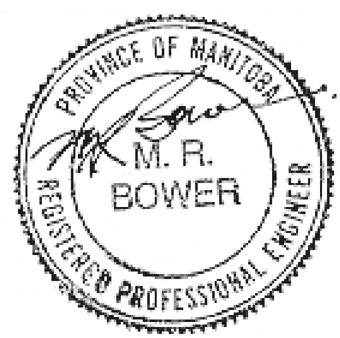
Certification

This report was prepared by CH2M Gore & Storrie Limited, Reid Crowther & Partners, Ltd., Wardrop Engineering Inc., and TetrES Consultants Inc., under the direction of a professional engineer registered in the Province of Manitoba. It is intended solely for the use of the City of Winnipeg, Manitoba, for which it was prepared, and for the purposes and within the limitations stated in the report.



Engineer's Seal

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Acknowledgements

The Winnipeg Water Consortium and TetrES Consultants gratefully acknowledge the contributions of The City of Winnipeg, Water and Waste Department for making this project a success. Special thanks to the Project Advisory Committee for the many hours spent reviewing documents, participating in workshops and advising the Consultant Team. The Project Advisory Committee consists of:

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Executive Summary

Since 1919 Shoal Lake water has been of sufficiently high quality that the addition of chlorine for disinfection and fluoride for prevention of tooth decay was the only water treatment required. However recent planning studies have recommended that the City plan to implement additional water treatment for three major reasons:

- Evolution of much more stringent Canadian Drinking Water Quality Guidelines to protect public health

- Concerns relating to the public health of the utility customers in two areas; the risk of an outbreak of waterborne disease caused by chlorine resistant pathogens, and the existence of disinfection by-products in excess of the guidelines.
- Concerns regarding the aesthetic parameters of drinking water (e.g. taste and odour)

This report summarizes the results of a four-year program carried out by a team of consultants to identify the most appropriate water treatment for the City. This report provides the science on the recommended type of water treatment and will assist in the decision making process of whether or not to build a water treatment plant (WTP).

Currently, Winnipeg's water supply is continuously chlorinated at the Shoal Lake headworks before flowing through an aqueduct to Winnipeg. Continuous chlorination at the headworks serves the following purposes:

- Pathogen control for public health protection
- Control of slime forming on the aqueduct walls, which decreases flow capacity
- Improvements to taste and odour by oxidizing taste and odour-causing compounds
- A deterrent to zebra mussels entering the aqueduct, colonizing and decreasing flow capacity, should zebra mussels be found in Shoal Lake.

The reliance on chlorination for treatment has two shortfalls; it has little effect on chlorine-resistant organisms such as the pathogen-parasite *Cryptosporidium*, and chlorination also forms disinfection by-products (formed when chlorine reacts with natural organic matter in the water) that are associated with adverse health effects such as cancer. Another public-health concern is that Winnipeg's drinking water does not have a physical barrier against pathogens; i.e. filtration.

An additional water quality issue is taste and odour, which is primarily related to seasonal algae blooms at Shoal Lake and the Deacon Reservoir.

In 1996 public health and water treatment specialists, including world-class authorities, assessed the health risk associated with Winnipeg's current water supply system. They unanimously recommended that Winnipeg provide additional treatment for the protection of public health. Subsequently, the consultant team reviewed existing and anticipated water quality guidelines in both Canada and the U.S. to identify the water quality goals to be achieved through treatment. A review of a long list of potential water treatment processes to achieve the goals resulted in a short list of two treatment processes to be examined in detail. Should new technologies develop which may be applicable for Winnipeg, a process comparison model has been developed to compare the ability of the process to meet the established treatment goals.

A pilot-scale WTP was designed to test each of the two treatment types. The pilot plant was fabricated and installed at the Deacon Booster Pump Station by Water and Waste Department forces. The pilot plant was operated over 16 months through four different Shoal Lake water quality seasons which provided strong confidence in the recommendations regarding the best water treatment process, currently available, to meet the goals established for the City.

The pilot program report recommended a four step treatment process of (1) *Dissolved Air Flotation (DAF)* for suspended solids, algae, and organics removal, (2) *Ozonation* for primary disinfection (including *Cryptosporidium* disinfection) and taste and odour control, (3) *Biological Activated Carbon (BAC) Filters* as a second (physical) barrier for pathogen removal and organics removal, and (4) *Chloramination* for disinfection throughout the distribution system. The comprehensive pilot program also demonstrated the suitability of higher than normal design parameters for Winnipeg's source water, which could save millions of dollars in WTP construction costs over a conventional design.

The recommended four step treatment process is necessary to meet all the water quality goals established for the City, and it has the additional benefit of providing multiple treatment barriers to maximize the delivery of the key water treatment goals of pathogen removal, DBP control and taste and odour control.

A remaining issue is the need to control zebra mussels and slime in the aqueduct, which would still be required even if a WTP was built. Currently this is accomplished with continuous chlorination at the entrance to the aqueduct. The disinfection by-products produced by continuous chlorination may exceed future guidelines. Two options are available; (1) include additional, costly, treatment facilities for removal of disinfection by-products (e.g. *Granular Activated Carbon (GAC) Contactor)*; or (2) use a different method for controlling zebra mussels and slime. Alternative methods for zebra mussels and slime control will be evaluated in the future. Therefore a *GAC Contactor*, the likely more expensive method, was not included in the conceptual design of the WTP.

After the evaluation of several potential sites for a new WTP, two sites were selected as being the most appropriate for the conceptual design: (1) adjacent to the Deacon Reservoir (Deacon) and (2) in the City represented by a location near the MacLean Reservoir (MacLean). The size of the WTP was selected to meet the maximum day demand during a hot, dry year, which was estimated at 515 megalitres per day (ML/d). It was forecast that the maximum day demand of 515 ML/d would not change during the 40-year design period. This was due to the conclusion that the anticipated modest increase in population would be offset by the reduction in per capita water demand from more efficient use of water.

The layout of the WTP would be basically the same whether at Deacon or MacLean. The main difference between the two sites was the need for a new raw water pumping station at Deacon (the existing Deacon Booster Pumping Station would become the finished water pump station) versus the need for a new aqueduct interconnect and raw water storage for the MacLean site.

The operation of the WTP will result in the production of waste materials (residuals). The residuals could be processed in a number of ways from disposing of all residuals to the sanitary sewer to processing the residuals on site and disposing the solids in a landfill.

The estimated project capital cost for the WTP ranged from approximately $137 million at the Deacon site to approximately $167 million at the MacLean site. Cost estimates done at the conceptual design stage are not considered refined enough for budgeting purposes; therefore a second, more detailed, cost estimate was carried out and reported in a separate study. The annual operating and maintenance cost was estimated to be approximately $8.3 million.

The conceptual design also recommended that a comprehensive flushing program be carried out in the water distribution system prior to operation of the WTP. The intent is to clean out "old" deposits in the distribution system prior to the addition of the "new and cleaner" water.

If the decision is made in 2000 to construct the WTP, it is estimated that it could be in service at the end of 2006. Approximately three years will be required for site selection and optimization studies, environmental approvals, functional design, value engineering review and City approvals. Delivery of the project can take many paths from conventional design and tendered construction to complete privitization. The evaluation of the different types of project delivery would take place after a decision is made to construct the WTP.

Glossary of Terms

µg/L	micrograms per Litre	Small concentrations of substances in water
% TS	Percent total solids	A measure of the consistency of sludge
°C	degrees Centigrade	Temperature

BAC	Biological activated carbon	Filter media (exhausted GAC) supporting biological activity for enhanced organics removal
Cl	Chlorine	Common water disinfectant
Crypto	*Cryptosporidium*	Gastrointestinal disease causing parasite; causing cryptosporidiosis
DAF	Dissolved air flotation	Water treatment clarification process
EIA	Environmental Impact Assessment	A study required under Federal Law to assess the probable impacts of a development on the environment
FTW	Filter-to-waste	The practice of wasting the initial volumes of (typically low quality) filtered water immediately after backwashing
GCDWQ	Guidelines for Canadian Drinking Water Quality	Drinking water quality guidelines for Canada
giardia	*Giardia Lamblia*	Gastro-intestinal disease causing parasite; *Giardia* causes giardiasis, or “beaver fever”
G-value		A measurement of mixing intensity
H_2O_2	Hydrogen Peroxide	A strong oxidizing agent used for destroying excess ozone residual and for advanced oxidation processes
HAA	Haloacetic acid	By-product formed when chlorine reacts with organics in water (health concern)
HRT	Hydraulic residence time	Theoretical time required for water to pass through a process
log	logarithm	90% reduction of water contaminant
mg/L	milligrams per litre	Concentration in water; also known as ppm, or parts per million
mL	millilitre	small volume of water constituent (1/1000th of a litre)
ML/d	Megalitres per day	Water flow rate (1 megalitre = 1 million litres)

NTU	Nephelometric turbidity unit	Measure of clarity of water
O&M	Operation and Maintenance	Cost to run the WTP
O_3	Ozone	Strong oxidizing agent and water disinfectant
PACl	Polyaluminum Chloride	A polymeric coagulant
PSA	Pressure swing adsorption	A process for separating oxygen from air; used for on-site oxygen production as a raw material for ozone generation
T & O	Taste and odour	Aesthetic quality of water
THAA	Total Haloacetic Acids	Total HAAs formed when Cl disinfection or waters with organics present
THM	Trihalomethane	By-product formed when chlorine reacts with organics in water (health concern)
TOC	Total Organic Carbon	Measure of organic content in water; a possible indicator of THM formation potential upon Cl disinfection
TON	Threshold odour number	Parameter to measure odour in water
TTHM	Total Trihalomethanes	All THMs formed when Cl disinfection or waters with organics present
UFRV	Unit filter run volume	Measure of the efficiency of filters
USEPA	Environmental Protection Agency	Water quality regulator in the U.S.
USEPA	United States Environmental Protection Agency	Water quality regulator in U.S.
WTP	Water treatment plant	Required for public health protection

The City of Winnipeg's Drinking Water Quality Enhancement Program

Introduction

This report will assist in the decision on whether or not to proceed with a water treatment plant

Need for This Report

Since 1919 the City of Winnipeg has enjoyed a high quality reliable water supply from Shoal Lake. The water quality has been high enough that the addition of chlorine for disinfection and fluoride for prevention of tooth decay was the only treatment required. Recent planning studies have recommended that the City plan to implement full water treatment**.**The need to consider implementation of treatment has been driven by three major issues:

- Evolution of much more stringent water quality guidelines (Canada) and regulations (U.S.) to protect public health
- Concerns regarding public health with respect to the existence of disinfection by-products in excess of guidelines in Winnipeg's drinking water resulting from chlorination of the water; and the risk of a significant outbreak of waterborne disease caused by chlorine-resistant pathogens.
- Concerns regarding the aesthetic parameter of drinking water (eg. taste and odour)

The City of Winnipeg will be deciding whether or not to proceed with the construction of a water treatment plant. In preparation for making this decision, the City has been evaluating its long term water supply and treatment needs, and has recently completed a four-year program analysing applicable water treatment technologies and developing the conceptual design of a water treatment plant. This report summarizes the results of this four-year program and will be a valuable resource to assist in the decision making process.

A planning study carried out by the

Background

City's Water and Waste Department recommended that the City plan to implement water treatment to improve public health protection.

The City of Winnipeg (the City) Water and Waste Department has carried out a series of studies to ensure water quality and quantity requirements are adequately met for the next 50 years.

The 1993 Regional Water Conceptual Planning Study recommended that the City begin preparation for construction of a water treatment plant. Bench-scale testing and preliminary pilot testing was carried out in 1994 by CH2M Gore and Storrie.

In September 1995, the City retained the consultant team of CH2M Gore and Storrie Limited (CG&S), Reid Crowther and Partners (RCPL), and Wardrop Engineering Inc. (Wardrop), with TetrES Consultants Inc. (TetrES) as an associate, to carry out the next phase of the water treatment plant project:

- A scoping study
- Phase 2 pilot program
- Conceptual design of the water treatment plant

Subsequent to project award, the three firms – CG&S, RCPL, and Wardrop – formed the Winnipeg Water Consortium (WWC).

Scoping Study

The scoping study involved the preparation of four separate technical memoranda (TM) and one report:

TM # 1 *Future Water Quality and Treatment Goals*
TM # 2 *Evaluation of Alternative Plant Locations*
TM # 3 *Discussion of Continued Chlorination of Aqueduct (Zebra Mussel Control)*
TM # 4 *Water Quality Database Management System*
Report *The Winnipeg Water Supply – Water-borne Health Risk Assessment*

These documents are discussed within this summary report.

Phase 2 Pilot Program

The Phase 2 pilot plant, constructed by the City at the Deacon Booster Pumping Station, was commissioned in June 1996 and operated continuously through five raw water quality seasons and completed operation in September 1997. The results of the pilot project were important input to the conceptual design, discussed below. The successful pilot program was written up in a three-document final report, subitted to the City in June, 1998 and titled *City of Winnipeg, Water Treatment Plant, Phase 2 Pilot Program*. The two documents, comprising the final report are titled:

- Volume 1 Executive Summary and Summary Report
- Volume 2 Report
- Volume 3 Appendices

Conceptual Design – Phase 1

Prior to the start of conceptual design of the water treatment plant (WTP), the scope of the project was changed to include a WTP site evaluation study that became Phase 1 of the WTP conceptual design . The study analyzed potential WTP sites within the City, as well as a site at the Deacon Reservoir. The product of the study was a technical memorandum titled *Phase 1 Conceptual Design – Site Evaluation*, discussed in this report.

Conceptual Design and Final Report

The conceptual design report was expanded to include an overview of each of the topics addressed in the scoping study, as well as an overview of the pilot programs. This report is a separate document and is a summary of the final report.

Water Quality Considerations

Future water quality regulations will require treatment of the Shoal Lake water supply

The City's drinking water originates in Shoal Lake, located approximately 160 km east of Winnipeg. The water is continuously chlorinated at the Shoal Lake headworks before flowing through a closed aqueduct to the four-cell open-air Deacon Reservoir located in the Rural Municipality of Springfield, east of Winnipeg. Continuous chlorination at the aqueduct headworks serves four purposes:

- Pathogen control for public health protection
- Control of slime forming on the aqueduct walls, which decreases flow capacity

- Deterrent to the potential of zebra mussels entering the aqueduct, colonizing on the walls, and decreasing flow capacity
- Improvements to taste and odour by oxidizing taste and odour-causing compounds in Shoal Lake water

Water for the City is drawn from the Deacon Reservoir and rechlorinated; the water then flows by gravity (plus supplemental pumping when required) to the City's three distribution system reservoirs—McPhillips, MacLean, and Wilkes where chlorine is added for disinfection and taste and odour control before being pumped to the distribution system.

The quality of Shoal Lake water has met most of the Canadian Drinking Water Quality Guidelines and has been accepted by the public. However, as water quality guidelines and regulations are becoming more stringent and public water quality expectations are increasing, the City recognizes the need for increased treatment of Shoal Lake water.

The water quality parameters of concern are pathogens, disinfection by-products, plankton, and lead

Particle Removal (Pathogen Control)

Turbidity is a physical measure of the clarity of water and also serves as a surrogate measure for pathogens; as such, turbidity removal is a good measure of pathogen removal. Although turbidity in Deacon Reservoir is quite low and averages 1.0 NTU, (which is the maximum per the *Guidelines for Canadian Drinking Water Quality*), there is a concern that no physical barrier exists at Deacon Reservoir to remove any water-borne pathogens that may be present in the water.

Disinfection By-products

The present system does not have a physical means to remove water-borne pathogens

When a disinfectant such as chlorine reacts with background organic matter in the water, disinfection by-products (DBPs) are formed. Total organic carbon (TOC) is an indicator of the amount of organic material available for DBP formation. Since TOC levels in Shoal Lake water are moderate to high, the potential for DBP formation is significant. Continuous chlorination at the Shoal Lake intake for public protection against microbial contamination results in significant DBP formation as the water flows down the aqueduct to Deacon Reservoir. Although a wide range of chlorinated DBPs enters Deacon Reservoir, the two compounds of immediate regulatory concern are trihalomethanes (THMs) and haloacetic acids (HAAs). These compounds have been linked to chronic health effects.

Plankton

Disinfection by-products are linked to chronic health effects; plankton causes taste and odour events, as well as possibly producing toxins

Plankton (i.e. algae) levels are particularly high in Shoal Lake and Deacon Reservoir water for a large part of the year. Taste and odour (T&O) events in Winnipeg's distribution system normally coincide with or follow elevated algae levels in Deacon Reservoir and / or Shoal Lake. T&O is an aesthetic water-quality parameter subject to public perception. As the public's expectations for water quality increase, T&O will be subject to increased scrutiny.

A second concern with respect to elevated algae levels is the toxic nature of some of the by-products of algae metabolism (specifically blue-green algae). Algae toxins have been detected in surface waters worldwide and, although at essentially non-detectable levels in Winnipeg's drinking water, need to be considered in water treatment plant design.

Lead

Lead levels are currently exceeded in some customer's homes with lead pipe service connections. This water quality concern is being addressed by the water stabilization program, which originates out of a new facility.

It is time to assess the impact of future water quality guidelines on Winnipeg's current drinking water quality

Future Water Quality Goals

The City's requirements for public water systems are administered by Manitoba Environment and Health. Although not formally adopted, Manitoba Environment generally follows the guidelines published by Health and Welfare Canada. These guidelines are prepared by the Federal-Provincial Subcommittee on Drinking Water and are published as a document titled *Guidelines for Canadian Drinking Water Quality*.

Historically, changes in Canadian drinking water guidelines have followed changes in drinking water regulations in the U.S., which are defined and administered by the United States Environmental Protection Agency (USEPA). Accordingly, many of the changes anticipated in the Canadian guidelines are based on changes in U.S. regulations.

Ten Water Quality Parameters Were Evaluated

The following water quality parameters were evaluated for adherence to regulations and / or guidelines :

- Turbidity
- Particles
- Total organic carbon (TOC)
- Disinfection
- Disinfection by-products (DBPs)
- Taste and odour
- Colour
- Algae toxins
- Aluminum
- Lead

Eleven water treatment issues pertaining to the City of Winnipeg were identified

The results of the evaluation identified 11 treatment issues:

1. Removal of turbidity and particles as surrogates for pathogen removal
2. Impact and treatability of disinfection by-products (DBPs) resulting from chlorination at the Shoal Lake headworks
3. Alternative strategies for zebra mussel and slime control to minimize production of DBPs at the Shoal Lake headworks
4. Treatment strategies for taste and odour control
5. Minimization of DBP formation through water treatment plant processes (chlorinated and ozonated DBPs)
6. Prevalence and effects of algal toxins
7. Treatability of Natalie Lake water and a groundwater supply as potential supplemental raw water sources
8. Aluminum residuals in the filtered water (if alum is used for treatment)
9. Treatment plant residuals management
10. Disinfection efficacy
11. Control of biological regrowth in distribution system

These treatability issues were used to develop water quality goals and Phase 2 Pilot Program performance targets.

Maintaining the program of continuous chlorination of the Shoal Lake Aqueduct is creating water quality

Disinfection By-products Created by Aqueduct Operation

Water entering the aqueduct is continuously chlorinated to provide disinfection, prevent slime build-up, deter Zebra Mussel infestation, and treat for taste and odour. Construction of a WTP would eliminate the need to continuously chlorinate for pathogen control and taste and odour control. However, the City will need to implement a program to prevent slime buildup and deter Zebra Mussel infestation.

Unfortunately, free chlorination of naturally-occurring organics in Shoal Lake water (as with all surface waters) produces disinfection by-products that may pose a chronic health risk to consumers and will

concerns

probably fail to meet future water quality quidelines. The City must then choose between the following alternatives:

- Maintain the continuous chlorination program and add an expensive facility to the WTP to remove DBPs (a GAC contactor, an interim pumping facility, and a GAC regeneration facility), or
- Change to a different method of controlling slime and zebra mussels

For the purpose of conceptual design and costing of the WTP, it was assumed that a facility to reduce disinfection by-products would not be required because alternatives to change from continuous chlorination would be available.

In the interim, it is recommended that the City monitor any developments regarding these issues. Once a decision is made about construction of a WTP, a scoping study should be undertaken to determine specific actions and budget for an R&D program to identify alternatives to continuous chlorination at the headworks.

Assessing the Need for Water Treatment

Health-effects research has identified the need for improved water treatment to protect public health

The effects of drinking water quality on public health have been under increased scrutiny since the detection and identification of water-borne diseases, such as giardiasis and cryptosporidiosis, as well as a link of disinfection by-products to chronic health effects such as cancer. This has resulted in upgrades and installation of new water treatment facilities throughout the world.

For example, Calgary, Edmonton, and Vancouver are currently upgrading their water treatment systems to exceed the current guidelines in order to meet anticipated future, more-stringent water quality guidelines.

Calgary

Calgary has started the design and construction of a four-phase upgrade to the Glenmore WTP that will meet the following objectives.

Reduction in filtered water turbidity to improve the physical barrier to *Cryptosporidum* and *Giardia* (<0.1 NTU)

Other large Canadian cities are upgrading their water treatment systems

- Increase the chlorine contact time in the clearwell as a disinfection barrier to *Giardia* (2.5 log inactivation)
- Future allowance for an ozonation disinfection system (2.5 log *Cryptosporidium* inactivation)
- Reduction of disinfection by-products to meet the expected future low limits (0.05 mg/L THMs)
- Reduction in aluminum levels to best management practice levels

Edmonton

Edmonton is conducting a study to upgrade both water treatment plants to meet the following objectives:

- Filtered water turbidity < 0.1 NTU
- Short-term pathogen reduction equal to 5.5 log *Giardia* reduction
- Long-term pathogen reduction equal to 6 log *Cryptosporidium* reduction
- Disinfection by-products goal of 0.02 mg/L of THMs

Vancouver

Vancouver currently has three raw water reservoirs and uses chlorination as the only treatment (the same as Winnipeg). Plans are underway to make the following treatment upgrades:

- Direct filtration plant for the Seymour Reservoir with the provision for addition of dissolved air flotation and ozone
- Ozone disinfection only for the Capilano and Coquitlam Reservoirs with future provision for filtration

The City of Winnipeg carried out a water-borne public health risk assessment

Workshop Approach

The City of Winnipeg undertook a review of the public health risk assessment with the present drinking water supply. An intensive two-day workshop was convened in April 1996, with participants including a range of specialists (both Canadian and International) in water-borne disease and water supply issues, and representatives of the water treatment project consultant team. Representatives of the City of Winnipeg and public health officials from City and Province also attended the workshop as participants and observers.

Judgement of the Workshop Participants

Workshop participants were unanimous in their opinion that implementation of comprehensive water treatment facilities for the existing water supply for Winnipeg is justified from a public health perspective. The workshop participants identified the following two main public health issues associated with the Winnipeg water supply system:

1. Water-borne Pathogens

- Providing protection against water-borne pathogens is considered to be the highest priority. While the risk is relatively low, this is an acute health risk. A single exposure to the pathogen can result in a disease.

- Lack of a filtration facility means that chlorine is currently the only barrier to water-borne pathogens and chlorine is ineffective in killing *Cryptosporidium*.

- While the available evidence indicates a low level of risk for the City's water supply system, water-borne disease outbreaks have occurred in other systems that also showed little apparent risk. Some of these systems, such as Kelowna, are similar to Winnipeg in that they do not have a filtration barrier, with water treatment consisting only of chlorination. Others, such as Milwaukee, who had a water treatment plant in place prior to a very large cryptosporidiosis outbreak, have since upgraded the treatment process.

2. Disinfection By-products (DBPs)

- With the present system, the City has little choice but to apply fairly high levels of chlorine to achieve the best possible disinfection. This results in the production of DBPs that periodically exceed the Canadian drinking water guidelines.

Workshop participants also recommended an interim action plan

Workshop participants discussed some elements of the short-term strategy and recommended that the City consider a number of actions relating to water-quality maintenance, public communication, and networking with public health officials.

Many of these recommendations have already been put in place by the Water and Waste Department. Table SR-1 summarizes the status of the Interim Action Plan implemented by the Department.

Table SR-1
Recommendations for Interim Action (prior to Installation of WTP)

Recommendation	Status (June 1999)
Improve effectiveness of disinfection in distribution system	New chlorination equipment has been installed
Minimize generation of DBPs	Pilot program includes experiments and tests to reduce DBP formation in the aqueduct
Improve on-line monitoring of chlorine	More monitoring in place; higher residuals being maintained
Review emergency response plan with respect to accidents or sabotage events at Shoal Lake	Underway
Create collaborative effort with respect to monitoring cases of gastro-intestinal disease as an indicator of potential water-borne disease outbreak	Under review by Water Quality Task Force
Establish a sustainable development plan for the Shoal Lake watershed	Discussions continuing with the provinces of Manitoba and Ontario and the First Nations
Inform City Council regarding public health issues and action plans	Reports provided
Educate physicians on the identification of water-borne disease	Physicians' information packages have been provided
Inform immuno-suppressed population about the risk of water-borne disease	Information packages provided
Monitor for presence of *Cryptosporidium* and *Giardia lamblia* at Shoal Lake	Monitoring of Shoal Lake is continuing
Investigate on-line monitoring of specific water quality parameters at aqueduct intake at Shoal Lake	Under review
Sample Shoal Lake water near potential discharges from the First Nations' wastewater sources	Underway
Sample Falcon River outlet at Shoal Lake for the presence of parasites	Periodic sampling is being conducted
Analyze sediments in Deacon Reservoir and goose stools for parasites and bacteria	Monitoring of water out of Deacon Reservoir is being conducted
More accurately determine disinfection residuals/exposure time from Deacon Reservoir to customer	Data assembly underway

Investigate measures to have Province make cryptosporidiosis and giardiasis reportable illnesses	Province has taken such action as of January 1, 1999
Seek physician support for random testing of diarrhea stools for the presence of *Cryptosporidium* and *Giardia*	Under review by Water Quality Task Force
Encourage the development of joint databases between City and public health for correlation of water quality and illnesses	Under discussion with Ministers of Health
Liaise with public health nurse responsible for First Nations Bands #39 and #40	Under review regarding practicality
Implement cleaning program for Deacon Reservoir	Under review

Recommended Water Treatment Process

A comprehensive water treatment pilot program was carried out to define a state-of-the-art and cost-effective water treatment process for the City of Winnipeg

Water Treatment Performance Targets (Pilot Plant)

Short-term and long-term water treatment goals were identified. Short-term goals would be applicable to the construction of the initial WTP. The WTP should be designed with built-in flexibility to achieve long-term targets, if necessary. These goals are presented with the pilot program results later in this report.

Pilot Treatment Processes

The Phase 2 Pilot Program involved two basic types of water treatment:

- Direct filtration treatment with and without ozone
- Dissolved air flotation (DAF) treatment with and without ozone

A schematic of the Phase 2 pilot plant is presented in Figure SR-1. These base treatment processes were evaluated using deep-bed filters with monomedia anthracite, dual-media anthracite over sand, and GAC media. The filters were also tested as biological filters.

Figure SR-1 Winnipeg Water Treatment Pilot Plant Configuration

- **DAF Treatment Process.** Raw water was pumped from Deacon Reservoir outlet, prior to chlorination, to the pilot plant. The water was initially treated with coagulantsin a rapid mix tank and then delivered to a three-stage flocculation tank. The flocculated water entered the DAF tank, and the DAF float layer was continually scraped off the surface by a mechanical scraping system. While ozone was being tested, the DAF-treated water was pumped to an ozone contactor that flowed into an ozonated water holding tank. Progressive cavity pumps were used to pump water from the ozonated water holding tank to the filters at a constant flow. The filtration system was similar to the direct filtration process stream.

- **Direct Filtration Process.** Raw water was pumped from the Deacon Reservoir outlet, prior to chlorination, to the pilot plant. The first step of the pilot plant was the ozone contactor. Coagulation and pH adjustment chemicals were then added upstream of two in•line static mixers, and flocculation was achieved in a three-stage flocculation tank. Flocculated water was pumped to four deep-bed filters operating in a rising-head, constant-rate mode. Filter aid chemicals could be added ahead of the filters, and hydrogen peroxide could be added ahead of the ozone contactor for advanced oxidation experiments. Filtered water flowed to a filtered water holding tank to be used in backwashing the filters.

- Additional GAC may be needed for DFBs and taste and odour control.

Four different water quality seasons were piloted

Four distinct raw water quality periods were defined during the pilot program. They can be characterized by the following raw water temperature:

- Warm Water - (Temperature > 15°C) (June to Sept. 1996 June to Sept. 1997)
- Cool - Fall (Temperature > 4°C, <15°C) (mid Sept. to Oct., 1996)
- Cold Water- (Temperature <4°C) (Nov. 1996 to March 1997)
- Cool - Spring (Temperature > 4°C, <15°C) (April to May 1997)

The success of the pilot program allowed some of the recommended unit processes to be sized at higher rates (compared to conventional designs) which substantially reduced the estimated cost of the WTP

Pilot Program Results

- Direct Filtration

Direct filtration with or without pre-ozonation did not meet all the performance goals, primarily due to the unacceptable filter loading rate, water production volumes, and TOC reduction limitations. Also, when plankton counts exceeded 30,000 / mL, direct filtration could not simultaneously meet turbidity, particle, and water production targets. Therefore, the direct filtration process was not considered further.

- DAF Treatment Process

The DAF treatment process was found to be superior to direct filtration in all the experimental categories investigated. Also, since the DAF process reduced ozone demand and enhanced the filtration process, the Phase 2 Pilot Program verified that a full-scale DAF water treatment plant was cost-competitive with a direct filtration plant. The DAF process required a smaller ozone facility and filters with less than half the footprint required by a direct filtration plant.

Recommended Treatment Process

Based on the pilot program results, the following process is recommended for water treatment process for the full-scale water treatment plant:

> **Rapid mix + enhanced coagulation (ferric chloride) + flocculation + dissolved air flotation (DAF) + ozone (O_3) + biological activated carbon filtration (BAC) + monochloramine (NH_2Cl) (secondary disinfection) + water stabilization**

The pilot program results are shown in Table SR-2. Comments on each unit process follow:

- ***Coagulation.***, Ferric chloride performed better than alum as it removed more particles and organic material and provided lower levels of taste and odour, disinfection by-products, and residual aluminum in the treated water.
- ***The DAF treatment process*** provided several benefits. With ferric

chloride, DAF removed up to 60% of background organic material, minimizing further DBP formation, and lowered the amount of ozone needed. The DAF process removed 99% of the raw water particles, reducing the particle load on the filters and allowing the filters to operate at higher rates. This translates into smaller filter area requirements and significant capital cost savings. The DAF process effectively removed algae during periods of high algae counts in the Deacon Reservoir; the filters following the DAF process were not affected by high algae levels.

- ***Ozone*** for primary disinfection provided an additional level of protection against viruses and protozoan pathogens. Research has shown that ozone is the only single disinfectant that is effective against *Cryptosporidium*. In this case, *Cryptosporidium* inactivation will dictate ozone system sizing as they are more difficult to inactivate than viruses. In addition to disinfection**,** ozoneimproved particle removal and filter efficiency, improved taste and odour control, and allowed downstream filters to operate in a biological mode so that they could remove biodegradable organic material. These benefits allow the City to consider chloramination for secondary disinfection.

Deep-bed biological activated carbon (BAC) filters offered overall benefits for particle removal, taste and odour control, and ozone by-product removal. The total particle removal using a DAF/deep bed filtration process was in excess of 99.99% (4-log), which is judged by the USEPA as a high level of public health protection against water-borne pathogens. If future U.S. regulations are adopted, there may be a total *Cryptosporidium* reduction requirement of 3 to 6 log. Even if a conservative 3-log removal credit is applied to the treatment process, the log inactivation (disinfection) requirement is reduced to 0 to 3 logs. Testing also showed that biological activated carbon filtration can remove 80-100% of ozone by-products.

Table SR-2
Water Treatment Targets and Results Using the Recommended Treatment Process

Treatment Goal	Specific Parameter	Typical Winnipeg Drinking Water Quality	GCDWQ	USEPA		Water Quality Goals (1)	Pilot Results
				Current	Future		
Clear water	Turbidity (NTU)	0.3 – 2.6	< 1.0	0.3	0.1	<0.1	0.04 - 0.08

Particulate removal	Particles >2 µm (# mL)	1,000 – 10,000	NG	NG	NG	<20	5 -20 (summer) 1 - 5 (winter)
DBP control	TTHMs (µg/L) THAAs (µg/L)	50 – 205 50 – 120	100 NG	80 60	40 30	100 (40) NG (30)	<100 without GAC, <30 with GAC <30 with BAC
Organics removal	TOC (mg/L)	4 – 17	NG	>40%	>40%	>40% removal	60-70% removal
Taste and odour control	TON (threshold odour number)	10 - >200	Aesthetic	3	3	<10	TON <10 (year-round)
Efficient filter water production rate	Unit filter run volume (UFRV)	N/A	NG	NG	NG	>200 m^3/m^2	>600 m^3/m^2 (year-round)
Maximize filter loading rate	m/hr	N/A	NG	NG	NG	>15	35 (year- round)
Filter Maturation Time	Minutes	N/A	NG	FTW	FTW	<30	<30 minutes (year-round)
Treatment consistency	Observation	N/A	NG	VG	VG	High degree	Consistent, no fluctuations in treated water quality

(1) - bracketed numbers are long term goals
N/A – not applicable since City does not have WTP
NG – no guideline
VG – Variable goal – 95% for 0.3 NTU turbidity limit and never greater than 1 NTU, THMs compliant 100% time on quarterly average changing to all values
FTW – Filter to waste required to achieve the 0.3 NTU 95% of the time

- ***Chloramination***, rather than chlorination, is recommended for secondary disinfection (after the filters). Chloramination (a process where chlorine is combined with ammonia) provides lower levels of DBPs and lower levels of taste and odour; it is also a more persistent disinfectant in the distribution system.

Potential Future Process Addition

It was recommended that provisions be made for a separate future facility for GAC contactors, to allow the City to meet potentially more-stringent DBP regulations and more-demanding T & O requirements.

Conceptual Design of Winnipeg's Water Treatment Plant

Introduction

The conceptual design of the water treatment plant (WTP) was completed to indicate the potential size, shape, cost and location.

Each of the water treatment processes was sized, based on the pilot plant results, and the plant was designed to accommodate the long-term water demand and the climate.

Potential Locations for the Water Treatment Plant

Two sites for the WTP were identified for the conceptual design

The first phase of the conceptual design compared seven potential locations for the WTP. For the purpose of completing the conceptual design, Site No. 3 (MacLean Reservoir) and Site No. 7 (Deacon Reservoir) were selected for comparison.

The WTP design was essentially the same for each site, although the arrangement of each plant is different. The only significant changes involved the raw water supply and the treated water pumping and feeder mains.

Design Flows

Winnipeg's water demand is expected to remain constant over the next 40 years

The WTP is designed to supply the total volume of water required on the highest water demand day of the year (peak day). Because the per-capita water demand in the City is projected to reduce over the next 40 years as a result of water saving fixtures and other water conservation measures, the predicted rise in population will not result in increased average day demands. Therefore the potential peak day demand is estimated to be steady at 515 ML/d. The design finished water production rates are as follows:

- Summer peak day – 515 ML/d
- Winter peak day – 364 ML/d

- Average annual day – 298 ML / d
- Minimum winter day – 200 ML / d

Note that the Shoal Lake Aqueduct has a maximum capacity of 386 ML / d.

Building Layout

One size plant for the City's stable water demand

Water Treatment Plant Building

Due to the stable projected water demand, staging of the WTP is not a concern, and a single-building "block" layout has been selected for the majority of the WTP. This arrangement groups unit processes together under one roof, allowing most plant areas to be accessed without going outdoors. This will result in heating and ventilation savings (compared to remote buildings connected by tunnels) and increased operator convenience. An artistic rendering of the WTP is shown in Figure SR•2.

Plant layout reduced in size as a result of pilot program

Plant Layout and Process Flow Diagram

Extensive piloting allowed the consultant team to confidently design the treatment processes at relatively high rates, resulting in a reduced plant footprint and cost savings compared to traditional process designs. A process flow diagram for the proposed WTP is shown in Figure SR-3; the hydraulic profile is shown in Figure SR-4. While the hydraulic profile has elevations specific to a location within the City, the profile can be taken as generic.

To simplify the equipment tagging procedures and provide a clear delineation between the various unit processes in the plant, the plant was subdivided into the following process areas:

[Figure SR-2](#)

[Figure SR-3](#)

[Figure SR-4](#)

Area	Unit Process
100	Raw Water Storage and Pumping
200	Pre-treatment Chemicals Coagulation
300	Flocculation and Dissolved Air Flotation Clarification
400	Ozonation (Primary Disinfection)
500	Filtration
600	Post-treatment Chemicals
700	Treated Water Storage and Pumping
800	Residuals Handling
900	Granular Activated Carbon Filtration Adsorption (Future)

The layout of the plant is shown in Figure SR-5. The layout design is suited to a large flat site and configured for a balanced cut and fill, assumed to be the most cost-effective construction method. This layout is more suited to the MacLean site but can also be applicable to the Deacon Reservoir location.

Main access to the facility will be through the administration lab area located at the front of the building. Chemical delivery and storage areas have been located at the rear of the main building to reduce truck traffic at the front of the building. This location also facilitates chemical delivery by rail, if that option is chosen. Similarly, the solids handling processes have been located in a separate building located behind the main plant building for ease of large truck access.

The overall building elevation was determined to allow the large treated water clearwell to be just below grade, thereby minimizing the visual impact of this large structure. The resulting building profile shows approximately two stories aboveground.

Raw Water Facilities

Raw water supply facilities are different for each plant location

WTP at Deacon Reservoir

Currently, the raw water supply flows by gravity from the Deacon Reservoir (with supplemental pumping by the Deacon Booster Pump Station in the summer) to the City's three distribution reservoirs (MacLean, McPhillips, and Wilkes). If the WTP were built at the Deacon Reservoir, two options for raw water supply exist; gravity supply or pumped supply. A schematic of the hydraulic profile for Deacon is shown in Figure SR-6.

The existing pumps in the Deacon Booster Pump Station are low enough that the WTP could be built below grade and have raw water supply by gravity, thereby eliminating the raw water pumping station. (The original Booster Station design anticipated a WTP being built at the Deacon Reservoir.) However, the additional cost to build the WTP below grade would exceed the cost of the raw water pumping station. Therefore a raw water pump station has been assumed for the final design.

Figure SR-5

Figure SR-6

Modifications to Deacon Booster Pump Station are required for raw water supply to WTP in City

WTP in City

The Deacon Booster Pump Station was designed to accommodate two pumps for the Branch I Aqueduct and four pumps for the Branch II Aqueduct, with one spare pump for either aqueduct. Currently, 2 pumps (plus one stand-by pump) in the Deacon Booster Pump Station supply water to Branch II. Building a WTP in the City would require installing two new pumps for Branch I, modifying the existing two pumps for Branch II, and adding a third pump for Branch II. The pumps would likely be installed so that they could pump to either Branch Aqueduct in order to pump the maximum flow possible down one aqueduct if the other aqueduct were out of service. The maximum allowable flow capability for each aqueduct, without exceeding the design pressure or maximum flow velocity, follows:

- Branch I Aqueduct 275 ML/d
- Branch II Aqueduct 306 ML/d

Additional raw water facilities are required for a WTP in the City

A raw water facility at a WTP within the City could require three components that would not be required at the Deacon Reservoir location; these components are shown schematically in Figure SR-7.

Balancing Storage

A water treatment plant operates most efficiently when it runs for long periods of time at a steady flow rate. It is not practical to operate the Deacon Booster Pump Station at a constant flow rate that exactly matches the WTP process rate. Therefore approximately 1.25 ML of storage would be required at the WTP to balance the small fluctuations in the aqueduct supply rate. This would require an above ground storage reservoir to allow gravity flow into the rapid mix and flocculation basins.

Surge Control Facility

The raw water supply into the balancing storage reservoir cannot be regulated at the WTP since control devices could cause high pressure surges in the aqueducts, resulting in possible structural damage, especially to the older Branch I Aqueduct. A surge control tower could be added to the balancing reservoir to eliminate this possibility.

Emergency Storage Reservoir

A remote possibility exists for a power failure at the WTP and not at the Deacon Booster Pump Station when the pumps were running. Since there is no flow control on the raw water supply at the WTP, the balancing storage reservoir might quickly fill and spill over while the Deacon pumps continue to run. A 9.3 ML underground storage reservoir has been included in the conceptual design to store the excess water. This reservoir could also be used to contain other periodic flows such as filter-to-waste, return backwash decant, and excess finished water.

Figure SR-7
Plant Process Systems

Five process steps provide multiple levels of public health protection and desired aesthetic benefits

The recommended treatment process that accomplishes all the water quality goals consists of five different process steps. Although these process steps are the minimum number of process steps to meet all the goals, an added benefit is that each process step accomplishes more than one goal. The result is that there are multiple barriers which substantially reduces the risk of not meeting the treatment goals. Table SR-3 presents an overview of the treatment benefits provided by these five processes.

Table SR-3 Treatment Benefits Provided by Recommended Water Treatment Processes

	Pathogen Removal and Disinfection	DBP control	Taste and Odour treatment	Organics Reduction	Distribution System Regrowth and Corrosion Control
Enhanced Coagulation + Dissolved Air Flotation	X	X	X	X	X
Ozone primary disinfection and oxidation	X	X	X	X	
BAC filtration	X	X	X	X	X
Chloramination secondary disinfection	X	X	X		X
Water stabilization					X
Total number of treatment barriers	4	4	4	3	4

Enhanced Coagulation and Filter Aid Addition

During the Phase 2 Pilot Program, the primary coagulants tested were aluminum sulphate (alum), ferric chloride, and polyaluminum chloride (PACl). These coagulants were tested with different coagulant-aid polymers and several ionic filter-aid polymers. The preferred chemicals resulting from the program follow:

- Sulphuric Acid for pH adjustment for coagulation
- Ferric Chloride for coagulation
- Percol LT22 for filter-aid polymer

These chemicals provide superior organics and particle removal.

Primary Disinfection

An ozone system was selected to provide primary disinfection downstream of the DAF system and upstream of the filters. The overall water treatment process is designed to provide 4-log (99.99%) removal/inactivation of *Cryptosporidium* oocysts. *Cryptosporidium* disinfection is not currently regulated in Canada but it is likely to be an expectation of the guidelines of the future. In the interest of public health protection, a target of 4-log removal was selected since it represents the most stringent regulatory requirements currently under review in the U.S. where it is currently believed to be appropriate for public health protection. The following points describe the ozone system:

Ozone source either off-site purchased liquid oxygen or on-site produced oxygen gas

Number of ozone generators two duty, one standby – each with capacity of 340 kg/day

Number of ozone contactors three in parallel

Number of stages per contactorsix

Ozone destructors one duty, one standby – thermal catalytic

In addition, hydrogen peroxide will be added prior to the filters to quench any residual ozone and to provide advanced oxidation capabilities for taste and odour treatment.

Secondary Disinfection

Choramination was selected over chlorine for the following reasons:

- Lower levels of potentially-harmful disinfection by-products (DBPs) in the distribution system
- Lower levels of taste and odour
- A more persistent disinfectant in the distribution system

Chloramine production would begin after the backwash supply piping, downstream of the filters but upstream of the clearwell. Gaseous chlorine and aqua ammonia have been selected as the system to generate the chloramines. An optimization study is recommended prior to detailed design.

Final pH Adjustment and Stabilization

Chemicals are added downstream of the chloramination and prior to the clearwell for final pH adjustment so that the chemical added for water stabilization (phosphoric acid) continues to work as designed. The water stabilization program addresses lead levels in the drinking water caused by lead pipe service connections. Fluoride is also added to aid dental health.

Two types of particle removal processes are utilized in the WTP

Dissolved Air Flotation (DAF)

The DAF system involves rapid mixing of the coagulant, ferric chloride, a flocculation phase to develop the flocs for removal by DAF, and the DAF step. Pilot testing determined that a very high design loading rate could be selected, resulting in a smaller facility. Since the WTP is not designed to be operated as a direct filtration plant, the DAF system is designed to not be bypassed (i.e. the flocculation basins are directly coupled to the DAF basins). Following is a summary of the DAF system design:

Rapid mixing type
sidestream diffusion mixing using pressurized water jets

Flocculation system
mechanical vertical

Number of flocculation trains
two
Number of flocculation basins per train
five
Number of cells in series
three
DAF trains two
DAF basins per train
five
Float removal
mechanical using reciprocating scraper to one sump per train

Filtration System

The pilot program also determined that filters could be designed for a very high loading rate and identified a media and filter depth that offered additional benefits over typical designs. GAC media, operated in a biological mode, was selected over anthracite since it performed better for ozone by-products removal and removal of taste and odour compounds.

Filter operation will be constant rate, constant head with a control valve to control each filter flow. Clean bed head loss is expected to be between 0.7 m to 1.0 m. Terminal head loss is an additional 3.0 m. Filter backwashing will be with non-chloraminated water and initiated at any of the following points:

- Turbidity > 0.1 NTU
- Total particles > 20 mL
- Terminal head loss

Backwashing will be air only, followed by simultaneous air and water, followed by water-only sequencing. Filter-to-waste will go to the head of the WTP. Additional design information for the filters include the following:

- Filter loading rates - 30 m / h on peak day; 17 - 25 m / h normal operation
- Filter layout - nine duty, one standby

A granular activated carbon contactor facility has been considered but may not be needed

Potential Future Granular Activated Carbon Contactor

If the City continues with the current practice of continuous chlorination of the Shoal Lake Aqueduct after the WTP is operational, a granular activated carbon (GAC) contactor facility might be required at the WTP. The continuous chlorination would continue as a deterrent to zebra mussels entering and / or surviving the aqueduct and slime growth within the aqueduct. The need for the facility would result from more-stringent regulations for the removal of chlorine disinfection by-products, specifically THMs.

However, it is likely that the City would change to another method of aqueduct protection rather than building a very expensive GAC contactor facility.

Finished water storage will be the same at each WTP location but the finished water pumping stations will be different

Finished Water Storage and Pumping

The conceptual design of finished water pumping at a WTP at the MacLean location identified three separate pumping stations—one for each of the three distribution reservoirs. The pumping stations are designed to supply the peak day demand, proportioned as follows—McPhillips (40%), MacLean (30%) and Wilkes (30%). Each high-lift pump station would have two duty pumps and one standby. Optimization potential would include common variable speed pumps as standbys.

For the Deacon Reservoir alternative, the existing Deacon Booster Pump Station could easily be converted to a finished water pump station, with the following modifications:

- Addition of two new pumps to the Branch I supply piping (none exist now but the space is available)
- Addition of a surge control tower to Branch I aqueduct (similar to existing tower for Branch II)
- Replacement of the three existing pumps on the Branch II piping with larger impellers and motors

The clearwell for each WTP alternative is sized at 15 ML, providing a balancing volume between the variable combined pumping rates of the pumping stations and the constant production rate of the WTP. The clearwell is not required to provide contact time for disinfection.

Water Treatment Residuals

Some or all of the plant residuals will go to the sanitary sewer system

Residuals Streams

The following residuals streams will be generated by the water treatment process:

- Filter backwash
- Filter-to-waste
- DAF float

Each of the residuals streams would be expected to contain the following components in widely varying quantities:

- Natural turbidity particles removed by the filters
- Microorganisms (including *Giardia* and *Cryptosporidium*)
- Chemical floc particles
- Small amounts of heavy metals
- Algae cells

Residuals Handling Options

Projected peak residuals production indicates that, while the backwash waste and filter-to-waste streams can be considered to be essentially liquids of low to moderate solids content, the DAF float can be collected in a reasonably thick form directly from the process.

Filter-to-Waste

Filter-to-waste will be returned to the head of the treatment plant and added to the raw water prior to coagulation.

Filter Backwash

Two options are possible for the handling of this stream:

- Recycling of the filter backwash to the head of the plant following flow equalization and clarification / thickening. Only clarifier / thickener supernatant would be recycled to the head of the plant; the sludge would be sent to on-site processing (mechanical or freeze thaw)

- Direct disposal to the sanitary sewer, including flow equalization to attenuate large surges to the sewer system.

DAF Float

The following options are considered viable for the handling of the DAF float:

- Direct discharge to sanitary sewer
- Mechanical dewatering
- Freeze-thaw dewatering ponds

The residuals will be thickened and dewatered, with the sludge going to landfill and the water going to sewer

Residual Handling Alternative Selected For Conceptual Design

While there are several options for the management of the residuals, for the purposes of the conceptual design, on-site residuals handling systems using mechanical dewatering have been assumed for handling of both the thickened filter backwash and the DAF float.

In this option, filter backwash is collected in backwash equalization basins and pumped continuously to clarifier/thickeners, thereby thickening the solids fraction and producing a supernatant suitable for recycling to the head of the plant. Thickened sludge is pumped to combined sludge blending and storage tanks, where it is blended with DAF float (pumped to these tanks without pre-processing). Blended sludge is then fed continuously to decanter centrifuges that generate a sludge cake in the 20-25% TS range, suitable for landfilling. Centrate (the liquid waste stream) is discharged directly to the sanitary sewer.

Mechanical Dewatering - Conceptual Design Requirements

Mechanical dewatering was selected for the conceptual design as there may be some public reluctance to accept the installation of freeze thaw ponds. This would be a subject of an optimization study prior to final design.

Backwash Waste Equalization

Number of equalization tanks two

Backwash Waste Thickening

Backwash waste transfer pumps three total, two duty (one per thickener)

Thickener underflow sludge pumpsthree pumps, two duty (one per thickener)

Sludge Storage (for backwash thickened sludge and DAF float)

Number of sludge storage tanks two (one duty, one standby)

Sludge Dewatering

Dewatering system Centrifugation
Number of centrifuges two total
Centrate disposal To sanitary sewer

Further Studies of Residuals Disposal

The above is a conservative approach in terms of establishing the total construction cost of the water treatment plant as it likely involves a higher capital cost than direct discharge of residuals to sewer. The impact of direct discharge to the NEWPCC would need further assessment. The approach to residuals management should be revisited prior to detailed design.

The preceding discussion has focused purely upon the residuals-handling process itself. The more global issues surrounding the choice of the residuals handling process include such items as the public acceptability of the use of freeze-thaw ponds and the availability and cost of land at the selected site.

Standby power facilities can provide various levels of power during a power failure

Standby Power for the WTP

Standby power facilities can be designed to supply a wide range of standby power, from a minimum of emergency power for control system operation and operator safety to full operation of the WTP. The conceptual design sized the standby power to run the complete WTP (including finished water pumps) at a rate equal to pumping capabilities of distribution pumps during a power failure. Optimization studies during final design will be carried out in three areas:

- Optimum level of standby power at the WTP during a power failure
- Optimum mode of supply standby power (electric power generation vs. engine-driven pumps)
- Other uses of standby power (peak shaving, power producer to Winnipeg Hydro, waste heat recovery)

Staffing of the WTP will be to a level that is competitive with a private operator

WTP Staffing

The wide variety of approaches to staffing a large WTP must consider current services offered by the City and other City policies:

- "Competitive" approach to staffing, in keeping with the City's Computerized Work Management System (CWMS)
- Compliance testing and reporting to be carried out at the City's main lab at the NEWPCC
- Personnel from the St. Boniface Shops to carry out "heavy-duty" maintenance activities
- WTP SCADA system to be tied into the Department's over-all SCADA System
- Plant to be unattended at night and possibly on weekends with monitoring by personnel at the McPhillips Pump Station; sufficient treated water storage exists at the WTP and the three distribution reservoirs to allow the WTP to be remotely shut down when responding to an emergency call-out

Based on the above approach, the following staffing options are recommended:

- One plant manager who is also certified as an operator with the highest required classification
- Full-time administrative assistant
- Four maintenance personnel
  - Maintenance coordinator / mechanic
  - Electrician
  - Instrument technician
  - Labourer
- Four full-time operators
- Two laboratory chemists

A comprehensive distribution system flushing program is recommended before the WTP is commissioned

Distribution System Enhancement

Two main reasons exist for a comprehensive distribution flushing program to be completed before the WTP is put into service:

- The WTP will remove more than 99.99% of all the suspended matter that currently enters the distribution system. Removing the sediment and other deposits currently in the distribution system will mitigate any negative effects on the "new" water quality caused by the "older" distribution system conditions.
- A change in the chemistry of the water in the distribution system may cause some short-term water problems (taste and odour and colour incidences) before the new equilibrium is reached. Removal of the existing deposits will provide better water quality and allow equilibrium to be attained sooner.

The flushing program will likely require a four-year duration, necessitating startup in 2002. The flushing program should not affect the water stabilization program that begins in 1999, as the flushing program will not include the service connection piping.

Estimate of Total Capital Costs and Annual Operating and Maintenance Costs

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The total capital cost of the WTP project is estimated as $137M at the Deacon Reservoir location and $167M at the

Capital Costs

Table SR-4 documents all the capital costs required to design and build the WTP assuming a conventional delivery method; i.e. detailed design and tendered construction. Using the information developed during the conceptual design as the basis for determination of capital costs for construction of the project typically results in an accuracy range of -15% to +30%. In other words, if the total costs of the WTP at Deacon at the conceptual design stage are estimated at $137M, the actual total costs after the WTP is designed and constructed are likely to be between $116M and $178M. Since there were many items identified during the conceptual design that could be optimized during the detailed design (e.g. residuals disposal) the capital cost estimate should not be used for

City (MacLean Reservoir) location

budgeting purposes.

The City decided to obtain a more accurate cost estimate and retained a separate group from the consultant team to complete a more detailed and accurate cost estimate. The results are presented in a separate report.

Determining a more accurate estimate of the total capital costs was the topic of a separate study

Table SR-4
CAPITAL COSTS ESTIMATE (Based on Conceptual Design)
(Costs in $1998 x million)

Item No.	Item Description	City Site (MacLean)	Deacon Reservoir
Water Treatment Plant Structure			
101	Raw water pump station at Deacon	1.0	1.5
102	Raw water reservoir / surge tower / emergency reservoir	2.0	-
201	Rapid mix facility	0.5	0.5
301	Flocculation facility	6.1	6.1
302	DAF facility	14.6	14.6
401	Ozonation facility	13.4	13.4
501	Filtration facility	16.4	16.4
701	Clearwell	4.5	4.5
702	Treated water pump station	7.6	4.5
601	Chlorination facility	4.2	4.2
602	Chemical storage and feeding facility	4.9	4.9
603	Chlorine scrubber facility	0.5	0.5
604	Stabilization & fluoridation facility	1.4	-

1001	MCC and electrical facility	2.8	2.8
1002	Stand-by power facility	1.9	1.9
801	Solids handling facility	4.8	4.8
901	Tunnel to future GAC facility	0.9	0.9
1101	Arch/Admin/Control/Lab/Staff/Shops	4.0	4.0
	Premium for conjested site construction at Deacon	-	1.3
	Premium for more difficult subgrade conditions at Deacon	-	2.0
	Subtotal:	**91.5**	**88.8**
Conveyance Piping			
C1	1500 raw water feed	2.0	0.9
C2	Treated water feeder mains	0.7	0.6
C3	900 treated water (plant tunnel)	0.3	-
C4	Valve chamber on Branch I Aqueduct	0.1	-
C5	1350 treated water feeder main to Branch II Aqueduct	16.6	-
	Subtotal:	**19.7**	**1.5**
Site Servicing			
S1	Access roads	0.9	0.6
S2	Power supply facility	-	-
S3	Electrical substation	0.8	0.8
S4	Natural gas supply facility	0.1	0.2
S5	Sanitary sewer + Storm sewer (CS)	0.5	2.1
S6	Rail Access	0.2	0.2
	Subtotal:	**2.4**	**3.8**
Site Preparation			
P1	Site roads and parking	0.3	0.2
P2	Lighting / irrigation / landscaping	0.3	0.3
	Subtotal:	**0.6**	**0.5**
Contingency allowance (10% of total)		11.6	9.4
Construction change order allowance (5% of total)		6.4	5.2
	Total Construction:	**132.6**	**109.6**
Architecture/Engineering/Project Management (12% of construction)		15.9	13.1
Land purchase		0.3	-
	Subtotal Capital:	**148.8**	**122.7**
	PST @ 7% of subtotal capital	10.4	8.6
	GST @ 3% of subtotal capital	4.5	3.7

Administration & legal costs @ 2% of subtotal capital		3.0	2.5
	Total Capital Cost:	**167**	**137**

Operating and Maintenance Costs

The following table, Table SR-5 documents all the costs that have been identified at this time that will be necessary to operate and maintain the WTP. There is little difference between the two sites, with the annual O & M costs at the MacLean site approximately $0.3 million more costly.

Table SR-5
ANNUAL OPERATING and MAINTENANCE COSTS
(Costs in $1998 x million)

Item No.	Item Description	City Site (MacLean)	Deacon Reservoir
1	Hydro power - raw water pumping at Deacon Reservoir	0.32	0.48
2	Hydro power - water treatment	0.40	0.40
3	Hydro power - treated water pumping	0.10	0.19
4	Chemicals	3.25	3.25
5	Consumables	0.80	0.80
6	Natural gas for WTP heating	0.35	0.35
7	Operations staff	0.72	0.72
8	Residuals processing	0.31	0.31
9	Residuals' solids hauling and disposal at landfill	0.65	0.11
10	Sewer use surcharge (residuals' centrate disposal)	0.13	0.13
11	Plant maintenance costs	1.40	1.40
	Total:	**8.43**	**8.14**

Capital funding will be required from 2000 to 2006 to complete the WTP project

Capital Funding Requirements

The following Table SR-6 illustrates the capital funding requirements on the basis of the conceptual design capital cost estimate and assuming the project proceeds in a timely manner. The capital funding requirements also assumes that Winnipeg's water treatment plant project will proceed through the conventional delivery process of functional design, detailed design and tendered construction.

The construction costs used in Table SR-6 are for the Deacon site. Note that this table is based on the conceptual design and is presented to demonstrate a cash flow requirement scenario. The table should not be used for budgeting purposes.

Table SR-6
CAPITAL FUNDING REQUIREMENTS
(Costs in $1998 x million)

Year	Capital Funding Item	Estimated Cost
2000	Site selection study; Optimization studies; Environmental impact assessment; Functional design start	0.9
2001	Environmental approvals; City review; Completion of Functional Design	1.0
2002	Value engineering and Detailed design	4.2
2003	Detailed design	4.5
2004	Construction award and first construction year	16.8
2005	Second construction year	61.2
2006	Final construction year and commissioning	49.3

Implementation of Winnipeg's Water Treatment Plant Project

Introduction

The current schedule provides for the water treatment plant to be operational by the year 2007. Three "external" tasks are required to meet this scheduled date:

- Public consultation program
- Environmental and regulatory approvals
- Determination of the project delivery method

Public Consultation Program

The City wishes to obtain input from the drinking water customers

1. Since this project has key strategic importance in the City's long-term plans, it is consistent with City policy to solicit public participation on the related decision making. A history of public participation in the project already exists with respect to the previous Regional Water Supply Study. In addition, Manitoba Environment, under *The Manitoba Environment Act* and *The Public Health Act*, expects that the affected public will be consulted and allowed to participate in the regulatory review process. Most importantly, the City wishes to obtain input from the citizens (customers of the utility) about their opinion on the need for the water treatment plant.

Environmental and Regulatory Approvals

Significant issues need to be addressed to obtain regulatory approval and community acceptance of the WTP.

Issues

If the WTP project is approved and the site has been selected, the following issues must be resolved before the WTP can be constructed:

- WTP residuals management and disposal
- Traffic
- On-site chemicals (delivery and storage)
- Odours
- Noise
- Air quality
- Land use planning considerations
- Property taxes and grants
- Site security and emergency response

The WTP will require Provincial approvals for construction and operation

Regulatory Review Process

The operation of a public water system is governed by the Public Health Act and related regulations. Alterations to a public water system, such as the addition of a water treatment plant, require a Certificate of Approval from the Minster of Health.

As well, proponents require a licence under the Manitoba Environment Act to build or operate a development. A water treatment plant would likely be considered a development requiring a proposal for approval complete with an EIA. The review process would depend on the level of public interest or concern. The regulatory review process is involved and can involve the following acts and committees:

- *Public Health Act*
- *Manitoba Environment Act*
- Manitoba Environment - Technical Advisory Committee
- Clean Environment Commission
- *Sustainable Development and Consequential Amendments Act*
- *The Planning Act*

Alternative Service Deliveries

The City has many options available for the final design, financing, construction, and operation of the WTP.

There are many alternatives on how the WTP can be designed, financed, constructed and operated:

- Conventional approach
- Project management / construction management
- Design / build
- Design / build / operate
- Modified design / build
- Privatization approaches:
  - Design / build / own / operate / transfer
  - Design / build / rent / transfer
  - Design / build / operate
  - Build / transfer
  - Full concession
- Shared risk / shared savings conventional approach

The AWWA Research Foundation has just completed a study that defines a process for evaluating alternative project deliveries, as well as a model for financial analysis. The City should consider using these models to evaluate different proposals.

Comparing Alternative Treatment Processes

The project team (consultant team and City advisory team) have identified a treatment process that best meets the needs of the City, based on selected and prioritized water quality goals and related costs. The City may receive unsolicited proposals for different water treatment processes. A model of the project team's decision making process has been developed so that the City can evaluate proposals for alternative treatment processes, as well as alternative delivery methods.

Optimization Studies

Ten optimization studies have been identified for the functional design phase

Following is a list of studies that should be completed as part of the first phase of the functional design task. The bullets list the main issues in each study scope.

1. **Coagulant Selection**

- Ferric Chloride versus Alum (rail or truck delivery)
- Sulphuric Acid versus CO_2 (rail or truck delivery)

2. **Post-Treatment Chemical Selection**

- Lime versus Caustic
- Type of post-chlorination (chlorine gas Vs sodium hypochlorite)
- Chlorine delivery options (rail, tonners, onsite generation, scrubbers)
- Aqua versus gaseous ammoniaResiduals Handling Options
- DAF - mechanical versus hydraulic float removal
- DAF - sludge treatability – winter vs. summer
- comparison of dewatering methods
- land application with ferric chloride sludge
- potential for zero discharge
- direct discharge to sewer

3. **Oxygen Generation Method for Ozone**

- liquid oxygen versus onsite generation
- City versus private ownership and operationOptimize Filter Design
- 3 m versus 2.4 m developed headloss
- 8 versus 9 duty filters
- locating clearwell under filtersRaw Water / Emergency Storage Reservoirs and Surge Control (assuming MacLean site)
- raw water volume for flow balancing vs. control from Deacon Reservoir
- emergency storage to accommodate aqueduct supply if WTP down
- surge protection of Branch I and Branch II Aqueducts vs. flow control into WTP

4. **High Lift Pumps (assuming MacLean site)**

- common discharge header vs. 3 pumping stations

- common supply pipeline serving new and existing interconnect aqueduct with pressure reducing valve serving the McPhillips Reservoir
- same VFD pumps serving as standby pumps for each of the three reservoirs

5. Standby Power Requirements

- emergency power only
- pumping capability to supply the three distribution reservoirs
- treatment and pumping capability to match standby pumping capability of distribution pumps

6. SCADA and Controls

7. Administration and Plant Staffing

- control room location
- lab and office size
- staff size and job descriptions

8. Overall Plant Elevation (assuming MacLean site)

- lower plant to allow gravity flow from aqueduct
- raise plant to allow gravity flow into MacLean Reservoir
- plant elevation for minimum cost

9. Overall Plant Elevation (assuming Deacon site)

- lower WTP to eliminate raw water pump station vs. raw water pump station
- put filters over clearwell to reduce footprint in congested site

10. Chemical Delivery and Storage

- truck vs. rail
- storage capacity
- access
- containment
- rail car heating vs. heated storage
- containment

Other Studies Prior to Detailed Design

Other studies that will be required prior to the final design are:

- Continuous Chlorination at Shoal Lake
- Direct Discharge to Sewer of Some or All Plant Residuals
- Site Selection Study

This concludes the summary of the main report.