

**Developing a Domestic Water Supply for Winnipeg from Shoal Lake
and Lake of the Woods: The Greater Winnipeg Water District
Aqueduct, 1905 – 1919**

by
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ABSTRACT

The water source for The City of Winnipeg is Shoal Lake near the Manitoba-Ontario border, 145km east of the city, and is delivered by a gravity powered system known as the Winnipeg Aqueduct. The system was constructed during World War I by the Greater Winnipeg Water District. The District was an inter-municipal corporation. The system is 150km in length of which 134km are in an enclosed conduit operating under open channel flow. The other 16km operate under internal pressure as inverted siphons. The aqueduct crosses eight rivers.

This study consolidates information on the concept of the Water District, the District's administration, the design of its components, the contract administration, and the construction procedures employed in implementing the system. After more than 90 years the Winnipeg Aqueduct continues to supply the domestic water for Winnipeg. The original civic entities of the District were amalgamated into one city in 1972. Its area became much larger and the population is now three times that of the District at the time the aqueduct was built. Authorization for the project was required from four governments, including that of the United States of America through the International Joint Commission. The concept and design of the project involved engineers from both the USA and Manitoba. They had to overcome some unique problems, and a number of the construction challenges were also unusual. The purchase and topographical modification of land belonging to the First Nation residents of Shoal Lake Band 40 was essential to the development of the project. There are ongoing issues for this First Nation arising from that purchase.

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Dedication

This thesis is dedicated to my family, in particular to my wife Melita Louise Ennis whose tolerance of a septuagenarian husband indulging in the idiosyncratic pursuit of formal education for its own sake has been remarkable.

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List of Abbreviations

General Abbreviations

CPWA	Canadian Public Works Association
GWWD	Greater Winnipeg Water District
IJC	International Joint Commission
US	United States of America

Abbreviations of Measurements

Imperial Measurements

Abbreviation	Dimension
mi	miles
ft	feet
in	inches
lb	pounds
cy	cubic yards
gpd	imperial gallons per day
psi	pounds per square inch

Metric Measurements

Abbreviation	Dimension
km	kilometres
m	metres
cm	centimetres
mm	millimetres
m ³	cubic metres
L	litres
L/d	litres per day
kPa	kilopascal
MPa	megapascal

Developing a Domestic Water Supply for Winnipeg from Shoal Lake and Lake of the Woods: The Greater Winnipeg Water District Aqueduct, 1905 – 1919

1.0 Introduction

In the early 20th century Winnipeg was being touted as “the Chicago of the North.” Between 1890 and 1910, the population of Winnipeg proper had grown from 23,000 to 132,000, and by 1913 the population of the area that became known as the Greater Winnipeg Water District (GWWD) stood at 215,000 (CPWA 2000, p.ii). It was well known in civic circles that the area’s continued development would be linked to the supply of a sufficient volume of safe pure water for domestic and industrial needs. Nevertheless, and despite the city’s location on two rivers both with significant watersheds, providing that supply was a problem. It was only in 1913 that Winnipeg committed to a lasting solution (Artibise 1975, pp. 215-22). Collaborating with its neighbouring municipalities to form the Greater Winnipeg Water District (GWWD), the City decided to invest \$13,500,000 to access Shoal Lake, a tributary of the Lake of the Woods watershed some 150km away and straddling the recently established Manitoba-Ontario border (Figure 1.1).

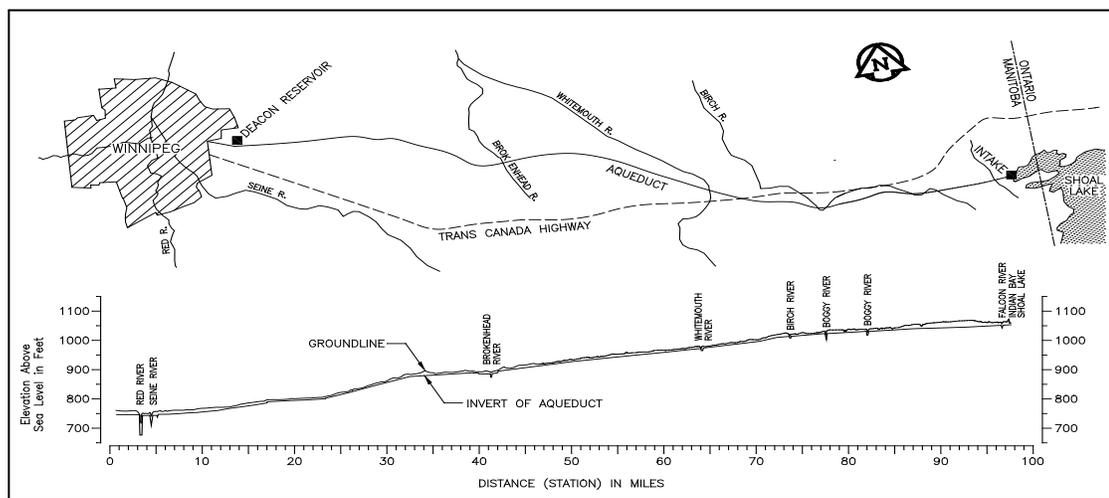


Figure 1.1. Plan and profile of GWWD Aqueduct (CPWA 2000, p.8)

Despite Shoal Lake being nearly 300 ft (91m) higher than Winnipeg, achieving that delivery was not all downhill from there. There were matters of administration, authorizations, design engineering, financing, materials supply, construction, and changed circumstances to be dealt with.

The objective of the research has been to understand and provide comment on the issues from the perspective of an engineer and former contractor. As such, this thesis is unconventional. It examines some of the political and financial issues that confronted the project's proponents and the Water District's administration in its implementation. It then examines the design engineering and the construction challenges, and describes the solutions and techniques employed. A timeline of events on the lead up to and building of the project is provided in Appendix 11.1.

The Winnipeg Aqueduct project was implemented more than 90 years ago at a time when Canada was at war and Manitoba was beset with legislative turmoil and social change. Yet, it continues to provide Winnipeg's water supply effectively and efficiently. That success is a testimony to the Water District's administrative and engineering leadership.

2.0 Background

Supplying water to population centres for their domestic needs has been an issue throughout much of human history, and it has been fundamental to the rise and fall of great cities. Solomon (2010, p. 475) captures that thought with his observation that

Momentous innovations in water history only become clear in hindsight, after they have meandered and permeated through society's many layers, catalyzing chain reactions in technologies, organization and spirit that

sometimes combine in new alignments to foment changes transformational enough to alter the trajectory and destinies of societies and civilizations.

Winnipeg's aqueduct certainly affected its "trajectory and destiny."

Domestic needs and, increasingly since the early 20th century, industrial needs are commonly understood as providing sufficient safe and reliable water for human consumption. However, a city also has other water requirements such as for fire fighting. Others less vital, though necessary, include municipal requirements such as street cleaning, the flushing of sewers, and for horticulture. The conveyance of potable water in aqueducts, i.e. delivered primarily by gravity, has been a solution for water supply to cities for thousands of years. The word "aqueduct" has its origin in the Latin "aqua" for water and "ducere" to lead. The basic principles used in the design of the Winnipeg aqueduct were the same as those that evolved over time by the early aqueduct builders.

Hodge (2002, p. 93) notes that "to most people familiar with pictures of the great [Roman] bridges and arcades, arches and aqueducts are largely synonymous." But for engineers, they are only part of the concept. As an aqueduct is an engineered system, it is useful to first be aware of the distinction in the commonly understood engineering terms. Babbitt (1962, pp. 131-135) provides distinctions: "An aqueduct is a conduit designed to convey water from a source to a point, usually a reservoir, where distribution begins. An aqueduct may include canals, flumes, pipe lines, siphons, tunnels, or other channels, either open or covered, flowing at atmospheric pressure or otherwise." Further, "A canal is an open conduit, either covered or uncovered, designed to convey water." And, "a canal supported on or above the surface of the ground may be called a flume. A siphon (technically an inverted siphon) is "a conduit crossing a valley either on or under the ground with each end at or near the hydraulic grade line ... [and] pressures in it are

usually greater than atmospheric.” The hydraulic gradient, or pressure gradient, comes into play for conduits under pressure (siphons and pipelines). It is the imaginary line representing the static pressure at various points along the conduit while it is under flow. Lastly “The choice between available types of conduits in an aqueduct depends on topography, available head, quality of water, conditions of construction, and possibly other conditions.” The GWWD aqueduct with challenges for designers of topography, head, and construction conditions uses a covered open-channel flow conduit and siphons.

Further to Babbit’s comments on the possible components of aqueducts, Hodge (2002, p. 130) continues by noting that “strictly speaking, a bridge carries a route of some kind (e.g. a road or an aqueduct) across an obstacle such as a river or a gorge where intermediate support is difficult or impossible; a viaduct carries it across a dip in the land where almost continuous support can be provided and the purpose of the structure is to maintain the level of the route.” The Romans used arcades when crossing the plains between the hills and their city and where short spans could be used. In that way they maintained a workable hydraulic gradient for open-channel flow. Lastly, when structures are used to carry a canal for water based transportation over valleys and rivers, they are often labelled as “aqueducts,” presumably because of their resemblance to the arcades of a Roman aqueduct. With few exceptions, such structures are more accurately described as bridges.

The Romans are recognized as the preeminent builders of aqueducts for domestic water supply, having built eleven between 312 BC and 226 AD to supply Rome itself plus numerous others for cities throughout its empire. However, they were not the first. There are examples of aqueducts being used as early as 7000 BC. One in particular built by the Greeks around 530 BC on an island off the coast of present day Turkey is the

tunnel of Samos. It is 1200m long and penetrates a mountain to bring water to the city then known by the same name (Apostol 2004, pp. 30-40). Built in a straight line and at a constant slope at a time when optics-based surveying instruments were not yet available, the accomplishment is intriguing to engineers.

In modern times, one of the more well-known North American examples is the Catskill Aqueduct which is part of a system that brings water to the city of New York. It was constructed a few years before the Winnipeg Aqueduct and the politicians, administrators, and engineers involved with the GWWD benefited from its example. One expects that it was not a coincidence that two of the engineers on the Board of Consulting Engineers that authored the report which led to the decision to construct the GWWD's Aqueduct supply system were from New York. One of them, James H. Fuertes, also served as the District's consulting engineer for the implementation phase of the project.

American engineers had already developed extensive water channelization projects with the completion of the 363-mile-long Erie Canal in 1825, and with the rapid growth of their cities also had expertise in water supply projects. That expertise had been recognized by Winnipeg politicians. Engineers from the US had been consulted on the city's water supply from as early as 1897 when Dr. Rudolf Hering from New York provided a report advising on issues and options for Winnipeg's water supply. While, at that time, at least one prominent citizen was advocating Lake of the Woods, Hering's report considered only the City's artesian well system and the option of a pipeline from the Winnipeg River. By the time the 1913 engineering report that finally convinced the Winnipeg City Council to build the aqueduct from Shoal Lake was received, six out of the eight consulting engineers who had ever been engaged to advise on Winnipeg's water

supply were from the US. A chronology of engineering reports and authors is provided in Appendix 11.2

Water supply was an issue in Winnipeg civic politics for many years before the decision to use Shoal Lake. The factors influencing public discourse on the matter included the amount available, the security of supply, its quality, the proclivity for the business elite to favour private ownership of utilities, and latterly a health issue. Prior to 1882, water was taken from the City's rivers and delivered to homes and businesses in barrels carried on horse-drawn conveyances. The first supply and distribution utility was started under a private corporation – the Winnipeg Water Works Company. Its source of supply was the Assiniboine River just downstream from the present day Maryland Bridge. The Company was incorporated by an act of the Manitoba Legislature in 1880 with an exclusive franchise covering the City of Winnipeg. However, soon after the company began delivering water, there were issues with the capacity of its infrastructure and the service being provided. After years of legislative manoeuvres, confrontation, and wrangling, the City bought out the corporation and its franchise in 1898 (Artibise 1975, pp. 210-12). In the lead-up to the purchase, City Engineer H.N. Ruttan, who had been hired in 1885, had investigated the use of artesian wells for the city's supply. After its purchase of the Water Works Company, an artesian well system was developed by the City but only to a limited extent. With that limitation, the supply operation acquired in the purchase was kept on standby for emergencies.

One of those emergencies occurred in 1904 when a serious fire broke out and the City was forced to pump Assiniboine River water into its mains. Shortly after that, there was a typhoid fever epidemic. At the time, the more affluent residents, and the business leaders who controlled the city, lived in its southern parts which had water and sewer

service. They tended to attribute disease outbreaks, which were usually more prevalent in the largely underserved north end of the city, to cultural and character deficiencies in the area's largely non-British residents (Artibise 1975, pp. 198, 223-36). However, when the south-end residents also became affected by the typhoid outbreak and their infection was subsequently attributed to contaminated river water, perceptions changed. There was a heightened civic interest in the importance of clean water, and ending the use of Assiniboine River water became a priority. The option chosen was to expand the artesian well system.

3.0 EARLY SOURCES AND INVESTIGATIONS (1905 to 1912)

While expanding the artesian well system after the typhoid epidemic was an improvement, it was not to be the long-term solution. The certainty of supply and hardness of the water continued to be an issue for the business community. The primary influence was the need to demonstrate an assured supply in amounts sufficient to satisfy the requirements of the fire insurance providers. In the aftermath of the 1904 fire, the industry had imposed "very excessive fire insurance charges, due largely to the fact that the development of the Water Works system had not kept pace with the extraordinary growth of the City" (Ruttan 1909, p. 3).

The next years saw expansion to the system of artesian wells to the north-west of the City. Proximity to those wells was the reason for the location of the McPhillips reservoir, which was also the beginning of the City's distribution system. For that reason it was necessary for the Shoal Lake system to connect to the reservoir even though it was located across the City from the aqueduct's point of entry. By 1908, under the administration and guidance of City Engineer Ruttan, seven wells had been dug. They

averaged 18 ft in diameter with depths ranging from 46 to 102 ft (Scott 1938, p. 1875). While the water was quite satisfactory for human consumption, its hardness made it undesirable for laundry. Its hardness was also a major problem for the owners of boilers because the scale build-up caused high maintenance costs. Both were seen as disincentives for new industry to locate in the City. To put the hardness issue in perspective, the total solids in the well water was 1,014 parts per million whereas the figure for Shoal Lake was 130ppm (Scott 1938, p. 1875). It is not that Winnipeg was unfamiliar with water softening. The City had built the first municipal water softening plant in North America in 1901, but as the City grew, softening became no longer feasible (Scott 1938, p. 1875). Another underlying factor, probably heightened by the memory of the typhoid epidemic, was concern over the possibility that the draw-down of the water table by the well system could bring water levels below that of the rivers, exposing them to the hazard of contamination.

The adequacy of the water supply was tackled on two fronts concurrently. In 1906, on the authority of an act of the Manitoba Legislature, the City established a Water Supply Commission to develop an adequate supply (Scott 1938, p. 1876). The other initiative was that, by 1908, a high-pressure pumping station and a fire-fighting distribution system were in operation to service the City's closely-built business section. The system produced water pressures of 2,100kPa as compared to a maximum of 550kPa available for firefighting purposes in the rest of the City (Ruttan 1909, p. 4). The pumping facility, which became known as the James Avenue pumping station, was located near and drew its water from the Red River. However, it too was not without issues. The limitations on its service area would have had an effect on commercial expansion. There was also an issue with the use of the river water as its source of supply.

Often, when a fire was over, it was found that merchandise was ruined beyond redemption by the deposited sediments from the water.

Two members of the City's 1906 Water Supply Commission were James H. Ashdown and Thomas Russ Deacon. Both men later served as the Mayor of Winnipeg and were also instrumental in the success of the Administration Board of the GWWD in accomplishing the Shoal Lake project. Deacon had lived in the Keewatin-Kenora area of Ontario working in the mining industry, and was aware of the water supply potential of the Lake of the Woods and Shoal Lake. He was a consistent proponent of that area as the source for Winnipeg (Shropshire 1994, p.3). The 1906 Commission considered a number of sources. Included were the Red River, the Winnipeg River, Lake Winnipeg, and Lake Manitoba. In 1907 the Commission received a report from a Board of Consulting Engineers; two were from the US, including J.H. Fuertes, and two from Canada. That report recommended developing the City's supply from the Winnipeg River. Apart from the higher cost of using Shoal Lake, there was also a concern that despite its purity, the water would still require treatment to overcome coloration from the effect of Falcon River that discharged into Indian Bay. The Commission recommended proceeding with the Winnipeg River as the City's source. However, perhaps fortunately for Manitoba, the City did not act for reasons of finance. Nineteen hundred and seven was a time of world-wide recession, and a substantial financial commitment had already been made to build a City owned hydro-electric generation facility at Pointe du Bois on the Winnipeg River.

The expansion of the artesian well system had continued, and once the Pointe du Bois development was finished and operating in 1912, the focus on providing an adequate visible supply of soft water resumed. (The water in a source such as a river or a lake is visible to the consumer. However, with the source of an artesian well not being

“visible,” confidence in a well’s continuing reliability is not strong.) Despite its lack of visibility, the Council, on the recommendation of Engineer Ruttan, decided to expand the City’s supply from artesian sources still further north-west of Winnipeg in an area known as Poplar Springs. The water from there was much softer than from its other wells in Winnipeg. To pay for the expansion, the Council had called for a vote on a money by-law for September 13, 1912. However, in a separate initiative, it had also asked the recently appointed Manitoba Public Utilities Commissioner, Judge H.A. Robson, to recommend a secure system of permanent supply. Judge Robson had engaged another US engineer, Professor Charles S. Slichter, to provide an opinion. Slichter was an international authority on water who had provided advice to a number of US cities (Siamandas, p.2). The professor considered Winnipeg’s projected population growth, its available ground water supply, the earlier reports and the pricing that was used, and made his own analysis of Shoal Lake water. After considering the options, Professor Slichter, in a report dated September 6, 1912, recommended that the City use Shoal Lake as its source. He noted that “a perfect water supply is worth all its costs” and that “I recommend the water supply for Winnipeg be taken from Shoal Lake, basing this judgement on the fact that this is the very best supply available” (Slichter 1912, p. 1). Judge Robson endorsed Slichter’s recommendation, and in his report of the same date added that,

The advantage of the undertaking should not be confined to mere corporate boundaries. A scheme might be worked out whereby the environs of present Winnipeg might, on fair terms, secure with the city the inestimable benefits of abundance of the best water. The assurance of unfailing supply is indispensable to the growth of the city. (International Joint Commission 1914, p. 96)

That suggestion became the germ of the idea for the formation of the GWWD. The money by-law on the Poplar Springs project was narrowly defeated a week later.

4.0 THE CONCEPT AND POLITICS OF THE WATER DISTRICT (1913)

Thomas Deacon became the mayor of Winnipeg in 1913. A civil engineer and businessman, he was president of Manitoba Bridge & Iron Works. His strong support for Shoal Lake as a water source which began with his 1906 service on the Water Commission had not wavered. In his mayoral campaign, he made a pledge of “providing at once for the people of Winnipeg an ample and permanent supply of pure soft water which will forever remove the menace now hanging over Winnipeg of a water famine” (Shropshire 1994, p. 3).

The idea of the surrounding municipalities participating with the City of Winnipeg in a Shoal Lake water supply project caught on quickly. That they were able to come together on the issue of water was probably facilitated by the fact that Winnipeg was already providing water to four of those municipalities, and St. Boniface to one. Judge Robson seems to have had practiced in the area of municipal law and was later the coauthor of text books on the subject. He used that knowledge, together with the concept of an inter-municipal corporation modeled on one that had started in England, to assist the two cities and the municipalities in coming to an arrangement. In January of 1913, a series of meetings was held with Mayor Deacon and the Judge playing prominent roles. By the end of the month, there was agreement on draft legislation to form a water district.

After the adoption of resolutions by the various municipalities endorsing the proposed legislation, “An Act to incorporate the ‘Greater Winnipeg Water District,’ being Chapter 22 of 3 George V,” was assented to in the Manitoba Legislature on February 15, 1913 (Province of Manitoba, 1913). The areas included in the district were as follows: The City of Winnipeg, The City of St. Boniface, The Town of Transcona, the Rural

Municipality of St. Vital, a part of the Rural Municipality of Fort Garry, a part of the Rural Municipality of Assiniboia, and a part of the Rural Municipality of Kildonan. At the time, Kildonan straddled the Red River, but it was changed to become East and West Kildonan in 1914. Even with only parts of some municipalities included in the District, Winnipeg comprised only 26% of its area, but had 87% of the population. An April 1913 map of the District showing areas and population is provided in Appendix 11.3.

It is significant that, while Winnipeg was guaranteed the Chairmanship, it did not have a majority position on the governing Board and could not dictate. Winnipeg had five members on the Board and the other entities had seven. That position was further diminished with the 1914 amendment that gave representation to both East and West Kildonan.

Some of the more significant features of the Act were as follows:

- a) That the coming into force of the Act was conditional on approval by Winnipeg voters. The requirement was for a three-fifths majority of those eligible and participating in the vote;
- b) That the powers and functions of the corporation were to be exercised and discharged by an Administration Board. It was comprised of the mayor and the other members of the Board of Control of the City of Winnipeg, the mayor and one member of the Council of the City of St. Boniface, and the mayor or reeve (as the case may be) of the Town of Transcona and the Rural Municipalities of Assiniboia, Kildonan, Fort Garry, and St. Vital;
- c) That day-to-day management of the corporation would be carried out by a Board of Commissioners who were subject to the authority of the

Administration Board. An organizational chart of the District is shown in Appendix 11.4 ;

- d) That there were specific requirements for financing and that a sinking fund be established to pay off the debts of the corporation;
- e) That, with few exceptions, the value of all land in the district, but not including buildings or other improvements, was the basis for the taxation to finance the corporation;
- f) That a special Board of Equalization, appointed by the Public Utilities Commissioner, be established to determine the assessment to be levied on the taxable land in each municipality, i.e. it was not on the assessments decided by the individual municipalities;
- g) That the District was to supply water in bulk to the entities forming the corporation;
- h) That, should one of the participating entities decide not to take its water from the corporation, it would still have to pay the corporation for the loss of revenue resulting from so doing; and
- i) That there be prescribed penalties for any person(s) taking water from the District without permission.

An amendment in 1914 essentially provided that the progress of the project could not be delayed by any court action due to a dispute over damages or prices offered in expropriation (Chapter 47 of 4 George V). That effectively cleared the way for the corporation to quickly decide on its right-of-way for the works. Section 6.1 provides the details of the amendment.

The three-fifths vote of approval by the eligible Winnipeg voters bringing the legislation into force took place on May 1, 1913, four months after Thomas Deacon had become the Mayor. The residents qualified to vote on money by-laws approved the formation of the GWWD by a margin of 2226 to 369. With the population of Winnipeg in 1912 of 166,500 that might seem a low turnout on such an important issue. However, when one considers that, unlike today, to qualify as a voter one had to own property worth at least \$500, the turn out seems not to have been an indicator of voter apathy (Artibise 1975, p. 39). That participation was only 15% lower than the October 1, 1913 vote on the more significant major expenditure, that of the \$13,500,000 decision to proceed with the Shoal Lake project.

In the interim, the Winnipeg City Council had engaged another board of four consulting engineers in April of 1913, all from the US, and instructed them on May 20, 1913 to “submit a report on the best means of supplying the Greater Winnipeg Water District with water from Shoal Lake, together with an estimate of cost and general plan of work” (Greater Winnipeg Water District 1918, p 7). Then, with the GWWD official, the first meeting of the Administration Board took place on July 30, 1913. The most significant decision taken was to authorize the Chairman, Mayor Deacon, to meet with the lawyer Isaac Campbell to begin the process of an application to the International Joint Commission to allow the District to take water from Shoal Lake (GWWD minutes, July 13, 1913). The die had been cast. Mayor Deacon’s consistent vigorous efforts on achieving the Shoal Lake project were acknowledged soon afterwards. The site of the planned future reservoir, and a major transition point of the aqueduct system and the GWWD’s railway, 19 km east of Winnipeg was named in his honour (Figure 1.1).

The Board of Consulting Engineer's report was delivered on August 20, 1913, and on September 6, 1913, it was quickly adopted by the Administration Board of the GWWD, which at the same time, passed a by-law to create a debt of \$13,500,000 (GWWD minutes, September 6, 1913). Once again, a requirement of the legislation was that the debt had to be approved by the Winnipeg voters through a money by-law. That vote occurred on October 1, 1913, with 97% being in favour (GWWD 1918, p.7). To put that decision in perspective, and using housing prices as a metric, the author estimates that it would be the equivalent of a \$400,000,000 decision for a 2011 voter.

The Administration Board began its operations with the hiring of S.H. Reynolds, a civil engineer from Vancouver, as the Chief and only Commissioner and W.G. Chace as its Chief Engineer. Mr. Reynolds had been the Assistant City Engineer in Winnipeg under H.N. Ruttan from 1902 until 1907. Mr. Chace, who was from Ontario, had been previously engaged by the City of Winnipeg as a senior engineer on the construction of the recently completed Pointe du Bois hydro-generation project.

To pay for the project, annual payments were required from the member entities in amounts determined through an equalized property assessment. However, the Board of Equalization responsible for establishing that assessment was not appointed until 1918.

(Judge Robson had left the position of Public Works Commissioner in 1914.)

Accordingly, one of the most consistent issues before the Administration Board was the matter of cash flow to finance the work. Going into the project credit had not been an issue. But with the outbreak of WWI in August of 1914, just as construction expenditures in the range of \$7,600,000 were being committed, arranging credit became much more difficult. The options explored were many, as were the revisions to the legislation to authorize the options. This thesis does not track those efforts. However, two aspects are

worth noting. The first is that, in its early years, the Administration Board appointed J. H. Ashdown, who had steered Winnipeg out of its indebtedness following the 1907 recession, as its honorary treasurer. He was also later engaged as one of the members of the Board of Commissioners. The second is that the Bank of Montreal, which had been supportive of Ashdown in his financing of the City in its period of difficulties, handled the District's financial arrangements from the beginning and appears to have been very supportive of the initiative.

One issue on which the Administration Board and the engineering staff did not have an easy meeting of minds was on the matter of supply of the Portland cement and concrete aggregates (sand and stone) for the project. The engineering staff and Commissioners proposed that the District supply those materials to the individual contractors rather than include that responsibility in the contracts. They recognized that quality control in the production of the materials was essential and that such control could be more readily assured if the monitoring and inspecting of the product involved only one supplier rather than a possible five. The matter of that contract policy was on the Board's agenda for a number of meetings before the policy of supply by the District was approved. While the minutes of the meetings do not record the dialogue, one gets the sense that some members felt that, as private enterprise, the contractors would be more cost efficient than the District's administration. In the end, with the quality and consistency in the products provided, and the ability to coordinate and control deliveries, the right decision was made.

The Administration Board had many other issues to deal with, not the least of which was the cracking in the conduit that developed in some sections of the completed work at the end of 1915 (section 8.8.1). One of the Board's hindrances was that, with the

positions being ex-officio, its composition could change annually depending on the outcome of eight civic elections. Those election outcomes would not necessarily have been determined by a candidate's project management experience. Nevertheless, it is impressive that the Board appears to have conducted its affairs effectively, and with very little controversy despite the tensions that could have evolved between neighbouring civic entities.

5.0 APPROVALS (1913 -1914)

5.1 The Aqueduct Scheme Overview

The source of the water for the Winnipeg Aqueduct is Shoal Lake, a tributary of Lake of the Woods. The specific location on Shoal Lake was Indian Bay on the lake's western edge. The longer dimension of Indian Bay is east-west and on the south side is an east-west oriented promontory of land. The settlement of the members of the Ojibway First Nation that occupy Shoal Lake Indian Reserve No. 40 is located on that promontory. On its south side is another bay of Shoal Lake known as Snowshoe Bay. The narrowest portion of the land between the two bays is about 840m and is close to the western shore of Shoal Lake. A stream known as the Falcon River discharges into Indian Bay immediately south of where the water for the aqueduct is withdrawn. The Falcon River is the outlet of Falcon Lake some 10km to the west and also drains much of the muskeg area in between. The height of land forming the western boundary of Shoal Lake along the aqueduct route is 6km west of Indian Bay. The general layout of the area is shown in Figure 5.1.1 and Table 5.1.1 provides statistics on the drainage and surface areas of the region.

A history of modifications to the water levels of Lake of the Woods is provided by the Shoal Lake Watershed Working Group (2002, p.1):

Shoal Lake is connected to Lake of the Woods at a location known as Ash Rapids. Construction of a control dam at the outlet of Lake of the Woods in the 1880s raised the level of the lake by about a metre above its natural condition. In turn, this brought water levels in Shoal Lake into approximate balance with levels in the much larger Lake of the Woods, at least over an extended portion of the year. The channel at Ash Rapids was deepened and widened from its natural state, through blasting, around the turn of the century [1900]. This was reportedly done to provide a water based transportation route to serve both timber and mining operations in the Shoal Lake area.

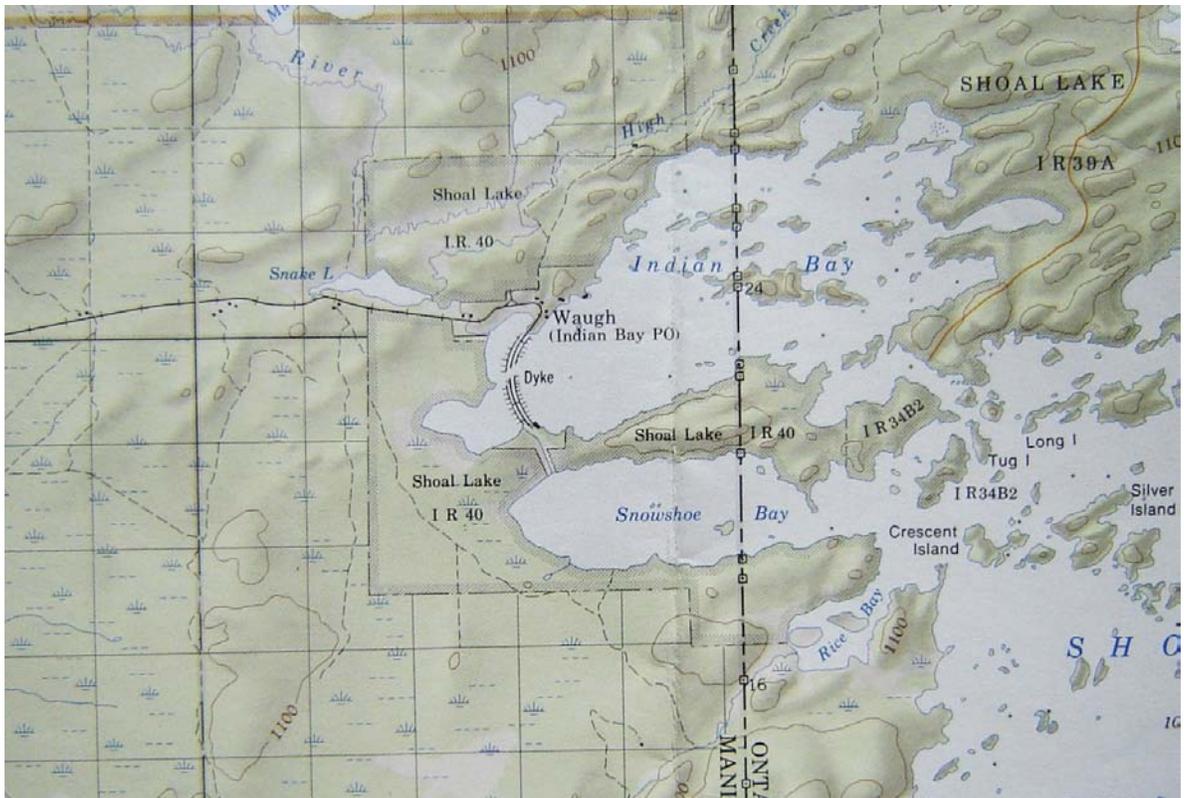


Figure 5.1.1. Indian Bay and Aqueduct Inlet area

TABLE 5.1.1. AREA STATISTICS LAKE OF THE WOODS AND SHOAL LAKE (Chace, 1920a, p. 394)

Aspect	Area in Square Miles (km ²)
Drainage area, Lake of the Woods	27,000 (69,000)
Surface area, Lake of the Woods	1,250 (3,200)
Ratio of drainage area to surface area	21.6
Drainage area, Shoal Lake	360 (930)
Surface area, Shoal Lake	107 (280)
Ratio of drainage area to surface area	3.5

The overall scheme of the Winnipeg Aqueduct, following the direction of the flow, entailed the following:

- a) a soft water source that required no treatment for potability, colour, or hardness ,
- b) a 2.4 kilometre dike across a portion of Indian Bay and a 840m channel excavated between Indian Bay and Snowshoe Bay to divert the water of the Falcon River,
- c) an intake structure on the edge of Indian Bay,
- d) a gravity fed enclosed conduit that conveys water, primarily in an unconfined channel, but with some portions under pressure, from the inlet to The City of Winnipeg's McPhillips Street water reservoir over a distance of 155km,
- e) provision for an equalizing and storage reservoir (Deacon) approximately 21 km east of the McPhillips reservoir,
- f) metering facilities for the measurement of the volume of water flowing at vital points, and
- g) a railway that facilitated the initial construction, and now the on-going operation and maintenance of the system.

Features of the enclosed conduit were as follows:

- a) it had a design capacity of 85,000,000 gpd (386,400,000 L/d) per day,
- b) it cut through the height of land that forms the boundary of the Shoal Lake watershed,
- c) it made provision for delivery of water into a future second conduit that could increase the combined design capacity to at least 100,000,000 gpd (454,600,00 L/d),
- d) it crossed six rivers by means of inverted siphons,
- e) it provided a system for water and air pressure relief during operations,
- f) it provided means for inspection during partial operation and for isolation and for dewatering of sections for maintenance, and
- g) it maintained the integrity of local surface drainage systems.

5.2 International Joint Commission

Among the earlier matters that the Administration Board had to deal with was obtaining permission to take its water from Shoal Lake. As the lake is connected with and part of the Lake of the Woods watershed, a trans-boundary water system, approval was required from the IJC which administered the *1909 Boundary Waters Treaty* between the United States and Canada. Shoal Lake is also a trans-provincial body of water with the Ontario border being just three kilometres east of the aqueduct inlet. Additionally, under the terms of Manitoba's entry into the Canadian Confederation, the province did not, in 1913, own the rights to the natural resources in its territory. However, Ontario did have ownership so permission to take water was also required from both those governments. The consent of the Government of Canada had been given in June of 1913 soon after the GWWD's act came into effect (Water and Waste Department n.d., Box 1-I, Doc 7).

Ontario's consent was provided by way of an Order in Council on October 2, 1913. The Ontario Order was subject to terms and stipulations. One stipulation was that the GWWD would be required either to remedy or pay damages should the removal of the water appreciably reduce the amount of hydro-electric power that the Town of Kenora could generate with its facilities at the outlet of Lake of the Woods (Water and Waste Department n.d., Box 1-I, Doc 19).

An application to the IJC was subject to the approval of the Government of Canada and could only be transmitted to the Commission by that government. Conveniently the cabinet minister at the time responsible for such transmission, Robert Rogers, the Minister of Public Works, was from Winnipeg. His letter of transmittal to the IJC was dated August 25, 1913, and the Commission began its hearing on January 13, 1914 (IJC 1914, p. 5, p.11). The application was for the GWWD to draw up to 85,000,000gpd (386,400,000 L/d). Not unexpectedly, given the stipulation in the Ontario Order in Council, the Town of Kenora was represented by legal counsel. Seven persons gave testimony on the water level issue. Five of them, including James H. Fuertes, were engineers. There was agreement among the witnesses that if a year's supply of water at 85,000,000 gpd (386,400,000 L/d) was to be removed from the Lake of the Woods-Shoal Lake system in a single day, the water level would be lowered by less than 1.5 in (38mm) (IJC 1914, p. 47, p.63). With that figure established, there was little basis to conclude that the power generation opportunity for the Town of Kenora would be affected. The Commission endorsed the application, sending its formal opinion recommending approval to the two governments on January 15, 1914. Later communication from the IJC put the GWWD on notice that it would not consider any application to increase the amount of water it could take to any amount more than 100,000,000 gpd (454,600,000

L/d) (Cherney 2009, p.3, Scott n.d., p. 25, Chace 1920b, pp. 2-3). One presumes that it was on the basis of that information, the design of the installed system between the intake structure and a point some 16 km to the west made provision to accommodate such an increase (Section 7.14).

6.0 ACQUISITIONS AND PURCHASING (1914)

6.1 Right-of-Way

Once the preferred route for the aqueduct was known, acquiring the right-of-way for the project was on the critical path, particularly so that the railway construction could be started. As mentioned in section 4.0, a provision of the GWWD Act passed in 1914 was very helpful. That section, an addition to section 22 of the 1913 Act, reads:

In no case shall the progress of the works or undertaking of the corporation be hindered, enjoined or delayed in any way, or by any court, on account of any pending arbitration of dispute or disagreement as to damages or value regarding any privilege, water or land entered upon or taken, or proposed to be entered upon or taken, for the purpose of the undertaking authorized by this Act, but the corporation may enter upon, take possession of, hold, use or occupy and enjoy all such land, water and privileges as they are by this Act authorized to do for all the purposes of the undertaking pending any arbitration or settlement of any dispute or disagreement as to damages or value aforesaid, subject to giving up possession of the same in case of default of payment as above provided.

The amendment did not vest the GWWD with the right to dictate terms of land acquisition. It still had the obligation to be reasonable in its offers and a purchase could still be subject to arbitration. However, it did have the opportunity to occupy an owner's land without becoming mired in legal proceedings which could have significantly delayed the project. One wonders whether it would ever have been built had delays prevented the start of major construction until after the beginning of World War I.

6.2 Shoal Lake Band 40 Land

The GWWD had the provincial act to rely upon for most of its property acquisition, but that was not the case for aboriginal reserve lands. The intake and the initial sections of the aqueduct were located on reserve land belonging to Shoal Lake Band 40 (See Figure 5.1.1). The reserve was regulated under *The Indian Act* of the Dominion Government. With virtually all of Indian Bay, Snowshoe Bay, and the adjacent shore lines being part of Band 40's reserve, it was necessary for the GWWD to acquire rights to some of that land. Conveniently, *The Indian Act* contained a provision whereby if a municipal authority had provincial statutory authority "for taking or using lands or any interest in lands without the consent of the owner," it could do so for reserve lands with the approval of the Governor in Council (Dominion Cabinet). The GWWD had such statutory authority, and while *The Indian Act* required that the proceeds of the sale were to go to the band, the Governor in Council had the authority to set the price. Such was the case when Canada sold the GWWD 355 acres (144 hectares) of the Band 40's land on the shore of Indian Bay for \$3.00 per acre and 3,000 acres (1200 hectares) of the lake bed and islands of the Bay for \$0.50 per acre. The transaction took place under Privy Council Order No. 463 on March 3, 1915, (Appendix 11.5). Two matters related to that sale are noteworthy in the context of current day negotiations with First Nations. The first is that the purchase included the land required for the Falcon River Diversion, and by the time that the transaction was authorized the dike across Indian Bay had already been substantially completed as evidenced by the date of July 11, 1914, on Figure 7.12.1. The other, and while it might not have seemed significant at the time, is that with the excavation of the diversion channel, the traditional settlement occupied by the Band 40 residents became landlocked, and that continues to be the case.

Another mistreatment from the aqueduct construction for Band 40 was that, while their members were probably able to obtain some employment working directly for the GWWD, they would have been barred from working for the contractors. There was a condition in the contracts that, since Districts land owners were paying for the project, workers be hired from within the District some 140 km away. On the other hand, in the post-construction period, the band would have had the advantage of transportation on the GWWD railway from Indian Bay to Winnipeg.

More recently, the Shoal Lake Watershed Working Group received representations from First Nations community representatives that the Falcon River Diversion has been the cause of increased sediments in Snowshoe Bay. That now seems less controversial as the Working Group indicated in its report that the water quality of Snowshoe Bay has likely not been adversely affected by the channel (Shoal Lake Watershed Working Group 2002, p.23).

6.3 Gravel

An assured supply of gravel was vital to the implementation of the project. Chace (1920a, p.937) notes that approximately 1,000,000 cy (765,000 m³) were moved during the construction. It is not known whether that figure includes the material for the Falcon River dike. That fill material was taken from land that was formerly part of the reserve belonging to Shoal Lake Band 40.

While it was generally understood that sources of gravel on Crown Lands in the vicinity of the route of the aqueduct could be accessed, a complication developed that the Administration Board and Commissioners eventually overcame. It arose from the fact that, at the time, the natural resources within the Province of Manitoba were owned by

the Dominion Government, and that gravel was one of those resources. The Mining Lands & Yukon Branch of the Department of the Interior administered such resources. While its regulations allowed a railway company easy access to gravel, the GWWD, even though it owned a railway, did not qualify as a railway company. The Branch's regulations, however, provided that gravel on a homestead belonged to the homesteader, but the area of a homestead was limited to 40 acres (16 hectares). As the District's requirements were large, and the quantities that could be available on a homestead uncertain, acquiring the rights to materials of the necessary quality and quantity would have involved a number of homesteads.

While there was correspondence from the District lobbying for a waiver of the regulations, one manoeuvre apparently condoned by the Branch, was that members of the GWWD Administration Board and senior staff filed applications for homesteads. In the end, that proved unnecessary as the representations for change seem to have had an effect. The controller of the Branch in a July 6, 1915 letter to the legal counsel for the GWWD advised of an addition to the regulations "[so] that any city, town municipality or other municipal district, requiring material for its own use, may obtain more than one location under the provisions of these regulations" (Library and Archives Canada, Mining Lands & Yukon Branch, 116619). As an aside to the homestead issue, the Administration Board found it necessary to dismiss two employees whose duties had been to explore for sources of gravel and who had filed homestead applications in their own names without the knowledge of the Board. Those applications were quashed. By the end of the project, the bulk of the gravel was obtained from privately owned pits and one that had already been transferred to the Province of Manitoba. After the completion

of the project, the business of providing gravel and concrete aggregates for use in Winnipeg via the GWWD railway became a source of revenue for the District.

6.4 Cement

The decision that the GWWD would supply the Portland cement to the contractors at the work site was an important contributor to the success of the project. It facilitated quality assurance and enabled the district to maintain control of inventories and deliveries. All of the cement for the aqueduct was manufactured by the Canada Cement Company Limited. It had begun operations in the Winnipeg area (Fort Whyte) in 1911 and was producing cement exclusively from Manitoba resources by 1913 (Cole, 1948). At the time, cement was priced by the barrel but packaged and shipped in bags. A barrel weighed 350 lbs (159kg) and a bag weighed 87.5 lbs (40kg). The bags were delivered to the work locations on rail cars. Supply contracts were tendered by the District for each year's construction season from 1915 to 1918. As noted above each year's contract was awarded to the lowest bidder, and for 1918, the only bidder was the Canada Cement Company Limited. The price was \$2.46 per barrel for 1915 and 1916. However, for the next two seasons there were increases and the overall increase from 1915 to 1918 was 24.4%. The cost of cement in the concrete and the price increases were not insignificant. The total value of the Canada Cement contracts was \$1,564,000, i.e. a 1% increase would be in the range of \$15,000.

6.5 Ancillary Purchases

To provide the organization of the required capacity, and to supply items both for its own use and for incorporation in the works by others, the District made a number of other direct purchases such as the following:

- rails, switches, frogs, and track accessories for the railway,
- the motive power and rolling stock for the railway,
- motor cars for the staff,
- equipment for the excavation, crushing and screening of gravel and rail cars equipped to dump materials,
- pipes, valves, and fittings, and
- Venturi meters and recording equipment.

6.6 Transportation

With its railway operational alongside the contractor's sites, the GWWD was able to facilitate their operations by acquiring the additional motive power and rolling stock to provide transportation for equipment, materials, and personnel. To offset those acquisitions, the contractors were charged on a ton-mile and person-mile basis (section 8.5.3). After the project was completed, the railway earned revenue for the transportation of not only gravel but for timber, firewood, and goods to and from the settlements that grew up along the line.

7.0 DESIGN (1914)

Koen (1985) defines the engineering method as “the strategy for causing the best change in a poorly understood or uncertain situation within available resources.” There is little doubt that the engineers responsible for the implementation of the Winnipeg Aqueduct, in seeking to cause the best change, were faced with uncertain situations and finite resources. While they had access to the experiences of other aqueduct designers, they also had to deal with factors that were specific to the locality of the project and that were not well understood. There were two in particular. One was the issue of selecting the most all-round economical route for the conduit. The other was developing a design for the concrete mixture for use in the conduit utilizing the available local aggregates that would meet the necessary compressive strength, permeability, and durability requirements.

7.1 Designing for the Terrain

The terrain between Shoal Lake and the prairie country just east of Winnipeg was treed, crossed by rivers, and some 80km of muskeg or swamp. It was also for the most part uninhabited and did not lend itself to ready access or communication. Despite those difficulties, there had been some exploratory work done on a possible route. As early as 1906-1907, C.A. Millican, C.E., Municipal Engineer and Contractor, made an exploratory survey beginning from Shoal Lake and working the territory to the west. One presumes that work was done on behalf of the Winnipeg Water Supply Commission established in 1906 as Millican’s report was addressed to the J.H. Ashdown, the Mayor. In his March 1907 report he suggested that the Boggy and the Birch Rivers, by using some supplementary and control works, could be utilized to deliver the water for much of

the easterly portion. Fuertes (1920) acknowledged that possibility but in so doing noted the greater water velocity that could be provided with a concrete lined conduit. Millican also cautioned that there would be rock outcroppings to be crossed or avoided. That information would have been important and significant to the final cost. Chace (1920a, p.935) reported that the as-completed project involved 12,000m³ of rock excavation.

The next terrain related information resulted from a 1912 decision by the Winnipeg City Council. Acting on instruction within days of the Council receiving the recommendation from Judge Robson (section 3.0), City Engineer Ruttan instituted a survey “to determine the practicality and cost of procuring a water supply for Winnipeg from Shoal Lake.” In his report, Ruttan (1913) stated that “the project is not only practicable, but that the conditions are more favourable than expected.” The report included for the first time a precise figure for the difference in elevation between Shoal Lake and the McPhillips Reservoir, namely 293.19 ft (89.42m). While the available information was preliminary, and construction access was assumed to be by road rather than rail, it is impressive that the estimated cost provided in the report was \$14,144,905. That is within 8.5% of the \$13,045,600 estimate produced by the Board of Consulting Engineers in its report of August 20, 1913. The survey information produced by Colonel Ruttan’s staff was no doubt available and very useful to that 1913 Board of Consulting Engineers in producing their report. It included topographical information on both a possible route and for the area around Indian Bay and Snowshoe Bay. Soundings were also taken in both bays.

Once the October 1913 vote by the Winnipeg ratepayers on the money by-law was settled, it was time for the GWWD engineers to determine the final route selection so

that the right of way could be established and the railway started. Doing so required more precise and extensive survey information. Survey parties were dispatched with one important task, that being to establish a precise set of benchmarks (Chace 1920, p 933).

During the winter of 1913-1914, the survey parties accomplished the following:

- 95 miles of precise levels,
- 362 miles of transit lines,
- 1,317 miles of levels, and
- 380 square miles of topography.

Additionally, some 12,000ft of borings were also made to assess the foundation conditions and determine the depths of muskeg. Anyone who has surveyed during a Manitoba winter with survey instruments of that era will recognize the accomplishment and appreciate the ordeal that those surveyors endured.

In approaching the route selection task, the GWWD engineers had available the preliminary design that was provided as part of the report of Board of Consulting Engineers (Hering et al, 1913) which included details of typical conduit arch sections. With that information, and on-going refinements of the sections, curves were developed showing cost variations for typical aqueduct cross-sections based on depths of excavation and for a range of slopes. With that information available, field staff could make on-site decisions in choosing an alignment that would minimize the costs and the line length while striving to maintain the average slope of 0.57 ft per 1,000 ft of length (Chace 1917, p.384). By that process, an alignment was established by March of 1914 on which over 30% of its length was very close to the average slope (the final average gradient was 0.62 ft per 1,000 ft) and with a length that was only an 8% increase over the straight line

distance (Chace 1920a, p.933). Landon (1918, p. 299) provides a listing of the slopes for each aqueduct cross section. They are shown in Table 7.1.1.

TABLE 7.1.1. SLOPES OF THE WINNIPEG AQUEDUCT FOR VARIOUS CROSS-SECTIONS [Landon, 1918, p. 299]

Slope of Aqueduct inches per 100 feet	Dimensions of Sections in feet and inches (width x height)
0.11	10'-9" x 9'-0"
0.279	10'-9" x 9'-0"
0.300	8'-9" x 7'-45/8"
0.382	8'-31/4" x 7'-0"
0.480	7'-111/2" x 6'-81/2"
0.600	7'-71/2" x 6'-51/4"
0.684	7'-51/2" x 6'-31/2"
0.744	7'-4" x 6'-21/2"
1.290	6'-7" x 5'-61/8"
1.537	6'-41/2" x 5'-41/4"

An early start to the railway was essential to the project, and once the route was decided, the right-of-way could be established and the railway construction could get underway. The right-of-way selected was generally 300 ft (91m) wide with the railway located 40 ft (12m) from the south boundary. At the easterly end, which had more construction challenges such as the depth of excavation, the width was increased to 500 ft (152m).

7.2 Designing the Concrete

Concurrent with the installation of the railway, the GWWD engineers undertook their other innovative work by producing an optimum design of the concrete mix for the project. In so doing they undertook a full program of analysing, selecting, and portioning of the available aggregates (sand and stone) to produce the desired product. Their back-to-basics approach was perhaps necessitated by their physical remoteness from the

mainstream engineering practitioners in eastern North America. But also, as they noted in referring to the published information available at the time, they concluded that “the most vital defect appears to be that each published report or series of experiments is lacking in some essential detail which prevents or curtails its application in other work” (Chace and McLean 1917, p. 397). An example of that uncertainty was that the listed unit weights of Portland cement powder as published by various authorities ranged from 94 to 107 lb/ft³ (1,500 to 1730kg/m³). For such reasons, they chose to rely on their own analysis and testing to decide on the best proportioning of their materials to achieve the performance that they desired.

The GWWD engineers were keenly aware of the effect that the amount of Portland cement used in a cubic yard of concrete would have on the cost of the project. That awareness would have been heightened by their knowledge that cement in Canada cost 45% to 50% more than in the US or Great Britain (Chace and McLean 1917, p. 423). Presumably part of that difference was because of less competition. The cement component eventually selected for the aqueduct concrete, based on their testing program, was 430.5 lbs/cy (255kg/m³) vs. 549.5 in the mixtures commonly used and recommended for water-tight work by other authorities of the time (Chace and McLean 1917, p. 431). Chace reported in the same reference that the savings achieved by relying on the recommendations of the GWWD engineers were projected to be \$350,000 for 400,000cy (306,000m³) of concrete. That figure was based on a 1915 cement cost of \$0.0079 per pound. To put that in 2010 dollars, with cement then at \$255 per metric tonne (\$0.1158 per pound), the saving would be \$5,500,000.

In achieving that economy, the GWWD engineers relied on their own methods. Knowing the sources of granular material available as a result of the ongoing 1914

railway construction, and other exploratory work, they undertook an extensive program of analysis and testing of materials from those sources (Chace and McLean 1917). The program consisted of five tests:

- a) a mechanical analysis of the aggregates from the available natural deposits,
- b) the weight per cubic foot of the various gradations and combinations of materials,
- c) volumetric tests of the materials for density,
- d) tests for compression and tension of various sand-cement mortar mixtures,
- e) tests for both permeability and compression of concrete with various mix proportions of stone and sand when selected by using the data derived from the other tests.

The testing program involved two lots of Portland cement, with the major difference between them being the time interval to final set after mixing. The cement used was manufactured by the Canada Cement Company Limited and purchased from local dealers. The specimens for the program were made from 28 distinct concrete mixes. There were 29 tests of permeability and 47 in compression (Chace and McLean 1917, Table No. 10).

The compression testing program, with specimens 8 in (20cm) in diameter and 16 in (40cm) long, seems to have followed standard procedures. However, the permeability test, if not unique, was at a minimum innovative. The concrete specimens were 13 in (33 cm) in diameter and 14.5 in (37cm) long and cast with a small internal chamber connected to a metal injection pipe with an external water-stop (Chace and McLean 1917b, p. 412). The test apparatus forced water into the chamber at a constant pressure with a gauge to measure the water entering the specimen with a means of measuring the

amounts passing through the concrete, and a separate measure of any leakage from around the pipe used for the injection. A photo of the apparatus used in the test is shown in Figure 7.2.1.

In their paper Chace and McLean (1917b, p.414) concluded from their testing program “that with lean mixtures and the gravel materials available, the addition of fine sand would give the work contemplated impenetrable concrete of the desired strength.” Their opinion was borne out by tests of the performance of the completed conduit. Chace also reported in (1917c, p. 282) that mixes adopted on the basis of those tests would develop “a strength of 2,800 pounds per square inch and a six-inch wall of concrete will be watertight against a hydrostatic pressure of 200 feet head.”

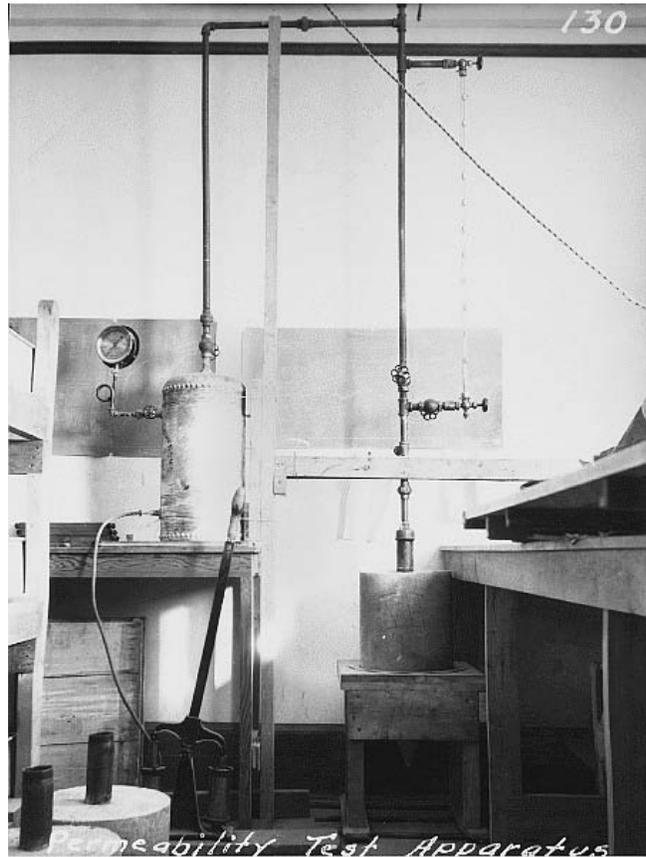


Figure 7.2.1. Permeability testing apparatus (GWWD No. 130)

Once the optimum mixture was determined, the next step was to develop standards for the selection and processing of the aggregates at the pits. As noted in section 4.0, the District had decided to supply the contractors with the concrete

aggregates to ensure the use of uniform material throughout the project. As a further quality control measure, it was decided that the materials would be delivered pre-mixed. As such, the operation of the pits required careful planning, management, and monitoring. That function, as well as the transportation of the materials to the contractor's work sites was undertaken by the District working out of two locations. The principle source was at Mile 31 and the other was at Mile 80. In essence, the GWWD was functioning as a contractor with the requirement for its concrete materials being as much as 1,200cy (900m³) per day (Chace 1920a, p.937). The pit run materials were screened, and when necessary crushed, and then segregated into bins. From there, they were fed onto a mixing belt which brought the mixture to self-dumping railway cars. The mixed product coming off the belt was monitored by inspection staff to ensure the target proportions as shown in Table 7.2.1 were being met.

TABLE 7.2.1. TARGET PROPORTIONS OF AGGREGATE SIZES FOR AQUEDUCT CONCRETE [Chace and McLean, 1917b, p. 416]

Description	Passing	Range
Fine Sand	No. 100 Sieve	10 to 20 % by weight of dry sand or 3.2 to 8.0 parts by weight in the aggregate
Sand	1/8 in. Sieve	32 to 40 % by weight of dry aggregate with 35 % as the objective
Sand and Intermediate	1/2 in. Sieve	Not more than 70% by weight
Oversize	3in. Sieve	Ordinarily not more than 15%

The mixture was then delivered as needed to the contractor's sites and deposited on platforms built adjacent to the railway. The fact that the aggregates were not separated would have made the contractor's platform operations less complicated and, as noted by Chace and McLean (1917b, p. 432); it also reduced the number of railcars required for the delivery operation, saving the District approximately \$10,000.

The Portland cement was also tested to ensure its conformance to the District's specification, which was essentially that of the American Society for Testing Materials. In the process, an automatic sampler intermittently collected samples that were accumulated in a container and the batch withdrawn on an hourly basis. It was then tested by both the District and the manufacturer (Chace and McLean 1917b, pp. 419-420). As it happened with all of the cement being manufactured in Winnipeg, the testing program would have been not only less complicated but also would have cost less than if the plant had been located in another part of the country. Like the aggregates, the cement supply was also managed by the District and delivered by rail to the contractors.

7.3 Cross Section Design

While the work on the aggregate supply and the mix details was ongoing, the other step was to finalize the shape and dimensions of the conduit sections. As part of that process, test sections were built and loaded as shown in Figure 7.3.1. It is of interest to note that W.M. Scott, the contractor for the test sections, seems to have been the same W.M. Scott (Scott 1938, and Scott n.d.) (an engineer) who sometime later became the Chief Commissioner of the GWWD.

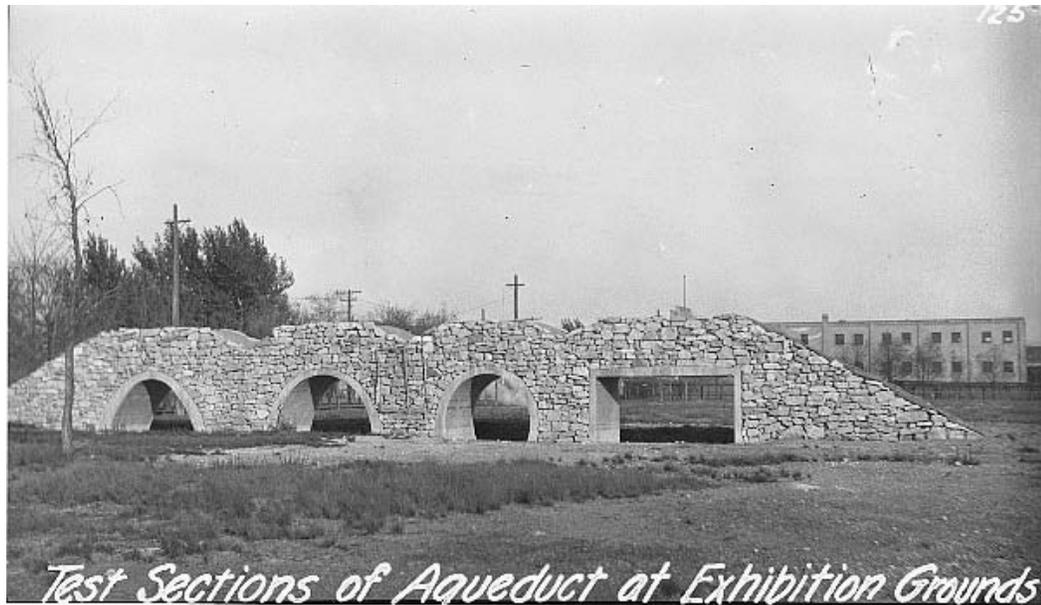


Figure 7.3.1. Test sections built in Winnipeg, summer of 1914 (GWWD No. 125)

With those test sections being located in Winnipeg, and available for public inspection, the step may have been as much of a public relations exercise as a contribution to knowledge. Nevertheless, recognizing the cost significance of the volume of concrete to be incorporated in the project, keeping it to a minimum was a priority. Chace and Sauer (1917a) estimated that a one inch increase in the sectional thickness would have cost \$400,000.

The engineers were also cognizant of the durability of reinforcing steel should it become exposed to water through cracking of the concrete. With that in mind, they elected to use the unreinforced self-supporting arch type cross-section for the cut-and-cover portions that comprised most of the aqueduct. The arch rested on the edges of a previously cast invert section as seen in Figure 7.3.2. The invert had a circular concave upper surface with the radius of the curve somewhat greater than the height of the arch. As an example, the radius for a section with a 2.25m interior height was 3.4m. The term “invert” refers to the lowest point in the internal cross-section of an artificial channel, and

is thought to have originated from describing an inverted arch. Ruttan et al (1916, p. comment on the function of an invert in the chosen system as follows:

Although, as actually constructed, the side walls of the arch rest upon the ends of the invert, the greater part of the load, in a section like the one shown, may be assumed to be borne by those portions of the trench bottom directly beneath the side walls, because the central part of this relatively thin unreinforced type of invert is not considered to provide much in the way of support, but rather to serve merely as a firm water-tight bottom to the aqueduct.



Figure 7.3.2. Chief Engineer W.G. Chace at a typical arch section on an invert (GWWD No. 264)

These typically unreinforced arch sections were configured such that, under all loading conditions, the concrete in the arch would be in compression and thereby resistant to cracking (Fuertes 1920, p. 724). The cases where reinforcing steel was required in the arch section were as follows:

- a) at road crossings and undeveloped road allowances,
- b) for railway crossings, and

- c) in the arches where the weight of the backfill material was so light that there was a risk of deformation from outward ground water pressure and separation from the invert.

In each of those cases the concrete thickness was increased to protect the steel.

In selecting the system of the arch resting on a previously cast invert section, the designers decided not to stand on the principle of no risk of cracking. The decision later proved to be controversial but not calamitous (section 8.8.1). They recognized that given the nature of the areas to be crossed, the foundation conditions under the inverts would vary considerably, and at times that might result in unanticipated settlement and cracking. But, in so doing, they rationalized that should a problem arise, the cost of repair would be minor in comparison to the cost incurred by a design used over the full length of the conduit that would perform without cracking (Fuentes 1920, p. 728).

When the conduit crossed a river as a siphon, it was under internal pressure, and as the concrete would then be in hoop tension, those sections were reinforced with steel and the wall sections thickened for protection purposes. The same treatment was used for the 6.7km cast-in-place pressure section east of the Deacon Reservoir location. The circular sections were also built in two castings with the edges of the invert section thicker than the nominal thickness in the upper portion. The reinforcing steel was circular and crossed the construction joint where the steel was lapped. Figure 7.3.3 shows one end of a circular section.



Figure 7.3.3. Circular pressure section west end of Brokenhead River slough (GWWD No.230)

Aside from its cost, the use of reinforcing steel was an issue because at the time it did not come prefabricated. It was manufactured and delivered as a straight twisted square bar that had to be bent on site. Figure 7.3.4 shows an example of the bending process.

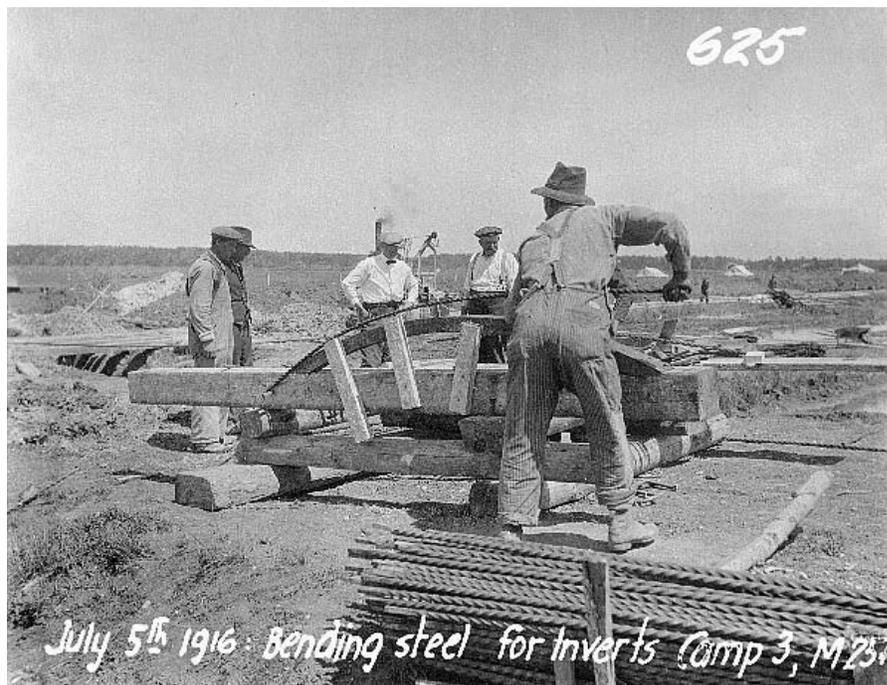


Figure 7.3.4. Method of bending reinforcing steel (GWWD No. 625)

7.4 Hydraulic Design

Once the arch and circular shapes had been chosen, the dimensions of the individual aqueduct cross-sections to be used for specific stretches were arrived at by a technique using Chézy's formula. The requirement was to ensure that the water level in the arch sections followed the hydraulic gradient and that the sections would not be under internal pressure. The selections were made on the basis of a flow equivalent to the 85,000,000 gpd (386,400,000 L/d) (Chace and Sauer 1917b, p. 386). Chézy was a French engineer who in the 1760s devised a means of determining the velocity in a channel under a condition of steady uniform flow based on the dimensional properties of the channel and its slope (Rouse and Simon 1957, p.118-120). In so doing, one uses a resistance coefficient, or roughness factor, derived from previously measured velocities in channels with known properties and a known slope. The formula then being

$$V = C\sqrt{RS}$$

where V = average velocity
 C = the coefficient
 R = hydraulic radius
 S = slope

The hydraulic radius is the ratio of the cross-sectional area to the wetted perimeter which can be easily calculated. In modern hydraulics, there are a number of ways of calculating C, chiefly by using factors determined through experiments. These days the more commonly used one is the Manning formula first proposed in 1889. In the case of the GWWD, the engineers wisely chose to base their C value on known results from a similar aqueduct that had been built in the US and studied. The one selected was the Sudbury Aqueduct which was part of the water supply system for the city of Boston, and as a cautionary measure the GWWD engineers reduced the published Sudbury C value by

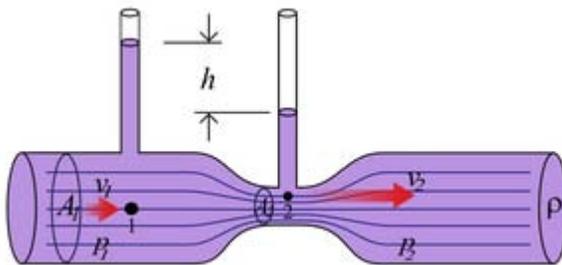
5% (Chase and Sauer 1917a, p. 386). The Chézy formula method lent itself to graphical solutions which would have made calculations less time consuming. Today the calculations would be done with a computer program. With that procedure, and by the time the tenders were called on the major construction contracts, those between Deacon and Indian Bay, the design involved 19 distinct cross sections. Thirteen of them were arch configurations and six were circular where the siphons crossed the rivers and were under pressure. While the dimensions of the sections were important, with 22 changes of section, careful attention was paid to the capacity of the transitions sections too. The inverted siphons for the river crossing were sized so that the loss of head over its length would be no more than if the easterly section had been carried through as an arch section for the length of siphon (Scott n.d., p.9).

Given the critical nature of the siphon installations, measures were taken to ensure that they were well reinforced and not subject to cracking. Cracks which would allow water action on the reinforcing steel would have been serious. To be confident of the required performance, the allowable design stress for the steel was set at 10,000 psi (69MPa) in tension, and the compression strength of the concrete at 500 psi (3.5MPa) (Fuentes 1920, p. 729). An indication of the importance placed on certainty of the performance of the steel is that the tender documents for the supply of the reinforcing steel specified a minimum ultimate tensile strength of 52,000 psi (358MPa). Confidence in the selected design stress of the concrete would also have been heightened by the results of tests conducted on 8 inch cube specimens made during construction on a contractor's work site. The 28 day results were 1900 psi (13MPa) and the cubes tested after six months could not be broken at a pressure of 3,165 psi (22MPa).

7.5 Measuring the Flow

In any water supply project, knowing the amount of water being delivered is important. The method selected by the GWWD for obtaining that information was the use of inline Venturi meters. The principle of the Venturi meter is that when the velocity of a volume of water moving along a closed conduit is increased by means of a constriction, the pressure decreases. That is known as the Venturi effect as shown in Figure 7.5.1.

By knowing the amount of the pressure change, and the diameters of the two conduit sections, one can then calculate the volume of the flow. In the case of the Winnipeg Aqueduct, three Venturi meters were incorporated in the main section.



One was located just downstream of the inlet and installed in the siphon section crossing under the Falcon River.

Figure 7.5.1 The Venturi effect (Wikipedia)

The two others were located at the site of the future Deacon Reservoir. One was just before and the other just after, the valves that would control the movement of the water into and out of the reservoir. The meter system at the Falcon River crossing transitioned from diameters of 9 ft to 3.5 ft (2.7m to 1.1m) at an excavation depth of 5.5m. Added to the difficulty of the depth of excavation, was that the water level in the nearby Snake Lake was probably about 5m above the elevation of the excavation. The forming of the concrete to achieve an internal shape of varying diameter and provide for the embedment of meter components under such conditions would have been a challenge to say the least.

7.6 Design for Containment

A great deal of care had been put into designing the concrete to be impermeable. To maintain that containment, and because the aqueduct sections were all to be built in longitudinal segments, preventing leakage at the transverse construction joints was also a significant requirement. That was accomplished by means of a copper sheet cast into each side of a concrete pour. It had a crimped portion centred on the joint to accommodate both flexing and expansion. The waterstop for the longitudinal joint between the foot of the arch and the invert was a wooden strip cast into both pours (Figure 8.7.4.1). It too is reported to have worked well.

7.7 Foundation Treatments

Chace (1920a, p.941) states that “the material encountered in this hundred miles of trench work varied all the way from peat to rock, including soupy clay, waxy clay, the various intermediate mixtures of clay and sand, sand dry or under water pressure and quicksand, granite and trap rock.” The reality of those variations was that, for the less than firm soils, the engineering staff and the contractors had to assess each situation and decide on the treatment to be used. The need for such on-site changes was contemplated in the tenders. For the main sections, those tenders required unit prices for such work as timber piling, sheet piling furnished and ordered left in place, and timber furnished and left in place. The timber pile foundation became necessary in some locations. In one other case, the depressed section at the Falcon River crossing, the drawings show the conduit supported on pedestals dug below grade and resting on rock. For other locations, imported fill was used to replace unsuitable material excavated from below the grade. It was paid for under tender unit price for Refill and Embankments.

7.8 Flotation Prevention

Another case that required special consideration on the arch sections was when the natural ground water level was at or above the top of the aqueduct and the weight of the available backfill material would be less than needed to keep the aqueduct in place when emptied. To prevent flotation and damage to the conduit, additional weight was required. After considering the alternatives, the engineers decided to use extra weight in the invert sections. That involved excavating the earth below the grade to depths of 60 to 80cm more than normal and constructing an additional thickness of invert. While the extra thickness was made of lower strength concrete, it was also contiguous with the normally specified invert thickness so that the two would act as a unit (Fuertes 1920, p.740).

7.9 Design for Overflow, Pressure Relief, and Inspection

The designers recognized and addressed the need to provide for such eventualities as too much water in the conduit, and for the relief of air pressure that could build up from changes in the depth of flow. In the sections from the Deacon area easterly the release was accomplished by special concrete structures built into the aqueduct itself, primarily at the river crossings. With stop log provisions incorporated in the structures and the overflow openings available, the normal flow could be shut off or reduced. If it was shut off, a section could be isolated for repair or maintenance, and for inspection purposes, a downstream section could be inspected using a boat when the flow was reduced to provide clearance. The structures included an opening in the top of the conduit permitting the lowering or removal of the boat.

The build-up of air could be released through the same structure as the water but the main release provision was a vent pipe installed in manholes that were built into the conduit at 1.6km intervals.

7.10 Frost Protection

The model for the Winnipeg aqueduct might have been New York's Catskill aqueduct but, when it comes to accommodating winter temperatures, Winnipeg in winter is not the Catskills. Particular attention was required to avoid damage and flow constrictions due to freezing and frost build up. The basic provision was to ensure that there was sufficient backfill over and around the conduit to prevent frost penetration. Such was the concern about the effect of winter temperatures on the performance of the conduit that, at the suggestion of then retired engineer H.N. Ruttan, a five kilometre section of completed aqueduct was tested under flow conditions during the winter of 1917. The results were positive. Fuertes (1920, p. 704) reported that "no ice nor frost appeared on the roofs or wall of the aqueduct nor on the water flowing."

One measure to prevent the ingress of cold air at the overflow structures was to have the top of the opening of the discharge culvert below the level of the invert of the aqueduct. A similar method was used on the cross drainage structures (Section 7.11). The boat entry structures were sealed and protected as were the manholes located at regular intervals. They were provided with both exterior and interior covers. A special measure to prevent the entrance of air was also incorporated in the design of the inlet structure (section 7.13). Lastly, one of the more innovative measures in preventing air from entering the system in the Red River siphon section was to equip the outlet of vents of chambers housing air pressure relief valves with an oil bath. The oil that was chosen did not congeal or freeze and served as an air seal (Chace 1920c, p25).

7.11 Accommodating Cross Drainage

With the aqueduct running slightly northeast southeast from Winnipeg and crossing terrain that had a slight drop to the northwest it was inevitable that it would intersect streams or ditches in the local drainage pattern. Because, when backfilled, the conduit is generally above the natural ground level it would block the flow of that drainage, so a method was needed to lead the water across the right-of-way. The one used was another inverted siphon. In this case it passed under the aqueduct. As with the overflow structures, care was taken to ensure that the top of the siphon in the area below the aqueduct was also below the bottom of the adjacent drain. The collected water prevented the cold air up and downstream from entering that portion of the culvert. Figure 7.11.1 provides an example. (The lower section in the middle shows the depression.) There were 56 such installations with many being built under much less favourable working conditions than the one shown (CPWA 2000, p.5)



Figure 7.11.1. Cross drainage culvert with depressed middle section (GWWD No. 302)

7.12 Falcon River Dike and Diversion

As previously noted the Falcon River drains much of the muskeg area west of Indian Bay, and had a brown colour. The dike and channel that diverted the water of the Falcon River to Snowshoe Bay was built to dilute that water with the much clearer, greater Shoal Lake water (see Figure 5.1.1). In that way before the diverted water could reach the intake of the aqueduct, it would have to make its way around the promontory and back into Indian Bay – a distance of 14 km. No doubt the opportunity of the diversion scheme was recognized because of the topographical work and soundings undertaken by City Engineer Ruttan's staff in 1912 and early 1913. The alternative to the diversion would have been to extend the aqueduct considerably further into Shoal Lake so that it accessed unaffected water. The District's cost for the dike and diversion work was \$147,000. Fuertes (1920, p. 699) indicated that the cost to extend the aqueduct a further eight km would have been \$1,000,000. Figure 7.12.1 provides an indication of the scope of the dike construction.



Figure 7.12.1. Construction of the Falcon River Dike (GWWD No. 84)

7.13 The Intake Works

With the dike and diversion decision settled, the designers were able to locate the intake structure in a rock outcrop on the shore of Indian Bay adjacent to the north end of the dike. Appendix 11.6 shows details of the area in the vicinity of the intake. Gathering dikes extend into the lake and a concrete structure in the rock cut controls the water entering the aqueduct. The structure includes the usual gates, trash screens, and stop log provisions that one might expect. Two features are noteworthy. The first is that the designers provided dual entrance chambers, each with its own screens and stop log facilities. In that way, one can be isolated for maintenance while the other was providing water to the aqueduct. The second feature had to do with preventing cold air from entering the system in the winter. The lower edge of the front wall of the structure, which is the top of the water opening, was constructed 1.9 m below the lake's lowest level. In that way, it was below the bottom of the ice and cold air could not enter the system, thereby preventing the formation of ice in the intake (Fuentes 1920, p 701).

The capacity of the intake structure was 85,000,000 gpd (386,400,000 L/d) at low water level. Chace (1920b, p. 4) suggested that at the high water level of Lake of the Woods established by the IJC in 1917, the intake could accommodate 100,000,000 gpd (454,600,000 L/d). Figure 7.13.1 shows the completed intake structure before flooding. The operating water level would be below the letters in the photo at a distance of approximately one and one-half times the height of those letters. To put the capacities of the intake and the aqueduct in perspective, the peak levels of water ever used by Winnipeg was 300,000,000 L/d (66,000,000 gpd) in 1988. That was just less than 500 litres per person per day. Since then, through the City's water conservation program, that

figure has been reduced, and in 2000, it was approximately 380 litres (84 gallons) per person per day (Shoal Lake Watershed Working Group 2002, pp.19-20). There is still plenty of unused capacity in the Winnipeg Aqueduct.

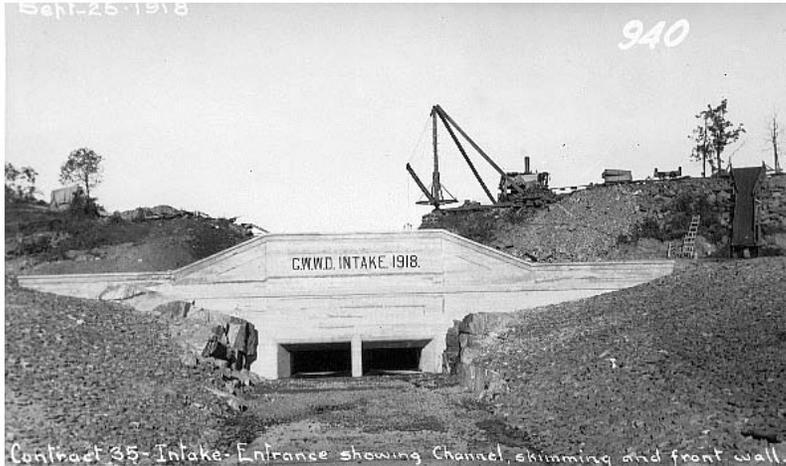


Figure 7.13.1. Intake structure before flooding (GWWD No. 940)

7.14 Design for the Future

As noted, the International Joint Commission had made it known that it would not approve an increase in the amount of water that the GWWD could draw from the Lake of the Woods-Shoal Lake system to any amount greater than 100,000,000 gpd (454,600,000 L/d). Recognizing that potential and presumably confident that Winnipeg would continue to grow well into the future, the GWWD incorporated that possibility into the project.

It was accomplished by three features in the design between the intake structure and the first 16 km to the west. The first was to continue the largest size of the aqueduct section, the one that was required because of the very low initial slope, further than necessary for a flow of 85,000,000 gpd. It was extended to a point well past the height of land that formed the boundary of the Shoal Lake watershed, but with a steeper slope. As such, that extended section could accommodate a flow of 100,000,000 gpd (Fuentes 1920,

p 707). The second was that the easterly (lower slope) section of the aqueduct was designed to accommodate an internal pressure on its roof equivalent to a head of 4 ft (1.2m) (Chace 1920b, p.4). That section could then accommodate the maximum observed water elevation in Shoal Lake up until the time of construction, namely 1064 ft (324.5m). At that head it was speculated that the easterly 16km of the aqueduct (the higher head section plus the higher sloped section) could carry 120 to 130 million gpd (Chace 1920b, p.4). However, 1064ft is 4ft (1.2m) above the maximum water level set by the international agreement in 1917. That being the case, it was also understood that should there be a need to assure an increased capacity, or to deal with lower lake levels, it could be accomplished by adding a low head booster pumping system to provide the small amount of head required (Fuertes 1920, pp. 707-708). The third feature was to build in an off-take from the aqueduct for a future second aqueduct at the end of the section with the higher flow capacity. The advantage of that arrangement was that, if increased capacity became necessary at the Winnipeg end, it could be accomplished in a future second conduit without having to build a new section of aqueduct for the 16km distance back to Shoal Lake through very difficult terrain. Furthermore, if the 100,000,000 gpd was still insufficient, a new parallel aqueduct section could be built for the 16km location back to Shoal Lake without interrupting the ongoing supply provided by the existing conduit.

7.15 Red River Valley Siphon

From a point approximately 27 km east of Winnipeg (Mile 17) to the McPhillips Reservoir, the aqueduct is designed as an inverted siphon, which means that the entire length of conduit is under pressure. (Unlike with Rome, the technology and hydraulic

capacity of pipeline systems had long since superseded the arcades system.) Appendix 11.7 provides a plan of the general area. The siphon ran westerly from the point marked “Overflow” in Section 21-10-5. The profile between Mile 0 and Mile 17 in the lower portion of Figure 1.1 gives a sense of the profile.

This siphon was by no means of a constant configuration. A significant change point was at the site of the future Deacon Reservoir. The other change point was at the crossing of the Red River. The section from the east end, “Mile 17”, to the Deacon Reservoir is an 8 foot (2.4m) diameter round cast-in-place reinforced concrete pipe. The section from the Deacon reservoir to the Red River is a 5ft-6in (1.7m) “Lock Joint” precast concrete pipe. The crossing of the Red River is a 5ft (1.5m) diameter cast iron pipe, and the section from the Red River to the McPhillips Reservoir is a 4ft (1.2m) diameter Lock Joint precast concrete pipe. The section between Deacon and the Red River incorporated the service connections to supply some of the partners in the GWWD: Transcona, St. Vital, St. Boniface, and Fort Garry. The section west of the Red River included a service connection to supply the James Avenue High Pressure Pumping Station, eliminating the need for Red River water. While there was an overflow provision at the east end of the siphon (Mile 17), the only pressure relief facility in the entire siphon section itself, as initially constructed, was a surge tank with a weir on the east side of the Red River.

7.15.1 Deacon Reservoir

The August 1913 report of the Board of Consulting Engineers had from the beginning planned that there be a reservoir approximately 19 km east of Winnipeg (Hering et al 1913, p. 4). Its primary purpose was to be for storage when the daily needs of the GWWD might be greater than the capacity of the aqueduct and for when it was

necessary to interrupt the flow from the east for maintenance or other reasons. A secondary purpose would be to provide for some relief of pressure caused by variations in the amount of water taken by the population of the District (Fuentes 1920, p.713). An aqueduct cannot be shut-off. However, with the reservoir in place, it could divert and absorb some of the flow and the overflow structure at Mile 17, which was limited to 30,000,000 gpd could serve as a backup (Chace 1920b, p.6). While the reservoir was not built until later, the design of the conduit at that location included the necessary valves and meters so that when ready, it could be connected with minimum interruption to the District's supply.

7.15.2 Deacon to the Red River

This section is one in which the as-built design differs significantly from the scheme set out in the 1913 Board of Consulting Engineers report. That report recommended that it be a 5ft (1.5m) diameter riveted steel pipe. As noted, this section was built as a 1.7m precast concrete pipe. The factors influencing that change in design were an initial misunderstanding of the District's legislated responsibilities in supplying water to the municipalities, and a concern over the expected useful life of the steel pipe. The misunderstanding with regard to the supplying of water had to do with the provision in the Act that the water be supplied "in bulk" to the municipalities, i.e. not under the operating pressure for their distribution systems as had been assumed by the Board of Consulting Engineers. That meant that a pumping station at the Deacon Reservoir was not required and that the pressures to be accommodated no longer required a steel pipe. On that basis, when the tenders were called for on the section from Deacon to the Red River, provision was included for a precast concrete alternate. Amid much controversy, the contract was awarded on the lower priced concrete alternative, which was based on a

patented system of connecting the pipe sections known as Lock Joint. Chace and Sauer (1917a, p. 390-391) cite the reasons for changing the design. Quite apart from the issues of serviceability, quality, and dependability of supply of steel during World War I, the change was probably wise as the concrete pipe was manufactured locally and could be closely monitored. It also had the added benefit to the District of utilizing local materials and labour.

7.15.3 Red River Crossing

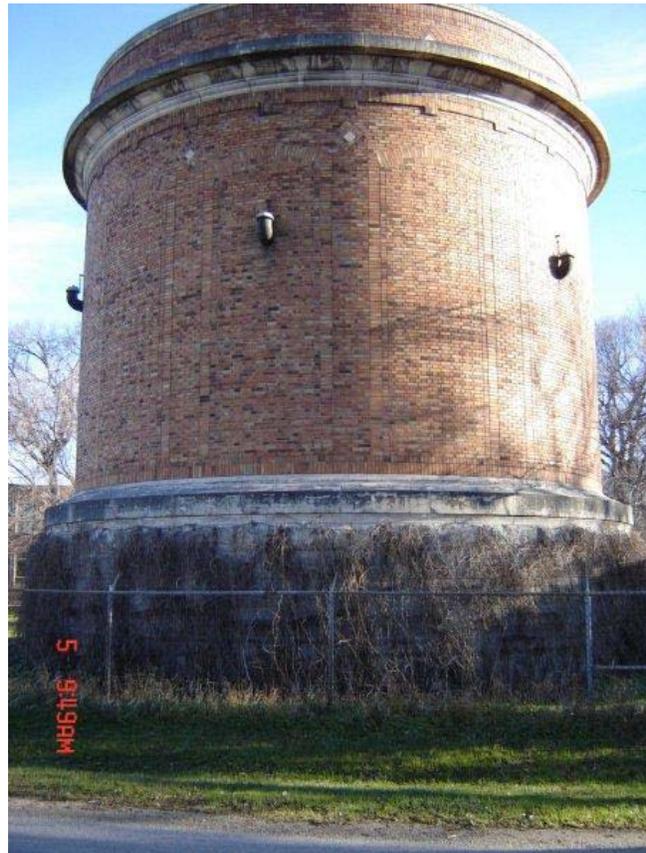
The crossing of the Red River is a siphon within a siphon. The conduit crosses the river in the limestone bedrock some 24m below the banks and 6m below the river bottom (CPWA 2000, p.5). The core drilling that established the depth and nature of the rock was one of the earlier contracts tendered by the District. One presumes that the engineers were comfortable with resulting information as the reports of the Chief Engineer in the minutes of the Administration Board meetings do not mention concerns.

As noted, the conduit is a cast iron pipe. The configuration is a vertical section on each river bank built in a shaft and a horizontal section built in a tunnel in the rock. The 16m vertical shafts were 5m in diameter and lined with a 600mm reinforced concrete wall. The upper portion serves as housing for the valving system. The annular space for the portion below the valve house floor down to the bedrock was backfilled with gravel. The tunnel for the horizontal section was nominally 3m by 3m and the pipe was centred on that opening. The cast iron pipe sections were specially fabricated so that they could be caulked from within. The material used for the caulking was hemp and lead (Chace 1920b, p.25). Once the cast iron pipe had been finished the space between the rock and the pipe was filled with concrete. Remarkably, this section has functioned since 1918 without ever being dewatered.

7.15.4 Siphon Surge Tank

Perhaps the most vital component of the Red River siphon system is the surge tank located on the east side of the Red River adjacent to the river crossing on the corner of Tache Avenue and Rue Messenger. It is also the most visible in that it stands the equivalent of a four-story building above the ground level. Figure 7.15.4.1 provides a view of its external structure in 2010.

As noted, the design of the tank provided the only pressure relief and overflow facility on the Red River siphon. That is significant because the inlet to the McPhillips Reservoir was controlled by valves which could have been inadvertently closed. Chace (1920b, p. 10) notes that “it must be kept in mind that there is flowing constantly west of Mile 17 at considerable velocity a solid volume of water of huge



weight. It is a serious matter to suddenly disturb the rate of flow of such a body of water.” As such, since the rate of flow out of the McPhillips reservoir would vary many times during the day, any excess arriving at the reservoir had to be accommodated. The engineers’ solution was that reinforced concrete surge tank designed to serve two purposes.

Figure 7.15.4.1. Surge Tank at Red River Crossing

They were, overflow to relieve pressure caused by too much water entering the siphon at Mile 17, and to spill the excess that might be created at the entrance of the McPhillips Reservoir. To do that, a closed circular structure was built with a concentric internal circular weir. The lip of the weir was at a fixed elevation. In that way, it spilled the excess water from either or both of the two causes.

The supply line from Deacon enters the base of the structure in a chamber at the bottom of the internal weir and a separate line leaves the chamber to bring water to the cast iron line that crosses the Red River. Both these lines are under pressure with the maximum head determined by the lip elevation of the weir. That elevation was about 9m above the ground line or 14m above the centre line elevation of the two pipelines. To collect the water that spilled over the weir, a second concentric wall of the same height was built outside of the weir wall leaving an annular space of 760mm. The excess water collected in that space was then taken away by a drainage line that discharged into the nearby Red River. Primarily for protecting the system from frost and secondarily for aesthetic reasons, the wall was faced with brick as is shown in Figure 7.15.4.1.

Significantly, there was no valve between the 1.7m incoming line and the surge tank. In that way, the pressure in the siphon to the east of the Red River could not be inadvertently increased to the point where it would damage the line. The system was operated so that there was always some water flowing over the weir (Chace 1920b, p10).

The structural features are also notable. Given the need to ensure that the pressure relief system would never have to be taken out of service, structural integrity was important. Unlike with the conduit, it seems to have been designed on the principle of “no risk.” The base of the structure was supported on a series of caissons under the walls, excavated to the bedrock. On top of the caissons were grillages made of steel beams and

four steel beams spanned from grillage to grillage around the base. The entire system was then encased in concrete. The concrete too was heavily reinforced once again using twisted square bars like those in some of the main aqueduct sections. This time, however, the drawings included bending diagrams for the reinforcing steel (GWWD drawing D-461) presumably to further ensure proper placement and clearances within the concrete.

7.15.5 Red River to McPhillips

As noted, the McPhillips Reservoir was an integral part of the water distribution system for the City of Winnipeg and had been since the time of the artesian well system. It was, therefore, necessary that GWWD deliver its water to that location. It was also from there that water had been, and would continue to be, supplied to some of the municipalities participating in the GWWD. The 1913 report called for the line from the west side of the Red River to be 48in cast iron pipe. That too was changed to the precast concrete Lock Joint system. With tenders for the supply being called on that section a year after the Deacon to the Red River section, one expects that indications of satisfactory performance by the precast system would have influenced the decision to change. There was another factor too. The engineering community had indications that the electrolysis effect on metal pipes caused by stray currents coming from electric street railways was a problem. With the exception of the service connection that was provided to the James Avenue High Pressure Pumping Station, the design features of that section of the siphon would have been not unlike those of other pressurized sections built as part of Winnipeg's distribution system.

8.0 IMPLEMENTATION AND CONSTRUCTION CHALLENGES (1915 TO 1918)

Even by today's standards the Winnipeg Aqueduct involved significant volumes of construction work. Chace (1920a, p.935) summarizes that with the notation, "the magnitude of the construction work is indicated by the following approximate figures of the more important quantities: Earth excavation and backfill, 7,500,000 cubic yards; rock excavation 16,000 cubic yards; concrete 455,000 cubic yards; reinforcing steel, 10,000 tons; Portland cement, 575,000 barrels." Additionally, he notes (1920a, p. 937) that, "throughout the entire construction approximately 1,000,000 cubic yards of sand and gravel were moved for concrete manufacture, for building up trench foundation where firm soil was at too low an elevation, and for backfill where native and local materials were scarce." To put that volume in perspective, it would fill a Canadian football field to a depth of 107m. It is not clear but that probably did not include the 176,000m³ that went into the Falcon River diversion or the amount used for the cofferdam at the intake structure.

In accomplishing the project, the GWWD operated primarily by entering into contracts. There is a list of contracts both large and small, including the various purchases, shown on the District's drawing marked P109. Those contracts that were awarded between late 1913 and mid 1919, number in the 70s. Of that list, only two of significance were eventually done by the District itself: the telephone line to Indian Bay and the Intake works.

8.1 Railway and Telephone

The first major contract (No. 9) was for the railway from the eastern side of Winnipeg to Indian Bay. It was awarded in March 1914 to the Northern Construction

Company. The company had links to the Mackenzie-Mann interests, which had developed a number of railway projects in western Canada (Manitoba Historical Society 2008). The line was for the most part completed by the end of that year's construction season but not without its challenges. Prodan (1979) reports that in one section crossing a muskeg area of about 9km, the grade was accomplished by building corduroy log floats that were then weighed down with excavated material and sunk until they could withstand the weight of the grade and a locomotive. The railway included nine sidings and five 545,000 litre water tanks (Chace and Sauer 1917a, p.392). Northern Construction figured prominently in the aqueduct project in that the company was later jointly awarded three of the five contracts for the construction of the conduit. While the railway was under construction, two other components of the project were also underway – the construction of the telephone line and the Falcon River Diversion.

The telephone line, also begun in 1914, was one of the “contracts” that the GWWD undertook with its own forces. Chace (1920a) notes that it was “in many sections built twice” as it often preceded the railway with the wire carried in on men's backs and strung on trees until poles could be delivered by rail. Presumably, it was urgent to have the line for communication with GWWD personnel at Indian Bay who were monitoring the construction of the Falcon River dike. Once permanent, the telephone became an invaluable communication tool for the GWWD staff as it enabled direct contact between the field and the head office in Winnipeg. It was also used by one contractor, likely the one responsible for the three most remote contracts.

8.2 Diverting the Falcon River

The Falcon River dike was well underway in the summer of 1914, as can be seen in Figure 7.12.1. Since the railway did not reach Indian Bay until late in 1914, one assumes that the equipment for its construction was brought to the site by barge from Kenora, Ontario. The contractor was Tomlinson and Fleming. Landon (1918, p.300) indicates that they were from Toronto. That such heavy equipment (a steam shovel, locomotive, and rail cars) was transported and unloaded is but one remarkable aspect of that part of the diversion works. The others are the method of constructing the earth-fill dike and the excavation of the diversion channel. Figure 7.12.1 shows some of the dike building procedure. Chace (1917a, p. 389) provides a description of the technique.

The dyke was built in 1914 by the scow and bridge method. The scow was held in position beyond the end of the work by means of spuds and connected to the outer end of the completed portion of the dyke by a bridge on which a narrow-gage track was erected and extended back along the dyke to the gravel pit located a short distance from the shore. Trains of 4-yard dump cars filled with sand and gravel by a steam shovel at the pit were run out and dumped from the connecting bridge, the empties being backed upon the scow. As the dyke was formed, the scow was gradually pushed out and the bridge dragged along with it.

By that method, 230,000cy (176,000m³) were placed (Landon 1918, p.300).

When the dike had progressed close to the shore where the channel was to be built, the scow was removed and a trestle installed so that the dike could be closed once the diversion channel was completed. Figure 8.2.1 shows that the channel (Contract No.36) was excavated with a barge mounted steam shovel in 1915.



Figure 8.2.1. Channel excavation from Indian Bay to Snowshoe Bay (GWWD No. 159)

8.3 Intake Works

Tenders were called for the contract to build the intake structure in November of 1917. The low bidder was a contractor from Kenora – the same one that had excavated the channel to Snowshoe Bay under contract No. 36. However, for reasons not apparent from reading the minutes of the meetings of the Administration Board, the bidder refused to sign the contract. It is known that after four Board meetings the bidder’s deposit was returned “in line with the solicitor’s recommendation,” and the GWWD did the work itself with day labour (GWWD minutes, March 21, 1918). One wonders whether the contract requirements that labour be from the District was a factor in it not being signed.

As the intake was generally below the lake level and the works extended into the lake, a major requirement was the dewatering of the site. The cofferdam was accomplished by building an earth-fill enclosure around the work area using the technique employed on the Falcon River dike. As the lake level was probably about 3m

above the bottom of the excavation and the cofferdam subject to wave action, it is impressive that the site was dewatered so that the intake structure could be built. Figures 8.3.1, 8.3.2, and 8.3.3 provide an indication of the scope of that work.



Figure 8.3.1. Intake cofferdam construction – closure (GWWD No. 866)

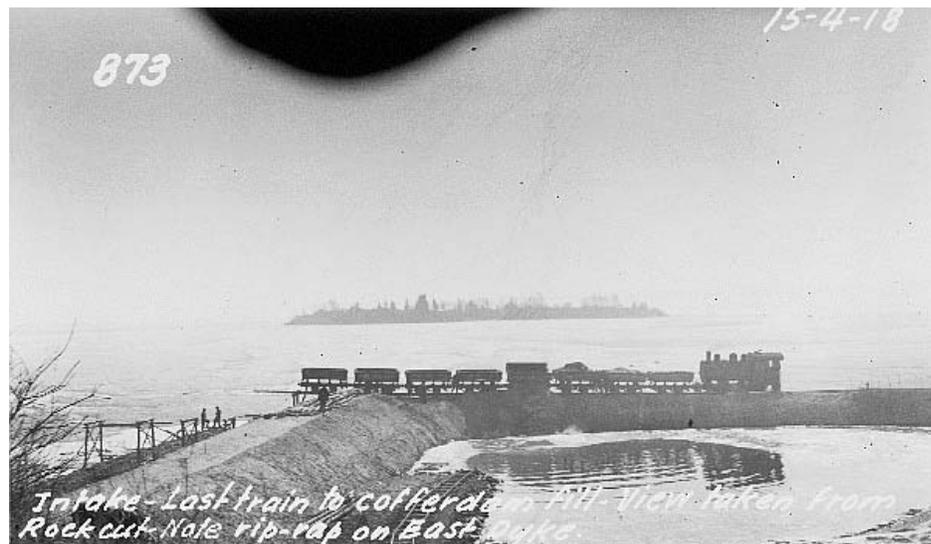


Figure 8.3.2. Intake cofferdam before dewatering (GWWD No. 873)



Figure 8.3.3. Intake cofferdam unwatered (GWWD No. 880)

As part of the overall design, the cofferdam side walls that extended out into the lake (Figure 8.3.2) were left in place and protected from wave action with riprap. In that way, they served as guide walls to minimize the amount of floating materials reaching the entrance.

8.4 Contract Distribution and Tendering

The major construction work tendered and constructed was for the portion of the conduit between the site selected for the reservoir (Deacon) and the intake structure. That was a distance of some 136km. The District divided that length into five separate contracts taking into consideration the terrain, site conditions, and complexity of the work. The call for tenders on those contracts was advertised nationally and internationally and bidders were allowed to bid on one or all five of the contracts. Tenders were received in September of 1914, a month after the beginning of WWI, and awarded in October. That timing was planned, as noted by Chace and Sauer (1917a, p.392), “thus giving the contractors a winter season to perfect their organizations, to order materials and forms, and to thoroughly evolve their plans for carrying out the work.”

Notwithstanding the broad advertising, the contracts were awarded to Winnipeg-based companies on the basis of lowest prices. Tables 8.4.1 and 8.4.2 provide a listing of the significant information regarding the awarded contracts. While Table 8.4.1 shows the contractor on contracts 32, 33, and 34 to be The Winnipeg Aqueduct Construction Company, the low bidder was Northern Construction Company Limited which had also been the successful contractor on the railway. The Winnipeg Aqueduct Construction Company was a new company formed by Northern Construction and another Winnipeg company, Carter Halls-Aldinger Company Limited, to take over work on the aqueduct. The two companies had complementary expertise: Northern in excavation and heavy machinery and Carter Halls-Aldinger (later Commonwealth Construction) in concrete work. Work began on the main aqueduct contracts on May 15, 1915.

TABLE 8.4.1. MAIN CONSTRUCTION CONTRACTS (NOT INCLUDING THE COST OF CEMENT AND AGGREGATES) [Chace and Sauer, 1917a, p. 392]

Contract No.	Section	Mile Begin	Mile End	Amount	Contractor
30	Prairie	13	31	\$945,945	J. H. Tremblay
31	Brokenhead	31	51	\$1,301,485	Thomas Kelly and Sons
32	Whitemouth	51	71	\$1,268,680	Winnipeg Aqueduct Construction
33	Birch	71	84	\$1,137,010	Winnipeg Aqueduct Construction
34	Summit	84	97	\$1,489,520	Winnipeg Aqueduct Construction

While the overall contract amounts seem to be in that same range they are not reflective of the construction difficulties both anticipated and realized. Table 8.4.2 lists some representative unit prices and gives a sense of the contractor's assessment of the difficulty of the work on sections. The concrete prices include the cost to the contractor of the cement and aggregates as provided and delivered by the District.

TABLE 8.4.2. REPRESENTATIVE UNIT PRICES [Chace and Sauer, 1917a, plate 38]

Contract No.	Earth Excv./cy	Rock Excv./cy	Embankment cy	Concrete cy	Rebar lb	\$ Per Mile
30	\$0.29	\$2.50	\$0.20	\$6.50	\$0.034	\$52,500
31	\$0.60	\$4.00	\$0.40	\$6.25	\$0.045	\$65,000
32	\$0.55	\$3.00	\$0.25	\$9.90	\$0.050	\$63,400
33	\$0.55	\$3.00	\$0.25	\$9.90	\$0.050	\$87,500
34	\$0.55	\$3.00	\$0.25	\$9.90	\$0.050	\$114,500

The cost per mile for Contract No. 34, the Summit section, being more than twice that of the Prairie section, is an indicator of the difficulties expected on that section. It included the area in which major difficulties were experienced in building the railway. It also passed through the height of land that forms the boundary of the Shoal Lake watershed where the trench excavation would be the deepest.

The other notable contracts on the project, which as it happened also went to local contractors, were for the following:

- the annual supply of cement awarded to the Canada Cement Company which over the years amounted to \$1,564,000,
- the section from Deacon to the Red River crossing (Contract No. 55) awarded to the Winnipeg Aqueduct Construction Company for \$1,308,000,
- the crossing of the Red River including the surge tank(Contract No. 56) awarded to Thomas Kelly and Sons for \$310,500, and
- the section from the Red River to McPhillips reservoir (Contract No. 65) awarded to Thomas Kelly and Sons for \$292,000.

8.5 Contract Provisions – Main Aqueduct Contracts

The form of contract and common provisions for those contracts had been approved by the Administration Board in mid 1914. However, it is apparent that from the title of the tender documents for the portion of the work included in contracts 30 to 34 it was considered to be the main component of the overall project as the title read, “For Construction of Aqueduct from Shoal Lake” (Greater Winnipeg Water District 1914).

8.5.1 Performance Requirements

While the tender documents set out the information on the five contracts, wording in the Information for Bidders section made clear the District’s interest in keeping its options open. It read, “tenders may tender for any one or more or the whole of such Contract Sections and either for each Contract Section separately or for any two (2) or more of said Sections together, but when it comes to entering into the proposed agreement a separate agreement will be prepared for each Contract Section.” The tender

included requirements that would not be unusual for the construction industry in later years such as a bid bond, a consent of surety, a list of drawings, and the form of contract agreement. The specifications, however, were more atypical when it came to emphasis on quality of work, time of completion, and authority of the Chief Engineer (W.G. Chace) to intervene in the contractor's operations.

In regard to the quality of work, a statement in the Information for Bidders section reads,

The rigid requirements of the Specifications in order to secure a safe, efficient and water-tight conduit are called to the attention of the tenderers; particularly those who have not had personal experience in aqueduct construction, and who consequently are likely to make insufficient allowances for the character of the work necessary.

In the context of the quality of work and achieving a water-tight conduit, two other provisions of the contract were emphasized to bidders. One was for providing an "unyielding bottom" of the excavation on which the concrete was to be placed, and the other was for leakage testing of the completed sections. On requiring an unyielding bottom, there was a requirement that machine excavation of earth could be used no closer to final grade than six inches and that the final six inches be dug by hand using pick and shovel. That was to ensure that the concrete was placed on undisturbed soil. There was also a requirement to ensure that the optimum foundation conditions were maintained.

The specification in that regard reads,

In order to avoid this [drying of clay] the Contractor shall keep the final trimming advanced only just ahead of the concrete, and shall keep all prepared surfaces damp, by sprinkling, in such a manner as may be directed by the Engineer, until the concrete is in place against the excavated surfaces. The trenches shall be kept free of water in so far as to prevent softening of the foundation for the Aqueduct. The Contractor shall be responsible for all settlement of foundations and shall replace all faulty work built upon

foundations which settle and cause the cracking of the masonry, whenever so ordered by the Engineer, at any time before the acceptance of the work.

While that last part sounds ominous to a contractor, the implied stringency seems to have been at times foregone (see section 8.8.1 on cracking). There was probably some tolerance too in the being “kept free of water” for some sections of contracts 33 and 34 (see Figure 8.7.2).

Another somewhat open-ended provision was that if the engineer judged that tests were necessary to “determine the supporting power of the soil,” the contractor was required to do so and that there would be no payment for such testing as it was to be incidental to the contractor’s payment for excavation. Figure 8.5.1.1 seems to be of one such test. Landon (1919) provides the results of 17 such tests conducted along the route in Contract 34 alone.



Figure 8.5.1.1. Onsite soil bearing test (GWWD No. 533)

The other provision regarding the authority of the Chief Engineer was related to the matter of water-tightness and the criterion for its acceptability. One of the unit prices in the tender was for conducting leakage tests on portions of the completed aqueduct. The test section was to be isolated with bulkheads and water levels established through and monitored at temporary manholes in the top of the aqueduct. The specification did not state a leakage rate that was unacceptable other than “a loss of water sufficiently great to demand remedy.” Indications are that leakage turned out not to be an issue. However, based on information provided by Ruttan et al (1916), the term water-tight seems to be relative. The report suggested that a leakage figure of 5,000 gallons per mile (14,000 litres per kilometre) of aqueduct length would be satisfactory performance.

8.5.2 Contractor’s Personnel

Still with the authority in the contract of the Chief Engineer, it went beyond the contractor’s work outcomes. The Chief Engineer could also order the use of additional resources and had areas of jurisdiction over the contractor’s personnel. In the area of personnel, which included the superintendent and foremen, the wording was,

and if the Engineer shall consider any person or persons employed upon or about any portion of the work to be incompetent, negligent, disorderly or otherwise unsatisfactory, and shall give the Contractor written notice to that effect, the Contractor shall forthwith remove such person or persons and shall not employ him or them upon the work, except with the permission of the engineer.

While that might seem intrusive, it was probably necessary in the circumstances. Chace (1920a, p.938) notes that, at one point, there were 2,500 men working on the project. The GWWD had anticipated the issues and the importance of clearly defined rules in such circumstances. Among the other contract provisions relating to personnel

was the requirement that the contractor's workers be paid a minimum wage in accordance with a Fair Wage Schedule listed in the tender. Preference was also given to residents of the District. Although later, when the war effort affected the availability of labour, that requirement was lifted. One presumes that the minimum wage schedule had been established by the Manitoba Government. Based on some of the listed trades, it seems to have been intended more for the construction of buildings than for a project such as an aqueduct. Under the schedule, carpenters were to be compensated at a minimum of 35 cents per hour and were not required to work more than 10 hours per day. It did not, however, specify the number of hours per month. However, when a grievance came before the Administration Board in 1917, it ruled that "260 hours work should constitute a month on any work under contracts."

The contractors were also required to provide board and shelter for the workers at the specified sum of \$5.00 per week, i.e. the carpenter would have to work 14 hours to pay for room and board. The specification for the sleeping apartment provided by the contractor was that it contain at least 300 cubic feet (8m^3) per occupant. The contract also required that the employer "employ the necessary duly qualified medical practitioners, furnish and provide all necessary medicines, surgical instruments, and hospital accommodation to the satisfaction of the Chief Engineer." For providing this benefit, the employer was allowed to deduct 75 cents per month from the employee's wages. One hopes that facilities shown in Figure 8.5.2.1 were not indicative of those deemed satisfactory to the Chief Engineer.



Figure 8.5.2.1. On-site medical facility (GWWD No.786)

Yet another provision of the contract was that the “contractor shall not bring nor permit to be brought anywhere on or near the said works any spirituous or intoxicating liquors” and that any employee so doing was to be discharged. Quite apart from the good judgement of such a requirement, it could also have been an indication of the political climate of the time. The Temperance Movement had been active in Manitoba for some time and prohibition was legislated in 1916.

Not unexpectedly given the isolated nature of the project and the conditions under which a large number of workers lived, it is not unusual that there were complaints about working conditions. The minutes of the Administration Board refer to representations in that regard but do not indicate any ordering of remedial action. It could also have been that living conditions in the city brought on by the War affected the Board’s perceptions of hardship.

8.5.3 Items Supplied by the District

Another provision in the contract specific to the structure of the GWWD's operations and the nature of the aqueduct project were linked to its ownership of the railway and the telephone system. The bidders were informed of the policy of providing the Portland cement and concrete aggregates and also of the conditions. Regarding the cement arrangement (section 7.4), there was wording designed to ensure that the contractors were careful in its usage. It was "in bidding on concrete masonry, the bidder is to note that the cement will be delivered to him by the District, and that he will be charged with the value thereof, as delivered and then credited with the amounts used in the work at the same price." In that way, the cost of any loss due to spoilage from poor handling or careless mixing practices was borne by the contractor. The cement was delivered in bag form and the contractor was also charged for the bags, but there was a credit for the ones returned in satisfactory condition. The concrete aggregates and gravel used for fill by the contractor were charged for the amounts shipped at the cost specified in the tender document. The stipulated charge to the contractor in the contract was \$0.75 /cy (\$0.58/m³) regardless of the point of delivery. In the case of the fill gravel the contractors were only paid for the amounts needed to fill the authorized excavation. On that basis, they probably paid for more gravel than they were compensated for under the payment at the unit price for backfill.

The GWWD had arranged access to what was known as the Paddington transfer yard where other railways could switch railcars. With that arrangement, transportation of the contractor's equipment and supplies was made by the District's railway at a fixed rate for carload lots. Transportation of employees was handled on a voucher basis for each contractor. The charge was three cents per passenger mile each way and deducted from

the contractor's payment monthly. On that basis, the return trip charge for an employee to travel to Indian Bay would have been \$5.40. There is no indication of the contractor back charging the employees. As the District had already installed a telephone line over the full length of the contract sections, the contractors were allowed to use it for their own communications under specified rules. There was also an opportunity for a contractor to install lines on the District's poles. The charge for that usage and the general maintenance was \$5.00 per mile per year, i.e. the cost for telephone service to Indian Bay would have been about \$900 per year.

8.6 Contract Administration and Coordination

Throughout the project, engineering work was under the monitoring of J.H. Fuertes as the consulting engineer hired by the Administration Board. While he made periodic trips to Winnipeg, he seems to have been in New York most of the time. The remainder of the engineering organization of the project was structured on the typical model of the head office and field operations.

8.6.1 Office

The office was located in downtown Winnipeg at the Boyd Building. The organization as outlined by Chace and Sauer (1917a, p. 395) lists only some of the engineers but none of the office and other staff. As Chief Engineer, W.G. Chace was supported by M.V. Sauer as Assistant Chief Engineer "in charge of designs and next in authority" and D.L. McLean and F.G. Haven as assistants. D.L. McLean was responsible for the studies and testing of the concrete aggregates and cement. Given that at least 1,000 detailed drawings were produced and printed, and that cement samples were taken

hourly during production and tested, one presumes that there would have been many other District employees operating in and out of the Winnipeg office.

8.6.2 Field

During the design stages, the field personnel were mainly engaged in the survey operation. Once work began on the five main contracts, a Division Engineer was in charge of each contract and operated out of a divisional camp (Chace and Saurer 1917a, p. 394). The staff under the Division Engineer was “an assistant who is responsible for lines and grades, an office man to look after field records and sketches, an instrument party, a stenographer and senior and junior inspectors. These inspectors, in order that they may be present at all times on the work, live in tents at each point where work is in progress.” One speculates that, unlike today when inspection presence is often diluted because of costs, such continuous and close onsite inspection was instrumental in the success of the as-built project. Another matter of note regarding inspectors is that the specifications on the main contract stated that one of their functions was to monitor the sobriety of the workers.

The field staff was provided with motor cars that ran on the railway. By that means, they were able to move to points along the contract as needed. That would have been important when the setting of elevations for grades was required. The tender documents provided that “The Chief Engineer will give all such general lines and levels as he may consider necessary to indicate the position, elevation and layout of each portion of the work.” Landon (1918, p.3015) indicates that the stakes were set at 30 foot (9m) intervals. Considering that work would be ongoing at a number of locations on any contract, and recognizing the importance of setting the elevation of the concrete invert accurately so that adjoining works connected at the proper elevation and constant grade,

it is a testimony to the diligence of those surveyors that there seems to be no indication of significant error.

8.7 Construction on the Main Section

As shown in Table 8.4.1, there were three different contractors in the five main contracts. The contractors operated out of camps that were established along the route with the locations selected on the basis of the likely rate of construction in a season. As they endeavoured to keep their operations (excavation, trimming, and concreting) within a distance of 800 m, 77 such camps were established over the four years of construction (Chace 1920a, p. 937). With the site conditions generally different for each of the contractors, it is understandable that they would have chosen some differing construction methods. The main differences were in the choice of excavation equipment and the concrete manufacturing and delivery procedures. Another difference was that while the contractors were required to use steel forms for building the arch sections, the techniques for handling and placement were not the same.

As a general comment on the role of the contractor on a project, it is one matter to produce a set of drawings setting out the intended work, and another matter entirely to turn those drawings into a physical reality. Achieving that reality requires a well resourced skilled builder collaborating with the engineers. In the case of the Winnipeg Aqueduct the evidence is that the contractors and their people held up their end of the collaboration.

8.7.1 Excavation

Landon (1918) provides a useful overview of the excavation methods chosen for the bulk trench excavation. On Contract 30, the Prairie Section, some of the excavation was done with horse-drawn scrappers, but the major portion was by a walking dredge which straddled the excavation and moved by shifting its weight between supporting pads (Figure 8.7.1.1). On Contract 31, the Brokenhead Section, draglines were used for the deeper cuts and steam shovels for the shallower ones. On contracts 32 to 34, the Whitemouth, Birch and Summit sections, all of which were done by The Winnipeg Aqueduct Construction Company, draglines were used. Those draglines did not have the crawler type of propulsion that became common in later years, and that one normally associates with draglines. Rather they moved on rollers placed on the timber pads and were pulled forward by using the machine's bucket line after it was anchored to the pad. Figure 8.7.1.2 shows that setup.



Figure 8.7.1.1. Walking Dredge (GWWD No. 597)



Figure 8.7.1.2. Dragline with support and propulsion system (GWWD No. 748)

Landon (1918, p. 301) observed that, “this type of machine excavator will work on ground which will barely support the weight of a man.”

In the end though, as the final six inches (15cm) of the trench excavation had to be dug by hand, all contractors used the same instrument – a shovel in the hands of a person. While the construction of the overall project is impressive, that aspect alone – 6,000m³ of hand excavation, enough to cover a Canadian football field to a depth of 0.84m, done in the bottom of a trench seems formidable.

Dealing with the range of soil types referred to by Chace in section 7.7 would have been as much of an issue for the contractors as it was for the engineers. In particular, the stability of the side-slopes would have been a problem because of the soil conditions and depths of excavation. The problem of slope failure would have been most difficult on the contracts held by The Winnipeg Aqueduct Construction Company. McLean (1919), the engineer responsible for soils and materials at the GWWD, provides a description of

the slides that occurred in the side slopes of the excavation and the methods used to stabilize the situation long enough to build the aqueduct. He notes that,

in such cases as these slides, theory was of little use and reliance had to be placed on experience and sound judgement. In the employment of such the Winnipeg Aqueduct Construction Co. were fortunate to have Smaill as field superintendent and manager, while the Greater Winnipeg Water District were equally fortunate in having W.G. Chace as chief engineer (p. 471).

Figure 8.7.1.3 is an example of some of the disheartening situations that would have been faced by the contractor and engineers in those slide situations. Note the failed slope on the left and bracing of the trench to prevent further movement.



Figure 8.7.1.3. Remedial work on side-slope failure zone (GWWD No. 921)

8.7.2 Foundation Conditions and Solutions

In the striving for of an “unyielding bottom,” the contractors and engineers again had to resort to a variety of solutions in dealing with the occurrences of soft material below the finished excavation elevation. Chace (1920a, pp. 941-942) outlines some of the solutions:

- in soupy clay, broken stone was dumped in to make it firm;
- in quicksand, the excavation was continued below the grade line, built up again with gravel and stone, and then dewatered with under drains;
- in muskeg, when the peat was below the grade line it was removed and replaced with sand and gravel deposited underwater: after being allowed to settle the water was removed with under drains; and
- in of flowing clay, timber pile foundations and reinforcement of the invert was used in some cases.

The under drains were wooden boxes placed below the grade level and connected to sumps on the side of the excavation from which the water was pumped by gasoline powered pumps. Figure 8.7.2.1 provides some sense of the nature of that work.



Figure 8.7.2.1. Box drain installation (GWWD No. 442)

There are also indications that the aqueduct route was altered to get around a soft spot. One construction photo shows a partly completed aqueduct with a bend in the

alignment. The aqueduct was at more than the usual distance from the railway and the caption on the photo reads “showing offset to avoid poor foundation” (GWWD Photo 898).

8.7.3 Concrete Mixing and Delivery

As also noted by Landon (1918) the methods chosen by contractors for delivery of the concrete were not the same. There were two methods and both involved a rail system along the side of the trench. In one case the mixer was moved along the trench. For the other the mixer was stationary and hopper carts of mixed concrete were moved along the trench on rails. In that system the mixer was relocated as needed and was typically within 800 meters of the point at which the concrete was to be deposited. That method which put less weight on the trench side was used by The Winnipeg Aqueduct Construction Company. Figure 8.7.3.1 illustrates an example of that arrangement.



Figure 8.7.3.1. Concrete mixing and transport system, Winnipeg Aqueduct Construction (GWWD No. 787)

Regardless of the transportation system, the mixing procedure set out in the specifications, was the same for all three contractors. It was a batch process with specified amounts of cement, sand, and stone in each batch mixed for the period of time and to the consistency determined by the on-site inspector. The sequence of loading the batch was also specified. An unusual step specified in the contract documents seems to have been waived by the time the concrete work began eight months later. The specification was that the sand and cement were to be loaded into the mixer dry and thoroughly mixed before the stone and water were added. The rationale for that wording, one expects, came from the emphasis placed on the use of sand to minimize permeability in the concrete and, in that way, assuring a thorough mixing of the cement and the sand was seen as maximizing the density of the mortar. Presumably the rationale for the change in procedure included the trade-off of the lower costs of dealing with supplying premixed aggregates and a subsequent indication that careful monitoring of the mixing would provide a comparable density.

8.7.4 Invert Construction

Once the grade of the trench was at the required elevation and in acceptable condition, the forming of the invert sections took place. The aqueduct was built in multiples of 15 ft (4.5m), with the invert sections being 15 ft and the arch sections at 45 ft (13.5m). Both the inverts and arches were built in alternating sections so as to allow for the placement of the combination expansion joint and water-stop in the transverse construction joints. In both cases, but more so for the invert sections, the alternating sequence also allowed a working area for the placing and finishing of the concrete. Providing a smooth surface on the invert concrete was an important aspect of assuring the

hydraulic capacity of the aqueduct. The invert constitutes a high proportion of the interface between the concrete surface and the water, which is where the resistance factor in Chézy's formula comes into play (section 7.4). For that reason, special care was specified and taken in the concrete finishing. The top of the bulkheads at the ends of the inverts were made of steel and shaped to the profile in cross-section. Once filled with concrete, the length of the invert section was struck off to the shape of the profile using a sawing action with lengths of angle iron. Next, it was smoothed ("floated") with a long-handled wooden float. Later, once the concrete was set up, a steel trowel was used to bring it to a final smooth dense finish. Figure 8.7.4.1 provides an example of invert construction. It also shows the 16mm by 19mm wooden water stop used in the longitudinal construction joints between the invert and where the foot of the arch section would sit. To optimize the bond between the two concrete sections, the area of the invert under that arch section was cleaned with a wire brush after the concrete had setup but before it became hard.



Figure 8.7.4.1. Placing invert concrete (GWWD No. 809)

8.7.5 Arch Construction

The contract specified that steel forms be used for the interior surface of the arch



sections to maximize the smoothness of the concrete. With that requirement, all three of the contractors opted to use a patented system of manufactured reusable steel forms produced by the Blaw Company in the US. There was a further advantage in that the Blaw system also formed both the interior and exterior surfaces. The interior steel plates were held in place and centred by the use of turnbuckles, and the outer plates were held at the correct spacing by special bolts.

Figure 8.7.5.1 Blaw steel arch forms in position (GWWD No. 195)

The system was designed so that once the concrete was hardened, the interior forms could be collapsed and the exterior ones spread so that they could both be moved for reuse.

Figure 8.7.5.1 shows a general arrangement of the system and the means of moving the interior form on an internal rail setup. Figure 8.7.5.2 shows a typical traveller system used to move the exterior forms.



Figure 8.7.5.2 Traveller system for moving arch forms along conduit (GWWD No. 246)

With over 70 setups required for a kilometre, the system provided an efficient means of repetitive forming. As the shape of the Winnipeg Aqueduct is quite similar to that of the Catskill Aqueduct, one presumes that the Blaw system had been used previously on it and other earlier aqueducts in the US. The contract had specified that the maximum length of an arch section to be concreted in one operation be limited to 45 ft (13.5m) and, that once started, it be completed in the same operation without interruption. The contractors seem to have worked on the basis of that maximum length. An average pour then would have required about 40 m³ of concrete. Landon (1918, p. 302) notes that panels at predetermined heights on the outer arch form were removed to allow the placing of the concrete and then replaced once the concrete reached that level. That process was used until the full height was reached and the final concrete was finished off through an opening left at the top of the arch (Figure 8.7.5.1).

There is no indication of powered mechanical vibration being used to consolidate the concrete once it was in the forms. Landon (1918, p. 315) and Chace and McLean (1917b, p.421) both refer to “spading” of the concrete. The latter observed:

Different methods were tried by the contractors to obtain the required smooth finish on the inside of the arch, free from pitting due to air bubbles or drops of water. The best results appeared to be obtained from the use of a wet mixture with careful spading. Too much or too energetic spading resulted in the inclusion rather than the expulsion of air.

8.7.6 Backfilling and Embankment

Once the concrete in the conduit was poured and cured, and the forms removed, the backfilling and embankment operations followed close behind. The backfill material used was the excavated earth from the trench. Particular attention was paid to the filling of the space between the foot of the arch and the edge of the excavation. The specification was for the lower 1.2m to be carefully distributed and tamped by hand to ensure that it was well compacted and brought up evenly on both sides of the conduit to avoid unbalanced lateral pressure. Once that part was done the rest of the embankment could be placed by draglines.

While the specification called for hand placing and tamping, an article (*The Canadian Engineer* 1917, p.151) in discussing machine backfill reported that “material falling out of a bucket in a continuous stream, even from a small height, makes much more homogeneous and compact mass than can be secured by hand tamping.” That conclusion was apparently demonstrated by test sections of the two methods on a Winnipeg Aqueduct Construction contract. The article stated that the difference was “very noticeable.” On the other hand, neither Chace (1920a) nor Fuertes (1920) mentions

that conclusion in their papers. However, there must have been willingness for some experimentation as photographs on one contract show the tamping being done by horses walking on the fill between the conduit and the side of the excavation. Chace (1920a, p. 943) did acknowledge that in some of the muskeg areas the process as specified was impractical and that imported sand and gravel was used for filling the lower sections. The purpose of the embankment was not only to protect the conduit and weigh it down but also to serve as insulation for frost protection. The muskeg material was noted as being especially effective in frost protection but less than adequate in providing load.

The height of fill over the top of the conduit was limited to four ft (1.2m) and the width at the top was generally the same as the inside dimension at the foot of the arch, and then sloped downward at 1: 1 ½ to the adjacent ground line. In most cases, the backfill was mounded over the conduit forming a ridge above the surrounding natural ground line. Once the embankment had settled, it was trimmed and seeded as an erosion prevention measure. A mounded embankment was not always the case. The other case was when the aqueduct crossed the height of land that formed the Shoal Lake watershed boundary. With depths of excavation from 3.5m to 6.5m, the 1.2m limitation on the depth of fill over the conduit meant that the embankment would still be in the trench. However, at one location, that was not the case. Chace (1920b, p. 22) advises that

The summit of ground which encloses the waters of Indian Bay occurs about Mile 93 and its elevation is but 9ft above high water in Shoal Lake. In order to prevent escape of Shoal Lake waters westward by way of the aqueduct trench, this trench has been filled nearly to the brim and the original ground surface restored for a length of 200'. This dam should be carefully maintained.

He provides no indication of how the aqueduct was reinforced to accommodate that load.

8.7.7 River Crossings

As noted, the main contracts included five river crossings between the east end of the Red River Siphon and Shoal Lake; they were Brokenhead, Whitemouth, Birch, two on the Boggy, and the Falcon River close to Indian Bay. Other than the crossing of the Red River, they would have been the most challenging portions of the project for the contractors. The crossings were built in two lengths in the trench. The first length was built after the river flow had been diverted to one side of its channel. When that was finished, the river was then diverted over top of the first length and the second one was built. Keeping the trench sufficiently dewatered for the placing of concrete would have been very demanding. Figure 8.7.7.1, showing one end of such a crossing, provides an indication of the difficulties to be overcome. It also shows how far the present-day rules on worker safety in trench excavations have come. Figure 8.7.7.2, on the Boggy River at East Braintree, is an indication of the complexity of the concrete forming required to achieve the vertical curve at the ends of a siphon.



Figure 8.7.7.1. One end of an in-trench siphon construction (GWWD No. 355)



Figure 8.7.7.2. One end of a finished siphon showing the vertical curve and the housing of adjacent overflow structure (GWWD No. 391)

8.8 Design Issues and Remedies

It is not uncommon for unforeseen or unexpected conditions to occur on Manitoba construction projects that involve below ground work. The Winnipeg Aqueduct was no exception. Two of the unexpected developments were cracking of some of the concrete in sections built during the first construction season, 1915, and then shortly after the project was completed, a realization that there was a deleterious effect on the concrete in a section east of Deacon due to alkali in the wet soils.

The cracking issue attracted the most public attention. The issue of the alkali effect was not visible and less commonly understood, so remedial action was not taken until 1920 after the aqueduct was in operation. The remedy chosen was to install a post-construction under-drainage system. The Red River siphon section west of Deacon, which was tendered in 1916, included an under-drainage system as part of the contract. It is unclear whether the under-drainage was intended prior to the District becoming aware of the alkali effect in the area.

8.8.1 The Cracking Issue

The cracking issue emerged just after the end of the 1915 construction season. It first became apparent at Mile 23 in the Prairie section 18km east of Deacon. For the most part it appeared as a single crack along the centre of the invert and, in a few instances, in the side walls of the arch (Ruttan et al, pp. 10-11). The development was related to the vagaries of the foundation conditions in that area but some lesser cracking was also noticed along other sections of the conduit. Koen (1985) and Fuertes although decades apart are on the same page regarding the realities of design. Fuertes, in seeking to cause “the best change in a poorly understood or uncertain situation within available resources”

realized that “to have stood on the principle of ‘no risk’ in the designs [of the aqueduct] would have rendered the project totally impossible, on account of the great cost involved” (1920, p. 728). He and the others on the 1913 Board of Consulting Engineers had opted to accept the risk of repairing deficiencies, which were likely to be a nominal cost in comparison to that required for an aqueduct designed for no risk of cracking.

Nevertheless, since the public and those unfamiliar with concrete construction can readily comprehend the concept of a crack, and that is good fodder for the local newspapers, the matter attracted considerable attention. Not the least of that attention was from an electrical engineer, Charles F. Gray. A letter of his was published in the *Winnipeg Evening Telegram* (December 9, 1915) under the headline “Patching Aqueduct is Useless.” However, as predicted repairing the cracks was effective. Gray was elected to the Winnipeg City Council in 1917 after the issue had been resolved. Later, he became the Mayor of Winnipeg and thereby Chair of the Administration Board of the GWWD. One expects that it made for an interesting atmosphere when the reports of the Chief Engineer were considered at the meetings of the Administration Board.

The Administration Board handled the cracking issue effectively. It had been provided with a report from Fuytes and Chace assuring that the defects could be remedied at a nominal cost and prevented in future construction. After receiving that report, and hearing representations from local engineers other than Gray with opinions and offering to provide services, the Board opted to establish a Special Board of Consulting Engineers in February of 1916. Its appointees to the Board of Consulting Engineers were the former Winnipeg City Engineer, Colonel H.N. Ruttan, J.G. Sullivan of Winnipeg who later became a Winnipeg City Councillor, and R.S. Lea of Montreal. An excerpt from their instructions reads:

That the questions submitted, the replies thereto and the report of the Consulting Engineer James H. Fuertes and the Chief Engineer, W.G. Chace, thereon, be considered, and any other information [be] procured by the special board of Consulting Engineers to enable them to report specifically, agreeing or disagreeing with the conclusions or opinions of Messers. Fuertes and Chace,...

The Administration Board had also taken a decision to suspend further construction for the 1916 season pending the report. Construction had already been halted for the winter shut-down and was scheduled to resume in mid May of 1916.

8.8.2 Special Board of Consulting Engineers and Report

Because of the seriousness of the possible construction stoppage, the Consulting Engineers went to work quickly. While the problems were most pronounced in Miles 23 and 24, cracks had developed in sections of other contracts. In the other sections, the proportion of the completed work having invert cracks was low and in a high percentage of the affected area they were less than 1.6mm in width. In the final report the Consulting Engineers concluded that “we can state definitely our opinion that where arch cracks have occurred in the aqueduct work they are in no case to be attributed to any fault in the design of the arch” (Ruttan et al, p.7) Regarding the designs of the invert they acknowledged that “the necessity for special methods of dealing with foundations was [had been] anticipated and was recognized in the preparation of the plans and specifications.” They also agreed that the concrete was a “strong and dense mixture.”

Following their initial deliberations, the Consulting Engineers, in an interim report, advised the Administration Board in early May 1916 that the construction could proceed under certain conditions. The primary condition was to increase the width of the inverts, thereby providing a wider footing for the load of the arch, and in some cases adding reinforcing steel (Ruttan et al 1916, p. 4). The final report was not issued until the

end of September 1916. It provided information on repair procedures, the success of those procedures, and their nominal cost. It also stated that “as a result of our observations, and of hydrostatic and other tests, which have been made during the present season on portions of the completed aqueduct we are of the opinion that none of the work so far built will have to be removed.” Nevertheless and presumably as a follow-up to the overall question of the invert construction issue, a series of load tests were made at the Deacon site in late 1916. Fuertes (1920, pp. 735-739) discusses those tests and three types of invert design that were adopted for the 1917 and 1918 construction seasons on the basis of the test results. He was decidedly not in agreement with the invert designs used for the 1916 season as recommended by the Special Board of Consulting Engineers. He stated that “This [changed] policy resulted in a considerable saving over the extravagant policy of 1916” (pp. 733-734). In the same paper, Fuertes attributed the formation of cracks in areas other than Mile 23 to laxity on the part of the contractor’s people and the inspectors in assuring thoroughly compacted foundations along the sides of the inverts.

8.9 Deacon to the Red River

As noted in section 7.15.2, the portion of the Red River siphon from Deacon to crossing of the Red River was changed from steel to precast concrete pipe. The change permitted the pipe to be manufactured locally, other than for the reinforcing steel. An open-air manufacturing facility accessible by railway was set up in what is now known as South Transcona. The proximity to the point of use and the availability of the GWWD’s rail line was helpful. Figure 8.9.1 provides an indication of the process and scope of the manufacturing operation. The 1.2m diameter pipe for the portion of siphon from the west bank of the Red River to the McPhillips Reservoir was also produced at that plant.

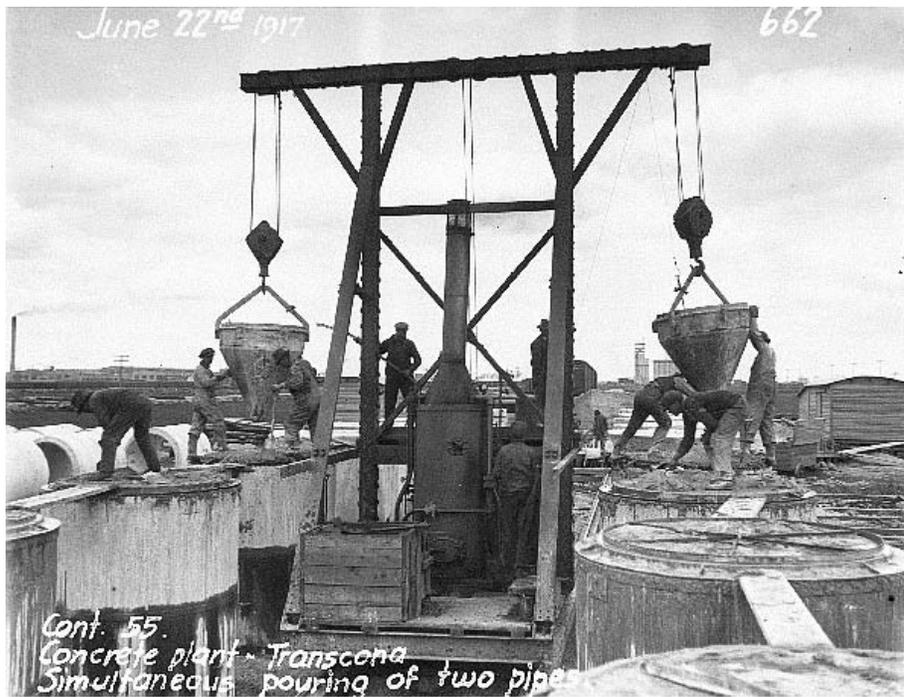


Figure 8.9.1. Lock Joint concrete pipe manufacturing (GWWD No. 662)

The routing of the conduit in St. Boniface was apparently a matter of some controversy. The minutes of the meetings of the Administration Board provide some details which indicate that the proposed route was changed, and then soon after the Board reversed its position and reverted to the original route (GWWD minutes, February 9, 1917; March 14, 1918; April 4th, 9th and 15th, 1918).

There was also an issue with the construction of the line in St. Boniface. The crossing of the Seine River was made at a severe skew and therefore longer than one might expect for a smaller stream (GWWD minutes, May 2, 1918). It was in that area that a dispute apparently arose over the excavation protection measures. It is known (Chace 1920b, p. 25) that timber sheet piling was left in place for part of the crossing. Again Colonel Ruttan's consulting services were sought; this time to resolve an issue between the contractor, Winnipeg Aqueduct Construction Company, and the GWWD. Given the

earlier involvements of all three on three of the easterly contracts, they would have been well acquainted. The matter was resolved but no indication was found as to whether that familiarity had a positive or negative effect on its resolution. Figure 8.9.2 shows a view of the general installation in north St. Boniface. The sides of the trench excavation were shored by driving closely spaced timber piles that were pulled once the trench had been filled and then moved forward to be used again.

One notable feature of the overall installation from Deacon to the Red River is that the pipe joints, which included a copper plate waterstop cast into the spigot end of the pipe, were grouted from both the outside and the inside. Landon (1918, p.316) describes it as follows:

Backfilling operations follow the setting of the pipe, and when this is in place for at least two months the inner or secondary portion of the joint is then filled with the material specified for the filler. The reason for proceeding with the jointing and backfilling in the manner stated is to allow for settlement and to make certain that when the joint has finally been made it will not be opened by future settlement.

Accomplishing that secondary grouting in a 1.7m opening would have been awkward. Chace (1920a, p. 946), who by then had become the President and General Manager of the Canadian Lock Joint Pipe Company, differs from Landon on the period of time after backfilling for the internal caulking. He indicates that it was done after the backfilled earth and pipe had come to a uniform temperature.

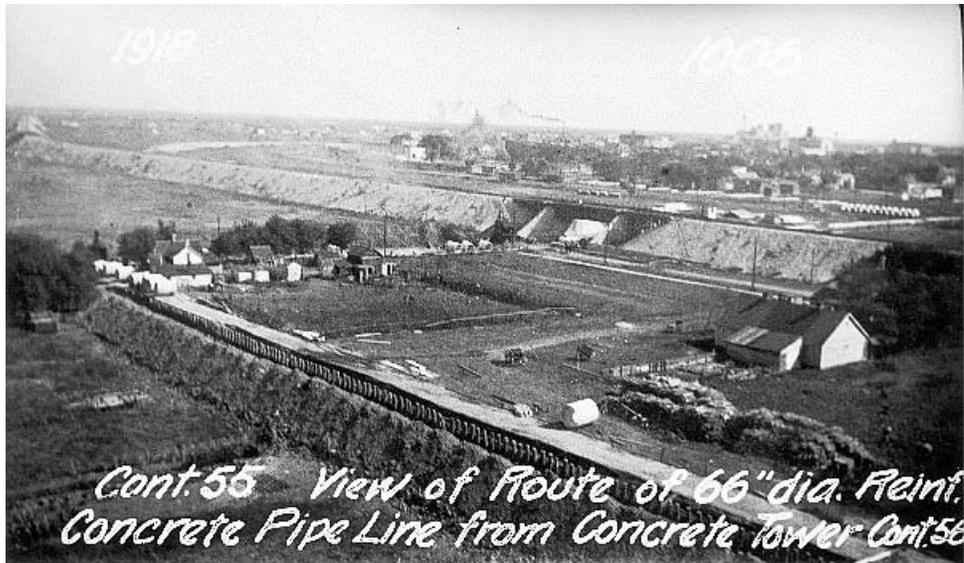


Figure 8.9.2. Pipe installation on Rue Hebert (formerly Arnaud) (GWWD No. 1006)

8.10 Red River Crossing

The construction of the crossing of the Red River and the siphon's surge tank required abilities and equipment quite different from those needed on the other contracts. It is unlikely that tunnelling in rock 24m below the river banks and 6m below the river bed had ever been done before in Manitoba. Also the complexity of the excavation for the foundation and forming of the concrete for the surge tank would have been uncommon. However, the supervisory staff of the contractor, Thomas Kelly and Sons, despite the owner's notoriety from involvement in the 1915 Manitoba Legislature building scandal, would have developed expertise applicable to the surge tank from their work on many buildings. The Legislative Building project also involved foundation caissons dug to rock.

Four aspects of the crossing construction are noteworthy. First, the reinforced concrete walls of the earth portion of the vertical shafts were an integral part of the excavation procedure. A steel cutting shoe was cast into the bottom of the section

intended for the deepest point of the shaft. Once the concrete had been cast, the section was sunk by excavating from within and below the shoe allowing it to sink by its own weight. When the top of that section was even with the ground line, another section was added and the sinking by excavation process repeated until the first one was at the surface of the bedrock.

The second aspect is that the rock excavation for the horizontal tunnel must have been done by the use of blasting. Photos in the collection of The City of Winnipeg Water and Waste Department indicate that a large air compressor was part of the onsite equipment. And while it would also have been used for ventilation air, another photo shows rock drilling equipment in the tunnel. Blasting would have been risky given that unknown fractures loosened by the blast could have caused a leak from the river only 4 to 5 meters above. As it was, the protective clothing worn by the party (party being a group, not a gathering for social enjoyment) in Figure 8.10.1 is an indication that the tunnel was not dry.



Figure 8.10.1. Visitors on tour in the Red River crossing tunnel (GWWD No. 932)

The third feature was that of the moving of concrete. Unlike today, when the concrete is delivered in a truck and pumped to the point of deposit, the contractor used a tower to provide height so that mixed concrete could be distributed by chutes and tubes. The tower at the west side of the river can be seen in the background in Figure 8.10. 2. It appears to have been positioned so as to serve both the crossing and the surge tank.

Fourth, the contract required that the space between the cast iron pipe and the tunnel opening be completely filled with concrete. While it would be feasible to place the concrete around and over the top of the pipe by working backwards with

bulkheads in a sequential

process, the upper space could not be placed that way and there would still be a void. So, a different process was used. Instead, the contractor inserted pipes through the river and drilled holes through the rock to access the void between bulkheads. The concrete in the



Figure 8.10.2 Trestle on Red River with concreting tower and surge tank in background (GWWD No. 963)

void was then placed by the process known as tremie. In that process, there would have been two tubes protruding into a confined void (Chace 1920a, p. 948). Fluid concrete with high cement content was then dropped into one tube until such time as it rose to a predetermined height in the other. When that happened, it was evidence that the void had been filled. Figure 8.10.2 shows the trestle and equipment being used in such an operation.

8.11 Surge Tank

The noteworthy aspects of the construction of the surge tank are the shoring used for the 7.5m deep excavation, the installation of the 9m deep supporting caissons below that level, and the forming of the concentric circular walls. The contractor took advantage of the circular shape of the structure's foundation to provide shoring without requiring struts extending across the excavation. Chace (1920a, p. 948) mentioned that as notable, saying that "this support consisted of a sixteen-sided timber mitred framing without shoring dressed with vertical sheeting." The earth pressure would have kept the sixteen horizontal pieces of timber of the waler system acting in compression and in place. Figure 8.11.1 provides a view of the system. From the pattern of the pieces in the vertical wooden sheeting, one can tell that from the second waler down, the sheeting was placed from below the frames as the excavation progressed.



Figure 8.11.1 Shoring for surge tank excavation (GWWD No. 969)

The walls of the caissons would have been supported in a similar way with the horizontal support being a circular hoop. Figure 8.11.2 shows that system. In this case, the sheeting and hoops would probably have been withdrawn for reuse as the concrete level in the caisson rose.



Figure 8.11.2 Caisson construction (GWWD No. 973)

Figure 8.11.3 provides a view of the forms for the circular walls. While it is difficult to discern detail from a distance, the photo suggests a well-thought-out system and quality workmanship.



Figure 8.11.3. Forming system for the circular weir and containment wall (GWWD No. 1000)

Once the walls were in place, providing the roof and the exterior finish (Figure 7.15.4.1) would not have been unusual tasks for an experienced building contractor such as Thomas Kelly and Sons. Neither, given their other construction involvements, would be the outlet into the river for the overflow water. However, as there would have been two rock filled cribs in the Red River in close proximity, one for the surge tank discharge and another for the intake to the James Avenue high pressure pumping station, it is interesting to speculate about the effect of two submerged obstacles on river traffic.

8.12 Contract Disputes and Claims

Disputes and claims on any major construction project would not be unusual. While undoubtedly there would have been day-to-day onsite differences of opinion over the four-year long 150km project, few formal claims are mentioned in the reports by the Chief Engineer and the Chairman of the Commissioners in the minutes of the meetings of the GWWD's Administration Board. While not all Change Orders would be mentioned in the Board's minutes, indications are, from the identification numbers of those that were mentioned, that approximately 300 were issued. The claims that did come before the Board were on the main contracts and had to do with escalated cost of reinforcing steel (presumably because of World War I) and transportation charges for materials. With the latter, the crux of the matter seems to have been whether the materials transported were incorporated in the work as contracted. While there were some letters from the contractor's lawyers, unlike today there seem to have been no law suits. Other issues had to do with requests for extensions of time. Given that a failure to complete one of the main contracts on time would, in effect, turn a four-year project into a five-year project, it is not surprising that extensions were not granted.

9.0 CONCLUSION

The Winnipeg Aqueduct was completed on time and quite close to budget by December of 1918. That was after four years of the country being involved in WWI with all its effects, and three months after the City's population had been severely affected by the Spanish Flu epidemic. Despite those complications the GWWD could have then begun delivery of water to the McPhillips Reservoir. However, because of a concern that there might be an adverse effect on the industrial boilers in the City due to the change from hard to soft water during the height of the heating season, the changeover was delayed. Water started to flow into the McPhillips Reservoir on March 29, 1919, and the system was officially opened by the Prince of Wales on September 9, 1919. Thomas Deacon's "menace of a water famine" had been subdued.

The objective of this thesis is to understand and provide comment on the issues affecting the development and implementation of the Winnipeg Aqueduct from the perspective of an engineer and former contractor. It is hoped that this account will help others to understand the scope and significance of the public asset acquired in Winnipeg's past, and kindle an interest in using that information to critically assess the concepts incorporated in future projects.

The engineers, administrators, and contractors on the Winnipeg Aqueduct executed a unique project that is remarkable for its scope and its lasting ability to serve the needs of The City of Winnipeg. In so doing they were confronted with and overcame unique physical and environmental conditions using creative design, testing and construction processes.

During the research for this thesis, potential areas of further work have been identified – both engineers and those from other fields might consider studies related to:

- The issues and solutions involved in the financing of the GWWD, and Manitoba projects in general, at the time of WWI. One expects that this would be suitable for someone with a commerce or accounting background. Among the records at the Water and Waste Department are audited annual financial statements of the corporation that should be useful for such a study.
- The politics of the sale of Shoal Lake Band 40 lands to the GWWD in the context of the times, and the present day effect on the First Nation. That would include the general relationship with The City of Winnipeg and the issue of the Band being land-locked by the construction of the Falcon River Diversion.
- The state of the art of the testing of materials for concrete mixing and the designing and testing of concrete mixes in Canada at the time of the work by the GWWD engineers (section 7.2), and the subsequent evolution of those aspects of concrete production as equipment and analytical methods evolved.
- An examination of the development of the corporate structure, administration and construction capabilities of the contractors of the era. That could include learning how Thomas Kelly and Sons maintained the ability to obtain, finance, and perform proficiently on three of the Winnipeg Aqueduct contracts, while its founder was embroiled in the Legislature Building scandal and sentenced to two and a half years in prison.
- An analysis of the embedded carbon footprint of the Winnipeg Aqueduct project so that it could be compared with that of later projects such as a hydro-electric power development. One indicator of greenhouse gas production is

that the GWWD purchased over 7,000 tonnes of coal in 1915-1916 (no record of purchases for 1917 and 1918) presumably for its railway operations.

Photographs suggest that the other steam driven equipment on the project was either coal or wood fired, and that pumping operations during construction were powered by gasoline engines.

- The history of the bridges of Winnipeg, both traffic and railway, from a combined engineering and political perspective. The issue of the bridge initiative subsidy that brought the CPR to Winnipeg instead of Selkirk would be of particular interest.

Manitobans are fortunate that the GWWD kept useful records and that much of that information has been preserved. With the continuing careful preservation of those records by The City of Winnipeg's Water and Waste Department, researchers will continue to have access to that resource.

10.0 REFERENCES

Note: The minute books of the meetings of the Administration Board of the Greater Winnipeg Water District between 1913 and 1918 are stored at the Winnipeg Water and Waste Department's Resource Centre, 199 Pacific Avenue, Winnipeg. Records of the Greater Winnipeg Water District are also at the Resource Centre. As part of those records there are 1,018 photographs taken at the time of the aqueduct construction at the Resource Centre. The identification number for the digitized collection is 000115291. Some of them have been included in the text as Figures and the GWWD identification numbers are indicated.

Apostol, T. M. 2004. The tunnel of Samos. *Engineering & Science* 2004 (1): 30-40.
<http://pr.caltech.edu/periodicals/EandS/articles/LXVIII/samos.html> (2009/10/10)

Artibise, A.F.J. 1975. *Winnipeg: A Social History of Urban Growth 1874-1914*. Montreal QC: McGill-Queen's University Press.

Babbit, H. E., J. D. James and J.L. Cleasby 1962. *Water Supply Engineering*. New York NY: McGraw-Hill Book Company Inc.

Canadian Public Works Association Manitoba Chapter (CPWA). 2000. *Greater Winnipeg Water District's Shoal Lake Aqueduct Nomination for the American Public Works Association's Top Ten Public Works Projects of the 20th Century*. Winnipeg MB: Self Published.

Chace W.G., M.V. Sauer. 1917a. The aqueduct for the Greater Winnipeg Water District. *Transactions of the Canadian Society of Civil Engineers*. Volume XXX Part II: 375-395.

Chace W.G., D.L. McLean. 1917b. Studies regarding concrete mixtures employed in the work: Supplement to the aqueduct for the Greater Winnipeg Water District. *Transactions of the Canadian Society of Civil Engineers*. Volume XXX Part II: 396-424.

Chace, W.G. 1917c. Sands and consistency of concrete. *The Canadian Engineer* 33: 282

Chace, W.G. Chace. 1920a. Construction features of the water works of the Greater Winnipeg Water District. *Journal of the American Water Works Association*, Volume VII: 931-949.

Chace, W.G. 1920b. Notes and Instructions for the Guidance of the Staff Responsible for the Care and Operation of Aqueduct Supplying Water to the Communities Comprising the Greater Winnipeg Water District. Winnipeg MB: The City of Winnipeg Water and Waste Department.

- Cherney, B. 2009. 90th anniversary of Shoal Lake aqueduct — first phase was construction of GWWD Railway. *Winnipeg Real Estate News*, October 16, 2009. www.winnipegrealestatenews.com/Editorials.aspx?id=968 (2010/11/29)
- Cole, G.E. 1948. Mining in Manitoba. <http://www.mhs.mb.ca/docs/transactions/3/manitobamining.shtml> (2010/11/27).
- Fuertes, James H. 1920. The basic principles used in the designs for the new water supply works of Winnipeg Manitoba. *Journal of the American Water Works Association*, Volume VII: 693-748.
- Greater Winnipeg Water District. 1913 – 1918. Minutes of meetings of the Administration Board. The City of Winnipeg Water and Waste Department
- Greater Winnipeg Water District. 1914. Contract numbers 30, 31, 32, &34 for construction of aqueduct from Shoal Lake. The City of Winnipeg Water and Waste Department, TA 180, .s658, 8900557530.
- Greater Winnipeg Water District. 1914. Contract numbers 30, 31, 32, &34 for construction of aqueduct from Shoal Lake. The City of Winnipeg Water and Waste Department, TA 180, .s658, 8900557530.
- Greater Winnipeg Water District. 1918. *Aqueduct Construction Scheme: What it Is What It Means*. Winnipeg MB: Telegram Job Printers Ltd.
- Herring, R., F. P. Stearns and J. H. Fuertes. 1913. Report on a water supply from Shoal Lake for the Greater Winnipeg Water District. New York NY: Stovel Company Limited Winnipeg.
- Hodge, A. T. 2002. *Roman Aqueducts and Water Supply*. London: Duckworth Publishers.
- International Joint Commission. 1914. *Hearings and Arguments in the Matter of the Application of The Greater Winnipeg Water District for Approval of the Diversion of the Waters of the Lake of the Woods and Shoal Lake for Sanitary and Domestic Purposes*, Washington DC.
- Koen, B.V. 1985. *Definition of the Engineering Method*. Washington DC: American Society for Engineering Education.
- Landon, C.S. 1918. The Greater Winnipeg Water District. *The Canadian Engineer*. 34: 290-301, 315-317.
- Library and Archives Canada, Canada. n.d. Mining Lands & Yukon Branch of the Department of the Interior, File 116619

- Manitoba Historical Society. 2008. Archibald C. McKenzie. Winnipeg MB
www.mhs.mb.ca/docs/people/mckenzie_ac.shtml (2011/01/020)
- Mclean, D.L. 1919. Earth Slides in Winnipeg Aqueduct Construction. *The Canadian Engineer*. 37: 469-471.
- Prodan C.S. 1979. The building of the Winnipeg Aqueduct. *Manitoba Pageant*.
www.mhs.mb.ca/docs/pageant/24/winnipegaqueduct.shtml
- Province of Manitoba. 1913. *Acts of the Legislature of the Province of Manitoba: Third Session of the Thirteenth Legislature*. Winnipeg MB: Kings Printer.
- Rouse, H. and I. Simon. 1957. *History of Hydraulics*. Ann Arbor MI: Iowa Institute of Hydraulic Research, Sate University of Iowa
- Ruttan, H.N. 1909. Winnipeg's water works: Visit to the City water works High Pressure Plant and artesian well system. British Association for the Advancement of Science, 1-8. Winnipeg, MB.
- Ruttan, H.N. 1913. Untitled report to the Mayor and City Council of Winnipeg dated May 8, 1913. Winnipeg MB: The City of Winnipeg Water and Waste Department.
- Ruttan, H.N., J.G. Sullivan and R.S. Lea. 1916. Report on the Aqueduct of the Greater Winnipeg Water District by the Special Board of Consulting Engineers. Winnipeg MB: The City of Winnipeg Water and Waste Department.
- Scott, W. M. 1938. The Water Supply of Greater Winnipeg. *Journal of the American Water Works Association*, Vol. 30 No. 11: 1872-1885. Winnipeg MB: The City of Winnipeg Water and Waste Department.
- Scott, W. M. n.d. The Water Supply of The Greater Winnipeg Water District. Unbound paper labelled as presented at a meeting of the American Water Works Association in March, 1938. Winnipeg MB: The City of Winnipeg Water and Waste Department.
- Shoal Lake Watershed Working Group. 2002. Shoal Lake Watershed Management Plan. Manitoba Water Stewardship, Winnipeg MB.
www.gov.mb.ca/waterstewardship/water_quality/quality/shoal_lake_wsmp.html
 (2010/12/28)
- Shropshire, L. 1994 (January 7). Mayor Battles Critics. *Winnipeg Real Estate News*. Winnipeg MB: self published.
- Siamandas, G. n.d. Winnipeg's Shoal Lake Aqueduct.
timemachine.siamandas.com/PAGES/winnipeg_stories/SOAL_LAKE_AQUEDUC T.htm (2011/02/7)

- Slichter, C.S. 1912. *The Water Supply of the City of Winnipeg to Public Utilities*
Commissioner, Province of Manitoba, Winnipeg, MB.
- Solomon, S. 2010. *Water: The Epic Struggle for Wealth, Power, and Civilization*. New
York NY: Harper Collins Publishers.
- The Canadian Engineer. 1917. Winnipeg Aqueduct Excavation. *The Canadian Engineer*.
32: 149-151.
- Water and Waste Department, The City of Winnipeg. n.d. Records of the Greater
Winnipeg Water District

11.0 APPENDICES

Appendix 11.1

Timeline: Winnipeg, its Water and the Aqueduct

- 1880 – An act incorporating the Winnipeg Water Works Company was passed by the Manitoba Legislature with a franchise that lasted until 1900. It drew water from the Assiniboine at Armstrong's Point.
- 1883 – Dr. Niven Agnew advocates Lake of the Woods as a source of supply in a letter to the Free Press. He also delivered a paper to the subject to the Manitoba Historical Society on this in February 1884.
- 1885 – Henry Norlande Ruttan becomes Winnipeg City Engineer. Before that he had been with the CPR and in general practice.
- 1886 – November 12th - City Engineer reports that Winnipeg Water Works Company was not honouring the terms of its act of incorporation.
- 1887 – April 8th - Report by Ruttan on the relationship with the Winnipeg Water Works Company.
- 1887- 1898 – Confrontation between City and Winnipeg Water Works Company over delivery and the franchise preventing the City from starting its own water service.
- 1893 – Winnipeg Water Works Company has legislation passed that the City could not build its own waterworks until the company's franchise expired.
- 1895 – Females given the right to vote in municipal elections – but only under the property qualification.
- 1897 – City hires Rudolph Hering from New York to give advice on water supply. He recommends artesian well system.
- 1898 – “The inadequacy of the privately owned water supply system prompted the city fathers to buy it out in 1898.” – for \$237,000.
- 1900 – Artesian well water, Well No1., begins flowing in the City's water works system.
- 1900 – Canada involved with the British in the Boer War.
- 1901 – Winnipeg builds the first municipal water softening plant in North America
- 1902 – City hires Rudolph Hering from New York to give advice on increasing the water supply. He recommends an additional artesian well.

- 1902 – Thomas Russ Deacon moves to Winnipeg from the Kenora area.
- 1903 – Roblin and Conservatives win Provincial election and “... was ready to move into the vanguard of the progressive public ownership movement.”
- 1904 –A serious fire broke out and the City was forced to pump Assiniboine River water into the mains. Shortly after typhoid fever epidemic broke out. It affected not only the North End but also the South End and was attributed to the use of the river water.
- 1905 – Tom Sharpe becomes the Mayor
- 1905 – Council orders investigations by a sanitary engineer and a medical authority on the causes of the typhoid fever epidemic. Professor Hazen, a sanitary engineer from New York pointed out the need for “... an abundant and well used water supply...”, and Dr. Jordan, of the University of Chicago, confirmed one of the causes being the use of Assiniboine River water. Both confirmed the opinions of the City’s own health officials.
- 1905 – A new well dug by the City – 2 million gallons per day but still inadequate – “... sanitation arrangements and fire protection where services were precariously inadequate owing to the limited water supply.”
- 1905 – The City of Winnipeg was “... subject to very excessive fire insurance charges.”
Ruttan
- 1906 – The Board of Control system over the Winnipeg City Council to provide for “best efficiency in municipal affairs” was implemented
- 1906 – Manitoba Legislature passes an Act authorizing a Water Supply Commission for Winnipeg
- 1906 – City Council appointed a Water Supply Commission to come up with a “permanent solution” to water supply. Deacon was an alderman and was appointed to the Commission.
- 1906 – October until March 1907 – C.A. Millican, C.E. (Municipal Engineer and Contractor) does an exploratory survey of Shoal Lake and the territory to the West.
- 1907 – J. H. Ashdown becomes Mayor by acclamation.
- 1907 – Roblin government re-elected on platform of public ownership of the telephone system
- 1907 – Board of Consulting Engineers appointed by the City’s Water Supply Commission in June “... to advise fully as to the selection of a permanent and

adequate system of supply of water for the City.” – 29 August it recommends the Winnipeg River

- 1907 – December – Roblin makes a deal to buy the Bell system in Manitoba for 3.4 million dollars in 4% bonds
- 1907 – Recession - “Canada’s difficulties were not unique; the recession of 1907 was worldwide, and amid the general depression, the plight of Western Canada appeared relatively mild.”
- 1908-1910 – W. Sanford Evans was Mayor of the City of Winnipeg
- 1908 – James Avenue High Pressure Pumping Station (for firefighting) completed.
- 1909-1911 – W. Sanford Evans is Mayor
- 1909 – Canada and USA sign the *Boundary Waters Treaty* which leads to the International Joint Commission
- 1910 – City Engineer Ruttan recommends to the Council that the artesian system be supplemented with an extension to Poplar Springs North-East of Stone Wall
- 1910 – Lockport Dam and locks opened providing better water transportation access to Lake Winnipeg
- 1910 – Workmen’s Compensation Act adopted in Manitoba
- 1912 – R.D. Waugh becomes the Mayor of Winnipeg
- 1912 – Public Utilities Commission established by the Manitoba [Roblin] Government.
- 1912 – September 6th – Winnipeg City Council receives the report of the Public Utilities Commissioner, Judge Robson, on the question of water supply with the attached report of Professor C.S. Slichter an international authority on water who had already advised Brooklyn NY, Los Angeles, St Louis, El Paso, and Holland, on their water supplies. The professor recommended Shoal Lake as the source for the City.
- 1912 – September 10th – Winnipeg City Council instructs Ruttan to conduct a “survey of the country between the City of Winnipeg and Shoal Lake, Lake of the Woods”
- 1912 – The boundaries of Manitoba extended to the current ones.
- 1913-1914 – Thomas Russ Deacon is Mayor
- 1913 – January 17th – Meeting of the municipalities “... including and contiguous to Winnipeg and St. Boniface...” at the Industrial Bureau, Winnipeg.

- 1913 – January 22nd – a second meeting of the cities and municipalities with Robson present. Decision taken to proceed.
- 1913 – January 24th – “An Act to incorporate the Town of Tuxedo” is assented to.
- 1913 – January 30th – A meeting of the representatives of the City of Winnipeg and several surrounding municipalities held to consider the question of incorporating the ‘Greater Winnipeg Water District’. Draft bill taken up clause by clause.
- 1913 – February – Los Angeles Aqueduct completed
- 1913 – February 15th – “An Act to incorporate the “Greater Winnipeg Water District” assented to. Only the sections authorizing the vote by the Winnipeg ratepayers came into effect. (The rest was proclaimed on June 10th 1913)
- 1913 – February 15th – “An Act to further amend the “The Winnipeg Charter” assented to
- 1913 – February 15th -- “An Act respecting the Rural Municipality of Fort Garry” is assented to – authorizes Fort Garry to enter into an agreement “for the supply or furnishing of water”
- 1913 – April 7th –a Board of Consulting Engineers was appointed. They were Rudolph Hering (New York), James H. Fuertes (New York), and Frederic P. Stearns (Boston) “all eminent water supply engineers”
- 1913 – May 1st – Winnipeg voters pass a By-law by 2226 to 369 on the question “Are you in favour of the creation of the Greater Winnipeg Water District?”
- 1913 – May 8th – Ruttan’s report to the Winnipeg City Council (requested September 10th 1912) made. He states “...the project is not only practicable, but that the conditions are more favourable than was expected.”
- 1913 – By 1913 Manitoba’s public debt was so great that it exceeded that of Ontario.
- 1913 – Canada Cement Company Limited begins producing cement using local raw materials.
- 1913 – Construction began on the new Legislative Building.
- 1913 – [May] Greater Winnipeg Water District formed.
- 1913 – May 20th – Council asks the Board of Consulting Engineers “to submit a report on the best means of supplying the Greater Winnipeg Water District with water from Shoal Lake, together with estimate of cost and general plan of work.”

- 1913 – June 6th - Dominion Government authorized GWWD to go outside of Manitoba for water.
- 1913 – June 10th – the GWWD Act assented to and became law
- 1913 – July 31st – The City of Winnipeg’s Clerk’s Office advertises for applications for the position of secretary to the Administration Board of the Greater Winnipeg Water District Corporation. Free Press
- 1913 – August 20th - Report from Hering et al – “Report on a Water Supply from Shoal Lake for the Greater Winnipeg Water District” received.
- 1913 – September 6th – The Administration Board of the GWWD adopted the August 20th report of Board of Consulting Engineers and adopts a By-law to incur a debt of \$13,500,000.
- 1913 – September 8th – The Winnipeg City Council adopted the Board of Consulting Engineers’ report – “passed without so much as one word of comment and the vote was unanimous.”
- 1913 – September 8th – application to the International Joint Commission filed to take water from Shoal Lake
- 1913 – October 1st – Vote by the eligible voters of the City of Winnipeg on the money By-law for \$13,500,000 for the aqueduct passes by 2,951 in favour and 90 against.
- 1913 – October 2nd - An order in Council of the Province of Ontario passed permitting the GWWD to take water from Shoal Lake up to 100,000,000 gallons per day.
- 1913 – October to November GWWD engineering office organized and survey parties dispatched to do route locations.
- 1914 – January 15 – The IJC authorizes the drawing by GWWD of 85,000,000 per day from Shoal Lake/Lake of the Woods
- 1914 – February 11th – tenders received for the building of the GWWD railway to Indian Bay.

- 1914 – February 20th – An Act to ratify and confirm certain By-laws of the Corporation of the Greater Winnipeg Water District and of the City of Winnipeg, and a certain agreement made between the Greater Winnipeg Water District and the Bank of Montreal.
- 1914 – February 25th – contract awarded for clearing of the Right of Way
- 1914 – March 12th – Contract awarded to Northern Construction Co. to build the GWWD Railway
- 1914 – March – the route of the aqueduct East of Deacon decided
- 1914 – May 19th – Contract awarded to Tomlinson & Fleming to build the Falcon River Dike
- 1914 – May 28th – contract awarded for to build test sections of aqueduct shapes at the Exhibition Grounds in Winnipeg.
- 1914 – August 3rd WWI declared
- 1914 – September - Panama Canal opened.
- 1914 – September & October Tenders for Contracts 31 to 34 for the main sections of the aqueduct from Deacon to Indian Bay received (September 19th) and awarded (October 27th) by the GWWD.
- 1914 – October 22nd – work completed by the GWWD on the telephone line
- 1914 – November - Railway completed with exception of some ballasting
- 1915-1916 – R.D. Waugh is the Mayor of Winnipeg
- 1915 – Winnipeg Aqueduct Construction Company formed to take over GWWD contracts 32, 33, and 34 awarded to Northern Construction.
- 1915 – March 3rd – Federal Government sells a portion of Indian Bay and some land along the shore belonging to Shoal Lake Band No. 40 to the GWWD (OC 463).
- 1915 – April 1st to May 12th - Legislative Building scandal. Premiere Roblin resigns and T.C. Norris [Liberal] becomes Premiere.
- Royal Commission found that the Conservative party acquired \$800,000 in election funds by way of extras in the contract with Thomas Kelly and Sons – Morton p341-346 (Note: Thomas Kelly and Sons had a contract on the aqueduct while this was going on, and was awarded another in 1918 for the Red River Xing.)

- 1915 – May 15th – Construction starts on the main contracts from Deacon Easterly
- 1915 – August 6th – Liberals and T.C. Norris win an election and form a majority government.
- 1915 – November 5th – Chace reports to the Administration Board that cracking has occurred in the inverts on contract No. 30.
- 1915 – December 3rd – the Administration Board of the GWWD received a report by James H. Fuertes and W.G. Chace recommending that the pipeline portion of the project from Deacon Reservoir to Winnipeg be a 5 foot-6inch reinforced concrete pressure pipe instead of the originally specified 5 foot steel pipe line. The recommendation was also endorsed by Hering and Stearns.
- 1916 – Women in Manitoba get the right to vote (the first) [Norris Government]
- 1916 – February 4th – The Administration Board of the GWWD asked for a report from Fuertes and Chace on the cracking
- 1916 – February 16th – The Administration Board of the GWWD received the report Fuertes and Chace on the cracking
- 1916 – February 25th - The Administration Board of the GWWD adopted a resolution instructing the Commissioners to procure a report from a Special Board of Consulting Engineers; H.N. Ruttan, J.G. Sullivan, and R.S. Lea on the cracking issue and the switch from steel pipe to concrete Deacon to Red River.
- 1916 – March 13th - The Manitoba Temperance Act passed [Norris Government]. (Came into effect on June 1st)
- 1916 – May 15th – An interim report of the Special Board of Consulting Engineers made stating certain conditions under which the construction of the cut and cover section of the aqueduct could safely proceed.
- 1916 – September 26th – Final report of the Special Board of Consulting Engineers on the 1915 cracking.
- 1916 – October – load tests made of various invert sections at the Deacon site
- 1917 – Income tax imposed by the Federal Government to try and pay for the war effort.
- 1917 – Norris Government amends the Roblin Government's Workmen's Compensation Act
- 1916 – December 29th – contract awarded for the section from Deacon to the Red River

- 1918 – January 30th – contract awarded for the Red river crossing and surge tank and for the pressure line from the Red River to the McPhillips Reservoir – both contracts to Thomas Kelly and Sons. Ltd.
- 1918 – November 11th - WWI ends
- 1918 – GWWD Board decides to delay introducing Shoal Lake water into the Winnipeg system because of possible damage to industrial boilers
- 1919 – March 29th – water started to enter the McPhillips Reservoir in Winnipeg. (It had entered the St. Boniface system the evening before)
- 1919 – September 9th – The official opening of the aqueduct by His Royal Highness, Edward, Prince of Wales
- 1919 – Legislative Building completed.
- 1930 – June 15 – Manitoba’s natural resources transferred from the Federal Government to the Province.

Appendix 11.2

Reports on Winnipeg's Water System

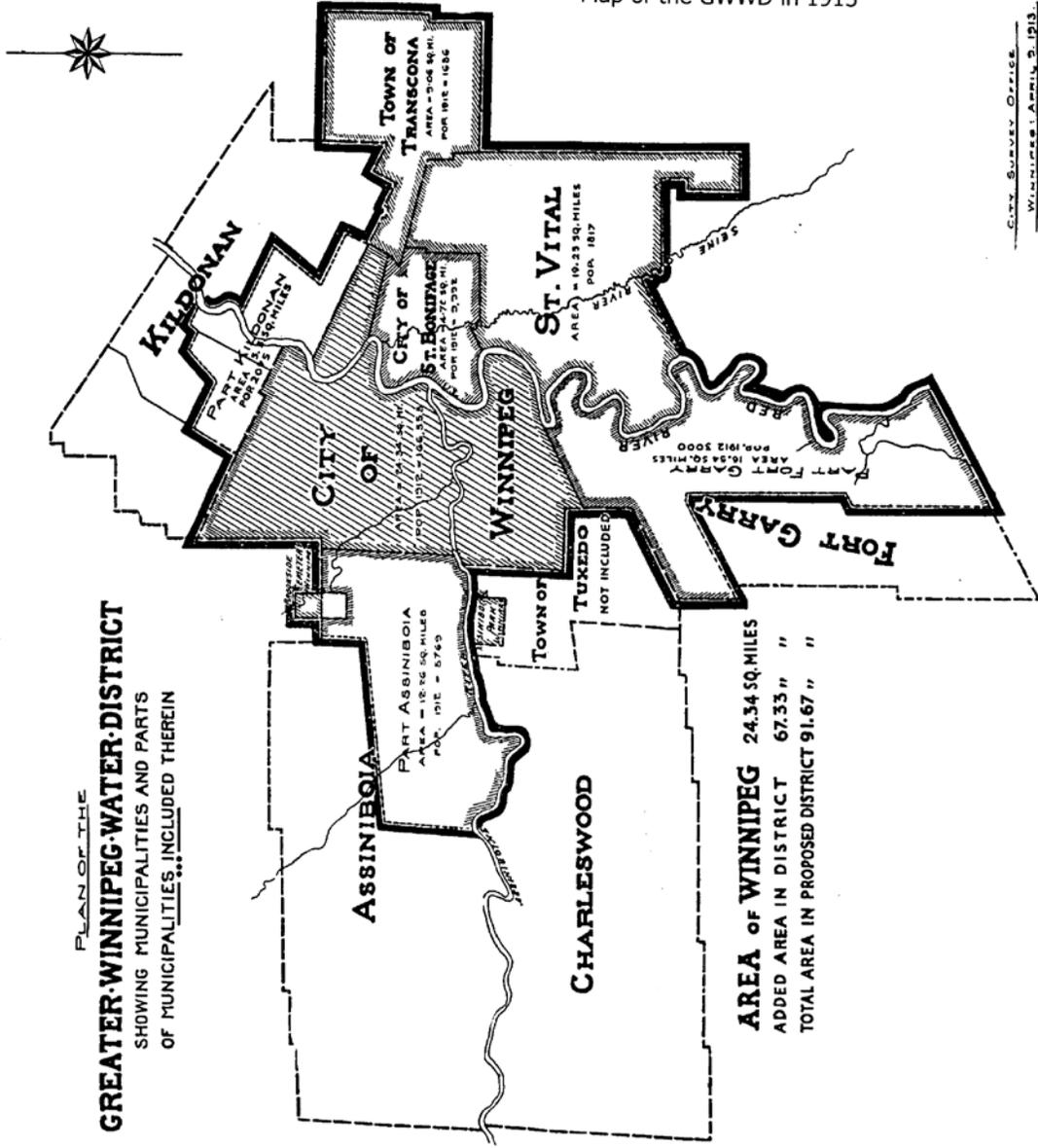
- 1884 – Dr. Niven Agnew provided a paper to the Historical and Scientific Society of Manitoba *Our water supply: suggestions as to the water we drink and where to get it from*, summarizing the circumstances and advocating Lake of the Woods.
- 1887 – City Engineer Ruttan reported to the City of Winnipeg's Committee on Fire, Water and Light on the issues with a proposal for extension of works by the Winnipeg Water Works Company citing issues and setting out other possible sources of supply.
- 1895 – Walter Moberly, a Canadian civil engineer, made a report advocating a new supply for Winnipeg from the Winnipeg River.
- 1897 – Dr. Rudolf Hering reported to the City on expansion of the artesian system and using the Winnipeg River.
- 1901 – City Engineer Ruttan reported to the Winnipeg City Council that the city faced a water shortage and recommended the expansion of the artesian well system.
- 1902 – Dr. Hering was consulted and reported on a proposal by Engineer Ruttan to expand the artesian well system, endorsing the proposal.
- 1904 – The Fire Underwriters Association presented a report to the City Council pointing out the inadequacy of the water system for firefighting purposes.
- 1905 – Report by Allan Hazen, a US engineer, on the sewer system and water supply following the 1904 typhoid epidemic.
- 1906 – A recommendation by the City Engineer to extend the artesian system to the Poplar Springs area near Stonewall.

- 1907 - C.A. Millican, reported on a survey on a possible delivery of water to Winnipeg from Shoal Lake
- 1907 – A board of Consulting Engineers (Hering, Fuertes, Lea, Schwitzer, and Whipple), appointed by the City’s Water Supply Commission, investigated and reported on using groundwater, Red and Assiniboine Rivers, Winnipeg River, and Lake of the Woods as sources. It recommended against expansion of the artesian system and favoured the Winnipeg River.
- 1912 – Professor C.S. Slichter, a US engineer, investigated the Winnipeg River and Shoal Lake as sources and strongly recommended Shoal Lake.
- 1912 – Judge Robson, the Public Utilities Commissioner for the Province of Manitoba, endorsed Professor Slichter’s recommendation and suggested joint development with other municipalities.
- 1913 – May, City Engineer Ruttan provided a report to the Winnipeg City Council indicating that a conduit from Shoal Lake was feasible.
- 1913 – August, the second Board of Consulting Engineers (Hering, Fuertes, and Stearns) that had been appointed by the Winnipeg City Council in early 1913 reported and recommended “To bring water through a concrete aqueduct, approximately 85 miles in length, laid with a continuous down grade to a point about 10 miles east of Winnipeg; and then in a five-foot steel pipe to the Red River and a five-foot pipe in tunnel to convey water under the Red River, thence a four-foot cast iron pipe through the streets to McPhillips Street reservoir.”

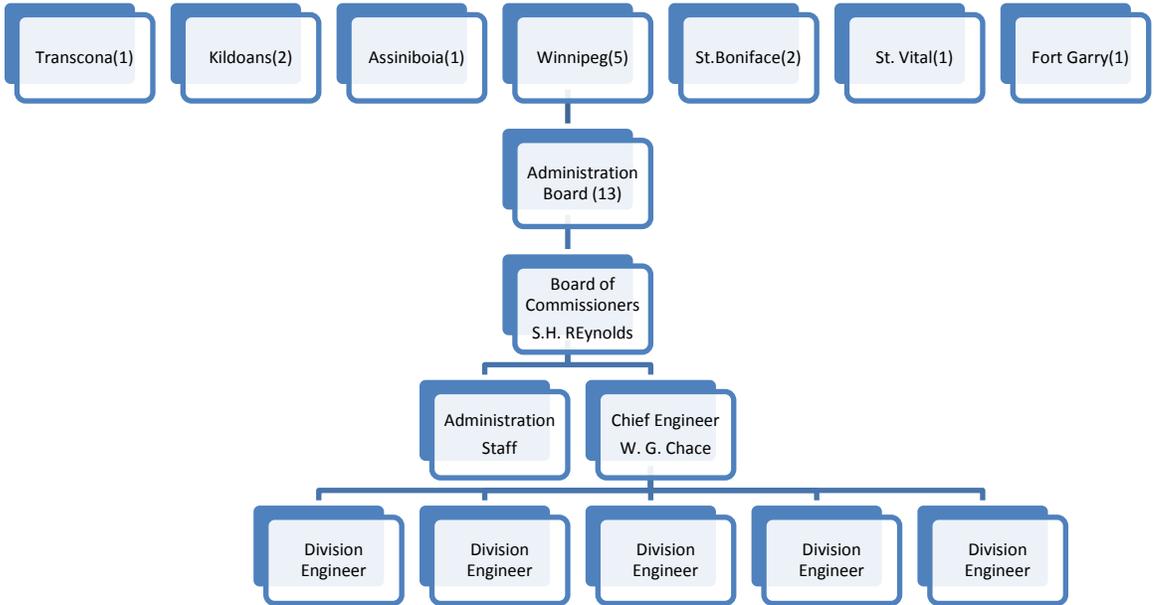
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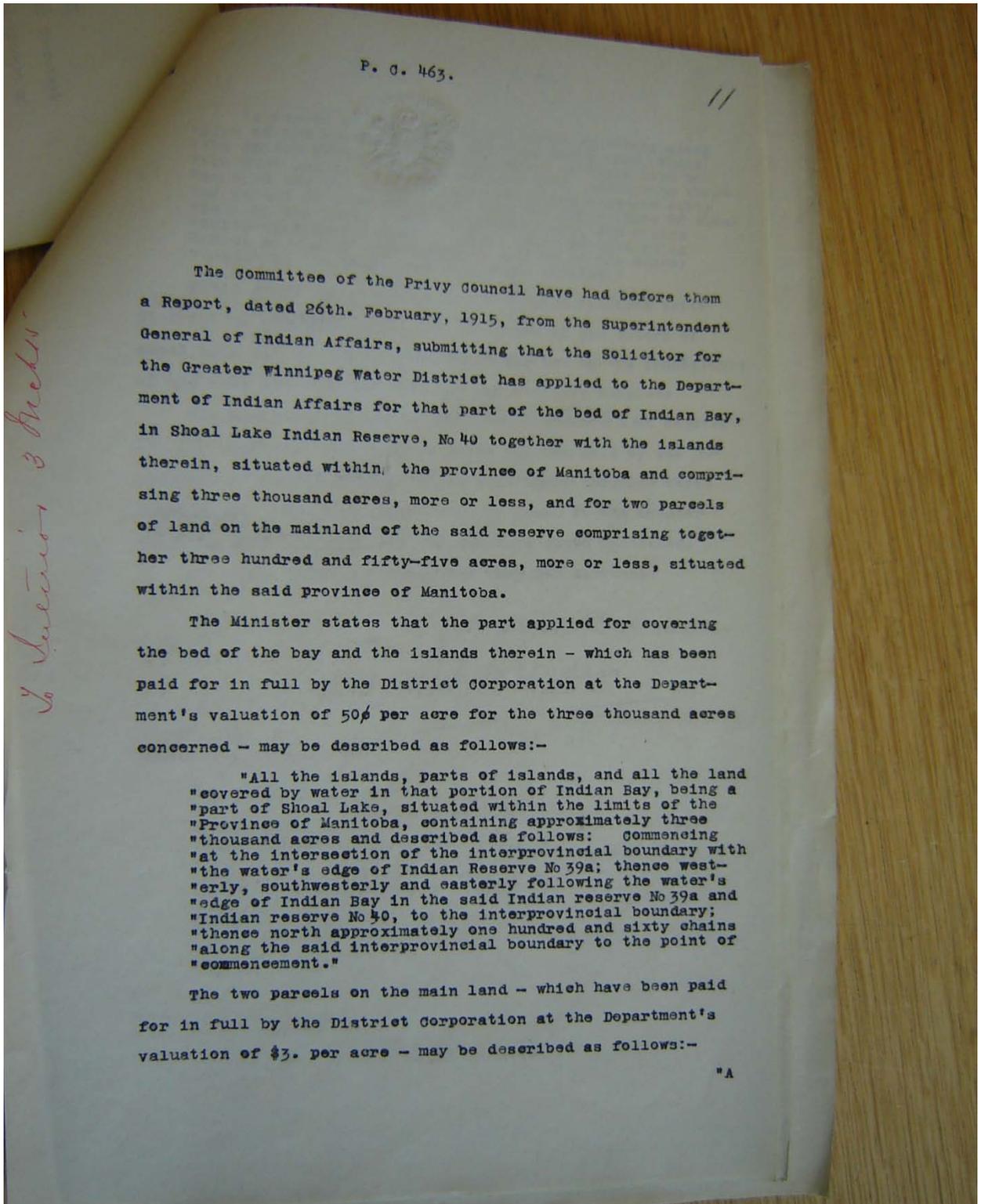
Appendix 11.3

Map of the GWWD in 1913



Appendix 11.4 Organization Chart 1





P. C. 463.

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In Indian & Fisheries

The Committee of the Privy Council have had before them a Report, dated 26th. February, 1915, from the Superintendent General of Indian Affairs, submitting that the Solicitor for the Greater Winnipeg Water District has applied to the Department of Indian Affairs for that part of the bed of Indian Bay, in Shoal Lake Indian Reserve, No 40 together with the islands therein, situated within the province of Manitoba and comprising three thousand acres, more or less, and for two parcels of land on the mainland of the said reserve comprising together three hundred and fifty-five acres, more or less, situated within the said province of Manitoba.

The Minister states that the part applied for covering the bed of the bay and the islands therein - which has been paid for in full by the District Corporation at the Department's valuation of 50¢ per acre for the three thousand acres concerned - may be described as follows:-

"All the islands, parts of islands, and all the land covered by water in that portion of Indian Bay, being a part of Shoal Lake, situated within the limits of the Province of Manitoba, containing approximately three thousand acres and described as follows: Commencing at the intersection of the interprovincial boundary with the water's edge of Indian Reserve No 39a; thence westerly, southwesterly and easterly following the water's edge of Indian Bay in the said Indian reserve No 39a and Indian reserve No 40, to the interprovincial boundary; thence north approximately one hundred and sixty chains along the said interprovincial boundary to the point of commencement."

The two parcels on the main land - which have been paid for in full by the District Corporation at the Department's valuation of \$3. per acre - may be described as follows:-

"A

P6 463

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"A parcel of land of varying width extending along
"part of the north-westerly shore of Shoal Lake, along
"the Falcon river and the south shore of Snake lake to
"the west limits of Indian reserve No 40, containing three
"hundred and ten acres more or less, and a narrow strip
"or parcel of land extending from the south shore of Shoal
"lake to the north shore of Snowshoe bay, containing
"forty-five acres, more or less, these parcels being
"shown on a plan recorded under No 1370 in the Survey
"Branch of the Department of Indian Affairs."

These areas are required by the Greater Winnipeg Water District in connection with the diversion of the waters of Shoal lake and the Lake of the Woods for use by the inhabitants of the said district for domestic and sanitary purposes.

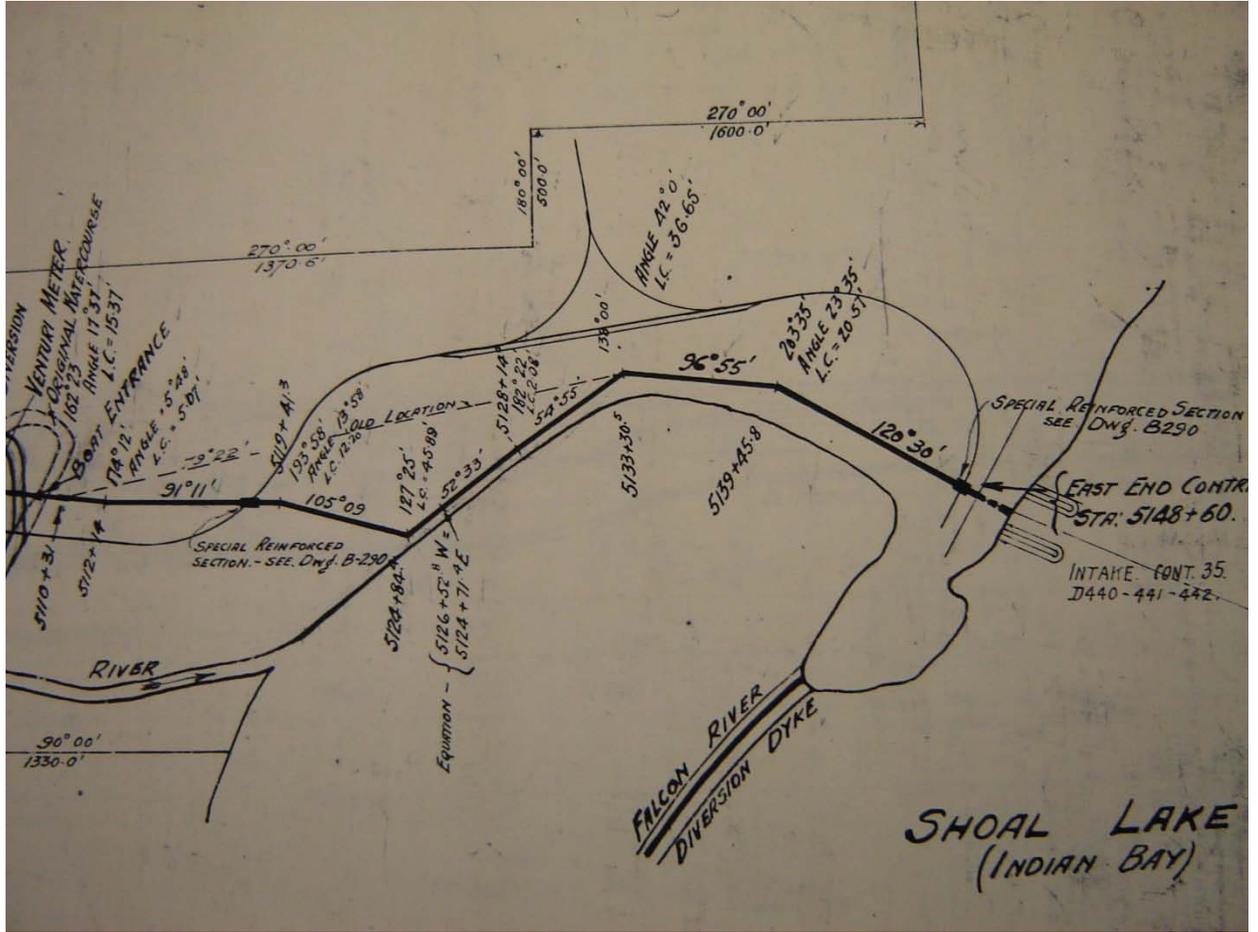
The Minister recommends that, under Section 1 of Chapter 14, 1-2 George V, authority be given for the sale by the Department of Indian Affairs of the said three thousand three hundred and fifty-five acres, more or less, to the Greater Winnipeg Water District for the purposes above mentioned.

The Committee submit the same for approval.

R. B. Baden

Approved
Boothman
March 23rd 1915

Appendix 11.6 Plan of Intake Area at Indian Bay



Appendix 11.7 Plan of Red River Siphon

