Fort William had always considered that Loch Lomond would eventually be the source of their permanent water supply, but the necessity of constructing a rock tunnel nearly a mile in length proved a stumbling block to the small population for many years. However, on two occasions, between 1896 and 1903, brief reports on the feasibility of the scheme and its approximate cost were made. These reports were lost when the old municipal buildings were destroyed by fire.

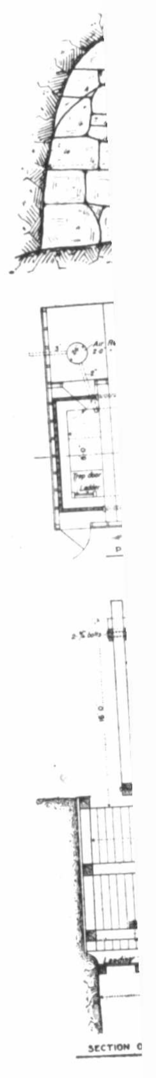
In 1904 the matter was again taken up, and Mr. John Galt, consulting engineer, of Toronto, then engaged on the construction of sewers for the city, was asked to report on the matter. His report, bearing date of June 24th, 1904, to the Board of Water Commissioners, gave a comprehensive description of the possibilities of the scheme. He also made a survey of the lake, and ran two preliminary lines into the city. The proposals contained in this report were, briefly, a 36-inch steel intake pipe from the loch, leading, *via* 500 feet of open cut to a 6½ foot by 4½ foot tunnel through the surrounding hills, to a small forebay, from which pipe lines were to be laid to the city. The first installation of pipe lines was to serve a population of 30,000 people. It embraced a 16-inch wood pipe line to a 30 feet by 90 feet steel compensating storage tank, located on a bluff midway between the forebay and the Kaministiquia River, the top of the tank to be at an elevation of 300 feet above Lake Superior. From this point two 18-inch cast-iron pipe lines were to be laid to the city, crossing the Kaministiquia River by a duplicate 18-inch main. Excluding one 18-inch main from the storage tank to the river, the estimated cost was $215,000.00.

At this time the population of Fort William was just over 6,000 people, and there was a general feeling that the cost of the undertaking was still prohibitive, and no further action was taken during that year.

At the close of 1905, and during the early weeks of 1906, the city was visited by a typhoid epidemic of alarming proportions, there being over 800 cases in a population of between 7,000 and 8,000, caused, primarily, by the water supply from the Kaministiquia River, which was found to be seriously polluted from various causes, the chief being the discharge of a small sewer about half a mile above the intake, and the large number of construction camps for power development and railway construction on the upper reaches of the river.

As a result, there was a general and vigorous demand for the carrying out of the Loch Lomond water supply scheme. The newly elected Council and Board of Commissioners failed to agree with Mr. Galt, and his connection with the work ceased in February, 1906.

The Council immediately made every effort to secure the services of Mr. A. G. Allan, A. M. Amer. Soc. C. E., who was then in charge of some important railway construction in the vicinity of the city, to carry on the work. Mr. Allan felt that he could not conscientiously relinquish the work on which he was then engaged, and suggested the writer as a substitute.



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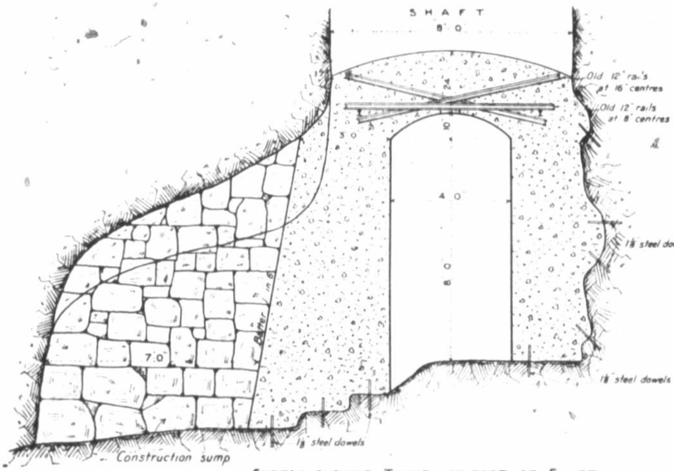
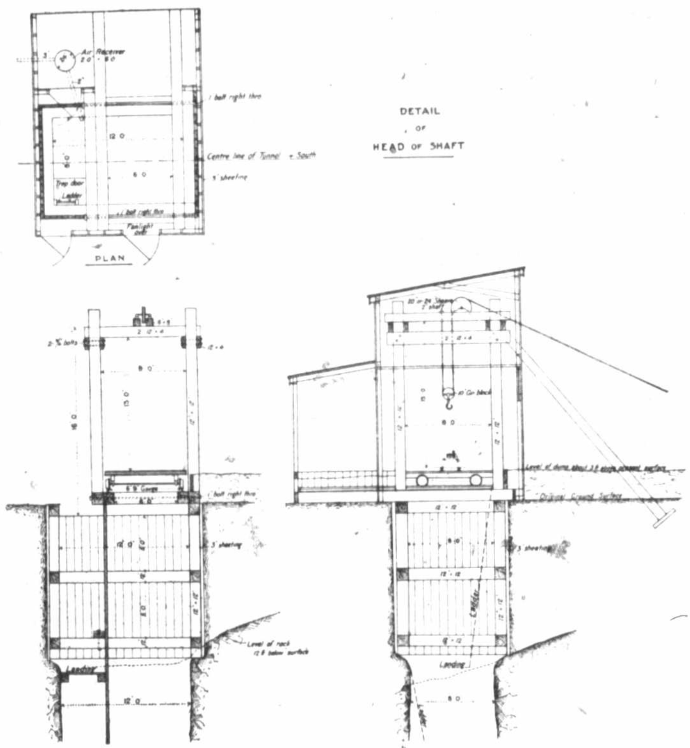


SKETCH SHOWING TUNNEL AT FOOT OF SHAFT



DETAIL OF HEAD OF SHAFT

SECTION ON CENTRE LINE OF TUNNEL

SECTION TRANSVERSE TO CENTRE LINE OF TUNNEL

Mr. Allan, however, gratuitously made several tunnel reconnaissances, and also assisted Council and the writer with valuable advice.

On March 5th the writer was engaged as city engineer, and was immediately asked to report on the proposed supply from Loch Lomond, mainly with the idea of reducing cost and finding a shorter tunnel location, so that more rapid progress might be made during construction.

The location selected by the earlier locators, and adopted by Mr. Galt, for a tunnel was in the extreme northeast corner, being that portion of the loch nearest the centre of the city. Due north of the loch the range extends to a width of three miles. The northwest side produced no tunnel location less than 4,800 feet in length, and added half a mile to the length of the pipe line. It therefore became evident, after running a portal contour on both sides of the range wherever a reasonable tunnel length could be expected, that the original location was in the best available country.

The line located by Mr. Galt, from the forebay to the stand pipe, necessitated a large amount of solid rock trenching, which became particularly difficult as the stand pipe was approached. It was, for this reason, considered desirable to change this portion of the location so that the pipe line would follow the sandy loam deposited in the basin of Whiskey Jack Creek. This change also caused the pipe line to pass close to a ridge, which made possible the construction of a concrete reservoir at a suitable elevation above, and distance from, the city. A desirable attainment, as, for obvious reasons, a well-banked concrete reservoir is to be preferred to a stand pipe in a climate that sometimes registers more than 50° F. below zero. The overflow level was fixed at 297 feet above Lake Superior, which is sufficient to give a hydrant pressure of 115 lbs. in any part of the city. The reservoir capacity was then increased to 800,000 imperial gallons, nearly twice that of the stand pipe, while its cost per gallon was reduced in the ratio of 3.2.

This compensating storage reservoir is, I think, an unusual feature in Canadian design. Its presence enables one 18-inch supply main from the forebay to efficiently serve the two 18-inch pressure mains required to deliver the water demanded by the Fire Underwriters' Association for a population of 30,000. It also maintains the balance between the maximum and minimum domestic consumption, and provides a fire service reserve at practically maximum pressure within two and a half miles of the city. The danger of water hammer is reduced, and smaller pipes are enabled to fulfil the demands of the service.

A direct line from the reservoir to an available crossing of the Kaministiquia River nearest to the distribution system would cross the Mission Flats. From one to two feet of water cover these flats during the greater part of the summer, the water being held back from the Kaministiquia River by a low, sandy ridge. The swamp is largely covered with small spruce and cedar, growing in from one to two feet of black, peaty matter, overlying a bed of very fine blue-grey quicksand, which is almost as fluid as water, when wet.

The construction of a pipe line across this territory would have necessitated a large drainage ditch, a corduroy road for the haulage of pipe and material, as well as extensive blocking for the support of the pipe.

Some four years previously a road and drainage ditch had been constructed to the foot of the mountain, a short distance west of a direct location. This ditch had drained a strip some 300 feet in width, much of which was firm sand. By following the hard ground at the foot of the mountain to the south end of the road, the distance was increased just over 500 feet, but all the swamp with the exception of about 700 feet, was eliminated, and even that had been partially drained. It was proposed that one pressure main should be first constructed and used to give a temporary supply from a small lake that will be referred to later. The serious condition of the city demanded a pure water supply at the earliest possible date, and the fact that much time could be saved on construction by adopting the longer route was an important factor in its selection.

Excepting 2,000 feet of cast-iron pipe crossing the Grand Trunk Pacific property, it was decided to use on this section the 18-inch wire-wound wood pipe manufactured by the Pacific Coast Pipe Co. Ltd., of Vancouver, B.C., because of its low cost and the speed with which it could be laid.

With this pipe it was proposed to use the "Perfect" cast-iron coupling originally used by the Seattle Corporation of the same name. However, on strong representations from the Company, accompanied by the most emphatic guarantees, a wood sleeve, 8 inches long, bound by five half-inch wrought-iron bands, cinched up with nut and shoe, was employed.

The Kaministiquia River, 350 feet in width at this point, was to be crossed by a duplicate 18-inch cast-iron main with flanged joints and corrugated copper gaskets. The adoption of flanged pipe was due largely to the strong objection of some members of the Water Board to the use of any flexible joints under water.

From the crossing of the river, some two miles of cast-iron pipe, varying from 18-inch to 10-inch diameter, were used in connecting to the distribution system.

These changes tended to decrease the cost of the work, but, after a careful study of the local conditions, the writer estimated the cost of the scheme at $359,000.00, excluding the second pipe line from the reservoir to the river.

The entire location south of the Grand Trunk Pacific Railway is in the Fort William Band Indian Reserve, and the terms on which the right of way was granted included the obligation to employ Indian labour when possible.

The estimated population to be served by the foregoing pipe lines has been computed as follows:

First, the 36-inch steel intake pipe, with invert 9 feet below the normal low-water level of Loch Lomond, will deliver not less than 60 cubic second feet, which is nearly four times the maximum safe capacity of the drainage area for a 24-hour service, and probably sufficient to take care of the maximum daily demand if adequate compensating reservoirs are provided. In any case, provision has been made in the Gate House for a second pipe when necessary.

With a reasonably high coefficient of friction, the tunnel should be capable of delivering not less than 100 cubic second feet if necessary, which is large enough for any demand that can be supplied by the watershed.

The 18-inch pipe from the forebay to the reservoir will deliver, with both forebay and reservoir full, approximately 3,800,000 imperial gallons per 24 hours, increasing, as the reservoir empties, to 4,800,000 imperial gallons per 24 hours, or 3,333 imperial gallons per minute.

Each 18-inch pressure main from the reservoir is expected to supply 15,000 people on the basis of 60 imperial gallons per head per day for domestic consumption, in addition to adequate provision for fire purposes.

The assumed domestic consumption will average 625 imperial gallons per minute.

Assuming that 75 per cent. of such supply is needed during the 12 hours between 7 a.m. and 7 p.m., the average is raised to 940 gallons per minute. Allowing a further 50 per cent. increase for hours of special domestic urgency, the maximum anticipated domestic demand for which pipe capacity must be provided was taken as 1,410 imperial gallons per minute.

The fire requirements were taken as ten streams operating simultaneously, delivering 2,080 imperial gallons per minute, making a total maximum demand of 3,490 imperial gallons per minute. As each 18-inch main will deliver approximately 3,800 imperial gallons per minute to the distribution system, there is a small margin of safety. When both mains are serving a population of 30,000 people, the safe concentration of fire streams may be proportionately reduced to sixteen, each of 208 imperial gallon capacity, providing a further margin of 800 imperial gallons per minute.

With the assistance of the compensating reservoir, maximum domestic and fire requirements together can be supplied for 250 minutes, which is longer than will be required in actual practice. With normal domestic consumption and maximum fire demands, sixteen fire streams can be operated for twenty consecutive hours. Assuming fourteen hoses as a maximum requirement instead of sixteen (*vide* Shedd, Fanning & Freeman), this service could be continued for several days.

TEMPORARY SUPPLY.

Two thousand feet from the site of the proposed compensating reservoir lies Crescent Lake at an elevation of 989, approximately 90 feet above the high-water level of the reservoir.

At this time it was a small pond of 12 acres in extent, averaging about 20 feet in depth. It is surrounded by precipitous hills, and has a drainage area of two square miles. Its overflow early in March was at the rate of 200,000 gallons per 24 hours, at which time the temperature was considerably below zero, and, as far as could be learned, no thaw had occurred at this elevation since the preceding October. No other records were available, excepting the statement of Indians and hunters that throughout the summer a torrent of water proceeded from the lake. It appeared to be an ideal solution of the problem of a temporary water supply for a small population.

The writer proposed placing the summit of the intake pipe four feet below normal water level elevation 985, and to build two dams to an elevation of 999. Spillway level to be 996. At this level the lake would have an area of sixty acres and a storage capacity of 110,000,000 imperial gallons, nearly four months' supply at 60 gallons per head for 10,000 people, it being anticipated that the population would not exceed that figure within the 18 months during which the scheme was expected to operate. The drainage area, on a basis of 12 inches effective precipitation, would average 900,000 imperial gallons per 24 hours. To be absolutely safe, however, it was recommended that one of the 750,000 imperial gallon pumps from the power house be placed on the north shore of Loch Lomond in order to supply any deficiency by pumping over the divide, 120 feet high, through a wood pipe line 7,000 feet in length, and thence by the natural creek bottom to Crescent Lake.

It was proposed to convey this supply to the reservoir by a 10-inch cast-iron intake and 8-inch wood main, the whole at an estimated cost of $15,300.00.

Lake Superior Supply.

A small, but powerful, section of the community considered the Loch Lomond scheme prohibitive, both as to time and cost, and suggested that a pumping station should be erected on the shores of Lake Superior.

The water is very shallow over a large area adjacent to the three discharging channels of the Kaministiquia River, being less than six feet in some cases over a mile and a half from the shore line. The danger of contamination is also great, as the muddy river water spreads at certain seasons in a large fan far out into the lake.

McNab Point is the nearest location, outside the turbid area, where any depth of water could be secured, and even there it is necessary to go 500 feet from the shore to secure ten feet of water, and a further 500 feet to secure twenty-four feet, a depth not safe from disturbance during a Lake Superior hurricane.

This location is 5½ miles from the nearest inhabited portion of the city, and is still so close to the polluted area that ordinary prudence would demand the installation of filter beds if it is to be utilized.

To provide the 3,490 imperial gallons per minute, assumed in the gravity scheme as possibly necessary to take care of a period when both maximum fire and domestic demands are made simultaneously on the supply, a pump of 5,000,000 imperial gallon capacity per 24 hours would be required. As the Canadian Fire Underwriters' Association insist on all pumping machinery being in duplicate, two pumps of this capacity would be necessary, unless a detour were made in the pipe line and a stand pipe provided on one of the adjacent bluffs.

Auxiliary pumps to supply the filter beds would also be required.

The first two and a half miles of the pipe line would pass through rocky and difficult country, the remainder through the Mission swamp before referred to. The river crossing and connections to the distribution system are the same as outlined for the gravity system.

Briefly, the necessary roads, dock, intake pipe, pumps, buildings, filtration plant, and pipe lines would cost little, if any less, than the gravitation supply. The operation of a pumping plant of this capacity in this location would not be less than $15,000.00 per year, which represents a capital outlay, on the basis of a 30-year 4½ per cent. debenture, of over $250,000.00. A further point in favour of the gravity system is the fact that the expenditure on the tunnel section, nearly 50 per cent. of the total cost, provides capacity for a population exceeding 150,000, only the pipe lines and reservoir having to be increased when the population exceeds 30,000 people.

For the above reasons, the writer advocated the Loch Lomond scheme. It was accepted by the Board of Commissioners, and a request made to the City Council for the necessary funds.

Before complying, the Council retained Mr. R. W. Leonard, M. Can. Soc. C. E., then chief engineer in charge of the development of 30,000 H.P. on the upper reaches of the Kaministiquia River, to report on the project.

His report endorsed the Loch Lomond scheme, including the temporary supply. He intimated, however, that he did not consider it safe to assume that more than 100,000 people could be permanently supplied from the Loch Lomond watershed, basing his opinion partly on the rainfall of two very dry years in the early eighties, and on a reported attempt made at about the same time to raise Loch Lomond for the purpose of floating logs down the Carp River. It was stated that this effort, extending over six months, succeeded in raising the Loch only fifteen inches. Data as to tightness of dam, evaporation, and rainfall covering this period is not available. Mr. Leonard stated that the estimated cost was sufficiently low and might even be exceeded.

Council, acting on this report, submitted a By-Law for $125,000.00 to cover the temporary scheme, and that portion of the permanent scheme necessary to convey this water to the city, including one pressure main, river crossing, and distribution pipes. The Council was of opinion that some further work and investigation should be done on the tunnel project before funds were provided for its construction.

The reservoir was not provided for by the By-Law, but was built at the same time as the first section. Its cost is included in Section 2.

The Board of Commissioners, whilst protesting at this delay in commencing the tunnel, proceeded to call for tenders for the construction of the authorized section. The proposals covered the dams at Crescent Lake, intake pipe, eight-inch supply main to reservoir, the eighteen inch pressure main, the river crossing, distribution pipe, and two miles of road construction in a lump sum bid, and the reservoir on a price per cubic yard for excavation and concrete.

Construction Section 1.

A contract was awarded to Wm. Newman & Co., of Winnipeg, on June 5th, 1906, their bid being the lowest of three received, on the following basis:

A lump sum bid of.. .. ..$ 97,900 00

Reservoir:

Earth excavation..	600 c.y. @	.50......$	300.00		
Loose rock..	580 c.y.	.75......	435.00		
Solid rock..	3690 c.y.	2.00......	7,380.00		
Concrete..	900 c.y.	12.00......	10,800.00		
Plaster	1633 s.y.	.50......	831.50		
Back fill..	1600 c.y.	.30......	480.00	20,226.50	
				$118,126.50	

The contract provided for completion on the fifteenth day of October, under a penalty of $100.00 per day.

The right of way was first cleared and grubbed fifty feet in width, where the construction road could follow the pipe line, and 30 feet in width where the pipe line and the road occupied separate locations.

It was necessary to construct roads to all parts of the work, from the point reached by the road already constructed across the swamp to the foot of the mountain. The section, 4,000 feet in length, paralleling the foot of the mountain, was expected at some future date to form a portion of a highway (since constructed), to an Indian village known as Squaw Bay, on the shores of Lake Superior. From this section, the very numerous boulders were first removed, stumps grubbed, and a ditch excavated on the upper side, properly graded, so that all surface water was carried through dry stone culverts, placed at every depression. On the bed thus prepared six inches of fine quarry debris was placed, consisting largely of a soft slaty rock which compacted into a firm even bed, after which, a two-inch layer of fine gravel was spread. It was impossible to use a steam roller, as no suitable scow was available for crossing the river, and the steep soft banks were practically prohibitive, unless a large amount of work was first done.

A further 5,200 feet of road were necessary to reach Crescent Lake, and as this was a construction road, the specifications permitted the contractor considerable latitude in its location. It was practically a dirt road twelve feet in width, constructed of the marl which forms the subsoil on all the surrounding hill sides that are not solid rock. When drained efficiently it forms a very satisfactory roadbed, and with a little care, stands up well under heavy traffic. The grade secured was in places as high as fifteen per cent., which proved too great for economical hauling. As a remedy an extensive cut off was made by the city force preparatory to the construction of Sections 2 and 3, thereby reducing the grade to seven per cent.

The intake at Crescent Lake is of cast iron pipe, 10 inches in diameter, 300 feet long, extending through Dam No. 1. Every fourth joint is a Ward flexible joint, excepting that portion under the dam. The outer end was formed by a quarter bend resting on a low crib. Fish being excluded by a rose eighteen inches in diameter, made of galvanized iron and closely perforated with one-eighth inch holes.

The backfilling of the trench through the dam site was puddled clay with cut off walls of the same material, placed two feet wide and ten feet centre to centre, carried across the trench, and one foot into the ground on either side.

The dams were simple earth embankments ten feet wide on top with $2\frac{1}{2}:1$ slopes on the inside heavily rip-rapped with rock boulders found in the borrow pit. The outside slope was $1\frac{1}{2}:1$. Dam No. 1 was located across the natural outlet of the lake and contained the intake pipe. Dam No. 2 was located on a low divide that would have permitted water to escape through an adjacent valley, when the level of the lake was raised four feet. The material used was a marl mixed with a fine gravel. Core walls of puddled clay, four feet in width at the base, were carried down to solid rock at No. 1 Dam, and to clay in No. 2 Dam. The material was deposited in nine-inch layers by two wheeled dump carts, and each layer watered. The core was hand rammed. Dam No. 1 contained 3,000 cubic yards with a maximum height of 11 feet, and Dam No. 2 contained 980 cubic yards with a maximum height of seven feet.

A rough hewn log manhole was constructed on the outside of Dam No. 1, containing a ten-inch gate valve on the intake pipe, and a four-inch branch with air pipe carried level with the top of the dam.

In the middle of Dam No. 2, a timber sluice way was constructed, which served the double purpose of a spillway and drain off, in the event of further work becoming necessary in stripping or treating the flooded area.

The sluice way was constructed of 8-inch x 8-inch timbers, well caulked and backed with puddle. The floor was placed at the normal water level of the lake, constructed of 8 inch x 8 inch timbers covered with three-inch plank. A groove was formed by vertical posts to take 6 inch by 12 inch by 8 feet stop planks, surmounted by a jack roll for hoisting. These were thoroughly caulked and made water-tight.

A trench of 6 feet bottom width was constructed from the lake to the sluice way, and from thence through the gap to provide drainage.

For the 8-inch supply main, 2,000 feet in length, from Crescent Lake to the reservoir, a right of way 30 feet in width was cleared and grubbed. The pipe used was the wire-wound wood pipe of the Pacific Coast Pipe Co., Ltd., guaranteed to work under a head of 150 feet, with 6-inch wire-wound sleeves. Each pipe contained nine staves one inch thick, wound with No. 6 gauge wire, spaced 1¾ inches, centre to centre. Three lengths of 8-inch cast-iron pipe were used at its junction with the reservoir.

The grade line was so laid that 3 feet of covering could be secured throughout. Where solid rock was encountered, the grade line was raised so that only 18 inches of excavation were required, and an embankment with 3 to 1 slopes placed over the pipe to secure the required covering. In reference to the depth of covering required, it has been found that in this locality frost penetrates to a depth of 6 and 7 feet on travelled highways or other exposed surfaces, whilst in the ditches at the side of the same highway, in the bush, and in all places where the snow is not disturbed, frost seldom penetrates more than 6 or 8 inches, and then only when cold weather is experienced before the first snowfall. The lines under consideration lie amidst some of the wildest and rockiest sections within the boundaries of an Indian Reserve, and there is little danger of any change of conditions.

In the valley a blow-off valve was placed in a log manhole and a drainage ditch excavated.

Reservoir.

A concrete-lined reservoir was constructed near the point of a ridge composed largely of solid rock, of approximately 800,000 imperial gallon capacity. Top inside dimensions were 85 feet 5 inches by 76 feet 10½ inches, and the depth ranged from 20 feet 6 inches at the Loch Lomond inlet gate chamber to 21 feet 6 inches at the waste pipe.

On the reservoir site, four test pits and some twenty borings revealed from one to five feet of marl overlying the solid rock (a black basalt), and construction was commenced on that assumption. It was found, however, as the work proceeded, that, at about 15 feet from the east wall, the rock took an almost perpendicular dip parallel to the wall, and that underlying the five feet of surface marl was a bed of boulders and marl that had been assumed to be solid rock in sounding. Underlying the boulders, and continuing to the bottom of the excavation, was a strata of exceedingly hard material, as tough as gumbo and as hard as cemented gravel. In the main excavation it was blasted, but, in trimming, six powerful Swedes with picks broke less than a cubic yard after an hour's strenuous work. It stood for nearly two months quite vertical, without the least sign of change.

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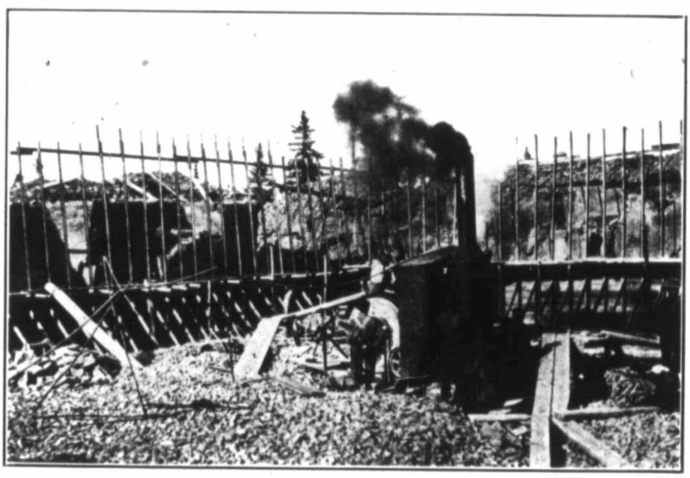

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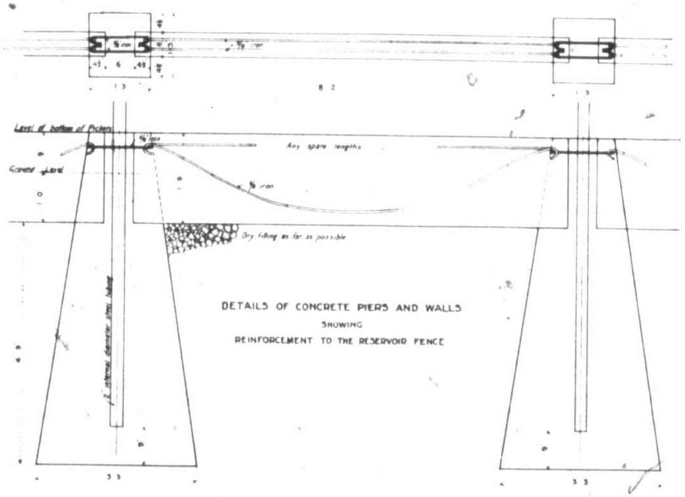
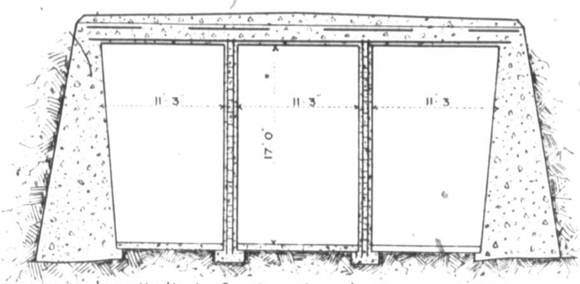
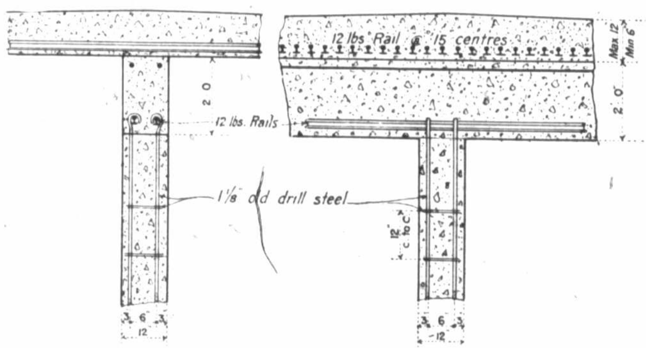


DETAILS OF CONCRETE PIERS AND WALLS
SHOWING
REINFORCEMENT TO THE RESERVOIR FENCE



Longitudinal Section through Beam and Slab



Section through Slab

Section through Beam and Slab

SKETCH SHOWING REINFORCED CONCRETE COVER TO FOREBAY.

The specifications provided that the utmost care be exercised by the contractor in excavating the rock, and any material shattered or broken down outside the cross-section, owing to carelessness or negligence or any cause not directly due to a fault in the rock, was to be replaced by 1 : 2 : 5 concrete at the contractor's expense. Notwithstanding the great care exercised, numerous slips occurred, which materially increased the quantity of concrete used in the lining.

The concrete used throughout was composed of one part of cement to two of sand and five of crushed rock.

The cement used was the "Sampson" brand, a marl cement of the Owen Sound district, after passing tests conforming to the Canadian Society of Civil Engineers' standards. The sand came from the shores of Isle Royale in Lake Superior, being delivered on the river bank and hauled by teams to the work. The rock was hand broken to 2-inch size on the site of the work. "Fillers" of about 1 cubic foot were permitted in the filling of gaps left by the rock slips, when surrounded on all sides by 6 inches of fine concrete.

The concrete was mixed in a steam-driven No. 1 Ransome mixer.

All exposed faces of the concrete were grouted, at the time the concrete was placed, with a mortar composed of 1 part of cement to two parts of sand, mixed dry with 1 per cent. of powdered alum. One per cent. of soft soap was dissolved in the water used for mixing. This grout was approximately 1 inch in thickness.

The floor was of concrete, not less than 6 inches thick on the rock section, and 12 inches thick on the gumbo. It was laid in sections 10 feet square. Alternate squares were laid and permitted to set, the omitted squares being subsequently laid. A 1-inch surface was floated and finished as for a sidewalk.

The walls were 18 inches wide at the top battering, 1 in 12 on the inside face, and 1 in 6 at the back.

The top of the walls had an elevation of from 3 to 5 feet higher than the natural surface, and were carried down on the above plan to solid rock, where they took the form of a concrete lining. No point of rock was permitted within 6 inches of the face, and the ragged nature of the rock brought the average well over 15 inches from it. The rock was first washed and cleaned, and all friable and loose portions removed, so that a good bond was obtained between the cement and the native rock.

The supply from Crescent Lake was admitted in an 8-inch cast-iron pipe, through a concrete gate chamber placed 10 feet from the floor level of the reservoir, and containing an 8-inch gate valve and 8-inch check valve. On the pipe projecting into the reservoir was fitted a balance float valve, with a galvanized-iron float of 30

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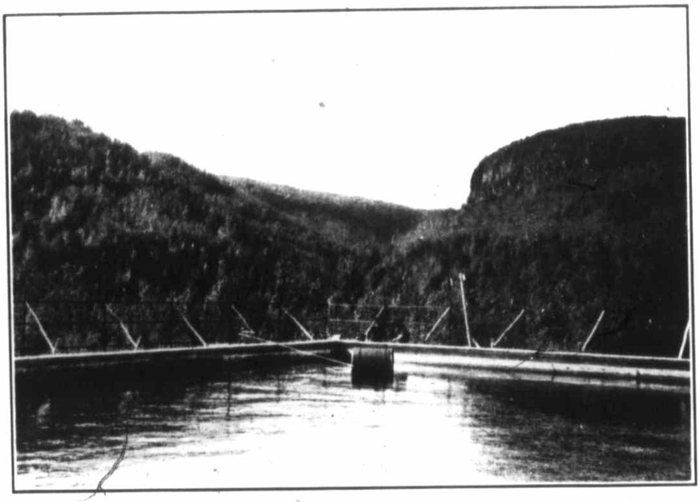
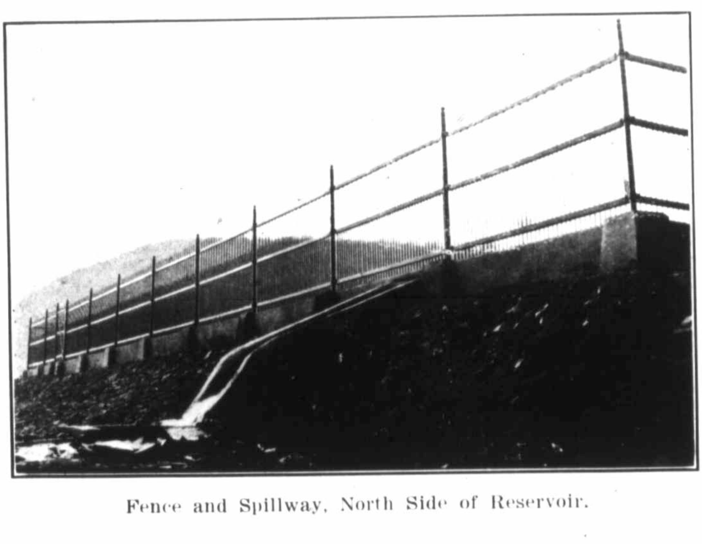


Southeast Corner of Reservoir. Crescent Lake Valley in Distance.



Fence and Spillway, North Side of Reservoir.

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inches diameter attached by a chain, which maintained the water at constant level without overflow or waste.

At the south end of the east wall a gate chamber, which contained an 18-inch gate valve and an 18-inch check valve, admitted the 18-inch supply main from Loch Lomond. The inlet being close to floor level, the check valve would prevent the loss of 800,000 gallons in case of breakage in the supply main. A float valve has since been placed on this pipe.

The outlet to the pressure mains is through a 6 feet by 6 feet gate chamber at the north end of the east wall. Four 18-inch sluice valves control the flow from the reservoir—two at the floor level and two 10 feet above the floor level. Two additional sluice valves control the flow to the pressure mains. Two 12 inch by 12 inch projections are grooved to hold two series of wood frames each in 6 feet by 4 feet sections and covered by screens of ¼-inch mesh copper wire.

In the northwest corner three lengths of 18-inch cast-iron waste pipe, with sluice valve, afford means of cleansing the reservoir through a waste channel excavated in solid rock. A spillway, 2 feet in width and 18 inches deep, was constructed to carry any overflow to the waste channel when the float valves are not in operation. This spillway was taken over the filled ground on piers 14 feet C—C, carried to solid rock. The floor of the spillway was reinforced with four 12-lb. steel rails.

Wrought-iron ladders were placed in all manholes and one to furnish access to the floor of the reservoir.

The covers to all manholes, excepting the outlet manhole, are made of 2-inch plank, resting on 3 inch by 6 inch joists, spaced 24 inches C—C, and are provided with hinged and padlocked trapdoors. Additional joists were placed under the bases of the wheel stands. The outlet manhole is covered with a grill formed of 2 inch by 4 inch lumber standing on edge and spaced 3 inches C—C to afford ample ventilation.

Before backfilling was commenced, all exposed outer faces were coated with two coats of coal tar. The filling was carried up in well-tamped layers, not exceeding 1 foot in thickness. Well-puddled clay was used adjoining the walls and carried up slightly in advance of the rest of the backfilling, so that, when finished, all exposed surfaces were backed with a coat of puddled clay not less than 1 foot thick. The backfilling was carried to within 6 inches of the top of the coping, and a berm formed 10 feet in width, trimmed from the crown on a 1½ to 1 slope. On the east side the filling formed an embankment approximately 30 feet high. The top 4 inches of the berm were formed from selected screened earth, raked smooth and level, sown with grass seed, and a similar coating provided on all slopes.

During the construction of Section 2 a simple wrought-iron fence, 7 feet in height, was erected around the reservoir, 8 feet from the walls. It is divided into panels of 9 feet 5 inches by 2 inch pipe posts, set in concrete piers, 15 inches square on top, with a base 3 feet 3 inches square carried into the ground to a depth of 6 feet 6 inches. The piers are joined by an apron wall of reinforced concrete, 6 inches by 21 inches, the top of this wall being level with the top of the piers and 3 inches higher than the berm inside the fence. On the outside the berm is lowered 15 inches, adding materially to the appearance of the fence, and rendering the interior more difficult of access to frogs and other obnoxious visitors.

A double byepass of 18-inch pipe, placed at the foot of the east slope, 60 feet from and parallel to the east wall 9 feet C.—C., was carried at right angles to the supply main from Loch Lomond by means of two Y branches and two 45° bends. Two 18-inch gate valves were placed on the byepass pipes immediately on leaving the supply main. Junctions were effected with the pressure mains by Y branches and 45° bends curving in the direction of the flow from the reservoir.

It is possible that a reinforced concrete reservoir might have been constructed at less cost than the above, but the uneven nature of the ground would have necessitated considerable excavation in any case, and the amount of backfilling demanded by the excessively cold winters, further aggravated by the exposed situation, would have been difficult to obtain within reasonable limits of haul.

PRESSURE MAIN.

Wood Pipe.—For a distance of approximately 10,600 feet, from the reservoir to the boundary between the Indian Reserve and the Grand Trunk Pacific property, this main was of 18-inch wood pipe. The location was chosen with care, in order to avoid, as far as possible, solid rock excavation. From the first preliminary line, cross lines were cut at every station from 1 to 800 feet on both sides of, and at right angles to, the preliminary line. Bar soundings to a depth of 6 feet were taken every 50 feet on the cross lines. The good soil and rock lines were plotted and a location projected that secured, with slight revision, a line containing only 135 feet of rock trenching, with little loss of distance. For the information of contractors, previous to calling for tenders, test pits were dug every five stations and bar soundings taken at every intervening station.

The pipe was laid on a true grade line, falling more or less from the reservoir to the river, obviating all summits and sags. The excavation nowhere exceeded 8 feet in depth, and where the trench was not sufficiently deep to secure 5 feet of covering, the deficiency was made good by embankment.

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In order that there might be no delay in commencing work after the contract was awarded, 7,000 feet of pipe were ordered by the city some weeks previous to that date. This pipe was manufactured by the Pacific Coast Pipe Co., of Vancouver, B.C., guaranteed to work under 300 feet head, and the remainder of the pipe was specified to be of the same make and the same specification.

The first negotiations between the city and this Company contemplated a pipe made up of 18 staves of selected Douglas fir, 1¼ inches in thickness, the staves being joined by a zigzag cut, with the edges in the form of a double V, a form of joint patented by the Company. The pipe was wound spirally with a continuous wire wrapping of No. 4 gauge galvanized wire, spaced half an inch C.—C., and the whole outside of the pipe covered with tar. The spigots, being slightly bevelled, were driven into a socket in a special cast-iron collar, known as the "Perfect" coupling. This coupling was used in practically all the earlier installations by this Company for pipe of this size, I believe, with uniform success. Before the pipe was purchased, however, the Company stated to the city by letter that "The cast-iron coupling is too expensive for such a size of pipe, and no object would be served in using it."

The sleeve first proposed by the Company as a substitute for the cast-iron coupling was wire-wound in the same manner as the pipe, a sample of which was submitted to the city. A sleeve of this form was used on the 8-inch pipe supplied by this Company for the "temporary supply" pipes, and gave satisfaction. The pipe was ordered by the Board of Commissioners on this basis.

Immediately on receipt of the order, however, the Company suggested that, instead of the wire-wound sleeve, it would be better to use soft steel bands, drawn up with shoe and nut similar to that used on continuous stave pipe, as they had discovered this to be the general practice in Seattle for pipe of this size for heavy pressure. In addition, they strongly recommended this form of coupling, and were quite willing to bear the extra expense entailed in order to have the very best form of coupling. They still held to the opinion that the sample wire-wound coupling was fully capable of filling the bill, but that the suggested band coupling was even better.

They also undertook to send a good man, who would be a working foreman, and, with a gang of unskilled laborers, would lay the pipe to the city's satisfaction. In a later letter, this man was to be an expert from their factory.

Briefly, in a voluminous correspondence, the Company, backed by their local agent, exhausted every means to impress on the Board of Commissioners the reliability of the pipe, the ease with which it could be laid, and the satisfactory service it would render.

The contractors duly took over the pipe from the city and requested the Company to furnish the expert to lay the pipe at the price stated, provided the Company guaranteed the pipe against all leaks, damages, etc., in the completed line, and the contractors from all loss, cost, and damages caused by leaks, etc., in any of the pipe or specials. No reply appears to have been received to this communication, excepting the arrival of the man in due course.

The wire spacing on the pipe as supplied was increased as the head diminished, and the pipe quantities of each kind were as follows:

7,650 feet pipe for 300 feet head, wire spaced ½ inch C.—C.
2,000 feet pipe for 250 feet head, wire spaced ¾ inch C.—C.
1,000 feet pipe for 150 feet head, wire spaced 1¼ inches C.—C.

Five band couplings were furnished for the 300 feet head pipe and four band couplings for the lower heads.

Pipe-laying commenced the first week in July in charge of the pipe Company's expert. From one to four hours' work daily on the part of the pipe-layers was usually sufficient to keep up with the excavating gang, who prepared from 1 to 500 feet of trench per day. On one occasion the pipe-layers, after being delayed for some days, laid just 1,000 feet in 10 hours. The gang consisted of 5 men. Couplings were driven half on to one end of each pipe at the side of the trench. These couplings were 8 inches in length, held together with five half-inch bands of round, soft steel, fitted with shoe and nut. The bands were left moderately loose during the process of driving. The spigot of the pipe to be laid was first placed in the collar of the last pipe in the trench. A tompion of turned wood, 2 feet long and 22 inches diameter, with 4 inches at the end turned down to fit the inside of the collar, was then placed in the coupling, and a pole ram of 12-inch diameter, 18 feet long, slung on a tripod, legged across the trench, was used to drive the spigot into the coupling. These spigot ends were turned in the factory, but arrived on the work with some defects, principally due to a slight warping in individual staves, and to small slivers being knocked out during transportation. Apparently, however, great care was taken to rasp the outside of the spigots to secure a smooth surface, and about 8 per cent. were cut back from 6 inches to 2 feet and a new spigot rasped. When the driving was completed, the bands were cinched up.

To prevent the floating of the pipe by the surface water, back filling was placed on only the middle of every pipe, so that all joints would be exposed until tested, excepting in the soft portions of the trench, where this procedure was impracticable.

Two untoward incidents occurred during the progress of the work. A heavy rainstorm floated up about 200 feet of pipe, in spite of the back filling between the joints, and partly filled the trench.

necessitating the relaying of the pipe. The other consisted in 700 feet of pipe, with five band couplings, being laid on the low-pressure section of the line, whereas the Company had provided four band couplings for this section. This had to be taken up and relaid on the high-pressure section.

Pipe-laying was completed within 200 feet of the reservoir by the third week in September, when a wait was enforced by a delayed shipment of pipe. Early in October the writer was suddenly attacked with typhoid fever that occupied his attention for eight weeks, but the subsequent course of events appears to have been as follows.

The contractors, fearing the approach of winter, proceeded to backfill all joints, although the writer had taken special pains to impress on them the importance of leaving them open. The inspector, who was aware of these instructions, had been transferred to other work when the pipe-laying ceased in September.

The remaining section of pipe was placed in position about the 20th October, and water turned into the pipe during the second week in November, when the reservoir was sufficiently completed for use. With the reservoir full, and the Crescent Lake supply feeding 1,000 imperial gallons per minute, it was impossible to fill either the whole pipe or the 5,600-foot section between the reservoir and the first valve. On November 16th the contractors wired the Company that the pipe was full of leaks, and that their expert refused to remain on the job. The Company sent a second representative, who co-operated with the first in attempting to repair the leaks.

The winter was a severe one, and 5 feet of snow covered the ground until the following April, so that excavation was a difficult process. The serious condition of the pipe line was not at once revealed to the city. In fact, the Company's representative, on several occasions, stated to the Board of Commissioners that a matter of two or three weeks would make the line tight. Practically every leak was located at a coupling, the pipe itself holding generally in good shape. Of the thirteen or fourteen collapsed pipes taken out during the long series of repairs, two collapses were due to defective and wind-shaken staves, and the remainder largely due to the cutting of the wire at the spigot by the action of sand and water causing the collapse of the staves.

Early in March substantial progress appeared to have been made on the repairs, and a test was made. A gauge at the river end of the pipe line recorded within 2 lbs. theoretically correct pressure, and only four or five leaks appeared through the snow. These were repaired and the test again applied, when, in the course of a few hours, three or four other leaks appeared. This process was continued until the spring thaw at the end of April, when a really appalling state of affairs was revealed. Between Station 202 and the reservoir the gravelly nature of the soil, aided by the snow water from the side hill, made it impossible to ascertain the number of leaks, as almost every joint had been excavated, and the holes were now partly filled with running surface water. It was evident, however, that many joints were leaking.

From Station 209 to Station 260 the water came up freely through the sand, and a count on May 4th revealed 138 serious leaks in this section. The pipes were of various lengths, but probably averaged 12 feet, and the defective joints were, therefore, 36 per cent. of the total number. Little work had been done on this section up to this time, as the winter operations had been largely confined to the hill section above Station 209.

Commencing at the lower end of the wood pipe line at the Grand Trunk Pacific boundary, Station 260, the pipe lies, as far as Station 229, in firm sand, which, although wet, packs well around the pipe. From Station 229 the pipe is laid in a grey quicksand mixed with fine particles of mica, as far as Station 213, where firm ground lying at the foot of the mountain is encountered. Proceeding along the base of the mountain to Station 177, the material is alternately marl and coarse sand, mixed with water-worn boulders, varying from pebbles up to 15 cubic feet in size. Above Station 177 a section of solid rock, 60 feet in length, was encountered, overlaid by 2 feet of marl. Stations 176 to 168 produced a species of stiff, sandy loam. At Station 168 an old pebbled beach ridge intersected the line, above which was a 400 feet section, reaching to the foot of a steep rise, of water-worn flat stones of a slaty shale rock. From Station 164 to 156 the ground was a stiff marl and loam, with an occasional small boulder. At Station 156 there was a solid rock outcrop extending 125 feet to the point where the trench entered the regular hillside marl to the reservoir.

In spite of this large variety of material, the leaks were very impartially distributed.

Two methods of repair were adopted. First, wedges of Douglas fir were driven between the collar and the spigot, following from the main leak around the collar until the water had ceased to flow. Later, these wedges were driven into the centre of the staves forming the collar, with better results.

The representatives of the pipe company were still quite confident that the pipe could be repaired, and attributed the non-success of the winter operations to the amount of ice accumulating around the bands between the collar and spigots. After some negotiations, the contractors put on a large force of men under the direction of the pipe company's experts, and at the end of two months of strenuous work the leaks on the entire line were reduced to about 30. Many holes were, however, not backfilled, and the surface water prevented accurate inspection. A gang of six men, with a No. 3 Edson pump, was able to repair from three to seven leaks daily, but some joints were repaired as many as fifteen times. In practically every case, excepting the very worst, all subsequent leaks occurred at a different point on the collar from that first repaired. A large number of the first leaks appeared at the point where the outside bands rode for some two and a half inches clear of the collar on entering the shoe. A broken pipe meant a whole day's work for a small gang. When the pipe was sufficiently tight, and the leak was not too large, repairs were made under pressure. To begin with, this pressure was kept low, but many leaks, thus repaired, broke out again when the full pressure was used. Early in June the gang was reduced to twelve men, and the pipe company's man left the work, with the expectation that the remaining leaks would be fixed in a few days. At the end of two weeks it was found that the number of leaks had increased in spite of all the work done, and the contractors threatened to abandon the work. This they did at the end of July, after some stormy negotiations, having spent $11,000 since the 1st of December on repair work.

The writer then made an attempt to continue the work with a gang of ten men. By extensive ditching, much of the trouble from surface water was removed, and each joint on the flat, sandy section was backfilled as soon as repaired. By this means the leaks were reduced at times to less than a dozen, and for some time stayed below 20. A gang of four men were able to maintain the number at this level. Any increase in force appeared to increase the number of leaks, as, apparently, a certain number of leaks were necessary to the pipe, although air valves were placed at frequent intervals. Water was turned on in October and the pipe operated with this small gang constantly at work, tests revealing that the daily loss from the pipe amounted to 200,000 imperial gallons.

At the end of December, when the Crescent Lake supply practically gave out, all uncovered joints were protected by spruce boughs and backfilled with snow to prevent freezing.

In the following April, when the pipe was again operated, four leaks appeared during the first five days, followed rapidly by many others. A gang of six men was again put to work fighting the old battle with the leaks. This gang was kept constantly at work, but at the end of July, when the Crescent Lake supply again gave out, there were 150 leaks of all kinds. Altogether, since the repairs started, over 3,000 leaks have been stopped, or, approximately, an average of three leaks for every joint.

In October, 1906, the city paid the pipe company $5,000.00 of the total charge of $9,500.00 for the 7,000 feet of this pipe, purchased by the city. The balance remained unpaid.

In June, 1908, the pipe company entered action against the city in the High Court of Justice of the Province of Ontario, for the recovery of this amount. A similar action was brought against the contractors for the recovery of $1,900.00, the balance due on the pipe purchased by them. The city taking the ground that the pipe was unsuited for the purpose for which it was purchased, counterclaimed for the amount already paid the pipe company, viz., $5,000.00, for the amount paid the contractors for the balance of the pipe, $6,000.00; and for the sums actually spent by the city in repairing leaks at that time, about $6,000.00. Also for the estimated sum provided in the Wm. Newman & Company contract for the trenching, laying, and backfilling of this pipe, approximately $20,000.00, as well as any other damage that had been sustained by the city. The contractors counterclaimed for $11,000.00, the amount spent by them on repairs. The two cases were tried together at Port Arthur June Assizes, before Chief Justice Falconbridge.

Briefly, the points stated for the Company were as follows:

1. The pipe was well made and delivered in good condition.
2. That in numerous other cases it had proved successful for similar purposes, at equal or greater pressure.
3. That it had been exposed to the atmosphere for too long a period.
4. That the pipe had been mishandled.
5. That it was not properly laid.
6. That the excavation was largely through solid rock, and the pipe insufficiently protected from jagged edges.
7. That the backfilling was carelessly done, and large boulders had been thrown on the bare pipe.
8. That it had been backfilled whilst empty, and was left too long in the trench before being filled with water, causing it to flatten out and lose its circular shape.
9. That the expert sent from the factory was an employee of the contractors, and the Company were in no way responsible for his actions.

The case for the city was based primarily on the guarantee contained in the various letters leading up to the purchase, and on statements contained in the Company's catalogue.

It was stated, on behalf of the city, that the pipe itself gave practically no trouble, and that, at least ninety per cent. of the difficulty was experienced at the joints, and that faults in the pipe, whilst not sufficient to be detrimental in the barrel, were fatal at the spigots. It was contended that the staves at the spigot varied as much as one-quarter of an inch in thickness in the same pipe, and were cut in such a promiscuous manner, in regard to the grain and the quality of the wood, that uneven shrinkage and expansion occurred; also the centre of the staves varied in thicknes from the edges to as great an extent as $\frac{3}{32}$ inch, and that many of the pipes varied over half an inch from a true circle, all these circumstances tending to leave a margin between spigot and collar. It was stated in evidence by the factory superintendent that, from the selected logs supplied him, the maximum number of staves were secured, only those showing flaws were rejected, and that such rejected staves formed a very small percentage of the whole. The city contended that if such an authority as Mr. Arthur L. Adams, M. Am. Soc. C. E., considered that only twenty per cent. of the staves cut from selected logs were fit for use in the wood pipe of the Astoria Water Works, (See *Transactions*, Am. Soc. C. E., Vol. XXXVI, p. 15), the methods adopted by the Company were not in accordance with good practice. It was also contended that the couplings suffered from the same haphazard selection; that they were too short for the work required of them, that the bands were not suitable where the outside of the pipe was in wet ground, as on the expansion of the wood by moisture, the bands buried themselves to half their diameter in the wood, whereas, the flat base of the shoe prevented its sinking to the same extent as the bands, thus emphasizing the space where the band rode clear of the wood to reach the shoe. This shoe being too large and heavy for such a small diameter pipe, many of the leaks occurred at this point.

It was also ascertained that the satisfactory cases quoted for pipe of this size at equal pressure, supplied by the Vancouver factory, had been fitted with cast iron couplings. Some Seattle cases were cited, but details as to pressure and conditions of laying were not forthcoming, and the pipe had been manufactured by the American company of the same name.

It was also established that the contractors gave the pipe layer full charge of the unloading and handling of the pipe, giving him all the men and appliances asked for. The pipe layer himself testified that such was the case, and that he put no pipe in the trench until he was thoroughly satisfied as to its condition. If there was the slightest flaw at the spigot, he cut back the pipe and formed a new spigot. Also that the pipe had been well and properly driven. This latter statement was borne out by the fact that every pipe taken out for any cause was found to be tightly driven to contact with the adjoining pipe. As to the exposure to the atmosphere, it was pointed out that the Company had shipped the pipe on flat cars from Vancouver, involving a journey of from three to five weeks duration through a variety of climates, totally unprotected from climatic conditions, and that evidently, they did not consider exposure injurious, as neither they, nor their expert pipe layer, mentioned such a possibility, until some time after repairs had commenced. However, the writer cannot do otherwise than surmise that the change from the humid coast atmosphere at the point of manufacture to the comparatively dry climate east of the Rockies might have had an important bearing on the distortion of some of the staves. This view would seem to be borne out by the fact that west of the divide, success has attended almost every installation, whilst in the Canadian prairie Provinces, wood pipe has left a marked trail of trouble and disappointment, although there may, of course, have been special local contributory causes.

As to the injurious effect of the solid rock, it was easily demonstrable that less than 200 feet of solid rock trench was encountered on the line, and even when encountered, sufficient good material overlaid the rock to provide at least a foot of packing for the pipe. In any case, the leaks on the solid rock sections were considerably below the average.

A large amount of testimony was given on behalf of the city as to the care exercised in backfilling. In all cases earth or sand was well rammed around, under and over the pipe until it was covered to a depth of one foot. The remainder of the backfilling was carried up in foot layers, but the same care in excluding stones and small boulders was not considered necessary. Large boulders were rigorously excluded. It is true that some small boulders were in contact with the pipe at various times, but this was due to two causes. First, a break or bad leak released such a large volume of water that the original bottom filling of earth and sand was washed out, particularly on the side hill, and some of the upper stones worked down to the pipe. Secondly, in excavating at a joint to repair a leak, the original width of trench was necessarily exceeded, and some small boulders encountered in this additional excavation slid so far as to remain in contact with the pipe. In reference to this alleged damage from boulders, it should be pointed out that the typical boulder section was between Stations 184 and 209. On this section, less work was done than on any other, and on no single occasion, after the first series of repairs did the writer ever count more than twelve leaks, and frequently only three or four. In fact, this section was the only one that approached any degree of permanent tightness.

The contention that the pipe had been backfilled whilst empty was true as to the upper sections of the line, but there is no doubt that the 6,000 feet crossing the flat was full from the time of laying, although not under pressure. The end of the pipe at the G. T. P. boundary, where it subsequently joined the cast-iron pipe, was kept plugged. This connection was one of the last operations performed and a large quantity of water was released by a short trench draining to the main drainage ditch of the railway company, when the plug was withdrawn. Some portions of the trench, especially those in quick sand, had to be covered to prevent the pipe being floated up by the pressure of the sand working under the sheet piling. The surface water had the same effect in the firmer portions of the trench at every rain storm, and it was with difficulty the joints were left uncovered. These were filled by the contractors only a short time before the water was turned on. The writer's object in having them open was to facilitate any repairs, and not with the idea of relieving the joint from outside pressure, for however weak in other respects, the joint is the strongest portion of the pipe to resist the flattening out action suggested. Again, if this had been even a principal cause of the leaks, they would have shown chiefly at the top or sides, depending on the greater ability of spigot or coupling to resist the pressure, whereas, the leaks were located in almost every position in the same joint, and in the majority of cases, were close to the heel of the shoe of the outside band. It is also inconceivable that an outside pressure that would affect the double thickness of spigot and collar should have absolutely no harmful effect on the pipe itself, no leaks at all being found in the pipe, excepting in the collapsed pipes previously mentioned. The cause of these collapses was due in two cases to wind shaken staves, and in all the others, the trouble had started at the spigot, the water under pressure mixing with the trench sand cut large holes in the stave, and completely cut through the wire wrappings for three or four coils back. With the wire wrappings released, the pressure quickly found a suitable stave with the grain at an angle which split easily. The consequent distortion caused the collapse of the pipe.

The contention that the pipe laying expert sent from the Company's factory was not a representative of the Company, is disposed of in the finding of the judge.

The witnesses on behalf of the pipe company were the managing director of the Company, the factory superintendent, the expert who laid the pipe, and the city engineer of the neighboring City of Port Arthur.

The witnesses for the city were all past or present members of the City Engineer's Department.

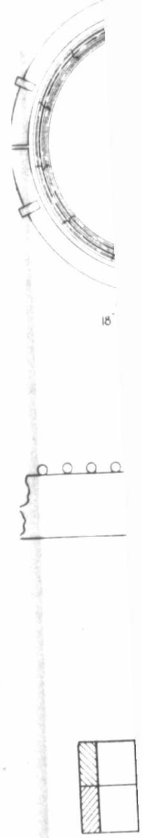
The contractors used evidence from two contractors who had previously had trouble with wood pipe in the Prairie Provinces.

In view of the conflicting nature of some of the evidence, the Chief Justice, with the approval of all parties, appointed Mr. E. H. Keating, M. Can. Soc. C. E., to inspect the work and make all the necessary tests and examinations, and report with a view to furnishing such technical assistance as might be necessary to arrive at a just verdict.

Mr. Keating spent several days early in August, in company with the pipe company's manager and the writer, in examining the work.

Shortly after inspecting the pipe line, Mr. Keating, in a letter to the writer, and one to the Pacific Coast Pipe Company, suggested the following method of repair, intimating that it seemed to him evident that the method hitherto followed of driving wooden wedges in the end of the sleeves was not a satisfactory remedy.

The drawing shows clearly the proposed method of repair, and Mr. Keating suggested that a trial be made on eight or ten of the worst joints.



Briefly, it provided for an angle bar 2$\frac{1}{4}$ inches by 1$\frac{1}{2}$ inches, being clamped around each end of the collar, held together by dog iron clamps $\frac{5}{8}$ inch square, packing being inserted between the ends of the collar and the angle iron as shown. This packing is of clean hemp fibre, thoroughly saturated with thick, neat Portland cement grout clamped up tightly and allowed to set before the introduction of water. This plan provided for moving the two outer bands around the present sleeve about $\frac{3}{4}$ inch inwards. If the moving of these bands was thought objectionable, Mr. Keating suggested the use of 1$\frac{1}{2}$ inch by 1$\frac{1}{2}$ inch angle iron, and the use of two additional dog iron clamps, aud reducing the size of these clamps to $\frac{1}{2}$ inch square iron. The wedges shown in the drawing were to be of steel.

The city was legally advised that the consent and co-operation of the pipe company should be secured prior to following this suggestion, but as such co-operation could not be secured, the case went to judgment minus this experiment.

The Chief Justice, the Hon. Sir Glenholme Falconbridge, gave judgment in February, 1909, in which he found "That the pipes were purchased by the defendants relying upon statements and warranties contained in the plaintiffs' catalogue, and in the correspondence, in effect that the pipe would give satisfaction and would fill all requirements perfectly." After quoting extensively from the catalogues and various letters, he continues: "I find that the defendants relied on the plaintiffs' skill and judgment to supply pipes fit for the purpose required, and that the pipes were purchased by the defendants relying upon the statements and warranties made by plaintiffs, that such pipes would give satisfaction, and would fulfil all requirements. I find that the pipes have not filled such requirements, but have proven unsatisfactory, insufficient, and unsuited for the purposes for which they were wanted, and I find that such condition of affairs has not been caused by any negligence on the part

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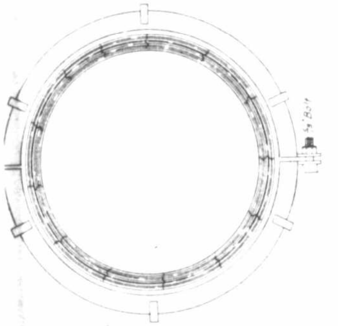
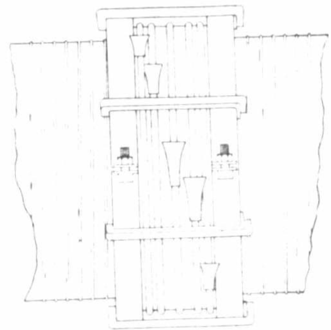
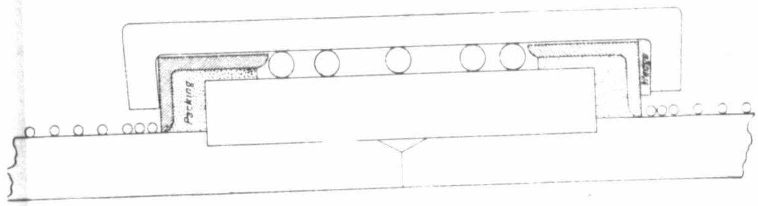
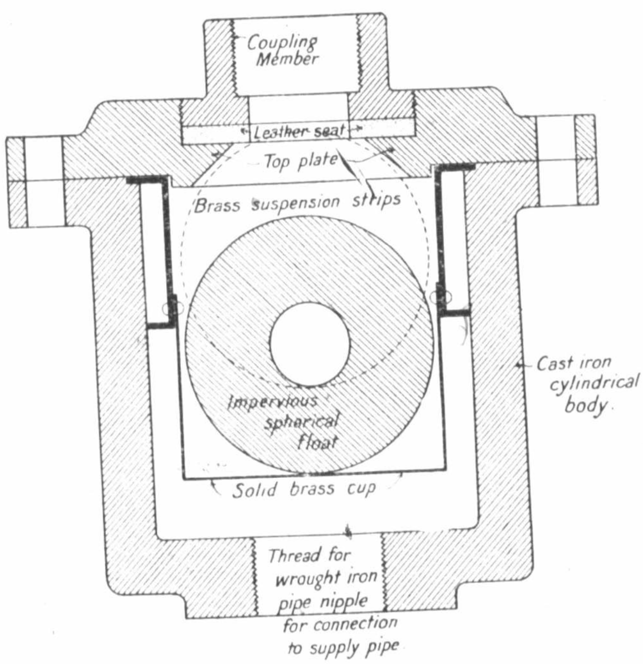


18" Wooden Pipe





SUGGESTED METHOD OF REPAIRING DEFECTIVE JOINTS
Keating & Breithaupt
Civil Engineers Toronto



SKETCH OF CRISPIN AUTOMATIC AIR AND VACUUM VALVE.

of the defendants in the laying of the pipes, which was done largely under the supervision of an expert supplied by the plaintiffs. The pipes were not reasonably fit for the purpose for which they were supplied. The chief, but not the sole defect, is in the coupling, which was proved to be absolutely defective. But there is also evidence that to some extent, at any rate, the staves did not answer the representation on page 29 of the catalogue, that they would be dressed on both sides to true mathematical segments, that when assembled would form a perfect circle."

"There was a total failure of consideration, and the plaintiff's action is dismissed with costs."

"There will be judgment for the defendants upon the counterclaim with reference to the Master to ascertain the damages.."

The Chief Justice further stated that in sending an expert of the standing of Mr. Keating, to the *locus in quo*, he was not without hope that the parties might adopt some temporary or permanent *modus vivendi* in order to avoid a result which would in the end turn out to be disastrous to one party or the other.

Mr. Keating's lengthy and closely reasoned report was attached to the judgment, the following digest of which will give the gist of Mr. Keating's observations:

After describing the pipe and its location, Mr. Keating stated that, "Practically the whole of the trouble in connection with this pipe line has occurred at the joints. The leakage in nearly every case was brought to my attention being at or near the shoulder, where the water spurts out through defects which exist at this point, or in that vicinity. In some cases, a number of such defects exist in a single joint, while in others the leakage is small and the water spurts out in a small jet. These small leaks, however, unless stopped soon after they start, cut into the wood and increase in volume rapidly. Several cases were noted where these jets had not only cut into the wooden staves to a considerable extent, but had also cut completely through and severed the banding wires at the pipe joints."

"The method hitherto adopted for stopping these leaks has been to drive wooden wedges into the ends of the collars, which has so far proved to be only a temporary remedy."

Mr. Keating also stated that this method of repair could never be satisfactory or permanent, and, if persisted in, could only have the effect of splitting off the upper portions of the collar staves and irretrievably ruining the collar.

Also that in numerous places where the pipe was bared between the joints, he could detect no leakage through the bodies of the pipe, and consequently inferred that the pipes individually had up to that time proved tight and satisfactory, and that the defects which have so far developed, are confined almost exclusively to the joints; being corroborated in this view by the representatives of the parties concerned.

Continuing, Mr. Keating says: "Regarding the total number of leaks in the pipe line, it is impossible to state definitely what the number is without stripping the whole pipe line, which, of course, would be an unwarrantable expense. This information, moreover, when obtained, would not appear to be of much practical value or reliable, except for the particular day on which the count was taken, if any reliance can be placed on the statements of the foreman of the repair gang, to whom I will refer presently. I attach, however, a list of the visible leaks on the 6th of August, giving the stations at which they were observed, but it should be noted that the reservoir on that day was at a very low level, the water standing at about 17 feet 4 inches below coping level, or only about 1 foot 2 inches above the top of the 18-inch pipe forming the outlet, when the observations were commenced. As the water-level, when the reservoir is full, would be some 16 feet to 17 feet higher, it is evident that the pressure on the pipe line under such a condition would be greater, and inferentially the leakage would also be greater and the leaks probably more numerous than shown in the list. It will be noted, by referring to the list, that the total number of visible leaks, omitting those of a doubtful nature, was 161, but there may of course have been other leaks, and probably are other leaks, which were not visible, and could not be detected without stripping the pipe.

I had an interview with Mr. Otway, the foreman of the pipe repair gang, in the presence of Mr. Perry and Mr. Hancock, who were the representatives who accompanied me during my inspection. Mr. Otway stated that he was engaged under the contractor, Newman, in October, 1906, at repairing the joints, and had remained on ever since at the same work. He asserted that every joint had been gone over at least three or four times since the water was first turned on, and that he had found from twenty to thirty new leaks every day in joints that had previously been repaired. This statement was not contradicted by either of the representatives, and I have no doubt that it is substantially correct. The inevitable conclusion to be drawn from this is that the method adopted for making repairs by means of driving in wooden wedges is not, and never will prove, satisfactory or permanent, and that, in the interests of all parties concerned, it should not be persisted in.

As it was impossible to determine by an examination of the pipe line, no matter how carefully made, what the total amount of leakage in the pipes was, I made a special examination of the concrete reservoir, from which the water supply is drawn, with this object in view.

"This reservoir has a total depth of about 20 feet below coping and is capable of containing, when full, 750,000 imperial gallons. Owing to doubts existing regarding its tightness, a test was made to ascertain what the leakage was, if any. It is, I presume, unnecessary for me to give the details of this test, which can be furnished if required. The result, however, was that no leakage could be detected, either in the reservoir or in the outlet chamber through which the pipe line is supplied. Both were found to be tight, with the water standing 17 feet 4 inches below coping level, which gave sufficient depth to test the pipe line. A greater depth of water over the outlet pipe could not be obtained without involving a delay of several days, which was deemed unnecessary.

"The total leakage in the pipe line was by this means ascertained to be at the rate of 15,400 imperial gallons per hour, or 369,600 gallons per day, on the 6th of August last. With the reservoir full of water, the leakage would of course be somewhat more.

"Under these circumstances, I do not think that the pipe line can be said to be 'fairly efficient,' nor can it be made so until some more effective method than hitherto tried of repairing the joints is adopted."

Mr. Keating then refers to his correspondence with the parties as to the suggested change in the method of repair, pointing out the danger of permitting the pipe line to remain in its present condition, and regretting that so much time has been allowed to elapse without some attempt being made to make the repairs effective.

Mr. Keating estimated the cost of repairing each joint to be $2.50 for material in quantities, and $2.50 per joint for labour, or a total of $4,450.00, assuming 890 joints in the pipe line.

In conclusion, Mr. Keating says, "I believe that the plan proposed would accomplish the object sought with the pipe line in the condition it was when examined by me, over five months ago. Of course, it may not be in the same condition now, and, in fact, must inevitably be in a very much worse condition."

The Company appealed this decision, but agreed to withdraw the appeal and pay $1,000.00 towards the costs of the city, if no further action was taken on the counterclaim.

In view of the fact that before any collection could be made on account of the counter claim, action would have to be brought in the courts of the Province of British Columbia, even after the appeal action had been successfully fought, the city was legally advised that in view of the delay and expense of further litigation, and the possible difficulties of collection, it would be wise to accept this compromise.

Mr. H. L. Drayton, K.C., of Toronto, and Mr. F. R. Morris, city solicitor, conducted the case for the City of Fort William, and Mr. F. H. Keefer, K.C., of Port Arthur, represented the Pacific Coast Pipe Company.

Since this settlement was effected, the writer has had some joints repaired, in accordance with Mr. Keating's suggestion, and has no hesitation in pronouncing it a decided success. The cost, however, was higher than anticipated, although due allowance must be made for the small scale of the operations, and the inexperience of local labour in making and installing the material.

In the flat section along the Mission Road, 5,000 feet in length, subsoil water and quicksand made the labour cost high. In this section the cost per joint averaged as follows:

Material..	$4.80	
Labour..	4.75	
	——	$9.55

In the upper sections conditions were more favourable, and the labour cost was reduced to $2.10 per joint.

Assuming 420 joints at $9.55 per joint	$4,001.00	
and		
Assuming 470 joints at 6.90 per joint	3,283.00	
	———	
Total cost of repairs		$7,284.00

With the operations conducted on a more extensive scale, this total could probably be reduced to $6,000.00.

The City Council are, however, chary of spending any more money on wood pipe, and it may not be possible to secure the necessary funds; in addition, the writer has considerable doubt as to the effect on the life of the pipe and collars produced by the bruising of the wood, inseparable from the operation of driving wedges.

That portion of the pressure main crossing the proposed yards of the Grand Trunk Pacific Railway, 1,930 feet in length, was of cast-iron pipe of standard specifications, with a minimum thickness of $\frac{82}{100}$ inches, and a minimum weight of 2,000 pounds per 12-feet length, tested to 300 pounds per square inch. The grade line by agreement with the company was kept at least ten feet below the proposed subgrade of the yard. Except where firm clay was encountered, the pipe was laid on wood blocks 6 inches x 12 inches x 48 inches, spaced 6 feet C.—C., the pipe being supported by wood wedges spiked to the blocks. Concrete chambers were built for the two gate valves on this section.

Kaministiquia River Crossing.

The river at the point of crossing is 330 feet in width and only one sounding revealed a greater depth than twenty-five feet. At this time the draft of boats operating beyond the proposed crossing to the coal docks of the Canadian Northern Railway, did not exceed seventeen feet, but before the work was completed the erection of a grain elevator and the establishment of a rail dock by the Grand Trunk Pacific Railway, developed a large traffic by ships drawing as much as twenty-one feet of water. This traffic was still further increased by tugs hauling scows to the dumping ground in the lake from the dredges working on the upper reaches of the river. The river has frequently a considerable current, and usually carries a quantity of alluvial matter in suspension. The water is naturally of a dark brown colour, owing to its passage through the muskegs and swamps that abound at the headwaters of the river. As a result fifty candle power lights can only be seen through it as a beacon at a short distance, and are of no value as an illuminant.

The bed of the river is covered by several feet of alluvial deposit and sand, overlying a bed of blue-grey clay, itself containing a small percentage of fine sand. Solid rock of uncertain character is found at a depth of from 55 feet to 58 feet below water-level. Overlying the rock is a bed of from 2 to 5 feet in thickness of gravel and small boulders, bearing water under a head that rises in the boring tubes some 4 or 5 feet above the surface of the river.

The question of a tunnel through the clay bed under the river was seriously considered, but it was decided that pipe lines would be sufficient for many years, and that this expenditure could be deferred until the growth of the city enabled it to bear the cost with less difficulty. Owing largely to an incomplete knowledge of the nature of the material to be encountered, this cost was originally thought to be much greater than will actually be necessary. It was also anticipated that pipe lines could be laid in a much shorter time, and the much-needed temporary water supply more quickly obtained.

It was the writer's original intention, when the pipe line had been decided on, to dredge two channels and lay a duplicate main of hub and spigot pipe, with a flexible joint at every fourth joint, as sufficient until such time as a tunnel became necessary. The majority of the Board of Commissioners objected to the flexible joints, and also to the ordinary lead joint for use under water. They wanted every joint under water to be a flanged joint, and were quite willing to bear any additional expense incurred by this method of construction.

The material for this work was ordered by the city from the D. Y. Stewart Co., of Glasgow, some weeks prior to the award of the contract.

A special Y connection was made with the pressure main on the south bank of the river, and two lines of hub and spigot pipe carried at a diverging angle of 45° with the centre line until the ends were 100 feet apart. 45° bends then carried the two pipe lines parallel 100 feet C.—C. to the bank of the river, where they dipped by an ⅛th bend at an angle of 45° degree to a grade line 28 feet below the normal water-level of the river. This grade was maintained for 300 feet on both lines, at which point 45° bends were used to bring them to the surface, where a duplication of the arrangement on the south bank connected them at a second Y with the 18-inch main leading to the city. Every joint under water was a flanged joint. The flanged pipes were 12 feet long, of standard specifications, ⅞ inch thick, and weighing not less than 2,000 lbs. per length. The flanges were ⅞ inch by 3 inches, supported by ribs, and provided with 12, ¾-inch bolts on a bolt circle of 22¾ inches diameter. Corrugated copper gaskets were used for all flanged joints, after the turned faces had been thoroughly cleaned and lightly smeared with "manganesite" paste.

Concrete cut-off walls were built around the pipes lying on both sides of every bend, as a support for the vertical bends and to resist the thrust tending to move the horizontal bends.

Two 18-inch valves with spur gearing were placed close to the south Y, and two laid flat with bevel gearing close to the north Y.

For the purpose of protecting the pipe at the water line from frost, and from the danger of contact with boats, two fifty feet piles were driven 6 feet C.—C., eighteen feet from the points where the pipes emerged from the river, six feet nearer the shore, and 12 feet C.—C., two more piles were driven, and two additional piles 18 feet C.—C. were driven close to the shore line. All these piles were securely tied together and into the bank with 8-inch x 12-inch walings, and 12-inch x 12-inch internal cross bracing. Any tendency to slide into the river was overcome by attaching the whole structure to four ¾-inch wire ropes anchored to dead men, 50 feet from the river bank. A second line of waling was sunk on the inside of the piles at a depth of six feet. 3-inch by 10-inch sheet piling was then driven on the inside of the walings around the frame thus formed, and the enclosed space backfilled to an elevation three feet above the top of the pipe.

The specifications allowed the contractor considerable latitude as to the method to be adopted in laying this pipe. The essentials were that it be laid to grade on a solid bed. That it should bear a test pressure of 200 pounds to the square inch. That the contractor should bear all loss from breakage or damage, until the final acceptance of the work, and the method of laying adopted was to be entirely at his own risk. He was also to provide all necessary appliances for laying the pipe, drive all necessary piling and furnish a satisfactory and permanent support for the pipe.

This somewhat indefinite clause was almost forced on the writer by the very short time available for the production of the specifications, and lack of time and opportunity to test some of the unknown factors in the problem.

Deferred delivery of the pipe delayed the commencement of this section until late in the summer. A sub-contract was let to the Great Lakes Dredging Company, of Port Arthur, the only company in the district, at that time, possessing the necessary dredges, scows, and diving outfit, and they placed an experienced diver foreman in charge of the work. The original soundings indicated that the solid clay foundation would be secured at the required depth. Two trenches, fifteen feet in width, were dredged across the river to a depth of twenty-eight feet below water level. The bottom of the trench was carefully prepared by a diver, assisted by careful measurements, and a firm level clay bed reported. Four lengths of pipe were then bolted together on the bank and lowered into a position by a hoist operating over the leads of a scow pile driver. Thus, every fourth joint was made by a diver under water. Before the first pipe line was completed the writer contracted typhoid fever, and tests were deferred until his recovery. Some of the bends had failed to arrive before winter set in, for which the contractor was not responsible, and it was necessary to extend the time of completion to the spring. The west pipe line had, however, been laid across and the most elementary tests proved it to be defective. The sub-contractors objected to doing any work during the winter, claiming, with justice, that the city had failed to supply pipe within the time contemplated by the contract. They finally, however, got their diver working, and just before the ice broke up, got the line in such shape that the loss could be approximately measured as not less than 2,000 gallons per minute at a pressure of 125 pounds. Immediately after the ice had left the river they made further attempts to improve the line by tightening the joints. The failure of their force pump, and the impossibility of procuring another, led, pending its repair, to the use of the pressure from the reservoir for temporary testing. One of the joints on the banks invariably blew out under this treatment, and some weeks were consumed in fitting a sleeve on this joint. When this had been fixed, gauges on opposite sides of the river showed a pressure loss in the crossing of three pounds, and it was quite obvious that the joints under water were so badly made that the whole pipe line must be moved to effect a closure. The contractors were, therefore, notified that the pipe line must be taken up and re-laid. They then took the position that the material supplied by the city was defective, and that a tight joint could not be made with copper gaskets. This latter statement was easily refuted by an object lesson on the bank. The sub-contractors were in a rather strong position, as they owned the only available equipment within a large radius. However, after several weeks of acrimonious negotiation, it was arranged that the chief contractors were to take over the work from the sub-contractors, and that the latter would supply the necessary equipment at an agreed price per day. The chief contractors then arranged for the writer to directly handle the work, they to pay all costs.

Examination by an independent diver revealed the fact that, contrary to the report of the sub-contractors' diver, a clay bed had not been secured, and that there were holes filled with unsatisfactory material in the trench, varying from 1 to 3 feet below grade, and in some cases extending over three or four pipe lengths. There was a slight deflection either up or down at each joint made under water, and some bolts were missing and others very loose. Work was commenced by raising the east pipe line, three lengths at a time, care being taken that the joints that had been made under water should not be disturbed until they had been examined on the bank. This bank inspection revealed the fact that the previous diver, in his efforts to stop the leaks, had driven wood wedges between the flanges, forcing the copper gasket into the centre of the pipe.

There being no effective hydraulic dredge on Thunder Bay, and the dipper dredges in service only working to a depth of 29 feet, it was impracticable to lower the grade line for the purpose of securing a firm bed, and it was decided to support the pipe throughout its length. The obvious solution was to drive a double row of piles and support the pipe on the caps joining the two rows. Suitable materials and equipment for this form of construction were, however, not available, and the following was adopted in lieu of it:

Concrete blocks, 1 foot by 3 feet by 5 feet, were cast on the bank, reinforced with four bars of ½-inch round steel each way. Two ¾-inch inverted U pieces of iron, with the points of the U hooked around the reinforcement, were placed in each block, so that, when set, two loops were exposed at either end of the block for the reception of the hooks of the hoisting chain. These blocks were laid at 12 feet centres, supporting the centre of each pipe. Often large quantities of silt had to be removed from the trench in order to reach clay. An 8-inch centrifugal pump was first used, with little success. Finally, two No. 4 Edson diaphragm pumps, attached to two lengths of hose, were found to work admirably.

Further assistance was furnished by a 2-inch hose with ¾-inch nozzle, supplied with water from the reservoir at 125 lbs. pressure. The diver directed the ends of the hoses and nozzle. When solid clay was reached and a bed levelled by excavation, a block was lowered and levelled by means of a 20-lb. plumb bob. If the final elevation of the block was more than 1 foot below grade, a second block, 4 feet in length, was laid on the first, leaving a 6-inch step In three cases, three blocks were necessary to raise from solid clay to within 12 inches of the grade line. The elevation of the top block was then carefully measured, and a piece of flat, slaty rock of the necessary thickness was laid on the block to act as a temporary support for the pipe. A sing'e pipe was then sent down and bolted up. A rich concrete of fine gravel was lowered in long sacks and worked between the pipe and the top of the block. The ends of the sack were padded up, so that when the concrete had set the pipe was supported by a cradle formed to the shape of the pipe. A blind gasket of ⅜-inch boiler plate was bolted to the open end of the pipe, and the whole line up to that point tested. A small hand force pump was the only pump available, and it refused to do better than 120 lbs. to the square inch. Ninety pounds was, however, easily secured after the pipe became full, the pump leaking badly above that pressure. If there was any fluctuation in the time required to raise the pressure, the last joint laid was carefully gone over until the best test was secured within the capacity of the pump, this capacity being checked on four lengths bolted together on the bank. Every joint was in this way tested under water. When the line was completed, a ¼-inch pipe from the pressure main was led through a blind gasket at the shore end of the river pipe. With the cock slightly turned, the river pipe held the same pressure, during a 24-hour test, as the pressure main on the shore side of the gate valve at the same elevation, or approximately a pressure of 125 lbs.

As concrete blocks were not considered in the original contract, an extra was allowed the contractor for this portion of the work.

The personnel of the gang was as follows:

Foreman, at $8.00 per day	$ 8.00
Diver, at $10.00 per day	10.00
2 Helpers, at $3.50 per day	7.00
Hoistman, at $4.00 per day	4.00
6 Labourers, at $2.50 per day	15.00
1 Diving Suit, at $10.00 per day	10.00
1 Scow and Hoist, at $15.00 per day.	15.00
Total per day of 10 hours.	$69.00

A record was kept of the time spent in excavating for and placing the blocks, and resulted in the city paying the contractors $747.00, in addition to supplying the blocks. Thirty-five (35) blocks were laid on this line under the horizontal 300 feet of pipe on the river bottom, and as each block cost $4.00, the charges for material and labour amounted to $887.00, or $2.95 per foot.

The large river traffic greatly increased the cost of the work. The pipe lines were located at a bend in the river where light boats in a wind were swung over a wide range, and, during the work in the middle of the river, the passage of every boat meant a cessation of operation, and the hauling of the scow well towards the shore line. This feature alone probably doubled the time spent on the work.

The summer was drawing to a close when the first line was completed and put in operation. It was therefore deemed advisable to defer the relaying of the second line until the river was frozen over. Work could then be conducted from the ice, and the delays due to navigation avoided. These advantages promising to more than offset the difficulty of working in very cold weather.

Prior to recommencing the remaining portion, however, a settlement was effected between the contractors and the city, by which the latter took over the work for an allowance of $2,500.00, its estimated cost, exclusive of blocks. When about half completed in January, 1908, the Dominion Government announced its intention of dredging the river to a depth of 25 feet, and a width of 500 feet, in the course of a five-year programme. In view of this, the advisability of abandoning the pipe line and driving a tunnel was seriously considered. However, the low position of muncipal bonds in the market at that time indicated that it would be sound finance to complete the pipe line and drive the tunnel at some future time within the five-year limit set for government operations, when the financial conditions would probably be more favourable. The second line was then completed at a total cost, including blocks, of $3,180.00. A slide at the north bank, and an unexpected accumulation of sunken logs, caused much trouble, but the cost only slightly exceeded expectations.

It is probable that a tunnel will be driven next year. While the main reason for this step is the contemplated widening of the harbour, it has become more necessary because of the rapid approach to a population of 30,000, foreshadowing the necessity of additional pipes, and to the fact that all large boats, in making this bend in the river, drag anchors if there is any wind, thus placing the pipes and cables (light and telephone) in constant danger.

Injury to the power cable seriously crippled the work on the Loch Lomond Tunnel, and in November last a boat dragging a large fluke anchor picked two lengths of pipe from one of the lines, and carried them up the river. Both pipes were broken close to a flange, the remainder of the line remaining intact. The pipes carried away were Nos. 5 and 6 from the south bank. The flanges between pipes 4 and 5 were left, but the flanges between pipes 6 and 7 were carried away. Pipe 5 was replaced by an ordinary flanged pipe, and pipe 6 by one with a flange at its junction with No. 5, and spigot end to join 7. The joint between 6 and 7 was then made by a special sleeve, 24 inches long, grooved and leaded and caulked under water with shredded lead. The pipe line is apparently as good as ever, having been in continuous operation since its repair.

The tunnel is to be 8 feet internal diameter, lined with three rows of brick. Three concrete benches, two feet wide, will support each 12-foot length of the first double line, either 18 or 24-inch pipe. A second double line can be laid above the first when necessary on a steel staging. Conduits for cables will be placed in the benches. and additional racks provided above the pipe. The Kaministiquia Power Co. expect to carry their cables in the same tunnel in order to furnish power to the Grand Trunk Pacific Railway terminals and elevators.

As a protection against accident, large notice boards were erected on both sides of the river warning navigators not to drag chains or anchors. Similar boards warning navigators of the presence of the pipe were placed four hundred yards up and down stream from the crossing. All boards are illuminated at night by red and white lights.

Connection with Distribution System.

The work under this heading necessitated laying the following main pipe:

2,163 feet 18-inch pipe, 160 lbs. per foot; minimum thickness, 75-100 inch.

1,285 feet 16-inch pipe, 135 lbs. per foot; minimum thickness, 71-100 inch.

1,194 feet 14-inch pipe, 110 lbs. per foot; minimum thickness, 67-100 inch.

1,686 feet 12-inch pipe, 85 lbs. per foot; minimum thickness, 63-100 inch.

1,800 feet 10-inch pipe, 65 lbs. per foot; minimum thickness, 56-100 inch.

Connections were made with the existing system at every street crossing. The contractors placed the necessary branches and crosses in their proper positions, and the actual connections were made by the city force.

A portion of the 18-inch main passed under five tracks of the Canadian Pacific Railway.

The pipe was of standard specification and laid on a true grade line in a trench not less than 6 feet 6 inches deep. About 2,000 feet of the trench excavation was in clay, and the remainder in a yellowish sand, varied by several stretches of gray and black quicksand. In the soft ground, the pipe was laid on 6-inch by 8-inch by 36-inch wood blocks, 6 feet centre to centre.

The making of the joints was carefully watched, and only two small leaks developed from defective caulking.

The backfilling was carried up in well tamped layers not more than one foot in thickness.

Fairbanks' gate valves of standard pattern were used on this section.

Pumping for Temporary Supply.

About the middle of September, 1906, it appeared that the Newman contract would be completed shortly after the specified time, and arrangements were made to supplement the Crescent Lake storage, in order to avoid any shortage during the winter.

Seven thousand feet of 8-inch wood pipe, manufactured by the Pacific Coast Pipe Co., of Vancouver, were laid from Loch Lomond over the divide (120 feet above Loch Lomond) into the main creek of the Crescent Lake drainage area. The bed of this creek consisted of clean sand and gravel to a depth of from 3 to 6 inches overlying clay, a formation that carried the water to Crescent Lake without appreciable loss.

Three weirs were maintained at various points along the creek, as well as one at the point of delivery, and even in the driest weather the lower weirs recorded a flow at least equal to that of the upper weir.

As no danger was anticipated from frost in this sheltered position, and because of the temporary nature of the work, the grade line was fixed at 30 inches below the surface, it being the intention to use snow as a further covering, in case the winter should prove of unusual severity.

The pipe was carried on a continuously rising grade to avoid summits or depressions, and an 8-inch blow-off provided at the pump house, so that the pipe could be rapidly drained during the winter, whenever it became advisable to cease pumping.

A road was built *via* the Crescent Lake valley and pipe line to the site of the pump house at Loch Lomond for construction purposes, and a second road constructed from about the centre of Section 2 to the pump house to avoid any contamination of Crescent Lake or its watershed.

A frame pump house was built on the shore of Loch Lomond, a 60 horse-power boiler installed in it, and a foundation prepared for the reception of a pump to be transferred from the power house.

Just at this time, the Canadian Fire Underwriters' Association intimated that under no circumstances would they permit the removal of a pump from the power house, until the gravity system was in operation. The previously mentioned attack of typhoid laid the writer aside at this time, and the Board of Commissioners decided to buy a new pump. One was purchased, installed, and put in operation during the winter. Unfortunately, an error was made in specifying its capacity, which proved to be only 300,000 gallons per 24 hours, instead of the 750,000 gallons contemplated by the writer.

The cost of this pumping extension was as follows:

Road Construction	$950.00
7,000 feet 8-inch Wood Pipe at 40c	2,800.00
Hauling and Laying Pipe, at 13½c. per foot	950.00
Cost of Pump House, Operators' House, and bricking up Boiler	1,800.00
Cost of Pump	640.00
Cost of Boiler	200.00
Hauling and Installing Same	250.00
Engineer Superintending, and Sundries	210.00
Total	$7,900.00

The first portion of the summer of 1907 was very dry, particularly so in the hills, and, as a consequence, the water used in testing the wood pipe made serious inroads on the storage of the Lake. During the month of August, there were some heavy rains in the district, aggregating about four inches, which, however, entirely avoided the Crescent Lake Valley. This valley lies approximately north-east and south-west, and is hemmed in by hills of considerable height. The writer noticed that practically every rain storm approached from the south-east or the north-west, flooding these slopes of the range, but seldom surmounting the hills surrounding the Crescent Lake Valley. At this time, there was every prospect of completing one line across the river in September, when the system could be operated. The failure of the Crescent Lake watershed to obtain normal rainfall, the knowledge that the wood pipe leaks would consume at least 200,000 Imperial gallons per 24 hours, the inadequate capacity of the pump supplied, and the unexpectedly large growth of population, caused the writer to advise the Board of Commissioners on the 21st day of August of the necessity of increasing the pumping capacity at Loch Lomond if the service was to be maintained. It was recommended that the power line be extended from the Loch Lomond tunnel, that a two stage turbine pump of 1,000 imperial gallons per minute capacity be installed and operated by a one hundred horse-power motor, and that a 12-inch cast-iron main, 7,000 feet in length, be laid for this purpose over the divide. The steam plant to remain in position as an auxiliary. The estimated cost of this proposed work was $20,000.00, with a probable salvage of $12,000.00, leaving a net cost of $8,000.00. As the city has been maintaining a pure water delivery service by wagons ever since the epidemic, at a cost of $7,500.00 per annum, and, in addition, had kept their power house plant in operation, this seemed a reasonable investment. The Board, however, declined to entertain the proposition.

When the River Crossing was completed in October, continuous pumping and some rain had very nearly filled Crescent Lake, and there was at least a chance of surviving the winter. This anticipation was not realized. The high pressure proved too much for the antiquated and low grade plumbing in the city. W.-C. tank valves refused to operate against the pressure, and hundreds of them were permitted to run unchecked. Much of the lead pipe was in little better condition, and leaks in the city mains were very numerous, due largely to the small quantity of lead and inefficient caulking in the joints of many of the pipes first laid in the city. As an anti-climax, there were some weeks of cold weather before frost fell, and the juvenile citizens flooded several hundred acres of skating rinks from the city mains. The normal usage from the city pumps of 600,000 gallons was thus increased to over one and a half million imperial gallons daily, for a population of about 15,000 people in a city where at that time commercial consumption was an almost negligible quantity. The Canadian Pacific Railway Co. pumped its own water supply.

During this period, the operation of the water system within the city was outside the writer's jurisdiction, and the efforts made to check the waste were desultory and ineffective, although it is doubtful, in view of the widespread character of the loss, if any practical restrictive measures could have been taken in the time available.

As a result, Crescent Lake gave up the unequal struggle two days before Christmas, after being in operation only nine weeks.

The Loch Lomond pump was kept in use in order to keep the wood pipe line full, and hold a fire reserve at the high pressure.

Operation was again commenced on the 23rd day of April, 1908, with water arising from the spring thaw, and the supply was continued without assistance from the Loch Lomond pump until the end of July, a period of thirteen weeks. The summer in this locality was of unprecedented dryness, and from the 8th of June until October, absolutely no rain fell in the Crescent Lake Valley. A heavy storm, which covered the entire surrounding country, and was recorded on two gauges as exceeding 5 inches of rainfall, did not lay the dust on the watershed. With the spring thaw of the present year (1909), operation was again commenced, and continued until Loch Lomond water was secured through the tunnel.

The failure of this temporary supply was peculiarly aggravating, in view of the fact that for 20 years prior to 1906 Fort William had an unequalled reputation for summer rains, it being stated that a day without some rain was a rarity. It had seemed quite safe to assume an effective annual precipitation on the rocky Crescent Lake watershed of 12 inches, equal to 348,480,000 imperial gallons, or 900,000 gallons per day, to which was to be added the 750,000 gallons expected to be pumped from Loch Lomond.

As a matter of fact, however, excluding the snow run off, no year since 1906 has provided two inches of effective rainfall on the Crescent Lake watershed, and, consequently, the crippled pumping facilities were totally inadequate to take care of the previously stated abnormal demands made upon the supply.

COST OF SECTION 1.

Newman's Contract		$97,900.00	
Less held on Wood Pipe	$4,450.00		
Less Second Pipe Line, River Crossing	2,500.00		
		6,950.00	
			$90,950.00
Extra for additional Pipe-laying		527.80	
Concrete Blocks and Pile-driving at River..		999.90	
Settlement on Wood Pipe..		1,000.00	
			2,525.70

City Expenditure on River Crossing:			
On Pipe for River Crossing..	5,317.00		
Valves for River Crossing ..	628.00		
Gaskets for River Crossing ..	134.00		
Labour on Second Line—Pipe	2,670.00		
Labour on Second Line—Blocks	892.00		
Cost of Blocks, extra Pipe, etc.	584.00		
Pile-driving and Bank Protection..	415.43		
		10,640.43	
On Wood Pipe Repairs:			
Labour and Material		5,390.00	
On Temporary Supply:			
Pumping Station and Pipe ..	7,900.00		
Seven Months' Maintenance, Labour and Fuel..	3,926.28		
		11,826.38	
On Connections to City System ..		1,203.08	
On Road Repairs and Ditches ..		393.22	
			29,453.11
By-Laws, Legal Expenditure, and Advertising..			548.07
Engineering, Superintendence, and Inspection..			2,945.14
			$126,422.02

CONSTRUCTION SECTION 3.

Tunnel Section.—In September, 1906, the writer was instructed to prepare plans and specifications for this section, but, because of illness, they were not completed until the third week in November. Tenders were called on the following basis. A lump sum bid for general work, to include 500 feet of 36-inch steel intake pipe, coffer-dam, masonry gate house, and 3 miles of road construction. A price per cubic yard for all excavation outside the tunnel, a price per cubic yard for all concrete outside the tunnel, a price per lineal foot for the tunnel for various cross-sections that might be required as work proceeded. No. 1 provided for lining sides and bottom only with 1 : 2: 5 concrete, with no point of rock closer to the face of the concrete than 3 inches. No. 2 provided for the foregoing lining, with the addition of an arched roof, where shale, loose rock, or other unsatisfactory material made a supported roof necessary. No. 3 provided for timbering in soft ground, with a 12-inch concrete lining.

The tenders received, compared with the writer's estimate (opened at the same time for the guidance of the Board), were as follows:

COMPARATIVE TENDERS BASED ON FINAL QUANTITIES.

	QUANTITIES C.Y.	HOUSTON & JONES		GOWANLOCK & TONKIN		WM. NEWMAN		FLANAGAN & CAMERON		E. ANDERSON		CITY ENGINEER	
General........			15,500.00		18,640.00		16,960.00		25,000.00		24,850.00		17,000.00
Earth Excav...	600	.35	210.00	.50	300.00	1.00	600.00	1.00	600.00	.50	300.00	.40	240.00
Loose Rock Ex.	520	1.50	780.00	2.00	1,040.00	1.50	780.00	2.00	1,040.00	.75	390.00	1.25	650.00
Solid Rock Ex..	2560	2.50	6,400.00	5.00	12,800.00	3.00	7,680.00	5.00	12,800.00	2.25	5,760.00	3.00	7,680.00
Back filling and grading	9170	.25	2,292.50	.50	4,585.00	.50	4,585.00	.25	2,292.50	.50	4,585.00	.40	3,668.00
Concrete.......	624	12.00	7,488.00	10.00	6,240.00	14.00	8,736.00	15.00	9,360.00	19.80	12,355.20	14.00	8,736.00
Tunnel.........	4819	22.50	108,427.50	27.00	130,113.00	28.00	134,932.00	26.82	129,245.58	35.00	168,665.00	26.00	125,294.00
TOTALS....			141,098.00		173,718.00		174,273.00		180,338.08		216,905.20		163,268.00

The lowest price of the various Tunnel cross sections quoted by Contractors is used for the above table, as in the finished work the lining was practically confined to supporting shattered hangings and weak spots of various kinds, less than 100 feet being completely lined. The changes and additions made to the work prior to, and during construction, especially under the "General" bid, rather cripples the value of a comparison of these tenders with the actual completed cost. Briefly, the writer's estimate was ample for all outside work, but 9% low on the Tunnel.

The bids were finally considered on Jan. 16, 1907, the writer recommending that the Board accept those submitted by either Messrs. Gowanlock & Tonkin, or Newman & Co., as the final estimate of quantities might prove either to be low; excluding the bid of Messrs. Jones & Houston, which the writer considered too far below a reasonable price for the work.

The January elections had changed the personnel of the Board, and it was decided that the work should be done by day labour under the direct supervision and control of the writer.

Prior to the commencement of the work, the Board insisted on the length of the intake pipe being increased to 750 feet, the grade line of the pipe through the cofferdam being lowered two feet, and the grade line of the tunnel being lowered four feet. In addition, they stipulated that no boarding camp should be erected inside the boundary of the Loch Lomond watershed.

These stipulations necessitated a slight change in location due to the moving of the tunnel portals, and the necessary increase in the height of the forebay. It was also found that the greatest depth of water (42 feet) at the end of a 750-foot intake pipe was approximately on the centre line of the tunnel produced into the Loch, and it was so located.

Work was immediately started on a winter road to the site, and the necessary clearing done.

The main camp was located about midway between the tunnel portals, approximately 800 feet south of the centre line, at an elevation of 180 feet above Loch Lomond. All buildings were constructed of a double thickness of 1-inch ship lap separated by tarred felt, and the roofs covered by three-ply pyroid roofing felt. Brick chimneys were used throughout. Wood burning box stoves were provided, and the stove pipes were conducted as far as possible within the buildings.

The main boarding and bunk house was of two storeys, 86 feet by 18 feet, with a wing 32 feet by 29 feet. There were sixty-four bunks in two tiers, divided into eight rooms, so that the various shifts could be kept separate and suffer a minimum of disturbance. A wash room and smoking room were provided for each floor. The dining room was 29 feet by 24 feet, and seated 50 men. Additional accommodation was provided for the kitchen staff. A 31 feet by 14 feet stable, with hay loft, and an 8 feet by 16 feet ice house were also provided. Adjoining the main boarding house, a compressor house was built, 38 feet by 18 feet, a portion of which was used as a machine repair shop. A bungalow was erected further up the hill near the camp, containing three rooms, each 10 feet by 12 feet, for the accommodation of the engineering staff. Special care was taken as to the cleanliness of the camp.

Garbage was burned periodically, and pail system latrines were built at the camp, at the shaft, and at the forebay. At both ends of the tunnel, blacksmith shops, 12 feet by 21 feet, were erected, as well as two drying houses for the accommodation of the men changing shifts. Each of the latter contained a room, 14 feet by 12 feet, surrounded by 12 seat lockers, 3 feet by 2 feet by 2 feet, and provided with drying racks, and a hot water boiler. Adjoining was a 12 feet by 7 feet store room. Two magazines, 10 feet by 12 feet, were erected in near-by locations, shut off from the work by high bluffs. Small thawing "dugouts" were built close to the work. In each was placed a galvanized iron box of 26 gauge metal, surrounded on all sides, except the front, which was provided with a door, by a 4-inch water jacket; the enclosed space was divided and bracketed for tiers of trays, on which the dynamite rested, accommodation being provided for two cases (100 lbs.). This box was mounted on a sheet-iron cylinder, in which was placed an electric heater, fed off the lighting circuit, which developed a heat sufficient to keep the water jacket at a temperature of 70° in weather 45° below zero. Thawing was more or less necessary during eight months of the year, and the heat was adjusted by increasing or decreasing the number of coils, in accordance with the season.

All buildings were lighted by electricity on a single phase, 110 volt circuit, transformed at three points by three 2½ K.W. transformers.

A water system was installed throughout the main camp, and supplied through a one-inch pipe by a small Fairbanks pump located on a creek about 500 feet from the camp, and operated by compressed air tapped from the main receiver.

A magneto telephone system was installed with stations at the north portal, the main camp, and at the shaft. A switch in the main camp enabled either of these points to be directly connected with the switchboard in the City Telephone Exchange.

Power.—Steam was practically out of the question for this purpose. Coal must first come from Pennsylvania, and then be hauled seven miles over a road that took many months to get into passable condition, and had some hills with 15 and 20 per cent. grades. The local supply of wood was limited, and although used only for heating purposes, had to be hauled more than three miles before the close of the work. Gasoline figured out at over $100.00 per h.p. Electric power at $25.00 per h.p. was available on the north side of the river, and it was decided to build a power line, although, unfortunately, the price of copper was at the time abnormally high. The current used was supplied by the Kaministiquia Power Co.

from their hydraulic plant at Kakabeka Falls—at 2,200 volts, three phase, 60 cycles alternating current. Poles, 35 feet in length, were secured from the surrounding country, and spaced 150 feet apart. Two four-pin cross arms were used on each pole, the lower arm carrying telephone lines. The wire was No. 6 solid weather proof copper, running 112 lbs. per thousand feet. The river was crossed by a lead-covered submarine cable of No. 6 copper, laid just within the trench dredged for the west pipe crossing. This cable remained undisturbed for nearly two years, after which it was a constant source of trouble. The first break, early in November, 1908, was caused by a dragging ship's anchor, and nearly five weeks elapsed before a new cable could be secured. The cable was so buried that only 100 feet could be salvaged, after three days work with scow and diver. The following temporary expedient was adopted to replace it. Three lines of ordinary W. P. stranded copper wire, heavily taped, were bound together. The cable thus formed, was passed through eight lengths of 2½-inch fire hose, and lowered to the bottom with fish plates, lead pipe, and other weighty debris. This worked well for two weeks, when another boat hooked the hose and punctured the rubber. It was taken up and dried, and again laid for a further run of five days. This performance continued until the arrival of the new cable, shortly before the close of navigation. On the opening of navigation during the present year (1909), the water level of Lake Superior and the Kaministiquia River was about two feet below normal, and the first boat down the river scraped the cable so that it had to be raised and dried. About two weeks later one wire went dead, and it was thought inadvisable to attempt to dry it again; consequently, one of the taped wires previously used in the fire hose, was strung through a one-inch lead pipe and connected at the shore ends. No further trouble has been experienced.

The cost per mile of the transmission line, excluding telephone, was as follows:

3 miles, 1,770 lbs., No. 6 Wire, at 28c.	$495.60
35 Poles in place, at $5.00	175.00
35 4-pin Cross Arms, at 41c.	14.35
105 Birch Pins, at 2½c.	2.62
35 Cross Braces, at 8c.	2.80
105 Double Petticoat Insulators, at 4c.	4.10
Freight, at $1.20 per 100 lbs.	24.00
Labour Stringing Wire	30.00
Total per mile	$748.47

The total expenditure on the line was as follows:

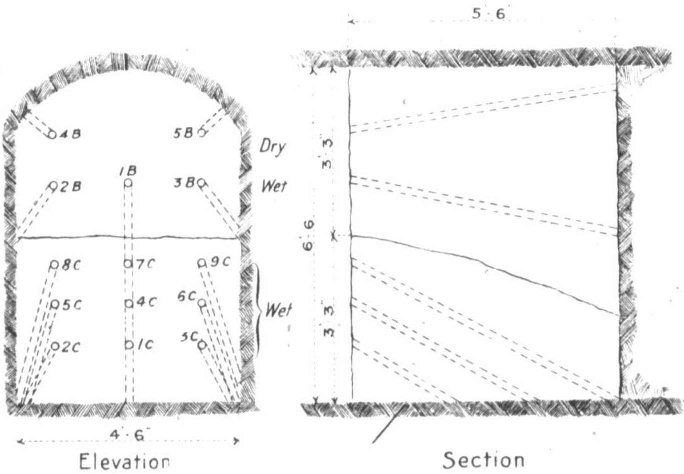
7 miles completed Line, at $748.47	$5,239.29
Cable and Work at River	358.20
Alterations and Repairs	317.00
Repairs and Renewals on Cable	580.00
	$6,394.49

The alterations were due to the necessity of three times changing the four-pole construction crossing the C. P. R. property to accommodate increased trackage, and of moving the line from the vicinity of a particularly heavy rock cut in the second pressure main.

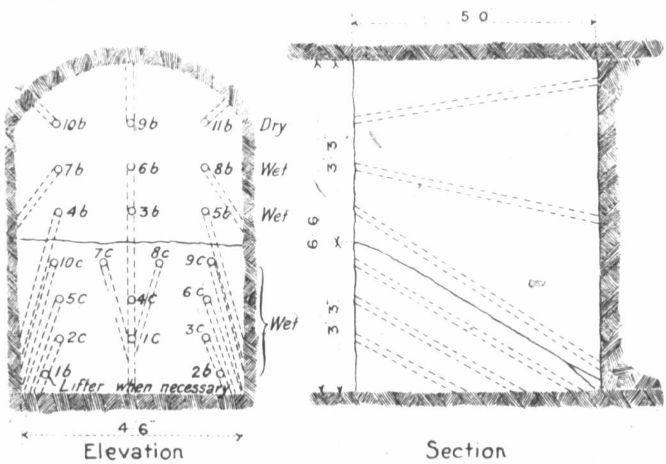
Plant.—A class E straight-line belt-driven Rand air compressor, capable of compressing 282 cubic feet of free air per minute to a pressure of 100 lbs. per square inch, was erected at the main camp. This compressor was operated by a 50 horse power Westinghouse induction motor, through three 15 K.W., 2,200 volts to 550 volts, transformers. A 4-inch air pipe, fed by a 36 inch by 8 feet receiver erected in the compressor house. From this air receiver 3-inch wrought-iron pipes, with a union joint every 200 feet, led to the shaft and north portal. At these points were placed 24 inch by 6 feet air receivers, from which 2-inch pipes served the various headings. The 3-inch pipe was carried on the surface of the ground, blocked up where necessary to secure a continuously falling grade. Serious trouble from frost not being anticipated, the expense of excavation in a rocky country was avoided. During continuously cold weather, with temperatures near the zero mark, no trouble occurred, but, at almost every mild spell, work was temporarily stopped by frozen air pipes, a cold night, after a comparatively warm day, being the chief cause. It was not feasible to cover the whole line with snow, owing to its height above the ground when crossing small ravines. To overcome this difficulty, drip cocks, threaded to take a small pressure gauge, were placed every 300 feet along the line, and a supply of wood and coal oil kept at numerous points. When a block occurred, a gauge inspection revealed the 300-feet strip affected, and an hour's work or less usually sufficed to thaw it out.

The drills used were No. 43 Rand "Little Giant" drills, with 3-inch cylinders, mounted on 6-feet double screw mining columns, and fed through 50 feet of 1-inch Monarch hose.

Black Diamond steel, with regular cruciform bits, were employed at the commencement of the work in the comparatively soft rock, but the change to the hard black basalt necessitated the use of the best grade drill steel, manufactured by the Jessop and Edgar Allen Companies.



Average Ground



Hard Ground

SKETCH SHOWING ARRANGEMENT OF DRILL HOLES

The track was of 50 c.m. gauge, 12-lb. rails, 15 feet long, laid on 4 inch by 6 inch by 30 inch ties, spaced 30 inches C.—C. The curves and switches were made of Koeppel portable track on steel ties.

The four cars at the north portal heading were Koeppel all-round dump cars of 18 cubic feet capacity, and at the shaft headings eight detachable body-side dump roller-bearing Koeppel cars of similar capacity were used.

A 5-inch double cylinder Jenckes hoist, operated by compressed air, with a 6 inch by 24 inch drum winding a half-inch steel wire rope, was erected at the shaft.

The shaft sump was drained by a Cameron pump, with a 3-inch suction and 2-inch discharge, rated at 100 imperial gallons per minute and operated by compressed air.

Buffalo forges were used at each end, but the centrifugal blowers were replaced by a compressed air nozzle.

Ventilation was secured by two belt-driven blowers, with 12-inch blades operated by 2 horse power Westinghouse motors, fed from the lighting circuit and delivering air through a 5-inch pipe made up into 20-foot lengths of 24-gauge galvanized iron.

The dry, hard nature of the rock in the north shaft heading caused much inconvenience from dust, and necessitated the use of a spray, which was furnished from the shaft pump through a ¾-inch wrought-iron pipe.

Light was provided by a single-phase 110-volt circuit, through No 12 weather-proof wire, from which 16 candle power lights, protected by wire guards, were dropped every 75 feet. The "breast" work was lighted by a heavily guarded 32 c.p. lamp, furnished with socket handle and hook, and attached to 100 feet of rubber-covered extension wire.

Tunnel.—The smallest cross-section, consistent with reasonable progress during construction, being more than sufficient for the contemplated water supply, the minimum finished dimensions were specified to be 4 feet by 5 feet 10 inches, carried at a grade of 1 in 1,000.

It was the original intention to line the whole tunnel with concrete, varying in thickness with the nature of the material excavated, but, finally, only those portions showing any sign of weakness were so treated. The generally close, hard nature of the rock removed all fear of seepage or erosion, and the use of a very high coefficient of roughness still brought the delivering capacity of the tunnel considerably over any possible discharge that could be secured from the watershed.

The rock was excavated on a minimum cross-section, 6 feet 6

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inches high by 5 feet wide, and all weak sections lined with 1:2½:5 concrete, leaving a clear waterway, 4 feet wide and 5 feet high, to the springing line of a segmental arch of 4-feet span and 10-inch rise.

Work was carried on at three headings with three machines, two working north and south from the shaft and one working south from the north portal.

Shaft.—The shaft was sunk at Station 9 + 68, 60 feet in depth and 12 feet by 8 feet inside dimensions. Four sets of 12 inch by 12 inch timber, 6 feet C.—C., backed by 3-inch sheeting, brought the excavation to solid rock. The shaft was divided into two compartments by 2-inch plank casing, the hoisting compartment being 8 feet by 8 feet, and the ladder, pipe, and wire compartment 3 feet 9 inches by 8 feet. Three "rollers" or landing platforms were provided in the latter, making three 16-foot stages and one of 12 feet.

The shaft was sunk by hand labour, prior to the arrival of the machines, at an average rate of 1 foot per shift. An ordinary "jack roll" was used as a hoist.

The head gear was carried on four 12 inch by 12 inch posts, braced against the hoist by 12 inch by 12 inch struts. A 24-inch sheave was supported on two 8 inch by 8 inch timbers, bolted to four 4 inch by 12 inch cross-timbers, which were again supported by four 4 inch by 12 inch timbers, secured to the posts by ¾-inch bolts, and a shaft house of 1-inch lumber covered the erection at the collar of the shaft. 12 inch by 12 inch stringers, to each of which was spiked a 40-lb. rail, formed a track of 6 feet 9 inches gauge, on which ran a platform car fitted with a section of track 19⅝-inch gauge of 12-lb. rail.

The cars used in the shaft drifts were the Koeppel steel side roller-bearing dump cars with detachable bodies. To the hook of the gin block was attached the Koeppel crane attachment. When the cars were brought to the shaft, the bodies were hoisted clear of the trucks to the pit head. A duplicate truck was then run in on the platform car over the shaft, the body car lowered into position, and the platform car run clear to a point where the dump track joined the platform track. The full dump car was then pushed on to the dump track and replaced by an empty car standing on the adjoining "empties" switch, the platform run over the shaft, and the empty car body attached to the crane. On the removal of the platform, the car body was lowered to the vacant truck awaiting it. The full car was then dumped by the "lander" and returned to the "empties" switch. Under ordinary circumstances, this method would have proved cumbersome, but the uniform hardness of the rock in both shaft headings reduced the quantity of material to be handled to the capacity of one "mucker," and as the "landers" soon became "speedy" at their work, this method of hoisting rendered satisfactory service.

The alignment was transferred down the shaft on an 11-foot base line by 12-lb. plumb bobs attached to fine piano wire and resting in buckets of water. A transit was then set up in line with the wires and the line produced. This operation was repeated several times whilst the drifts each made 200 feet of progress, and, finally, a centre line 300 feet in length was established on the mean of the five middle readings.

When the south heading was driven through, the alignment was checked by setting up on a hub near the shaft and back sighting 700 feet to a hub set from the surface at the south portal. The error at the breast of the drift heading north was found to be 1¼ inches, and was corrected by subsequent operations.

At the north portal Koeppel steel all-round dump cars of 18 cubic feet capacity were also used, the steep hillside affording ample dumping ground for the whole work within a haul of 200 feet from the portal.

The cars were all pushed by one man, and over distances of approximately 1,000 feet. Bye-passes were excavated and a switch installed so as to reduce the haul of the mucker at the breast to that limit. A small Koeppel flat car was provided for handling machines and tools for each drift.

Owing to the scarcity of capable machine men, the work was at first carried on by two 10-hour "shifts," but as men became available, three 8-hour "shifts" were organized. A "shift" consisted of one machine man and his helper, and from one to three muckers, depending on the length of haul and character of the work. Two blacksmiths, one at either end, each worked from 10 to 14 hours, varying with the hardness of the rock and the quantity of outside work. The hoistmen and landers at the shaft, as well as the compressor men, worked in two "shifts" of 12 hours. The track-laying, pipe-laying, light extensions, machine and general repair work was handled by two men working usually 10 hours.

The first 1,200 feet of the north heading consisted of a compact blue volcanic ash slate that drilled and broke well, and through which good progress was made. The remainder of the tunnel was through a tough, hard trap, containing numerous diorite dykes of phenomenal hardness, the specific gravity of which frequently reached 3.4.

Progress through the latter rock was painfully slow, although air was delivered to the machines at from 80 to 85 lbs. pressure. Bits of the best steel, tempered to a pitch that would notch a file, were worn smooth and useless without crack or flaw after drilling less than three inches. It frequently took over three hours to drill a 5 feet 6 inches dry back hole.

The machines were mounted on standard vertical mining columns with two jack screws, the small size of the drift preventing the use of a horizontal bar.

The average advance made by each cut was four feet six inches. In the slate rock eight five foot holes sufficed, the whole breast being fired in one blast, but the tenacious nature of the hard rock sections necessitated from seventeen to twenty-two holes, in order to break the full cross-section. The holes were arranged as shown in the sketch, and the lower nine holes forming the "cut," were fired first with a fuse, timed to explode in the order shown. After the "muck" had been cleared, the "back" holes were similarly fired.

The upper five holes in the back were practically "dry" holes, and proved a very hard drilling proposition in this rock. Two lfters were sometimes used at the bottom of the face to serve the double purpose of striking to the bottom of the cut, and lifting the "muck" away from the face, thus facilitating the speedy erection of the columns for the next attack.

Work commenced with sixty per cent. dynamite, manufactured by the Ontario Powder Company, but the fumes proved too much for the miners, who were constantly being overcome by gas, and forty per cent. dynamite was substituted with satisfactory results. When the very hard rock was encountered, the writer believed that a stronger explosive would be advantageous, and Nobel's seventy-five fumeless gelignite was adopted. After some trouble in getting it properly thawed, and the holes intelligently loaded, the results secured were good, but its odour, to which the "copper country" miners, who were in the majority, were unaccustomed, caused much vomiting and the experiment had to be abandoned. In the slate rock, about six pounds of 40 per cent. dynamite were used per foot of completed tunnel, but in the hard rock it was necessary to use from twelve to eighteen for the same distance.

In the slate rock firing by battery was more or less successful, but in the hard rock, time fuse gave infinitely better results. The "Bennet" fuse was used throughout the work and proved of uniform excellence.

Two accidents marred the success of the work. One on June 21st, 1907, and the second on June 21st, 1908. On the first date the two shaft drifts had each been driven less than forty feet, the ventilating fans not being then in position. Immediately after the midnight blast the two miners in charge of the shifts went down to recharge a missed hole, expecting to get away before becoming affected by the fumes. The air hoses were coiled on the lower "soller," and the precaution of blowing out with compressed air was not taken. Apparently both men were overcome immediately on reaching the bottom ladder, as one sustained a broken arm from the fall. A rescue party of two men from the surface placed the unconscious miners in the bucket, and then attempted to climb out, but both collapsed on the lower "soller." The casing had not been completed in the ladder compartment, so they were hoisted to surface by the bucket. One man, and he the most active of the rescue party, was already dead from the effect of the fumes and the effort of carrying a collapsed comrade up the first ladder. His name was Jos. Chichester, the son of Colonel Chichester, a distinguished British veteran of the Indian Mutiny.

Within a few minutes of one year later, a mucker in the north heading, whilst cleaning up in preparation for the blast, turned up a small piece of dynamite eight feet from the face. On being advised, the man left his machine and began to search with a pick for further fragments, thereby immediately causing an explosion. Both the machine man and his helper were killed and one mucker was permanently blinded, the other standing beside his car, six feet away, was uninjured. The amount of dirt moved did not exceed a cubic foot, but the whole quantity was apparently received in the faces and chests of the victims. Neither the air hose nor the light wire were damaged, and the incandescent globe hanging from the column, only five feet away, was uninjured. Subsequent examination pointed to the probability that the explosion of No. 3 cut hole had cut off No. 6, drilled in this case a few inches below grade, and leaving an inch or two of dynamite in the bottom of the latter hole. An extraordinary feature of the case was that this was the third time the hole had been mucked over, and as half of it showed plainly on the side of the drift it had been examined two days previous to the accident.

The machines commenced work on the 4th day of June, 1907, and the two long headings met at Station 27+56 on the 24th day of May, 1909. The closing error in alignment amounted to three-eighths of an inch, and the difference in elevation was 0.05 feet.

After the tunnel had been cleared out and concreted where necessary, the shaft was covered eight feet above grade line by a 24-inch slab reinforced by old twelve pound steel rails, supported on walls four feet apart keyed into rock at the sides with 1¼-inch drill steel. At the sump, the wall was made three feet wide on top, battering on the outside at 1 in 6. The whole shaft was then filled to the surface with earth.

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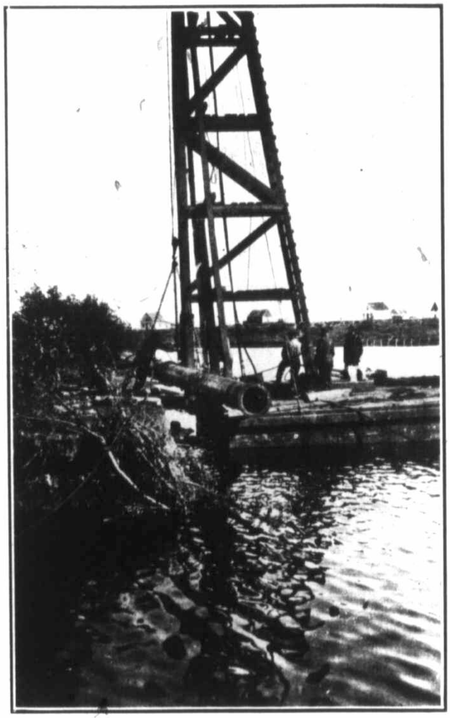
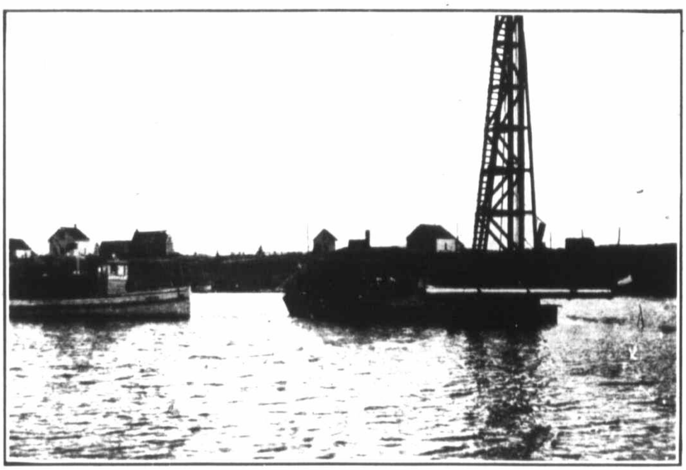


River Pipe in Slings, ready to cast off from Bank.



In Position, ready to drop Pipe.

The monthly progress in the three drifts was as follows:

Month.	North Portal Drift. ft.	North Shaft Drift. ft.	South Shaft Drift. ft.	Total feet. ft.
1907.				
May	48			48
June	141	43	47	231
July	138	85	98	321
August	142	72	85	299
September	130	105	80	315
October	162	111	64	337
November	160	82	75	317
December	209	103	77	389
1908.				
January	137	97	72	306
February	37*	75	51	163
March	68	81	80	229
April	65	70	37	172
May	73	76		149
June	62	66		128
July	69	71		140
August	73	69		142
September	71	63		134
October	76	80		156
November	30†	45†		75
December	51	66		117
1909.				
January	50	58		108
February	64	60		124
March	70	70		140
April	76	74		150
May	53	76		129
Totals	2255	1798	766	4819

The wages paid on the tunnel were as follows:

Tunnel Superintendent	$150.00	per month.
Machine men	$3.50 to 4.00	per shift.
Helpers	3.00 to 3.50	per shift.
Muckers	2.50 to 2.75	per shift.
Landers	2.50	per shift.
Hoistmen	.25	per hour.
Blacksmiths	.35 to .40	per hour.
Blacksmiths helpers	.25	per hour.
Compressor men	.25	per hour.
First mechanic	.40	per hour.
Mechanics helper	.30	per hour.

† Labour and machine troubles.
* Half month lost by power cable troubles.

The cost in detail was as follows:

North Portal Drift (Labour), 2,225 feet.

Machine men	$ 3.02 per ft.	$ 6,816.55	
Helpers	2.48 per ft.	5,587.95	
Muckers	2.84 per ft.	6,404.90	
Blacksmiths	2.06 per ft.	4,655.22	
Mechanics	.40 per ft.	895.45	
Tracklaying and trestles	.77 per ft.	1,725.55	
Powder and miscellaneous	.35 per ft.	787.91	
	$11.92 per ft.		$26,873.53

North Shaft Drift (Labour), 1,798 feet.

Machine men	$ 3.41 per ft.	$ 6,137.65	
Helpers	2.72 per ft.	4,893.37	
Muckers	2.34 per ft.	4,207.89	
Landers	1.47 per ft.	2,640.61	
Hoistmen	1.44 per ft.	2,598.94	
Blacksmiths	2.07 per ft.	3,715.13	
Mechanics	.47 per ft.	839.75	
Track and trestle	1.04 per ft.	1,866.38	
Powder man and miscellaneous	.57 per ft.	1,028.91	
	$15.53 per ft.		27,928.63

South Shaft Drift (Labour), 766 feet.

Machine men	$ 2.93 per ft.	$ 2,248.30	
Helpers	2.33 per ft.	1,783.92	
Muckers	1.95 per ft.	1,495.79	
Landers	1.95 per ft.	727.56	
Hoistmen	.99 per ft.	760.84	
Blacksmiths	1.67 per ft.	1,278.83	
Mechanics	.30 per ft.	229.85	
Track and trestle	.74 per ft.	561.87	
Miscellaneous	.37 per ft.	282.66	
	$12.23 per ft.		9,369.62

General Tunnel Maintenance (Labour), 4,819 ft.

Compressor men	$ .85 per ft.	$ 4,102.75	
Mechanics	.32 per ft.	1,541.75	
Wood thawing, etc.	.37 per ft.	1,762.60	
Miscellaneous labour	.36 per ft.	1,733.35	
	$ 1.90 per ft.		9,140.45

Total labour in driving $15.42 per ft. $ 73,312.23

General Tunnel (Material).				
Drill steel.. .. ..$	.46 per ft.	$ 2,240.00		
Explosives..	2.14 per ft.	10,302.50		
Fuse..	.13 per ft.	640.20		
Caps..	.04 per ft.	173.00		
Lumber..	.11 per ft.	529.69		
Coal..	.12 per ft.	579.50		
Dues on timber..	.02 per ft.	108.15		
Fan, motors, electric supplies.. ..	.18 per ft.	847.85		
Machine repairs..	.67 per ft.	3,234.78		
General hardware, pipe and comp. rep., etc..	1.54 per ft.	7,397.96		
	$ 5.41 per ft.		26,053.63	
General Tunnel charges.				
Power.. .. .. ..$	.56 per ft.	$ 2,693.37		
Power line..	1.32 per ft.	6,394.49		
Teaming supplies.	.50 per ft.	2,406.55		
Employers' liability insurance ..	.61 per ft.	2,933.63		
Accident expense..	.06 per ft.	296.50		
Sinking shaft.. ..	.69 per ft.	3,328.55		
Plant and machinery hauled and erected	3.38 per ft.	16,300.00		
Camp buildings ..	.83 per ft.	4,019.00		
Fire insurance ..	.06 per ft.	301.21		
Trimming and cleaning out tunnel..	.61 per ft.	2,919.20		
Concreting shaft and shattered sections	.22 per ft.	1,069.45		
Sundries, livery, scavenging, etc.	.09 per ft.	447.00		
	$ 8.94 per ft.		43,108.95	
Superintendent, time keeping, etc.	1.45 per ft.		6,974.09	
Engineering	.70 per ft.	$ 3,350.00		
Legal, By-Laws etc..	.08 per ft.	390.00		
	$ .78 per ft.		3,740.00	
				$ 79,876.67
Total.. .. ..$31.80 per ft.				$153,188.90
Less salvage plant 1.50 per ft.				7,200.00
Net cost 4,819 ft. $30.30				$145,988.90

The whole cost of the camp buildings has been charged to the tunnel, although the boarding camp was partly used by men on other work. This other work, however, did not justify such a building, and at times the men so engaged were accommodated in tents, as everything was subordinated to the interests of the tunnel.

Captain John King, of Hancock, Mich., was engaged as tunnel superintendent in March, 1907, and continued in that capacity until the completion of the work.

Roads.—About 4½ miles of road were constructed in connection with the tunnel section through difficult country, embracing rock, swamps, muskeg, and steep sidehill work. A road 14 feet in width was finally constructed with a smooth gravel surface, but to secure this result sufficient material for an average fill of 15 inches throughout its length had to be hauled from four gravel pits, located at intervals of about one mile along the road, and a surface ditch 2 feet in depth excavated on the upper hillside. Some 500 feet of corduroy were necessary, as well as two small bridges of 16-foot span and numerous log culverts. About one mile was macadamized with rock from the tunnel spoil bank.

With labour at 25 cents per hour and teams at 50 cents, the cost of this work was as follows:

Team Work	$1,140.00
Labour	5,368.10
Bridges and Culverts	350.00
Total	$6,858.10

Concrete Culvert.—The south portal of the tunnel was located at Station 1 + 90, from which point an open cut was excavated to the gate house at Station 0, some 50 feet from the lake shore.

The excavation consisted largely of solid trap rock and very large boulders, with various strata of sand, quicksand, and gumbo. A creek, discharging after rain as much as 5 cubic feet, crossed the line at Station 1 + 00, and was diverted by an extensive channel change parallel to, and 50 feet distant from, the centre line.

A culvert of reinforced concrete was then constructed, connecting the tunnel with the gate house, the dimensions conforming to that of the lined tunnel, viz., 4 feet in width inside dimension, with vertical walls 5 feet high to the springing line of a segmental arch of 2 feet 8 inches radius. The floor and walls were 10 inches thick at the crown.

Transverse reinforcing of ½-inch round steel, spaced 10 inches C.—C., was used throughout, the ends being bent so that the wall reinforcing hooked into the ends of the floor rods, and, in turn, the curved arch rods hooked into the ends of those in the walls. Longitudinal reinforcing of ⅜-inch steel rods, spaced 10 inches C.—C., was wired to the transverse reinforcing in arch and floor. The foundation was largely rock, intersected by pockets of sand, gumbo, and quicksand, and where the latter were too extensive to be filled with rock, the walls were supported by a reinforced foundation slab 9 feet in width and 12 inches thick.

The concrete was proportioned as 1 : 2 : 5, Star Portland cement being used. Sufficient sand was secured on the adjoining lake shore by team or boat haul, and stone of from ½-inch to 2-inch size was secured, after double screening, from the spoil-bank at the shaft.

When completed, the excavation was backfilled to natural ground level, and a space of about 2 acres in extent, adjoining the gate house, graded level. The excavated material was used to fill about half an acre of swamp, at the original outlet of the creek, to an elevation of 3 feet above high-water level.

The sides of the creek channel change were riprapped, and the whole space sown with grass seed and trees planted along the outer edge.

The cost of this work was as follows:

Excavation Labour (450 c.y. earth, 520 loose rock, 1,160 solid rock)	$3,890.00	
Depreciation of Tools	187.00	
Powder, 1,470 lbs.	235.00	
Cement, 190 bbls. at $2.50	475.00	
Reinforcing Steel	120.00	
Lumber	235.00	
Hauling Rock, 165 yds.	180.00	
Hauling Sand (boat and team), 85 yds.	160.00	
Handling and Screening Rock (Labour)	113.00	
Labour on Concrete, Reinforcing, etc.	668.00	
		6,263.00
Backfilling and Grading 7,320 c.y. (36½c.)		2,670.42
Total		$8,933.42

Gate House.—The gate house at Station 0 was built of concrete to a height of 14 feet above the grade line of the culvert. It is rectangular in form, the inside dimensions being 7 feet by 9 feet, and its long axis at right angles to the centre line. The walls were 20 inches thick at the top battering on the outside at 1 in 12. The concrete floor slab was 15 feet by 17 feet and 12 inches thick, reinforced with a grid of ½-inch steel, 10 inches C.—C., the foundation being a firm, coarse sand. The outlet to the culvert was of the same cross-section as that structure.

Provision was made for the entry of two 36-inch intake pipes, one of which was constructed with the present installation. Four inches of this pipe protruded through the concrete, and a 36-inch coffin sluice gate was bolted to its flange. The invert was set 6 inches above the floor level and 9 feet below the normal level of the loch.

The house was built to a further height of 18 feet 6 inches above the concrete in uncoursed rubble of red granite, broken from glacially deposited boulders collected from the surrounding hills. The walls were 18 inches thick, and the general treatment was that of an embattled tower. Two feet below the battlements, a roof of reinforced concrete was placed, draining through 1-inch pipes at the four corners. In the centre of the roof a concrete block held a socket for the support of a 20-foot flagpole.

At the top of the foundation concrete a floor of 2-inch plank is carried on 3 inch by 6 inch joists notched into 40-lb. T rails. On this floor is bolted the base of the sluice gate wheel stand, and access to the lower floor of the gate house is gained by means of a trapdoor and steel ladder.

Backfilling was carried to the base of the granite superstructure, forming a berm 10 feet in width, sloping at 1½ to 1, to the general elevation of the graded and cleared space 3 feet below the berm level.

An oak door, 3 feet by 6 feet 8 inches, with ornamental wrought-iron hardware, furnishes entrance from the berm on the east side of the building. Above the door is a vertical ventilating opening, 30 inches by 6 inches, protected by copper wire cloth of 4 by 4 mesh.

Built into the centre of the south wall is a polished black granite date stone, 5 feet by 3 feet, with "V" cut gilded lettering.

The cost of this work was as follows:

Excavation, 150 cubic yards	$115.90
Substructure, 50 cubic yards, at $12.65	632.55
Teaming and Collecting Boulders	350.00
Masonry, 38 cubic yards	547.18
Valves and Ladders	280.00
Flooring, Rails, and Joists, etc.	18.32
Door	38.00
Date Stone in place	102.00
Flagpole, etc.	37.00
	$2,120.95

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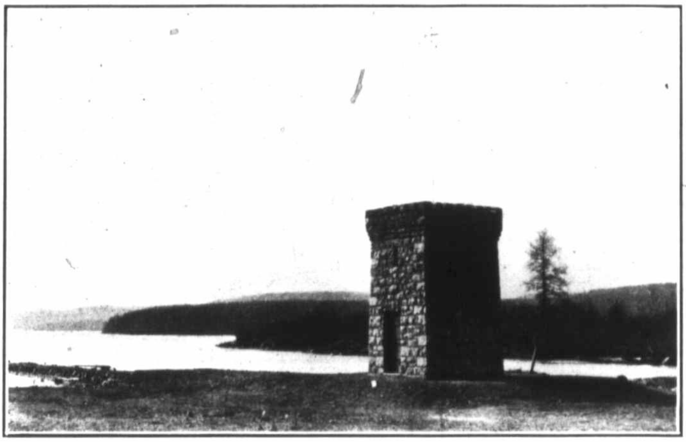

Gate House and West Shore Line of Loch Lomond.

Driving Cofferdam Piles for Intake Pipe. Tunnel Survey Line showing over the Hill.

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Intake Pipe.—The specifications on which bids were asked contemplated 500 feet of 36-inch steel intake pipe, ending in 22 feet of water. The invert was to be at no point less than 6 feet below the low-water level of Loch Lomond.

Before construction commenced, however, the intake was increased to 750 feet, ending in 42 feet of water, with the invert at no point less than 9 feet below the normal level of the loch.

The pipe was manufactured by the James McNeil Bros. Co., of Pittsburg, of ¼-inch plate and 36-inch internal diameter.

The material used in the construction of this pipe was of soft open-hearth steel of an ultimate tensile strength between 55,000 and 65,000 lbs. per square inch, and an elastic limit of not less than half the ultimate strength. Elongation, 22 to 25 per cent., and reduction of area, 50 per cent. Bending test of 180° to a diameter equal to thickness of pieces tested, without fracture on outside of bent portion. Variations in thickness or dimensions of pieces were not to exceed 5 per cent., and variations in cross-sections were not to exceed 6 per cent.

Both longitudinal and circular seams were single rivetted with rivets of ⅝-inch diameter, with heads clean and cup-shaped, both inside and outside, and a pitch of 1⅝ inches, centre to centre. All rivets were of the best Lowmoor, or equal quality iron, with an ultimate strength between 50,000 and 60,000 lbs. per square inch.

Flanges on the end of each length were of rolled angles, 3 inches by 3 inches by ½ inch in thickness, of the same quality steel as the plates, welded into solid rings. Special care was taken that the butt end of these flange joints made perfect contact, being machine faced and accurately levelled on a block before being drilled or rivetted to the pipe. Holes in flanges, both for rivetting to plates and for bolting together, were drilled; those for jointing were accurately pitched, 32 in number on a bolt circle of 40½ inches, to take ¾-inch bolts. The back and face of the angle flange were made perfectly parallel to give perfect bearing for the heads and nuts of the bolts. The faces were tested by rolling between two fixed points to ensure their being at right angles to the axis of the pipe. The pipe was made in alternate parallel rings, the small rings being of 36 inches internal diameter, and the end angles or flanges were placed on the smaller rings of plates, each ring being in one plate, with seams on alternate sides of the pipe. The edges of all plates were planed to a suitable bevel for Conway's style of caulking, all seams being caulked both inside and outside.

The ¾-inch bolts had the thread turned off and the ends rounded for about half an inch from the end, each bolt being 4 inches long from under the head to the point. Nuts and heads were hexagonal, and one wrought-iron flat washer was used with each. A lead joint ring formed the gaskets.

The length of each pipe was 30 feet, made up of 5 plates. Every 60-feet joining the second and third plates of every alternate pipe was a McNeil flexible and expansion joint, which gave ample flexibility within the required limits of about 2°. The drawing shows clearly the construction, but, briefly, the plate on the part of the pipe with a small pipe ring extended about 9 inches beyond the heel of a 4 inch by 4 inch by $\frac{13}{16}$ inch welded "L." A plate ring from the abutting pipe, but rivetted to the outside of the large pipe ring, around which was first welded a 4 inch by 4 inch by $\frac{13}{16}$ inch "L," formed a sleeve over the first projection and partly over the foot of the first "L." A gasket of $\frac{1}{2}$-inch lead pipe between the two projecting pipe rings permitted some flexibility of motion and still held the joint tight, being prevented from slipping off on the inside by a 3 inch by $\frac{5}{16}$ inch band rivetted to the end of the small projecting pipe ring. Twelve 1 inch by 15 inch bolts joined the flange angles and completed the joint.

When completed, and before coating, each pipe was tested to 25 lbs. to the square inch, all leaky rivets being cut out and replaced, and all seams showing leakage, were recaulked until a satisfactory test was secured.

After testing, the pipes were thoroughly dried and cleaned, and heated in an oven to a temperature of 300 degrees F., after which they were thoroughly coated by dipping in a bath of mineral rubber asphalt, manufactured by the Assyrian Asphalt Co., of Chicago. The bath being heated by steam to a temperature of 300 degrees F.

On receipt of the pipe at the city dock, all places from which the coating had been knocked or rubbed, were cleaned and temporarily vaselined. They were hauled to the work when winter had set in, on sleighs with bunks specially prepared, in the form of cradles, lined with old rubber fire hose at all points of contact, to prevent abrasion of the pipe coating.

At the outer end of the intake, a quarter bend supported by knee and foot plate, was provided finishing six feet above the invert of the pipe. Attached to the bend was a 3-foot length of pipe surmounted by a circular strainer, four feet in height and four feet in diameter at the top, the top covering curving to a six-inch rise at the centre. Top and sides were punched with holes 1 inch in diameter, 2 inches centre to centre.

To secure the required depth of 9 feet for the invert of the pipe, it was necessary to construct a cofferdam to a point 277 feet from the gate chamber. It was proposed to lower the remaining 473 feet from the ice in one piece.

Prior to the commencement of the work, the ice was kept comparatively clear of snow to insure rapid thickening, and operations began during the first week in January, 1908, with an ice thickness of 24 inches.

All the pipe was first examined for scratches and holes in the coating, and the steel thus exposed carefully cleaned of all rust by scrubbing with a stiff brush and dilute hydrochloric acid, followed by a mopping with a saturated solution of soda to remove the acid. After all rust had been removed the alkali was washed off and the plate thoroughly dried. In the case of scratches and very small holes, the coating was replaced by pressing over the adjoining coating with a very hot flatiron immediately after the preceding treatment. Where the exposed surface was too large to be covered by this method, it was painted with three coats of mineral rubber field paint manufactured for the purpose by the patentees of the original coating.

A detailed examination of the lake bottom was made by divers, who removed the few snags and logs found on the located line. For about 200 feet from the shore line a firm sand beach bottom was found, after which the sand was overlaid by about 1 foot of mud.

The outer eight lengths of pipe (480 feet), were bolted together in position on the ice and the quarter bend, over which was bolted a tight blind gasket, was attached. To the foot plate, two timbers, 12 inch by 12 inch by 18 feet, were bolted. At intervals of 60 feet along the pipe line a pair of 6-inch guide poles were let through the ice and driven into the lake bottom. These poles were 10 feet apart at the ice level and 4 feet at the lake bottom. Several ropes of the proper length were carried from the pipe to twelve-inch poles let through the ice and frozen in to insure that the shore end of the pipe rested in correct position. During the progress of this work the temperature did not rise above zero Fahrenheit, and occasionally fell to 40 degrees below zero.

A trench, 4 feet 6 inches wide, along the entire length of the pipe, was then cut through the ice, which was at this time upwards of 3 feet thick. The pipe was then temporarily supported on timbers extending across the trench. As it was the intention to drop the pipe into the water and to permit it to fill slowly through the shore end, a perforated gasket was fitted at that point. The timber footing under the quarter bend was loaded to make it very slightly heavier than the rest of the pipe line.

Four men were then stationed every 30 feet, two on either side of the pipe, and using long poles as levers held the pipe in place whilst the temporary cross timbers were cut away. On signal the pipe was gently lowered until it floated and the water gained entry through the perforated gasket. The ropes, previously placed and looped under the pipe, controlled its descent so that the top of the perforated gasket was the last to disappear. Failure on the part of some of the men to obey the starting signal, however, caused a slight unevenness in the lowering operations, and the two bolts on one flexible joint, and one on another, were broken. These were replaced by a diver and the accident apparently had no injurious effect on the pipe. Two hours and twenty-two minutes elapsed from the cutting of the last temporary cross-brace until the pipe rested on the bottom of the lake.

This somewhat crude method of laying the pipe avoided the necessity of hauling special machinery to a location which was difficult of access. The necessary labour was available at the cofferdam and other portions of the work.

It was originally intended to lay the pipe in cradles, but it was decided that the foot or eighteen inches of mud overlying the sand bed would serve as an effective natural cradle.

The inshore portion of the pipe, previously laid, was enclosed by a cofferdam, the blind gasket at the inlet having excluded the water during the process of pipe laying inside the dam.

The cofferdam provided an inside width of ten feet. Two double rows of 10-inch by 20 feet round piling were first driven seven feet apart on both sides of the pipe, and 12 feet C.—C. for 152 feet, until the water reached a depth of five feet, after which the longitudinal spacing was eight feet C.—C. for a further eighty feet. Up to the aforesaid five feet in depth, a single line of three-inch sheeting, fourteen feet long, was driven back of a 4-inch by 8-inch through waling. The inside piles were tied to the outside piles by ¾-inch by 8 feet 6 inch bolts, thus avoiding the necessity of inside bracing, and the clay filling was dumped on the outside of the sheeting, the ice preventing all possibility of wave wash. The 3-inch sheeting was ten inches wide sloped 45 degrees at the foot, and tongued and grooved by inch squares screwed every twelve inches.

All piling was driven with a small steam driver, provided with a thousand pound hammer and thirty-six foot leads.

The portion of the cofferdam in a greater depth of water than five feet, was double sheeted in a similar manner, but a 4-inch by 8-inch waling was run on both sides of each row of pilings and the sheeting driven on the inside of the waling next the core, which was composed of puddled clay. The round piles were similarly tied together by ¾-inch rods, but it was found necessary to carry struts across the top of the trench at every pile. The cofferdam was made tight at the outer end containing the pipe by forming the sheeting and dumping a considerable quantity of clay at the outer side.

A 500-gallon per minute centrifugal Lawrence pump with six-inch suction and five-inch discharge directly coupled to a five horse power Westinghouse 550 volt A. C. induction motor, unwatered the cofferdam.

The excavation revealed one foot of beach sand overlaying a stratum of very porous wet sand eighteen inches deep, under which was a fine quicksand. During the progress of excavating and laying, there were no less than five breaks, four of which were caused by the presence of a buried log at the outer end. A combination of baled hay and clay enabled operations to be resumed after delays varying from a few hours to two days.

When the pipe laying had been carried to the gate house and the sluice valve installed, a diver removed the blind gasket from the outer end and placed the 3-foot length of pipe and strainer. A large quantity of concrete was placed around, under, and over the foot plate and timbers at the bend.

Before the spring thaw moved the ice from the lake, back filling had been carried within about one hundred feet of the outer end of the cofferdam. As no danger was anticipated, operations ceased until work could be carried on to better advantage. During the summer, however, it was noticed that there was a hump in the middle portion of the pipe, that had not been backfilled, within the cofferdam. As an inch air pipe had been placed in this portion, it did not seem probable that an accumulation of air could have raised the pipe to the point of buoyancy, and it was thought that the pressure of the quicksand gradually raised the pipe, especially as the portion backfilled remained true to grade.

During the following winter the cofferdam was again unwatered. The only leakage of any moment was from the joint just inside the end barrier. The pipe was lowered to grade and the joints made tight. To avoid any chance of a recurrence of the trouble, 8-inch by 8-inch timbers were bolted across the pipe at every pile bent, and the pipe protected from abrasion by old rubber fire hose placed under each timber. Struts were also run down at an angle of forty-five degrees from the top of the piles to the centre of the cross-brace. The backfilling was then completed with sand and a layer of rock from the tunnel waste spread over the whole to a depth of one foot.

The cost of this portion of the work was as follows:

750 foot steel intake pipe with strainer and joints	$ 7,068.20
Unloading and treating pipe	144.90
Hauling pipe	204.40
Cutting ice, connecting and laying pipe	780.00
Lumber in cofferdam	2,278.36
Iron in cofferdam	255.21
Hauling clay for core	240.00
Tools and material	253.50
Hire of pile driver	201.60
Pump, motor and transformers installed	740.00
Labour on cofferdam, cutting piles and tamping clay	1,532.00
Excavation, including breaks and pumping	2,253.00
Lowering raised pipe	1,197.90
Backfilling 960 cubic yards	750.93
	$17,900.00

Forebay.—At the north portal of the tunnel 20 feet of open cut, concreted in the same manner as the south portal culvert, led to the forebay.

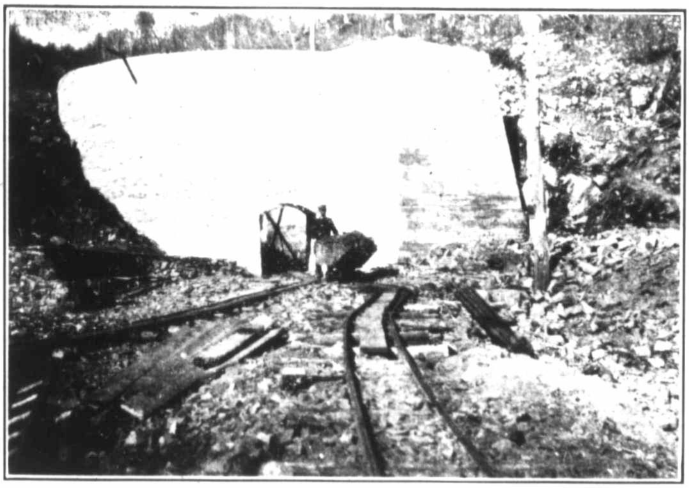
The natural slope of the hill side at this point was very steep, necessitating benching into the hill to secure a satisfactory site for this structure. A bench was cut approximately six inches below the tunnel grade line for a distance of 60 feet, affording a solid rock foundation for the waste pipe and backfilling, as well as for the forebay walls.

The general plan of the forebay is segmental, with an inside diameter of 36 feet, the rise being 24 feet. The chord is at right angles to the centre line of the tunnel, which bisects it. The concrete walls have a width of 2 feet at top, and are carried up to a height of 18 feet above grade with a batter on the inside of one in twelve, and on the outside of one in six. An 8-foot x 6-foot gate chamber was placed in the circular wall, on a radical line leading to the supply pipe line to the reservoir. The walls are vertical on the inside, 2 feet wide on top and battering on the outside one in six. Two centre pilasters, 1 foot by 1 foot 6 inches, were grooved to receive a 5-foot screen of a 4 by 4 copper wire cloth mounted on 3 frames, 6 feet high, of 1-inch galvanized iron pipe. Each section has a centre vertical brace of 1-inch pipe. All joints and bends were made with elbows or tees, and a $\frac{7}{8}$-inch bar which projected 8 inches from the lower corners of the top and middle sections, fitted into the open end of a T at each of the upper corners of the middle and lower sections.

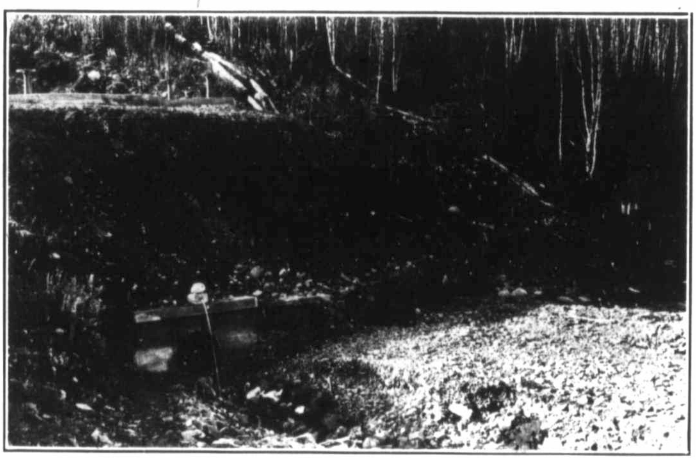
One 36-inch coffin sluice gate, bolted to a thimble set in the concrete wall, admits water from the forebay to the gate chamber, the floor of which is 1 foot lower than the forebay. Three 18-inch sluice gates, bolted to thimbles, provide outlets to the supply mains leading to the reservoir, one of which is now in use. Three lengths of pipe were attached to each of the other gates, in order to clear the toe of the backfilling slope.

Sixty degrees east, on a similar radial line, three lengths of 36-inch cast-iron waste pipe were installed, operated by a sluice gate rising with a vertical buttress from the inside of the forebay. The outer end of the pipe was set in a 12-inch concrete head wall, with 10-inch coping projecting 3 inches, and a sunk wall carried down 4 feet to shale rock foundation.

The walls rested on solid rock, in which a trench about 6 inches deep was excavated to receive them. Within the trench numerous holes were drilled about 6 inches into the rock to receive dowels of $1\frac{1}{4}$-inch scrap drill steel from 12 to 24 inches in length. Three inches from the inside face, expanded metal reinforcing was placed to take up temperature and contraction stresses.



Forebay and Gate Chamber, with Exit Lift for Tunnel Debris.



Forebay Backfilling, showing Waste Pipe and Head Wall.

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The concrete floor varied in thickness from 6 to 15 inches, and was laid to drain to the waste pipe, the invert of which was, 9 inches below the tunnel grade. A large number of rock "fillers" were used up to within 6 inches of floor level.

It was originally intended merely to fence in the forebay, but it was subsequently decided to construct a reinforced concrete cover containing a manhole, etc.

This cover was supported on two columns 12 inches square, each reinforced with four bars of 1⅛-inch old drill steel on a footing 24 inches square, carried from a solid rock foundation. The columns divided a line drawn parallel to the segmental chord and 12 feet distant therefrom, into three equal bents. A beam, 12 inches by 20 inches, was carried across the columns in the same parallel line, and was reinforced with two lines of old 12-lb. steel rails, placed 2 inches from the bottom. Two 7-foot lengths were also placed at the top of the beam above each column to provide against shear.

The cover extended to the outer edge of the walls, and had a minimum thickness of 6 inches, including the granolithic finish. It was reinforced at 10-inch centres with old 12-lb. steel rails, carried from walls to beam and finished with a 1-inch layer of granolithic, compounded of 1 part cement, 1 part sand, and 3 parts granite chippings. The surface was trowelled smooth and even, marked and rolled, with a grade of 6 inches from the centre to the walls. In the centre of the cover was placed a 5 feet by 3 feet red granite date stone.

The concrete used throughout was a 1 : 2 : 5 mixture, hand-mixed to the same specification as adopted for the south end culvert. The sand was practically all Isle Royale sand, hauled from the river bank 6 miles distant.

A 3 foot by 2 foot manhole was provided at the southeast corner, with steel ladder and ventilating cover.

The gate chamber was covered with a 2-inch plank floor, protected by 26-gauge galvanized iron, resting on and bolted to 40-lb. T rails. Trapdoors, 2 feet by 2 feet, were provided, one on each side of the screen with an additional narrow trap, 1 foot by 6 feet, to permit the screen to be hoisted. Two steel ladders were provided, and fixed to afford means of descent for purposes of examination.

The walls were constructed during the summer of 1908, when a 7 foot by 7 foot opening was left in the outer wall to furnish exit for the dump cars from the tunnel. This opening was filled in during June of the present year, 24 crossbars of ½-inch steel being placed as reinforcing, and holes drilled in the concrete to receive their ends. The face of the old concrete was "roughed," thoroughly washed, and painted with a neat cement grout immediately prior to running the new concrete. This process secured a perfectly tight joint.

When filling this opening a ¾-inch galvanized iron pipe was carried through the forming from the forebay to a hole drilled in a granite boulder set on the head wall over the waste pipe. A ½-inch copper goose neck discharges a constant stream from the boulder.

To secure backfilling, a borrow pit was opened in the adjoining hillside, and the whole forebay backfilled to the base of the cover, forming a minimum berm of 8 feet, from which the embankment slopes at 1½ to 1, the toe being retained by a dry wall 3 feet in height. The cars and rails from the tunnel were used for the conveyance of backfilling. Care was taken to have the surface of the berm and slopes covered with at least 3 inches of good loam, which was afterwards sown with grass seed.

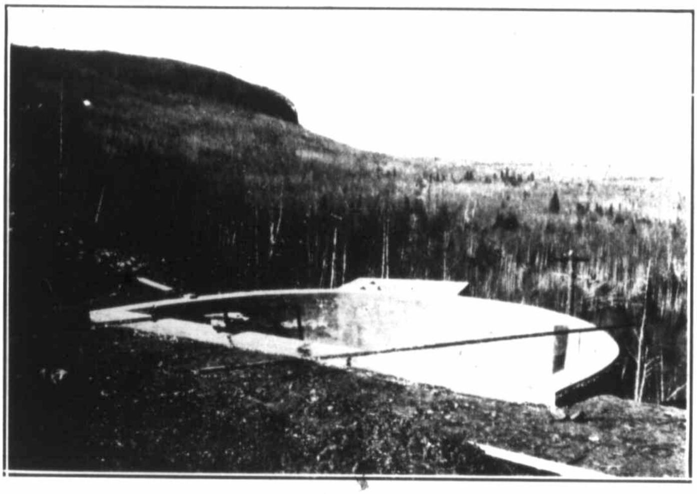
The cost of this portion of the work was as follows:

Forebay and Flume.

Excavating 1,400 c.y. solid rock (labour) . . .	$1,570.00	
Powder, 2,050 lbs.	329.00	
Steel, tools, fuse, etc.	85.00	
	————	$1,984.00
Labour on concrete, 472 yds. (including forming)	2,512.00	
Sand, 160 yds., at $1.25	200.00	
Hauling sand, 160 yds., at $2.50	400.00	
500 bbls. cement on the work, $2.50	1,250.00	
Teaming and screening rock, 480 yds	818.00	
Lumber for forming 29,600 f.b.m., at $25.00	740.00	
36-foot 36-inch cast-iron waste pipe in place . .	271.00	
Sluice gates	710.00	
Reinforcing	56.50	
	————	6,957.50

Cover and Piers, (22 cub. yds.)

Labour, mixing, forming (old lumber), and placing	$ 148.35	
Old steel, 4 tons, at $25.00	100.00	
Cement, 25 bbls., at $2.50	62.50	
Sand, 10 c.y., at $3.75	37.50	
Rock, 25 c.y., at .60	15.00	
Tool depreciation	18.75	
Date stone	77.00	
	————	459.10
Backfilling, 1,850 cub. yds		782.35
		————
		$10,182.95



Forebay before Covering. Fort William in distance.

North Tunnel Portal and Site of Forebay.

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SECTION 2. CONSTRUCTION OF SUPPLY MAIN TO RESERVOIR.

It was at first planned to construct this main of wood pipe, but the difficulties experienced with the first pressure main led to the adoption of cast-iron pipe of 18 inches internal diameter.

The line, which was 10,200 feet in length, was located to avoid solid rock as far as possible. 8,400 feet was in a marly clay with occasional boulders, 6,000 feet in muskeg, and 1,200 feet in solid rock.

The grade line was kept at a minimum depth of 4 feet 6 inches to insure at least 3 feet of cover. In the muskeg sections, clay, on which the pipe was laid, was found at a depth of about 4 feet.

One 18-inch gate valve was placed near the middle of the line, and a second close to the reservoir. A check valve was also placed 50 feet back from the reservoir, and two 18-inch valves in the 2 bye pass lines leading from the supply main parallel to the east wall and past the reservoir to the 2 18-inch pressure mains. A cluster of 3 1-inch Brook's air valves at every summit, and a 6-inch, off 18-inch, blow off at every depression, a drainage ditch on a five-tenths grade being executed at each.

Manholes of dry rubble were built over each air valve cluster and over the gate valves.

The pipes were of standard specification, the limits of weight being from 1,800 to 1,950 lbs. per 12-foot lengths.

To facilitate the haulage of pipe, the heavy side hill road cut off, previously referred to, was constructed with this section.

The top of the reservoir wall was surmounted by a 6-inch by 24-inch weathered coping, and some additional grading done.

The reservoir fence described under Section 1, was constructed with this section.

The entire work was done by day labour, with Mr. Frank Stewardson as superintendent and general foreman.

Wages paid were as follows:

Superintendent	$150.00	per month.
Sub-foreman	.40	per hour.
Blacksmith	.35	per hour.
Caulkers	.30	per hour.
Labourers	.25	per hour.

The cost was as follows:

Pipe Line.

Clearing and grubbing		$ 459.98	at	4.5 per ft.
Trenching and backfilling.				
Rock labour	$1,698.10			
Material	192.70			
	$ 1,890.80			

Earth and boulders.				
Labour..	4,504.05			
Tools and material	725.30	5,229.35		
			7,120.15 at	69.8 per ft.
Pipe laying labour			1,065.00	10.5 per ft.
Lead, yarn, tools ..			1,632.00	16.0 per ft.
Cast Iron Pipe.				
370 pipes, 342,250 tons, at $40.75..		13,946.70		
482 pipes, 418,608 tons, at $40.00..		16,744.34		
Sleeves and specials, 13,812, at $0.03		414.36		
		$31,105.40		
Less credits..		182.50		
			30,922.90 at	303.0 per ft.
Hauling pipe, etc ..			2,130.24	20.9 per ft.
Manholes, labour..	161.65			
material...	54.16			
		215.81		
Valves		651.85	867.66	8.5 per ft.
Total cost of pipe line ..			$44,197.93	$4.332 per ft
Road construction, labour ..		2,021.42		
Tools, etc..		136.81		
			2,158.23	
Reservoir.				
By contract..		20,226.50		
Coping and grading		995.90		
Material		399.40		
Fence, labour		487.15		
Iron, ($5.40 cwt.)		823.08		
Cement, 28 bb., at $2.00...		56.00		
Tools, etc..		118.00		
			23,106.03	
Engineering, inspection, and Supt.			2,625.40	
Total..			$72,087.59	

Second Pressure Main (Reservoir to River).

Construction Section 4.

The rapid growth of population during the construction of the tunnel made it obvious that a second pressure main would be necessary before Loch Lomond water was secured. One main would merely satisfy the Fire Underwriters' requirements for 15,000 people, and the Fort William population had reached that figure early in 1907. An additional reason for the early construction of a second main was the unsatisfactory condition of the wood pipe. As an auxiliary it may render fair service for some time, but as the sole conveyor of a water supply, it must continue to be a source of much anxiety.

The location of this line followed closely that of the wood pipe line, with the exception of a cut-off from the reservoir for a distance of 3,000 feet that saved 215 feet of pipe at the expense of some additional rock excavation. The expenditure, however, was justified in this case by the higher value per foot of the cast-iron pipe as compared with wood, and the much sharper curves that could be conveniently laid with iron pipe. After this cut-off, the second line was laid parallel to the first line at 9-foot centres.

Six inch, off 18-inch, "blow-offs" were placed every half-mile, as well as at depressions in order to facilitate emptying the pipe line for repairs.

Three clusters of three 1-inch Crispin automatic air valves were placed about 4,000 feet apart. This air valve is apparently an ideal one for its purpose. When the pipe is empty the ball float rests in a seamless brass cup, suspended by brass strips within the outside iron cylinder. There is ample clearance between the side of the cup and the inside of the cylinder. The inlet is at the bottom of the cylinder through an inch pipe, and the outlet at the top is fitted with a treated leather valve seat to form a tight seat for the ball when it floats, and so closes the valve. There are two small drip holes, which drain the cup and permit the ball to sit below the effect of any air rush, and also prevents the collection of sediment. The presence of this cup and the ample surrounding area removes any possibility, even with great air pressure, of the ball being raised to its seat until all the air has escaped. The cylinder being closed entirely, the valve can be kept below frost line and the air permitted to escape through a pipe attached to the outlet. One-inch globe valves were placed on the inlet pipe, between the main pipe and the air valve, to facilitate repairs to the air valves.

The pipe used was 18-inch diameter cast-iron pipe of standard specifications, from 1,900 lbs. to 2,000 lbs. for all heads over 200 feet.

and 1,800 lbs. to 1,900 lbs. for all heads less than 200 feet, excepting across the property of the Grand Trunk Pacific Railway, where no pipe of less than 2,050 lbs. was used. The pipes were manufactured at the new plant of the Canadian Iron Corporation in Fort William.

The line was cut into three sections by two 18-inch geared gate valves.

Connection was made with the river crossing lines, and valves placed in such a manner that either pressure main could be operated through either river crossing main. Five valves were used on each side of the river, so that repairs to any one valve would still permit water to be supplied to the city. Briefly, the pressure mains were connected through to the river mains with T's and a cross-over main on both banks. Two valves were placed in each main on either side of each T, and a valve in the middle of the cross-over.

As there was greater possibility of the territory through which this line passed becoming inhabited, the minimum depth for the invert of the pipe was fixed at 6 feet, but in deference to the wishes of the Grand Trunk Pacific Railway Co., the grade line across their property averaged a depth of 12 feet.

A 12-inch, off 18 inches, cross was placed for the future water requirements of the Grand Trunk Pacific Railway.

A small Indian village having been established on the lower portion of the pipe line, three ½-inch fountains, discharging through a masonry head wall into a basin formed from a 2-foot section of 18-inch pipe, were installed for public use.

The whole work was done by day labour, and the results obtained were far superior to those secured by the contractors over the same territory.

The contractors' labour cost over this section, as shown by the writer's force reports, averaged $3.80 per foot for trenching, laying cast-iron pipe, and backfilling through the Grand Trunk Pacific Railway property, 2,000 feet; $1.30 per foot for the wood pipe through the succeeding 5,000 feet of sand and swamp, and $2.15 per foot for the remaining 5,600 feet of marl, boulders, and rock.

It was decided that the sand and swamp portions of the line could be laid more economically during the winter, as at that season the movement of the sub-soil water is more sluggish and the depth of frozen ground obviated the use of sheet piling. These advantages were considered to more than compensate for the cost of shovelling snow and the difficulty of excavating frozen ground. Seven thousand feet of pipe were laid south from the river in February and March of the present year, at an average rate of 372 feet per day. The upper section of the pipe was laid during May and June.

No unusual features developed during the progress of the work, the cost of which was as follows:

Section IV.

Cost of 18-Inch Cast-iron Pressure Main (Reservoir to River)...

12,520 ft. (including Byepass)

Clearing right of way..$	.008 per ft.	$ 103.50		
Excavating trench				
Labour..	.423 per ft.	5,294 10		
Tools	.028 per ft.	356.25		
Backfilling and tamping	.104 per ft.	1,297.34		
			$ 7,051.19	
Cast-iron pipe (18-inch)	3.060 per ft.	38,310.87		
Inspection at foundry..	.021 per ft.	267.63		
Pig lead..	.147 per ft.	1,832.90		
Yarn..	.003 per ft.	37.45		
Specials	.041 per ft.	514.56		
Hauling material	.048 per ft.	607.20		
			41,570.61	
Skidding and laying pipe.				
Labour	.258 per ft.	3,228.02		
Tools, lumber, plant....	.043 per ft.	537.19		
Accident..	.004 per ft.	52.00		
			$ 3,817.21	
Culverts and road repairs	.021 per ft.		$ 262.81	
6 gate valves..	.080 per ft.	1,007.00		
8 blow off valves..	.015 per ft.	186.43		
9 air valves	.012 per ft.	151.08		
			1,344.51	
Manholes, fountain, head walls, etc.	.057 per ft.		702.76	
Engineering and supt..	.090 per ft.		1,131.20	
Total cost of pipe line.	$4.463 per ft.			$55,880.29
Repairs and alterations at river crossing..				1,015.40
Total cost, Section IV.				$56,895.69

In the above work common labour was paid 22½ to 25 cts. per hour, caulkers 30 cts. per hour, and a superintending foreman $150.00 per month.

Cast-iron pipe cost $36.75 per ton at the local foundry, and specials $65.00 per ton. Pig lead cost $3.80 per 100 lbs.. and yarn

8½c. per lb. Nearly half a mile of the line was inaccessible to teams, and as a consequence the cost of skidding and handling pipe was high.

SUMMARY OF THE COST OF THE WORK.

Section 1.			
By contract		$ 93,475.70	
Day labour		29,453.11	
Engr., Supt. and Legal		3,493.21	
			$126,422.02
Section 2.			
Pipe line		44,197.93	
Roads		2,158.23	
Reservoir		23,106.03	
Engr., Supt., Inspection		2,625.40	
			72,087.59
Section 3.			
Tunnel.			
Labour	$73,312.23		
Material	26,053.63		
Fixed charges	35,908.95		
Superintendence	6,974.09		
Engineering	3,740.00		
		145,988.90	
Outside Work.			
Roads	6,858.10		
Concrete culvert	8,933.42		
Gate house	2,120.95		
Intake pipe	17,900.02		
Forebay	10,182.95		
Employers' Liability Insurance	915.61		
Engineering	1,246.33		
		48,157.38	
By-Laws and Legal		519.79	
City contingency account		741.00	
			195,407.07
Section 4.			
Pipe line		54,749.09	
River crossing		1,015.40	
Engr. and Supt.		1,131.20	
			56,895.69
Total cost			$ 450,812.37

Conclusion.

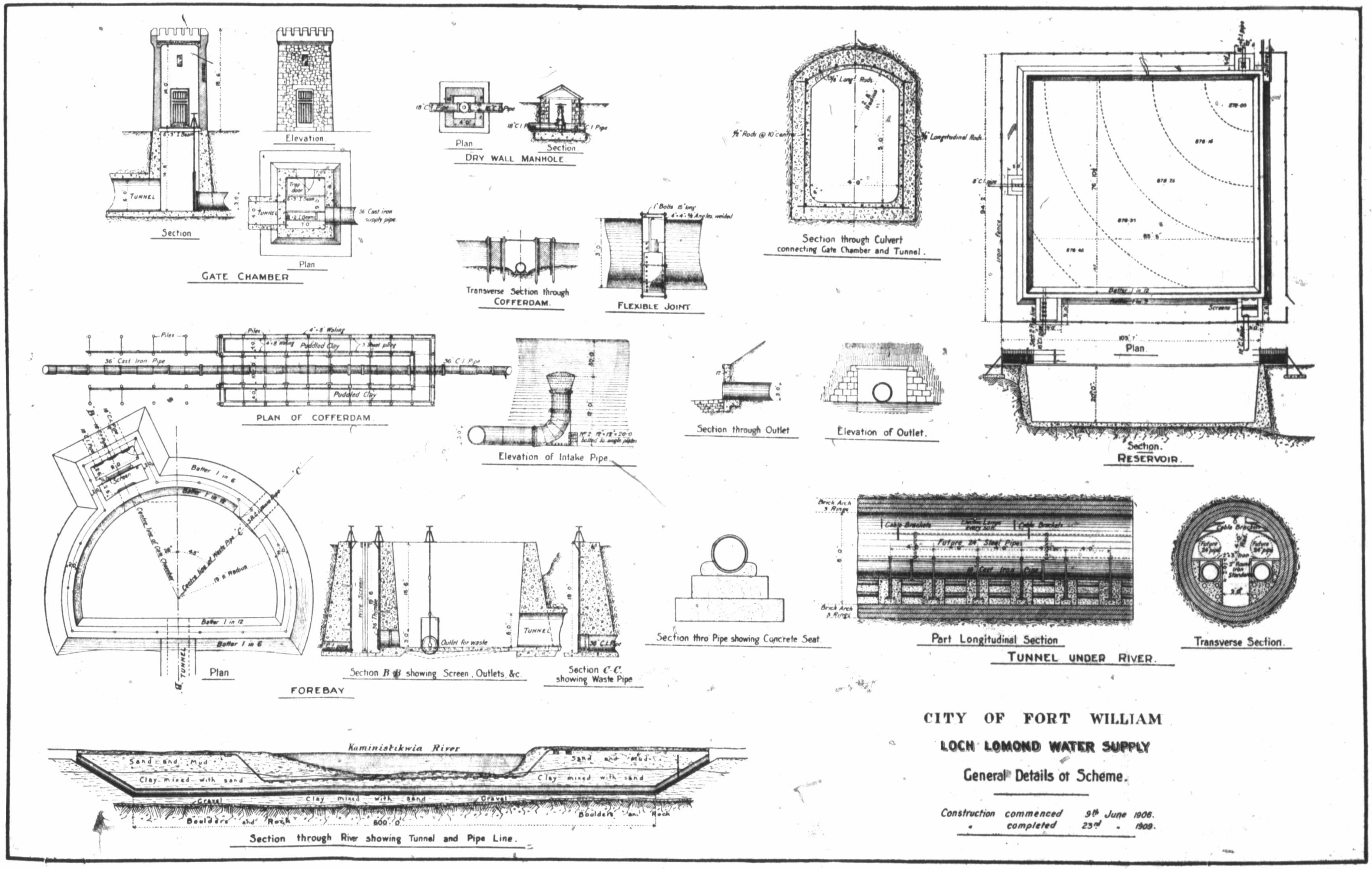
Water was let into the tunnel for the first time on June 21st, 1909, the valve at the gate house being opened by the present Mayor of Fort William, L. L. Peltier, and Chairman James Piper, of the Board of Water Commissioners. Two days were spent in flushing, and the supply officially turned into the city on June 23rd by James Conmee, M.P., the city's representative in the Dominion House of Commons.

Engineers in Eastern Canada may consider many of the difficulties which have been described to have been unnecessary and easily avoidable, but it is only justice to point out the isolation of the work from manufacturing centres, and the consequent delay in securing supplies and repairs; the extreme difficulty of procuring capable and skilled labour, as well as assistants, contractors, and foremen experienced in the various classes of work embraced in this undertaking.

In addition, there was always the temptation to take undue risks to keep down the cost. An expenditure within three years of over $500,000.00 for water, $700,000.00 for sewers, and large expenditures on other civic improvements, and on light and telephone plants and street railway, all municipally owned, is a serious undertaking for a city of 8,000 people. The growth of the city to its present population of over 20,000 has exceeded the expectation of the most sanguine, but there were periods of slackened enthusiasm when economies were attempted that did not make for the best interests of the work.

The writer does not wish the recital of the above facts to be read as an excuse, but rather for the purpose of making the controlling circumstances clear. The full object of this paper will be attained if it enables others to avoid some of the pitfalls that lie outside the straight and narrow way of constant vigilance and unceasing work.

The writer is indebted to Mr. F. C. Fforde, A. M. Inst. C. E., for four months of valuable assistance, from February to June, 1907, and he wishes to express his appreciation of the accurate instrument work of Mr. A. M. Ferguson on the tunnel. His thanks are also due to Mr. John Wilson, assistant city engineer, for generous help throughout the work, and to Mr. W. H. MacAulay, chief draftsman and city architect, for material assistance in the design of the various structures.

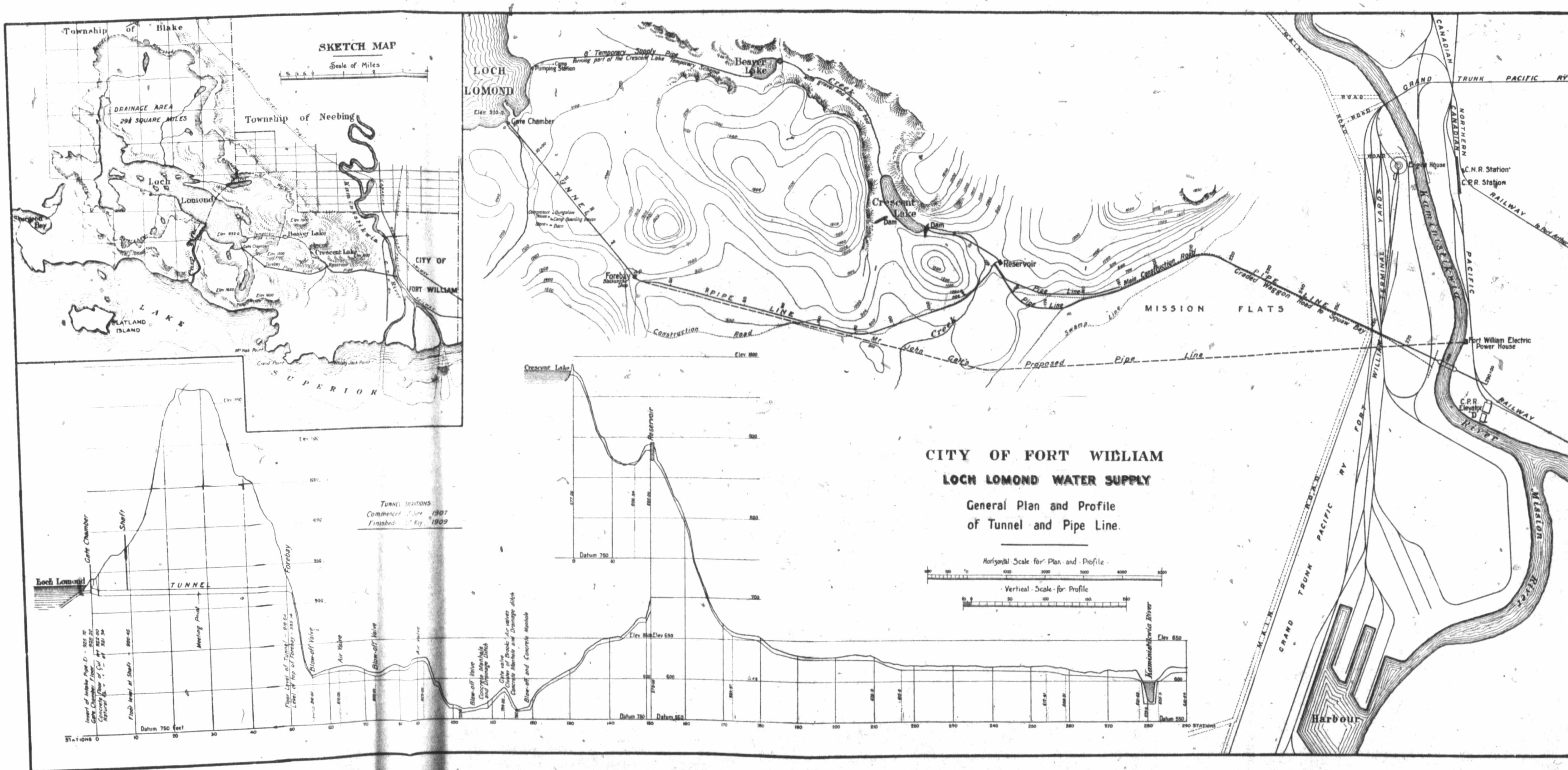


CITY OF FORT WILLIAM

LOCH LOMOND WATER SUPPLY

General Details of Scheme.

Construction commenced 9th June 1906.
" completed 23rd " 1909.



CITY OF FORT WILLIAM
LOCH LOMOND WATER SUPPLY
General Plan and Profile
of Tunnel and Pipe Line.
Horizontal Scale for Plan and Profile
Vertical Scale for Profile
SKETCH MAP
Scale of Miles
Township of Blake
Township of Neebing
DRAINAGE AREA
29½ SQUARE MILES
Loch
Lomond
Beaver Lake
Crescent Lake
CITY OF
FORT WILLIAM
FLATLAND ISLAND
LAKE
SUPERIOR
LOCH
LOMOND
Pumping Station
Gate Chamber
TUNNEL
Forebay
Beaver
Lake
Creek
Crescent
Lake
Dam
Reservoir
PIPE LINE
Construction Road
Main Construction Road
Graded Waggon Road to Squaw Bay
MISSION FLATS
Proposed Pipe Line
Pump House
C.N.R. Station
C.P.R. Station
GRAND TRUNK PACIFIC RY
CANADIAN NORTHERN
CANADIAN PACIFIC RAILWAY
Fort William Electric
Power House
C.P.R.
Elevator
Kaministikwia River
Mission River
Harbour
MAIN ROAD
GRAND TRUNK PACIFIC RY
TERMINAL YARDS
FORT WILLIAM
Loch Lomond
Gate Chamber
Shaft
TUNNEL
Forebay
Blow-off Valve
Air Valve
Datum 750 feet
STATIONS
TUNNEL OPERATIONS
Commenced 2 June 1907
Finished 27 May 1909
Crescent Lake
Reservoir
Datum 750
Elev 650
Datum 550
Kaministikwia River