# WATER MINIMIZATION ASSESSMENT - HEALTH SCIENCES CENTRE, WINNIPEG, MANITOBA

58

By

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Gerontology .......... 0351
History
- General .......... 0578
- Ancient .......... 0579
- Medieval .......... 0581
- Modern .......... 0582
- Black .......... 0328
- African .......... 0331
- Asia, Australia and Oceania .......... 0332
- Canadian .......... 0334
- European .......... 0335
- Latin American .......... 0336
- Middle Eastern .......... 0333
- United States .......... 0337

History of Science .......... 0585
Law .......... 0398
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- General .......... 0615
- International Law and Relations .......... 0616
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- Criminology and Penology .......... 0627
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- Plant Pathology .......... 0480
- Plant Physiology .......... 0817
- Range Management .......... 0777
- Wood Technology .......... 0746

Biology
- General .......... 0306
- Anatomy .......... 0287
- Biostatistics .......... 0308
- Botany .......... 0309
- Cell .......... 0379
- Ecology .......... 0329
- Entomology .......... 0353
- Genetics .......... 0369
- Limnology .......... 0793
- Microbiology .......... 0410
- Molecular .......... 0307
- Neuroscience .......... 0317
- Oceanography .......... 0416
- Physiology .......... 0433
- Radiation .......... 0821
- Veterinary Science .......... 0778
- Zoology .......... 0472

Biophysics
- General .......... 0786
- Medical .......... 0760

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Geochemistry .......... 0996
Geodesy .......... 0370
Geology .......... 0372
Geophysics .......... 0373
Hydrology .......... 0388
Mineralogy .......... 0411
Paleobotany .......... 0345
Paleoecology .......... 0426
Paleontology .......... 0418
Paleozoology .......... 0985
Palynology .......... 0427
Physical Geography .......... 0368
Physical Oceanography .......... 0415

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- Chemotherapy .......... 0992
- Dentistry .......... 0567
- Education .......... 0350
- Hospital Management .......... 0769
- Human Development .......... 0758
- Immunology .......... 0982
- Medicine and Surgery .......... 0564
- Mental Health .......... 0347
- Nursing .......... 0569
- Nutrition .......... 0570
- Obstetrics and Gynecology .......... 0380
- Occupational Health and Therapy .......... 0354
- Ophthalmology .......... 0381
- Pathology .......... 0571
- Pharmacology .......... 0419
- Pharmacy .......... 0572
- Physical Therapy .......... 0382
- Public Health .......... 0573
- Radiology .......... 0574
- Recreation .......... 0575
- Speech Pathology .......... 0460
- Toxicology .......... 0383

Home Economics .......... 0386

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- General .......... 0485
- Agricultural .......... 0749
- Analytical .......... 0486
- Biochemistry .......... 0487
- Inorganic .......... 0488
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- Organic .......... 0490
- Pharmaceutical .......... 0491
- Physical .......... 0494
- Polymer .......... 0495
- Radiation .......... 0754

Mathematics .......... 0405
Physics
- General .......... 0605
- Acoustics .......... 0986
- Astronomy and Astrophysics .......... 0606
- Atmospheric Science .......... 0608
- Atomic .......... 0748
- Electronics and Electricity .......... 0607
- Elementary Particles and High Energy .......... 0798
- Fluid and Plasma .......... 0759
- Molecular .......... 0609
- Nuclear .......... 0610
- Optics .......... 0752
- Radiation .......... 0756
- Solid State .......... 0611

Statistics .......... 0463

**Applied Sciences**

Applied Mechanics .......... 0346
Computer Science .......... 0984
Engineering
- General .......... 0537
- Aerospace .......... 0538
- Agricultural .......... 0539
- Automotive .......... 0540
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- Hydraulic .......... 0545
- Industrial .......... 0546
- Marine .......... 0547
- Materials Science .......... 0794
- Mechanical .......... 0548
- Metallurgy .......... 0743
- Mining .......... 0551
- Nuclear .......... 0552
- Packaging .......... 0549
- Petroleum .......... 0765
- Sanitary and Municipal .......... 0554
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Geotechnology .......... 0428
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General .......... 0621
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# WATER MINIMIZATION ASSESSMENT - HEALTH SCIENCES CENTRE, WINNIPEG, MANITOBA

*By*

*Mr. Bruce Baird*

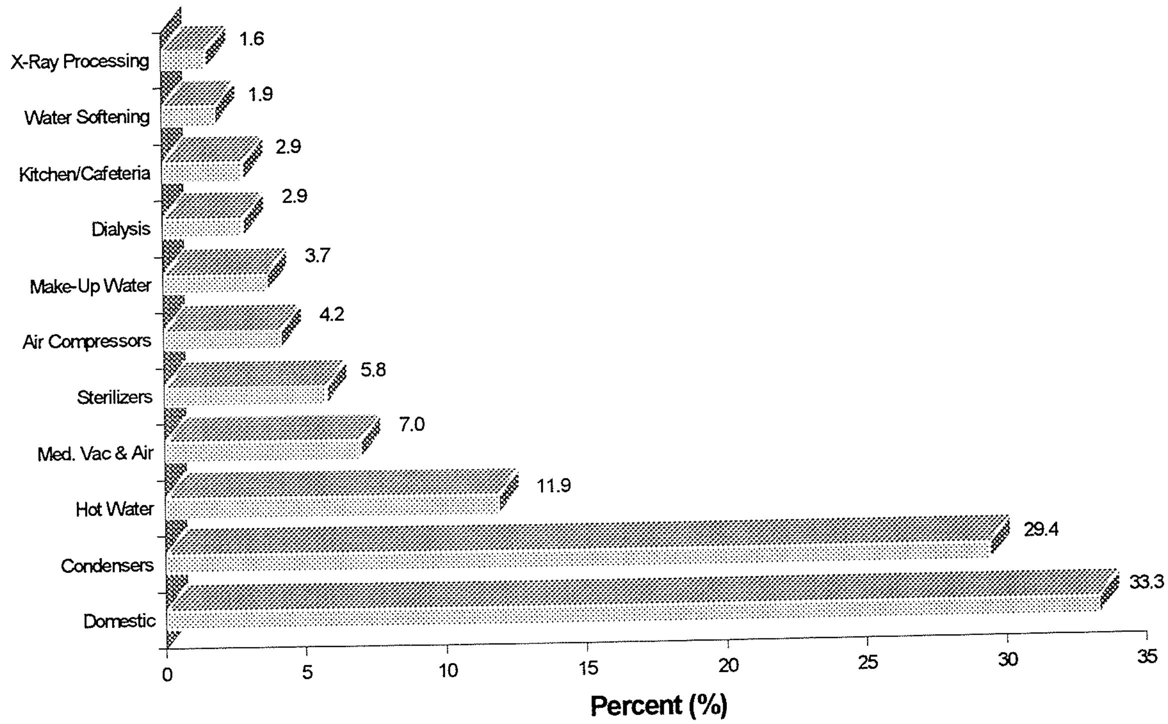
*A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfilment of the requirements of the degree of Master of Natural Resources Management.*

## Executive Summary

The Health Sciences Centre (HSC) is the second largest water user in the City of Winnipeg consuming more than 260,000 hundred cubic feet (CCF) of water per year (742 million liters/yr). Over the past ten years consumption has remained relatively constant (slight decreasing trend since 1990), yet the cost of consumption has nearly doubled. This trend should continue as the City of Winnipeg's water and sewer rates are projected to increase by approximately 10-12% per year. The purpose of this research therefore, was to conduct a Water Minimization Assessment to identify and evaluate a variety of water conservation measures as a first step toward reducing water-related expenditures. Specific objectives included: i) identifying and documenting water consumption associated with HSCs major water use categories; ii) identifying and evaluating water conservation options available; and, iii) prioritizing the implementation of feasible options.

To evaluate potential options, consumption estimates were required. A literature review and personal communications identified 11 major water use categories. Per category consumption estimates (see exhibit) were derived using information pertaining to flow duration and flow rate, by methods such as: metering, published values, non-structured interviews, accelerated current logging, timed volume measurements, and technical specifications. Once consumption estimates were derived, a review of trade journals and personal communications identified a number of water conservation options available to HSC. The economic feasibility of each option was evaluated based on capital and operating costs, annual cost savings, and payback periods. Using a 5 year payback period cut-off, replacing dishwashers based on energy and water savings alone was not feasible. The remaining options; year round supply of chilled water as a heat sink for water-cooled condensers, 90% recirculating retrofit kits for two medical vacuum pumps, and converting three water-cooled condensers to air-cooled; were feasible and subjected to a negative bias sensitivity analysis. Factors that could affect an options feasibility or implementation prioritization, such as cost increases (+25% and +50%), consumption overestimation (-10%, -25%, and -50%), and water rate increases

lower than expected (0%/yr and 5.3%/yr) were included to identify high and low sensitivity estimates for each option's payback period and five and twenty year net present values (NPV). Each option was then prioritized according to its five year NPV. As a result of the analysis, HSC should implement recommendations one to three in the order in which they appear.




1. HSC should proceed with the installation of the winter chilled water supply as described by Scouten Mitchell Sigurdson (SMS) (1996) so as to provide year round chilled water.

With year round chilled water available, almost all of the water-cooled condensing units can be converted to use the existing chilled water loop. This project will cost approximately $800,000 with a payback period between 3.4 to 4.6 years. It is the most significant water minimization option, as it represents 25.5% (66,711 CCF) of overall consumption.

2. HSC should proceed with the technical assessment required to operate the medical vacuum pumps in CS-008 and GG-048 at 90% recirculation.

Retrofitting these units will reduce overall consumption by 5819 CCF/yr or 2.2%. These retrofits have payback periods between 1.6 to 3.5 years for CS-008 and 1.2 to 2.6 years for GG-048.

3. HSC should convert three water-cooled condenser units not feasible in the SMS (1996) proposal (BA-001, GF-632, and GC-420) to air-cooled units.

Converting these units will reduce overall consumption by 4938 CCF/yr or 1.9%. The payback periods associated with these conversions are: 3.4 to 4.6 (BA-001), 1.8 to 3.5 (GF-632), and 3.3 to 6.7 (GC-420).

Implementing these water conservation options (recommendations 1-3) will reduce overall consumption by 82,204 CCF/yr or 31.4%. Additional savings are, or soon will be realized, as a result of on-going projects (replacing packing seals with mechanical seals in HSCs chilled water pumps and Dietetics Department restructuring eliminating the Oasis Cafeteria's dishwasher) and recently completed projects (sterilizer retrofits/replacements and a recirculating loop for the Central Energy Plant's air compressors). These should reduce overall consumption by 17,049 CCF/yr or 6.5%. Overall consumption can be reduced by 37.9% or 99,250 CCF/yr yielding annual cost savings of approximately $370,000.

Potential exists for additional savings as no water minimization recommendations were made with respect to HSCs largest water use, Domestic Consumption. It is recommended that HSC conduct a separate study pertaining to Domestic water minimization for hospitals that includes input from a variety of stakeholders to ensure implementation.

## Acknowledgments

I would like to thank Mr. David Koslowsky for believing in the idea and securing funding for the project, as well as his on-going advice and input. Thanks also goes to Dr. John Sinclair for his guidance and advice as my faculty adviser over the past year. I am grateful to my Practicum Committee for their invaluable input and constructive criticism. Thank you, Dr. John Sinclair (Natural Resources Institute), Mr. David Koslowsky (Health Sciences Centre), Dr. David Morgan (Tetr*ES* Consultants Inc.), and Dr. Daryl McCartney (University of Manitoba, Engineering).

I would also like to thank the staff at HSC for being extremely helpful by answering all my questions. In particular, Sally Plante and Ed Lehmann and the gents in the Central Energy Plant; Gord Berg and the guys in the Plumbing Shop; Larry Drebniski for downloading the ACR data, Manny Bettencourt; and Jane Maslowski for their time, advice, and information regarding HSC water use.

Loads of thanks to Jude at the NRI for keeping things organized.

TABLE OF CONTENTS

## LIST OF TABLES



## LIST OF FIGURES



## LIST OF APPENDICES

# Chapter 1 Introduction

## 1.1 Background

### 1.1.1 Water & Sewer Rates in Winnipeg

During the 1996 fiscal year, the cost of consuming water for large industrial or institutional users was $3.74/ hundred cubic feet (water rate = $1.18/CCF (hundred cubic feet) and the sewer rate = $2.56/CCF). These rates have been, and will continue to, increase as a result of the provincial government's Sustainable Development strategy for the Capital Region, which includes Winnipeg. Policy 2.6f (Water Service) of the strategy states that Provincial and Municipal governments should "adopt water pricing systems and amend by-laws to encourage water conservation and to pay for infrastructure renewal" (Manitoba Round Table on Environment and Economy, 1995, p.29).

Winnipeg City Council has adopted this strategy by incorporating price rate increases in their water supply plan (Wardrop Engineering Inc., 1992). Although recently, City Council has proposed, but not approved, a 35% reduction in the sewer rate (Free Press, June 6, 1996) for large water users in hope of promoting economic development. The benefits from a lower sewer rate should be short-lived[1], as the sewer rate increases were designed to help offset the City's increased borrowing costs for a $150 million upgrade to the water treatment facilities (Free Press, June 6, 1996). The water rate, on the other hand, has and should continue to increase by approximately 10% per year over the next few years (Chartier, 1995) in order to generate revenue for aqueduct rehabilitation and future expansion of Winnipeg's water supply (Wardrop Engineering Inc., 1992). As water is being allocated on a full cost basis, the result is a mid to long term trend toward higher water and sewer rates for all users.

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[1] HSC experienced a price rate drop in the 1988/89 fiscal year, but the price rate increased thereafter (see Figure 1.1).

### 1.1.2 Water Use at the Health Sciences Centre

Large institutional water users, like the Health Sciences Centre (HSC), can use water conservation as a means of controlling and reducing water-related expenditures. Figure 1.1 illustrates that water consumption at HSC has remained relatively constant over the past 10 years, but the cost associated with this consumption (water and sewer) has nearly doubled (not adjusted for inflation). Conservation which reduces consumption and costs takes many forms, from reducing wasteful practices; to repairing leaking fixtures and pipes; to retrofitting or replacing older and less efficient fixtures and appliances with efficient ones (Environment Canada, 1990); as well as, reusing existing water within a closed loop system.

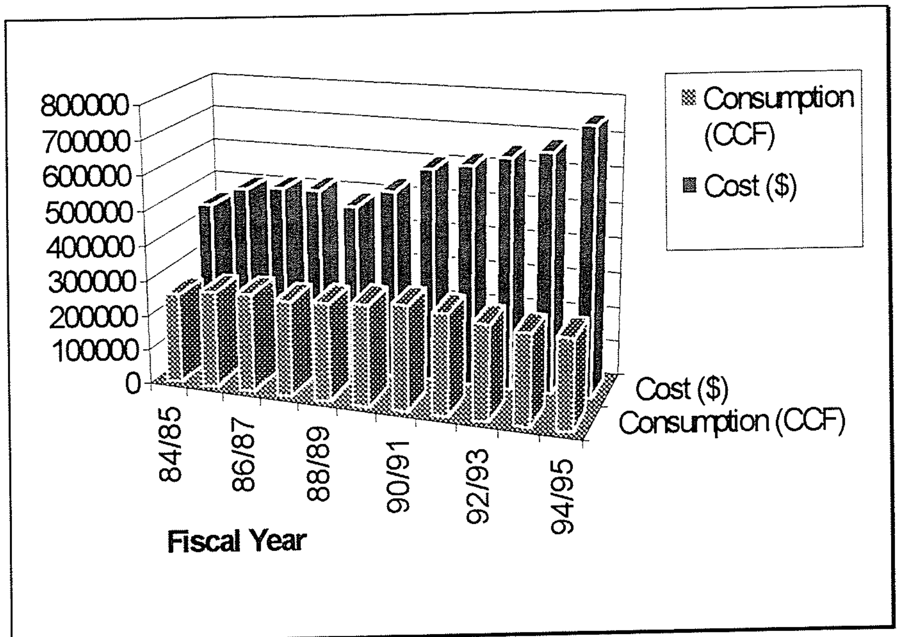


**Figure 1.1 HSC Water Consumption and Cost.**

## 1.2 Issue Statement

The Health Sciences Centre (HSC) is a major tertiary care teaching hospital comprised of 26 buildings on a 32 acre site (Koslowsky, 1995) and is the second largest water user in the City of Winnipeg (Parbery, 1994; Wardrop Engineering Inc., 1992). In the 1994/95 fiscal year (Apr. 1/94 to Mar. 31/95) HSC used 261,869 CCF of water at a cost of $769,350. Unless water conservation techniques are employed, water related costs will double in just under eight years . Thus, a water minimization assessment is a necessary first step in order to reduce future water related expenditures and conserve water resources.

## 1.3 Objectives

The objectives of this study were:

1. to identify and document water consumption associated with the major water uses at HSC;
2. identify and evaluate water minimization options available for the major water uses identified in objective 1; and
3. prioritize water conservation options available for HSC.

## 1.4 Methods

The Water Minimization Assessment Procedure[2] (EPA, 1990), identified in figure 1.2, establishes a systematic framework from which to evaluate potential conservation measures. However, this research report deals only with the first three phases, as obtaining funding required for installation was beyond the report's scope.

Within this framework, the methodology used to derive consumption estimates was similar to that used by Black and Veatch (1991a & 1991b). Estimating consumption required information pertaining to flow duration and flow rate. Flow duration and flow rate estimates were obtained by:

i. accelerated current logging to determine average run times, where the drawing of amperes was used as a proxy for run time;
ii. timed volume measurements to determine flow rates;
iii. in-hospital documentation (technical specifications, data files, etc.) to determine flow rates, or consumption per use estimates;

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[2] The US Environmental Protection Agency developed a Waste Minimization Assessment Procedure for waste water. However to avoid confusion, it will be referred to as a Water Minimization Assessment Procedure.

iv. non-structured informal surveys to establish frequency of use and hours of operation estimates;

v. published values to determine flow rates and consumption estimates; and

vi. water meters to determine consumption over a specified period of time.

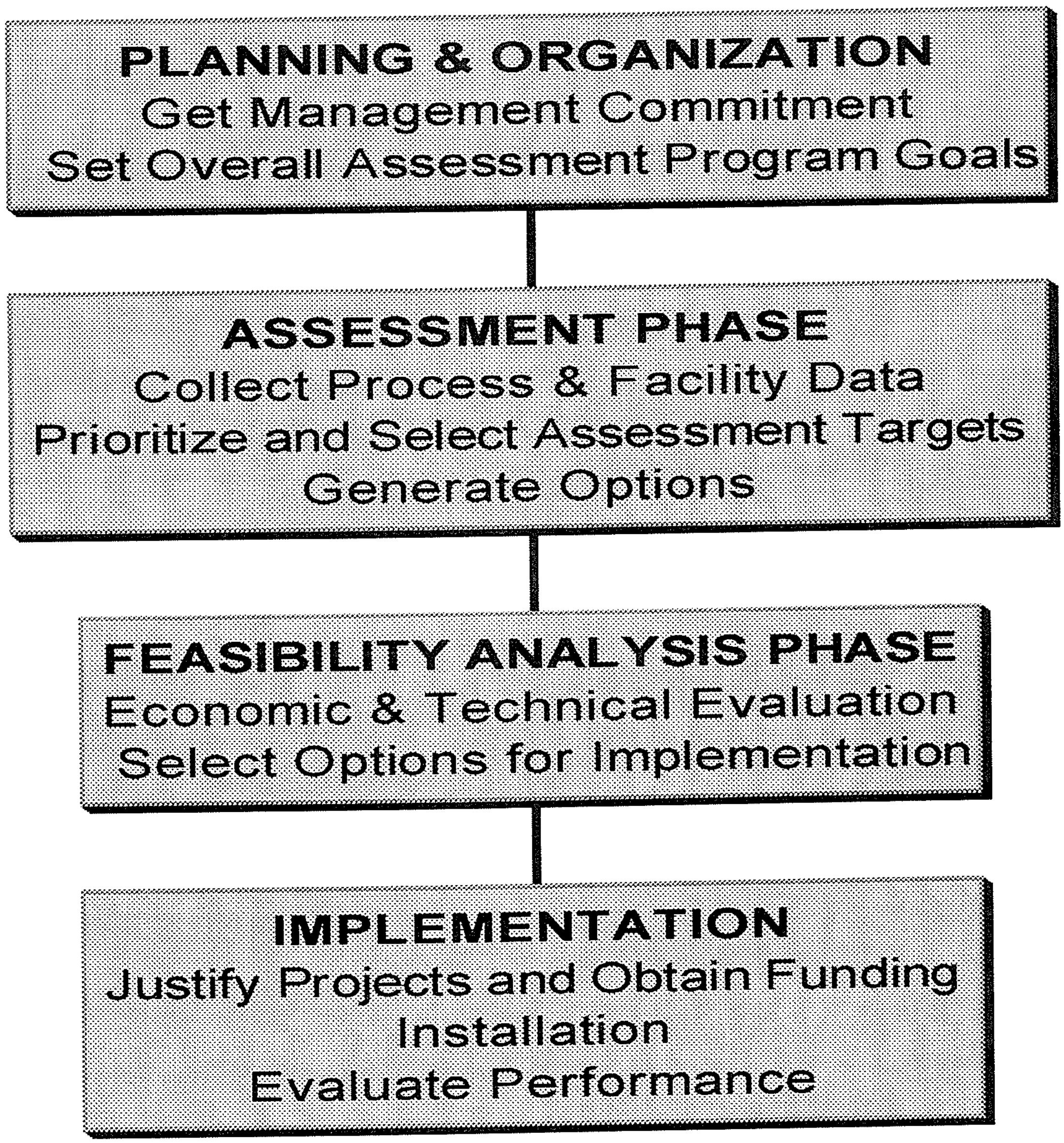


**Figure 1.2 Water Minimization Assessment Procedure**

Source: EPA, 1990.

Table 1.1 illustrates the techniques used to derive consumption estimates for each of HSCs major water uses[3].

**Table 1.1 Method Used to Determine Water Consumption for HSCs Major Water Uses.**

| **Major Water Use Category** | **Method Utilized** | | | | | |
|---|---|---|---|---|---|---|
| | M | PV | NSI | AC | TV | ED |
| Sterilizer Use | | | ✓ | | | ✓ |
| Dialysis | ✓ | | | | | |
| Kitchen & Cafeteria Use | | | ✓ | | | ✓ |
| Water Softening (Steam Production) | ✓ | | | | | |
| Air Compressors | ✓ | | | | | |
| Cooling Tower Makeup | ✓ | | | | | |
| X-Ray Processing | | | ✓ | | | ✓ |
| Medical Vacuum & Medical Air | | | | ✓ | | ✓ |
| Domestic | | ✓ | ✓ | | | |
| Hot Water | See Section 3.2.10 | | | | | |
| Water-Cooled Condensers | ✓ | | | ✓ | ✓ | ✓ |

Legend:

| | | | |
|---|---|---|---|
| ✓ | Included | AC | Accelerated Current |
| M | Water Meter | TV | Timed Volume |
| PV | Published Value | ED | Existing Data within HSC |
| NSI | Non-Structured Interview | | |

Once per category estimates were derived, they were compared to the hospital's average annual consumption (based on consumption from the previous two years)[4], via a water balance, in order to ensure estimated consumption equals actual consumption. Although not precise, this methodology does give a good indication of annual water usage, from which to evaluate a variety of water conservation measures.

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3 Black and Veatch (1991a &1991b) and Wilson (1994) identified major water uses for hospitals when they audited two hospitals in the Los Angeles area.

4 See Appendix B.

A review of trade publications and hospital journals, as well as personal communications identified water conservation techniques available for hospitals. From which, the feasibility of these options were evaluated based on capital and operating costs, annual cost savings, and payback periods.

## 1.5 Limitations

A number of limitations are present. First, the focus of the Water Minimization Assessment was to gather information concerning major water uses where significant cost savings may be realized. As a result, no information was gathered for the following:

- drinking fountains
- labs
- janitor and utility rooms
- operating rooms

Secondly, the water assessment primarily used time of use and flow rates to estimate consumption. It is realized that this is the least precise water auditing methodology; however due to the number of sensitive areas, pumps and fixtures, and plumbing complexities, it was deemed necessary.

Thirdly, ACR current logging measurements required the services of the Electrical Shop to install and remove the device. However, measurements were only taken when time permitted due to the lack of available resources resulting in a sample size of fifteen, not twenty-five.

Fourthly, samples associated with the water-cooled condensers were not truly random. Condensers that were difficult to access were excluded from the sampling list. The remaining condensers were randomly sampled.

Finally, only those buildings which are billed (water) directly to the Health Sciences Centre Energy Management Department were included in the study (Table 1.1).

### 1.6 Assumptions

Some assumptions were used throughout the Research Report and are noted at the time of use.

### 1.7 Organizational Preview

Chapter one has outlined the study's objectives, methodology employed to meet those objectives, and the reasoning behind them. The following chapter will explore the existing literature regarding water conservation, conservation practices and techniques available to HSC, and what is involved in a water minimization assessment (Chapter 2); Chapter 3, the assessment phase, will detail the methodology used to obtain each consumption estimate; Chapter 4, the feasibility analysis phase, will examine the economic feasibility of the various minimization options; and finally, Chapter 5 summarizes the findings from Chapter's 3 and 4, from which recommendations are based.

## Chapter 2 Water Management and Conservation Practices

### 2.1 Introduction

As a first step, the literature was used to identify current water management approaches available to municipalities; resulting in a noticeable trend toward demand management principles creating an incentive for all water users to conserve, especially large water users. The result is a number of water conservation options are available to HSC. However, to effectively evaluate such options requires a methodological approach for estimating water consumption.

### 2.2 Municipal Water Management

Municipal water is managed according to two principles, demand-side management or conservation and supply management or supply augmentation. These principles work in conjunction with each other, yet in many regions there has been a noticeable shift toward demand management as a result of slowing population growth (consumptive growth) and limited capital budgets. As for Winnipeg, conservation measures (i.e. price rate changes) are being used to delay infrastructure improvements into the future while generating capital reserves for future construction costs (at present) and to reduce the City's debt load associated with upgrading existing facilities.

Municipal governments are limited by provincial regulators as to which conservation measures council can enact (REIC Ltd. and Associates, 1991). REIC Ltd. and Associates (1991) explained that municipalities cannot legislate water conservation measures beyond lawn watering bans nor adopt stricter standards than those imposed by the province (e.g. plumbing or building codes). The latter which, limits a municipality from mandating water-conserving fixtures (REIC Ltd., 1991). Thus, incentive programs and rate changes are the only conservation measures that a municipality can enact that would directly impact institutional water users, such as the Health Sciences Centre. At present, Winnipeg does not have an incentive program for replacing inefficient fixtures, although Council has adopted a strategy to increase water and sewer rates over the next few years. Such increases will significantly impact large volume users unless they begin to adopt a variety of water conservation measures.

### 2.3 Technical Water Conservation Options Available To HSC

As water and sewer rates increase, water conserving technologies can be used by institutional users to offset the increasing cost of using large volumes of water. These technologies take many forms, such as; retrofitting or replacing water-inefficient fixtures, or utilizing a closed loop cooling system.

#### 2.3.1 Toilet Replacements

Toilet replacements are relatively costly (Gates, 1994), but can result in significant reductions in water usage. Changing the conventional 20L toilet to a ultra-low volume (ULV) model (less than 6L per flush) can result in water use savings of approximately 70% (REIC Ltd., 1992). In the past, the main disadvantage with ULVs was only a limited number of CSA (Canadian Standards Association) approved models were available (Gates, 1994).

#### 2.3.2 Flush Valves

Flush valves are used to control the flow rate in urinals and tankless toilets. Valve operated toilets use approximately 19-25L per flush, but can be retrofitted with a flow control valve to reduce water consumption to 15L per flush (Environment Canada, 1993). Urinals on the other hand use considerably less water than the standard toilet (7-9L per flush), with further savings achieved by installing a water-saving flush valve that only uses 3L per flush (Environment Canada, 1993).

#### 2.3.3 Showerheads

Conventional showerheads in many commercial institutions use between 13-19L per minute (Brooks and Peters, 1988) or approximately 100L per use (Environment Canada, 1993). Properly engineered showerheads (reducing water consumption without sacrificing performance) have been developed reducing water consumption to between 6-10L per minute (REIC Ltd. and Associates, 1991).

### 2.3.4 Faucets

Conventional kitchen and bathroom faucets deliver between 11-13L per minute during normal use (Brooks and Peters, 1988), far more than is required for most cases (REIC Ltd. and Associates, 1991). Low-flow faucet aerators can reduce flow rates by approximately 50% (REIC Ltd. and Associates, 1991), while automatic shut-off features (e.g. infrared sensors) can achieve further economies in the order of 85% of the total flow (Brooks and Peters, 1988). The aerator chosen must match the intended use of the fixture (REIC Ltd. and Associates, 1991).

### 2.3.5 Chilled Water Loops And Cooling Towers

Air conditioning, refrigeration systems, as well as many industrial processes require chilled water to act as a heat sink (Marley, 1982). Chilled water loops and cooling towers work in conjunction with one another as water is continuously heated (e.g. heat sink for pump cooling) and then cooled (via the cooling tower). The main reasoning behind such systems is to reduce energy costs by using the temperature differential between the ambient air and water entering the tower. This differential results in heat being dissipated through evaporation from the tower water to the atmosphere.

In addition to energy savings, water and sewer related expenses are minimized as the water is utilized more than once. The number of times water circulates around a cooling loop (cycles) depends upon the treatment method used to maintain the specified quality. In fact, water is only lost from the system in one of four ways: evaporation, bleed-off (Black and Veatch, n.d.), and leakage. Makeup water is then required to account for such losses.

#### 2.3.5.1 Evaporation

Cooling towers use evaporation to cool the water within the system. The evaporative rate is largely dependent on the amount of cooling achieved, approximately 1% of the rate of recirculating water for every 10°F temperature drop achieved by the tower or approximately 2.4 gpm per 100 tons of cooling (Black and Veatch, n.d.). Many large water and sewer authorities give credit for water that does not enter into the Municipal sewage system, for cooling towers these savings can be quite considerable (Saunders, 1994).

#### 2.3.5.2 Bleed-Off

Bleed-off is used to prevent damage caused by an increase in the concentration of dissolved solids as a result of evaporation. As only pure water evaporates from the cooling tower, dissolved solids become more concentrated (Black and Veatch, n.d.). Therefore, a portion of the remaining water (bleed-off) must be discharged and replaced with fresh water until the concentration ratio is within acceptable limits (Black and Veatch, n.d.). The frequency with which these bleed-offs occur depend on the quality of water used within the system and the method utilized (e.g. chemical treatment) to control and/or inhibit corrosion, scaling, and biofouling (Black and Veatch, n.d.). Since the rate of evaporative loss cannot be altered, water conservation for cooling towers focuses on reducing the frequency of bleeding.

#### 2.3.5.4 Leakage Within The Distribution System

Leaks in the distribution system can result from leaking pipes, fittings, cooling coils, or pump seals. At HSC, all distributional piping is located inside the hospital complex (tunnels or buildings). As a result, losses associated with leaking pipes and fittings should be identified and repaired quickly. With water consumption monitored on a daily basis, the potential exists to identify cooling coil cracks inside air handling units.

At present, HSC has a combination of packing and mechanical seals in their chilled water pumps. Packing seals, unlike mechanical seals, are not water-tight and require periodic maintenance and/or replacement to minimize water consumption. Packing seals, due to their frictional nature, reduce a pump's horsepower while increasing heat production within the system.

### 2.3.6 Medical Air & Vacuum Pumps

Many medical air and vacuum pumps use a liquid ring (water) to seal the vacuum chamber as well as to cool the pump (Black and Veatch, 1991a). For vacuum pumps, water is utilized in one of three ways: as a single-pass; partially recirculated; or, 90% recirculated service liquid. Partial recirculation, distributes approximately 50% of the water from the separator to the pump, whereas, 90% recirculation, distributes 90% of the service liquid through a shell and tube or air cooled heat exchanger (Miller, 1995a). As for medical air compressors, the CSA code stipulates that no recirculation is acceptable (Miller, 1995a).

Recently, CSA approval has been obtained for rotary vane vacuum and oil-less air systems that utilize no water. The new vacuum systems are air-cooled and utilize oil-lubricated rotary vanes on an eccentrically-mounted rotor to draw the necessary vacuum (Thomas Industries Inc., 1993). New medical air compressors use sealed bearings and self-lubricated pistons to deliver the 100% oil-free air required for medical operations (Thomas Industries Inc., 1993).

### 2.3.7 X-Ray Processors

X-ray film processors use a continuous stream of running water during the processing stage (Black and Veatch, 1991a). A three tank system is used: first, the film enters the developing tank, then the fixing tank, and finally the washing tank (Popoff, 1995a). For effective processing, a flow rate of 2 gpm or less is required (Wilson, 1994).

Modern processors use solenoid control valves to regulate the feed water, so that water is only used when a film is being processed (Wilson, 1994). The water is shut off after approximately 2 to 3 minutes have passed without a film being processed (Black and Veatch, 1991a). Retrofit valve kits are available for some older X-ray processors (Wilson, 1994).

### 2.3.8 Sterilizers And Autoclaves

There are two types of sterilizers, steam and ethylene oxide, of which both require water. The steam sterilizer uses steam to sterilize the load and water to recondense the steam for discharge and to draw a vacuum during the drying stage (Black and Veatch, 1991b; Wilson, 1994). The ethylene oxide sterilizer, on the other hand, uses steam to humidify the load and vaporize the EtO gas and water to draw the necessary vacuum to remove the spent ethylene oxide (Wilson, 1994).

As a result of the Canadian government's commitment to ban CFCs (chloroflourocarbon's), 12/88 (12% ethylene oxide and 88% freon) CFCs in hospitals had to be discontinued by December 31,1995 resulting in the elimination of 12/88 EtO sterilizers. Replacements for the 12/88 sterilizers include: 100% ethylene oxide, 12/88 EO/HCFC using the ozone friendly HCFC, and 10/90 EO/$CO_2$.

### 2.4 Conducting A Water Minimization Assessment

Given the concern over increasing water rates, many municipalities, industries and institutions are using water audits, water conservation studies, or water minimization assessments as a cost cutting strategy. The United States Environmental Protection Agency (1990) developed the Waste Minimization Assessment Procedure to provide a systematic framework from which conservation or minimization studies should be based. It was designed for waste water studies, however to avoid confusion, it will be referred to as a Water Minimization Assessment throughout the research report. The Environmental Protection Agency, identified four phases to a Waste Minimization Assessment, they are:

1. Planning and Organization
2. Assessment
3. Feasibility Analysis
4. Implementation

#### 2.4.1 Planning And Organization

The essential elements of this phase are getting management support and setting minimization goals (EPA, 1990). The importance of getting management support cannot be overstated as it directly relates to implementation of feasible options (EPA, 1990).

### 2.4.2 Assessment Phase

The Assessment Phase consists of a number of steps (EPA, 1990):

- Prioritize and select assessment targets
- Collect and process facility data
- Review data and inspect site
- Generate options
- Select and screen options for feasibility analysis

Conducting a water audit or adopting its methodology (water inventory) during the Assessment Phase is a necessary step toward achieving resource optimization since it takes a comprehensive look at the facility in order to understand resource flows, as well as focusing one's attention to areas where significant reductions or cost savings can be realized (UNEP, 1991).

#### 2.4.2.1 Water Use Inventory

In order to develop a comprehensive inventory of the facilities water uses, a variety of information sources are required, including (UNEP, 1991; Environment Canada, 1993):

- the use of existing data (e.g. space inventories, plumbing plans, etc.)
- meeting with area personnel
- surveying area personnel about water uses within the area
- transferring questionnaire information to spreadsheets and base maps
- verifying information using plumbing plans, visual inspections and building personnel.

All extraction points should be described and located as to the category of water use; volume, rate, and frequency of use; and whether the water is lost or consumed (Environment Canada, 1993).

Once extraction points have been identified, estimates as to their associated flows must be considered. These estimates can be obtained by either published values or actual measurements. Published values are available for most conventional water uses; from which location specific information such as, the number of users per day or duration of use, can be incorporated (Environment Canada, 1993). Should published values be unavailable or not appropriate, actual measurements should be obtained. These measurements should be taken over the same general time period to ensure periodic and seasonal of flows do not affect the water balance equation, as well as, if outdoor use is suspected, measurements should be conducted during the summer months (Environment Canada, 1993). Environment Canada (1993) has classified field measurements into four groups, flow metering, bucket and stopwatch measurements, volume/frequency measurements, and indirect measurements.

Metering the main flow of water into the facility is an integral component of any water audit (Environment Canada, 1993). In addition to the main meter, sub-areas throughout the facility can also be monitored by installing a water meter on the water distribution system or water using equipment (Environment Canada, 1993), The choice of water meter depends on the data accuracy requirements. Permanent flow meters provide highly accurate data (daily, weekly, monthly, etc.), however they are expensive and must be permanently fixed into the plumbing run (Environment Canada, 1993). Less accurate data can be provided by using temporary flow meters (clamp-on or inserted).

Bucket and stopwatch measurements can be utilized to estimate flows provided the flow is constant and free flowing (Environment Canada, 1993). Flow is calculated by determining the time required to fill a bucket of a known volume. Should the flow not be continuous but fills a known volume, the frequency by which it is emptied or replaced can be used to estimate its flow (Environment Canada, 1993).

Measurements, such as logging the operation of the water pumps or displacement tests on water storage tanks, provide an indirect indication of flow (Environment Canada, 1993). However, Environment Canada (1993) indicates that this method is the least accurate of the four mentioned, but does provide the user an understanding of water use within the facility.

### 2.4.3 Feasibility Analysis

For each water use category or unit operation, an option must be both technically and economically feasible. A technical evaluation assesses whether a particular option will work within it's proposed application (EPA, 1990).

A cost/benefit analysis (CBA) should be undertaken to determine the capital costs, cost savings and payback period associated with implementing a particular option (Environment Canada, 1993). In addition to the CBA, the option should also be assessed in relation to (Environment Canada, 1993):

- social/political impacts
- environmental/technical impacts
- reliability
- short and long term effectiveness.

The chosen alternative will be consistent with the goals laid out by senior management thereby facilitating its implementation.

## 2.5 Summary

Winnipeg has adopted water and sewer price rate increases in order to delay future expansion while generating capital reserves in addition to accounting for current borrowing costs for upgrading facilities. These increases create an incentive for large water users, like HSC, to reduce consumption by adopting newer more efficient technologies. However, a proper framework is required in order to evaluate the feasibility of adopting said technologies. As a result, the United States Environmental Protection Agency developed the Waste Minimization Assessment Procedure to outline the steps involved from planning to the successful implementation of waste minimization projects. Thus, the following chapter details the methodology used to obtain the consumption estimates within this framework, expressed as a percentage of total consumption, for HSCs major water use categories.

## Chapter 3 Major Water Use Consumption Estimation

### 3.1 Introduction

A variety of techniques were used to estimate flow rates and flow duration for each HSCs major water use categories, such as:

- Non-Structured Interviews,
- Metering (permanent and clamp-on),
- Timed Volume Measurements,
- Published Values,
- Current (AC) and Activity Logging,
- Technical Specifications from Existing Equipment.

The per use category estimates were derived by using one or a combination of the above techniques. These estimates, as percentages of overall consumption[5], were then summed and compared, via a water balance, against the hospital's annual average based on the previous two years consumption (262,041 CCF).

### 3.2 Use Category Methodology And Water Consumption Estimates

#### 3.2.1 Sterilizers

Sterilizer consumption was estimated using employee knowledge and technical information. Employee knowledge was provided by the Central Processing Department since it is responsible for the majority of the sterilizing at HSC. Susan Hatfield (1995) estimated the number of cycles per week and the duration of each cycle for the steam sterilizers in WT-069 and GG-049, the EtO sterilizer in GG-047, and the washer in GG-639. Consumption estimates for the steam sterilizers were provided by MGT (1994) and Hatfield (1995) provided estimates for the EtO sterilizers and washer.

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[5]Percentages were determined by dividing the estimated per use category consumption by the annual average based on the previous 2 years (262,041 CCF).

There are 22 smaller steam sterilizers located throughout the hospital (General O.R., 10 units; Children's O.R., 3 units; Women's O.R., 3 units; Thorlakson and Cancer buildings, 3 units each). The methodology used to estimate water consumption depended upon if sterilizer print outs (hard copies) were available. Where hard copies were available (General and Children's O.R.'s), print outs were collected for a two week period to determine the number and duration of sterilizing cycles. Due to technical difficulties, the Children's O.R.'s print outs were collected for only one week. For the remaining sterilizers, personal communications were used to estimate the frequency and duration of daily sterilizing cycles (Lorimer (1995) for the Women's O.R. and Maslowski (1995) for the Thorlakson building). No information was available for the Cancer building's sterilizers due to variable cycle frequency and duration. A generalized six US gallons per minute flow rate was used to estimate water consumption (MDT Technology for Life, n.d.) since it was not possible to differentiate cycle frequency and duration on a per sterilizer basis. Consumption estimates for all HSCs sterilizers is provided in table 3.1.

**Table 3.1 Water Consumption Associated with Sterilizer Use.**

| Location | Sterilizer | Cycles/Week | Gallons/Cycle | CCF/Yr |
|---|---|---|---|---|
| General (GG-049) | Steam | 64 | 598 | 3194 |
| General (GG-047) | EtO[6] | 6 | 13600[7] | 6812 |
| General (GG-639) | Washer | 46 | 11250 | 801 |
| Women's (WT-069) | Steam | 28 | 598 | 1398 |
| | | **Minutes/Wk** | **US GPM** | |
| General OR (10 units) | Steam | 4243 | 6 | 1770 |
| Children's OR (3 Units) | Steam | 481 | 6 | 201 |
| Women's OR (3 Units) | Steam | 700 | 6 | 292 |
| Cancer Bldg. (3 Units) | Steam | N/A | N/A | N/A |
| MS Bldg. (3 Units) | Steam | 1855 | 6 | 774 |
| | | **Total CCF/Year** | | **15,242** |
| | | **Percent of Total Consumption** | | **5.8%** |

[6] Two sterilizers operating on alternating cycles.

[7] 17 hours per cycle*800 gallons per hour.

### 3.2.2 Dialysis

HSC has two Dialysis units, Central (CDU) and Self-Care (SCD), each using reverse osmosis to produce the high quality water required. However, reverse osmosis is a water intensive process. Currently, for every unit of acceptable water produced, 1.5 units are rejected.

Since water consumption associated with Dialysis is relatively stable, the water meter in the CDU was monitored for a period of two weeks in July to determine the average daily flow. SCD meter readings were taken on a monthly basis by the Central Energy Plant for billing purposes so the two-year annual average was used to estimate water consumption. The SCD meter, however, accounts for all water uses in the building; therefore, to reduce the effects of double counting, domestic consumption was estimated based on the square footage of the building and then subtracted from the averaged total (see Table 3.2).

**Table 3.2 Water Consumption Associated with Dialysis.**

| | | |
|---|---|---|
| **Self-Care Dialysis Unit** | | |
| 2 year average (93/94 and 94/95 fiscal years) | | 4655 CCF/yr. |
| Domestic Consumption (8876 sq.ft*.04 CCF/sq. ft) | | (355) CCF/yr. |
| | SCD Total | 4300 CCF/yr. |
| **Central Dialysis Unit** | | |
| 2 week average = 4 Imp. GPM | | |
| CDU Total (4 gpm*60 min/hr*24 hr/day*365 days/yr./623 Imp. | | 3375 CCF/yr. |
| | **Total CCF/yr.** | **7675** |
| | **Percent of Total Consumption** | **2.9%** |

### 3.2.3 Kitchen And Cafeteria

HSC has two kitchens, Rehab and Main, producing approximately 7000 meals per day (Richardson, 1995). Black and Veatch (1991a; 1991b) estimated miscellaneous water use associated with meal production at 0.5 gallons per meal.

Dishwashing results in significant water use in HSCs kitchens and cafeterias. There are 5 dishwashers throughout the complex, three in cafeteria's (Oasis, Cafe on 2, and Tunnel) and one in each of the two kitchens. Kathleen Richardson (1995) provided the time of use estimates, while consumption estimates were taken from the Dishwasher's technical specifications.

Table 3.3 details HSCs water consumption associated with kitchen and cafeteria activities.

**Table 3.3 Water Consumption Associated with Kitchen and Cafeteria Use.**

| **Water Use** | | **Times per Day** | **Duration of Use** | **Imp. GPD** | **CCF/Year** |
|---|---|---|---|---|---|
| Miscellaneous | 7000 meals | | | 3500 | 2051 |
| Dishwashers | Main Kitchen | 3 | 4.5 | 1734[8] | 1016 |
| | Cafe on 2 | 1 | 10.5 | 2963[9] | 1736 |
| | Rehab | 2 | 1.5 | 733[10] | 430 |
| | Oasis | 1 | 5 | 1989[11] | 1165 |
| | Tunnel | 1 | 5 | 1989[12] | 1165 |
| | | **Total CCF/yr.** | | | **7563** |
| | | **Percent of Total Consumption** | | | **2.9%** |

### 3.2.4 Water Softening (Steam Production)

Water softening is required for steam production. HSC has three softeners in the Central Energy Plant and 1 small unit in GG-038. CEP monitors water softening on a daily basis using water meters. As a result, water consumption was estimated using a two-year annual average (4970 CCF/yr or 1.9% of total consumption). No information was collected for the small unit in GG-038.

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[8] Hobart FTM/FT-800 Series Dishwasher: 4.7 gpm plus 155 gallons to fill tank per use (Hobart, n.d.).

[9] Flight-a-Round FA-EEE Series Dishwasher: 4.6 gpm 65 gallons to fill tank per use (Brodeur, 1995).

[10] Hobart FTM/FT-800 Series Dishwasher: 4.7 gpm plus 155 gallons to fill tank per use (Hobart, n.d.).

[11] Hobart C-44 Dishwasher: 2.8 gpm per rack 203 racks/hr (King, 1995) using a 70% efficiency (Brodeur, 1995).

[12] Hobart SM-6 Dishwasher: No information available, therefore used information for Hobart C-44.

### 3.2.5 Air Compressors

HSC has four water-cooled air compressors that supply the majority of the hospital's compressed air requirements. The compressors are located in the Central Energy Plant and are monitored on a daily basis using water meters. Therefore, consumption was estimated using the two-year annual average (10,893 CCF/yr or 4.2% of total consumption).

### 3.2.6 Cooling Tower And Chilled Water Makeup

To operate HSCs chilled water loop from mid-April to mid-October, water is required to prime the system, as well as to account for losses associated with evaporation, bleed off, and leakage. The Central Energy Plant monitors water consumption on a daily basis using a number of meters. As a result, water consumption was estimated using the two-year annual average (9768 CCF/yr or 3.7% of total consumption).

### 3.2.7 X-Ray Processing

HSC has twenty X-Ray processors located throughout the complex. All but two of these processors (AACs M6AN & Rehab's M6AN) have stand-by switches. Since the stand-by switches shut the water off 2-3 minutes after a film has been processed, consumption estimates are complicated due to the fact that consumption depends not only on the number of films processed but also their frequency. As a result, Jacob Popoff (1995a) tried to account for these variables when estimating utilization in hours per day (see table 3.4).

Table 3.4 Water Consumption Associated with X-Ray Processing.

| Processors | Department | Hrs./day | GPM | Days/yr. | CCF/yr. |
|---|---|---|---|---|---|
| Konica | AAC | 2 | 1 | 365 | 70 |
| M7B Mammo | AAC | 2 | 1.5 | 180 | 72 |
| Kodak 460 RA | AAC | 4 | 1.5 | 365 | 211 |
| M6AN | AAC | 24 | 2.5 | 365 | 2109 |
| M6B | AAC | 3 | 1.5 | 365 | 158 |
| M6AN Angio | AAC | 2 | 1.5 | 250 | 72 |
| M8 #2 Angio | AAC | 2 | 1.5 | 250 | 72 |
| M8 #1 Multi-loader | AAC | 2 | 1.5 | 250 | 72 |
| M8 #3 Angio | AAC | 1 | 1.5 | 250 | 36 |
| Cine Processor | AAC | 1.5 | 2.5 | 261 | 94 |
| M7B Operating Rm. | AAC | 1 | 1.5 | 261 | 38 |
| M7B Laser CT | AAC | 6 | 1.5 | 365 | 316 |
| M6AN | Rehab | 8 | 2.5 | 250 | 482 |
| Dental (Phillips) | Dental | 1 | .5 | 250 | 12 |
| M6B | Nuclear Med. | 1 | 1.5 | 250 | 36 |
| M7B | Ultrasound | 3 | 1.5 | 250 | 108 |
| Konica | Children's | 2 | 1.5 | 365 | 70 |
| M7B Laser | Children's | 1 | 1.5 | 250 | 36 |
| M6AW (Satellite) | Children's | 1 | 1.5 | 250 | 36 |
| Cine (Gaevert R10) | Children's | 1 hr/week | 2.5 | 365 | 13 |
| | | **Total CCF/yr.** | | | **4113** |
| | | **Percent of Total Consumption** | | | **1.6%** |

Source: Popoff (1995b)

### 3.2.8 Medical Vacuum & Medical Air Pumps

HSC has 15 medical vacuum (11 medical and 4 laboratory) and 4 medical air pump units[13] that use a liquid ring of domestic water to seal the pump's chamber, as well as to dissipate waste heat.

An RCC Silent Partner data logger with a one second sampling rate was used to determine the load associated with 15 units. Measurements were taken over a period of three days on each pump from August to November. The order in which the

[13] 18 of the units are Duplex (2 pumps) and 1 is a Triplex (three pumps) unit.

measurements were made were completely randomized. Of the four units that were not included; three have run-time meters, whereas the only other one runs about 5 seconds every hour in order to maintain its pressure . For these units (run-time metered pumps), daily readings were recorded over a two week period in July.

Flow rates associated with each unit were supplied by Gord Berg (1995). With the exception of two units, the remaining medical vacuum or medical air compressors have flow restricters which prevent flows from exceeding a specified limit.

Table 3.5 illustrates the water consumption associated with the medical vacuum and medical air pumps.

**Table 3.5 Water Consumption Associated with Medical Vacuum and Medical Air Pumps.**

| Building | Room # | GPM | % On | CCF/yr. |
|---|---|---|---|---|
| **Medical Vacuum Pumps** | | | | |
| General Hospital | GG-048 | 6 | 66.7 | 3376 |
| | GH-014 | 7 | 80.2 | 4736 |
| Cancer | ON-S01 | 5 | 26.2 | 1105 |
| Women's Hospital | WR-126A | 15 | 5.2 | 658 |
| | WT-656 | 6 | 0 | 0 |
| Respiratory/Rehabilitation | RR-044B | 2.5 | 12.2 | 257 |
| Thorlakson Medical Support | MS-074 | 15 | 2.4 | 303 |
| PsycHealth | PX-030 | 2 | 0 | 0 |
| Sherbrook Parkade | SP-069 | 6 | 2.2 | 111 |
| Children's Hospital | CS-008 | 9 | 44.7 | 3394 |
| **Laboratory Vacuum Pumps** | | | | |
| General Hospital | GG-048 | 1.5 | .8 | 10 |
| Thorlakson Medical Support | MS-074 | 15 | 2.7 | 341 |
| Cancer | 0N-030 | 2.5 | 31.2 | 658 |
| Materials Handling | MH-005 | 1.5 | 4.8 | 60 |
| **Medical Air Pumps** | | | | |
| General Hospital | GG-811 | 5 | 16.9 | 713 |
| Women's Hospital | WS-018 | 4 | 24.2 | 817 |
| Children's Hospital | CS-008 | 9 | 24.2 | 1838 |
| | **Total CCF/yr.** | | | **18,380** |
| | **Percent of Total Consumption** | | | **7.0%** |

### 3.2.9 Domestic

Domestic consumption for HSC was estimated using a combination of published values and personal communications. The published values pertain to consumption estimates associated with the plumbing fixtures, the frequency and time of use with which people use the fixtures, and the number of visitors associated with inpatients. Table 3.6 incorporates these values to estimate the number of imperial gallons consumed per person per day. The methodology used is similar to that in Black and Veatch (1991a; 1991b). The personal communications related to the number of staff, patients (in and outpatients), students, volunteers, and day-care children. Table 3.7 incorporates these values with the per person consumption estimates from table 3.6 to estimate domestic consumption for HSC.

**Table 3.6 Estimated Consumption per Person per Day.**

| | Daytime | Overnight | Visitors | Source |
|---|---|---|---|---|
| **Toilets** | | | | |
| Imp. Gallons per Flush | 4.5 | 4.5 | 4.5 | Environment Canada, 1993 |
| Flushes per Day | 2 | 4 | 1 | Black & Veatch 1991a&b |
| Volume/Person/Day | 9 | 18 | 4.5 | |
| **Faucets** | | | | |
| Imp. GPM | 2 | 2 | 2 | Environment Canada, 1993 |
| Minutes/Person/Day | 7 | 8 | 2 | Black & Veatch, 1991a&b |
| Volume/Person/Day | 14 | 16 | 4 | |
| **Showers** | | | | |
| Gallons per Shower[14] | | 22 | | Environment Canada, 1993 |
| **Total GPD/Person** | **23** | **56** | **8.5** | |

[14] Based on a 5 minute shower.

**Table 3.7 Water Consumption Associated with Domestic Water Production.**

| | Daily | Overnight | Visitors | Source |
|---|---|---|---|---|
| Staff | 5000 | | | Koslowsky, 1995 |
| Students | 238 | | | Kirk, 1995; Loveridge, 1995; Nicol, 1995; Yachemitz, 1995 |
| Volunteers | 165 | | | Anderson, 1995; Good, 1995; Hickerson, 1995 |
| Day-care | 32 | | | Braun, 1995 |
| Lennox Bell Lodge | | 54 | | Squires, 1995 |
| Outpatients | | | 360 | Stack, 1995 |
| Inpatients | | 855 | | Koslowsky, 1995 |
| Visitors | | | 1710[15] | Black and Veatch, 1991a&b |
| | | | | |
| Total Persons/Day | 5435 | 909 | 2070 | |
| Total GPD/Person | 23 | 56 | 8.5 | |
| Days | 251 | 365 | 251 | |
| Sub total: CCF/yr. | 50,363 | 29,823 | 7089 | |
| | **Total CCF/yr.** | | | **87,275** |
| | **Percent of Total Consumption** | | | **33.3%** |

### 3.2.10 Hot Water

Hot water is produced in many locations throughout HSC, however, none of these locations are exclusively metered. As a result, the only way to estimate hot water production was via the Maintenance building's water meter. This meter accounts for HSCs central hot water supplied to the following buildings: GA-GH, AD, MA, LB, WR/WS/WT, LA2&3. Central hot water was then estimated by subtracting the two-year annual average (Maintenance Building) from all the known water uses within the Maintenance Building (Domestic and Condenser[16]).

Domestic consumption was not estimated using the same methodology as described in section 3.2.9, since it was not possible to determine the number of people working in

[15] 2 Visitors per Patient (Black and Veatch, 1991a; 1991b).

[16] Methodology described in section 3.2.11.

the Maintenance building on a daily basis. Domestic consumption was estimated based on the square footage of the building. Consumption per square foot was estimated by dividing the annual domestic value from table 3.7 (87,275 CCF) into the total square footage associated with all the buildings (1,999,965) except for the Central Energy Plant. The CEP was not included in the total due to its large square footage and limited number of people. As a result, per square foot domestic consumption was estimated to be 0.043 CCF/sq. ft.. Using 0.043 CCF/sq. ft. to estimate domestic consumption for the Maintenance building, table 3.8 estimates the amount of hot water consumed per square foot based upon central hot water production in the Maintenance building. The Maintenance building was chosen since it produces a significant proportion of HSCs hot water and other water uses within the building are limited.

**Table 3.8 Hot Water Consumption per Square Foot.**

| | | | |
|---|---|---|---|
| **Domestic** | **Square Footage**<br>37,431 | **CCF/Sq. ft.**<br>.043 | **Total (CCF/yr.)**<br>(1610) |
| **Condenser** | **CCF/period** | | |
| | **Summer Consumption** | **Winter** | |
| Plumbing Shop | 340 | 197 | |
| CCMS | 0 | 236 | |
| | | | (773) |
| **Annual Average** | **CCF/period** | | |
| | **Fiscal Year 93/94** | **Fiscal Year 94/95** | |
| | 14,025 | 14,295 | |
| | | | 14160 |
| | **Total Hot Water (CCF/Yr.) Produced in MA Bldg** | | **11,777** |
| | **Square Footage Served by Hot Water** | | **737,915** |
| | **Hot Water (CCF)/Sq.Ft.** | | **0.016** |

Using the 0.016 CCF/sq. ft. value, table 3.9 estimates consumption for the remaining buildings.

**Table 3.9 Water Consumption Associated with Hot Water Production.**

| Building | Square Footage | CCF/Year |
|---|---|---|
| PsycHealth | 179,073 | 2865 |
| Thorlakson Medical Support | 259,695 | 4155 |
| Children's | 235,231 | 3764 |
| Cancer | 99,941 | 1599 |
| School of Nursing | 89,324 | 1429 |
| Respiratory/Rehabilitation Hospital | 200,825 | 3213 |
| Materials Handling | 56,367 | 902 |
| Community Services | 59,150 | 946 |
| Financial Services | 15,186 | 243 |
| Self-Care Dialysis | 8876 | 142 |
| Maintenance Service | 737,915 | 11807 |
| | **Total CCF/yr.** | **31,065** |
| | **Percent of Total Consumption** | **11.9%** |

As domestic consumption is already accounted for, extreme caution should be exercised when interpreting hot water consumption as double-counting is likely.

### 3.2.11 Water-Cooled Condensers

HSC has approximately 95 water-cooled condensers located throughout the complex. They are used to provide local space or process cooling. All but 16 of these units use water in a single pass capacity, the remaining 16 can be converted to use the existing multi-pass chilled water loop (spooled[17]) during summer operations.

A preliminary list of condensers was identified by Navarro (1994), but it had a limited scope. Therefore, visual inspections of all mechanical rooms, as well as a literature search of project information by Rick Van Dulman (1995), identified the remaining condensers.

[17] Spool refers to a removable section of chilled water supply and return piping that is removed from the domestic water supply in summer, so that the condenser can run on the existing chilled water loop.

Since existing HSC horsepower data was insufficient, SMS consultants (1996) calculated the theoretical horsepower associated with each condenser[18] using formula 3.1.

For 3ph motor HP = 1.73*V*rla*0.9(motor factor)*0.8(power factor)*0.00134(conversion factor) (3.1)

In order to calculate the theoretical flows, the temperature differential between the inlet and outlet water temperature was required for all condensers. Inlet and outlet temperatures were recorded in July using a Thermocouple Type J digital thermometer, where measurements were obtainable. This method provided the summer differentials. For winter differentials, the same outlet temperature was used[19], but an inlet temperature of 45°F was observed in December. Where temperature differentials could not be obtained a 20°F delta was used in the summer and a 45°F delta in winter.

Theoretical flow rates were calculated using formula 3.2.

US GPM per horsepower[20] = 14,544/(500*(Δ°F)) (3.2)

When verifying the accuracy of these calculations, there was a discrepancy between the theoretical and actual flow rates. Bucket and stopwatch measurements in July, indicated that actual flow rates were in fact much smaller than the calculated flow rates. To provide additional data to this fact, an ultrasonic clamp-on flow meter was used in November. Due to time limitations, the flow meter only took measurements over a one

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[18] SMS (1996) calculated the theoretical horsepower for the following condensers: GC-107, GC-010C, GD-043 (F-37 & F-38), GG-347B, GG-346, GH-195A, GH-014, NA-029A, TW37B, TW37D, RR-044B, RR-029A, WT-563, WS-202A, WS-002, BA-001, ON-302, ON-245, ON-231, ON-040, CS-231, CS-111, CS-105, CS-006, MS BLDG, and FE-018. Horsepower's and flow rates for all the compressors are identified in Appendix C.

[19] All condensers have thermo-regulating valves that control the outlet temperature.

[20] Perry (1976).

day interval. As a result of these measurements, actual flow rates were on average 50% smaller than theoretical flow rate (see Appendix C).

To determine the run times associated with the condensers, an ACR current logger using an eight second sampling rate was attached to the load side of the condenser motor for a period of three days. The ACR recorded the amperage drawn by the condenser's motor. Amperage was used as a proxy for run time, since amperes are only drawn when the condenser is running. Condensers were chosen using a two stage process since the installation of the device required the services of the Electrical shop. First, all inconveniently located condensers were removed from the sample list; from which, twenty-five condensers were randomly selected. Time limitations resulted in the sample size being reduced from twenty-five to fifteen. Monitoring occurred from late July to the end of November incorporating both summer and winter loads. These measurement identified an average run time for HSCs water-cooled condensers at 59% (see Appendix D).

Consumption per condenser was calculated using formula 3.3 for winter and formula 3.4 for summer consumption resulting in an overall consumption estimate of 77,064 CCF/yr or 29.4% of total consumption (see Appendix E).

Winter Consumption = formula (3.2)*horsepower*60 minutes/hour*24 hrs/day*200 days*.59 (average load)*.50 (average theoretical adjustment) (3.3)

Summer Consumption = formula (3.2)*horsepower*60 minutes/hour*24 hrs/day*165 days*.59 (average load)*.50 (average theoretical adjustment) (3.4)

## 3.3 Summary

Sections 3.2.1 to 3.2.11 detailed the methodology used to establish estimates of per category water use. Table 3.10 is a water balance comparing the per category consumption estimates against HSCs annual consumption.

Table 3.10 only compares estimated consumption versus actual consumption for the entire hospital. A number of water meters located throughout the complex. That afforded an opportunity to assess the accuracy or acceptability of the entire methodology for estimating consumption. In Appendix F, per category estimates were compared to the two-year annual averages associated with the various water meters or sub-meters at HSC (see Appendix F), indicating that the overall methodology is more likely to be accurate as the number of buildings a water meter services increases. As a result, a sensitivity analysis should be conducted when determining the economic feasibility of a particular minimization option in order to account for the increased variability.

**Table 3.10 Health Sciences Centre Major Water Use Consumption Estimates.**

| Water Use Category | CCF/Yr. | Percent |
|---|---|---|
| Sterilizers | 15,242 | 5.8 |
| Dialysis | 7675 | 2.9 |
| Kitchen and Cafeteria | 7563 | 2.9 |
| Water Softening (Steam Production) | 4970 | 1.9 |
| Air Compressors | 10,893 | 4.2 |
| Cooling Tower and Chilled Water Makeup | 9768 | 3.7 |
| X-Ray Processing | 4115 | 1.6 |
| Medical Vacuum & Medical Air Pumps | 18,380 | 7.0 |
| Domestic | 87,275 | 33.3 |
| Hot Water[21] | 31,065 | 11.9 |
| Water-Cooled Condensers | 77,064 | 29.4 |
| **Total** | **274,010** | **104.6%** |

Given these figures, cost savings (benefits) are now identifiable permitting the use of a cost-benefit analysis framework to evaluate potential water conservation measures.

[21] Figure undoubtedly includes double-counting.

## Chapter 4 Feasibility Analysis

### 4.1 Introduction

For the majority of water uses identified in Chapter 3, options exist to reduce consumption, though not all are feasible at this time. Chapter 4 will identify and economically evaluate water saving measures for each water use category based on capital and operating costs, cost savings, and payback periods. Feasible options will be prioritized based on a sensitivity analysis of their net present value after five years.

### 4.2 Sterilizers

Changes in Manitoba's *Ozone Depleting Substances Act* resulted in HSC replacing the existing "12/88" (12% CFC-12 and 88% Ethylene Oxide gas) sterilizers with new disposable cartridge based systems using 100% Ethylene Oxide. Unlike the old system, no domestic water is required during sterilization. To meet demand, an additional steam sterilizer (135 gallon per cycle water saving model) was required.

In January 1995, water saving retrofit kits were installed on the existing steam sterilizers, in WT-069 and GG-049, converting them from 600 to 135 gallons per cycle units (Koslowsky, 1995). The result of these changes is an overall reduction in consumption of 8825 CCF/yr or 3.4%.

### 4.3 Dialysis

Reverse osmosis is a water intensive process and little opportunity exists to reduce consumption. Flow meters are monitored daily. However, they focus on quality (electrolyte analysis and conductivity measurements), not quantity, since the amount of water consumed by reverse osmosis is relatively fixed (Lepp, 1995).

### 4.4 Kitchen And Cafeteria

Dishwashing is the most significant water use in HSCs kitchens and cafeterias. Of the five dishwashers, two are relatively water-efficient (Rehab and Main kitchens), two have water efficient replacements identified (Cafe on 2 and Tunnel cafeterias), and one will be eliminated (Children's cafeteria). Eliminating the Oasis cafeteria dishwasher will reduce over consumption by 1165 CCF/yr or 0.4% as this cafeteria is going to disposable products. Recently, capital funding to replace the Cafe on 2 and Tunnel Cafeteria's dishwashers was rejected (Walker, 1996) as replacing dishwashers in not justified based on energy and water savings alone (see Section 4.13).

### 4.5 Water Softening (Steam Production)

The CEP monitors water consumption associated with water softening on a daily basis using a series of water meters. Water savings can be realized by reducing the amount of makeup water required by reducing the amount of steam required, changing operating procedures that reduce the number of regeneration's required, and/or increasing the amount of condensate (condensed steam) returned to the CEP.

Recently, boiler makeup water has decreased due to an increase in the amount of condensate returned (Lehmann, 1995). Also, Lehmann (1995) states that a change in operating procedures has reduced the number of regeneration's required. However, the savings associated with these changes have yet to be determined.

### 4.6 Air Compressors

In the past, approximately 65% (Lehmann, 1995) of air compressor cooling water was reused, via the "swimming pool[22]", for cooling tower and chilled water makeup during summer operations (6 months). Recently, a recirculating cooling loop was installed eliminating water consumption. Such a change will reduce total consumption by 6529 CCF/yr or 2.5% of total consumption.

### 4.7 Cooling Tower And Chilled Water Makeup

Makeup water is required to account for losses associated with evaporation, bleed-off, and leakage. The quantity of makeup water required depends on the rates at which losses occur. Of the three, savings can only be achieved from reducing the amount of bleed-off and leakage.

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[22] A storage tank with overflow drainage located in the sub-basement of the Central Energy Plant.

The Central Energy Plant uses conventional chemical treatment and sulfuric acid to reduce impurities within the chilled water loop. As a result , HSC is operating at a concentration ratio of 5 (Lehmann, 1995). Black & Veatch (n.d.) estimate that acid treatment in conjunction with conventional chemistry can achieve concentration ratios up to 6 cycles. In which case, savings associated with bleed-off are limited.

However, savings associated with system losses do exist. During the summer of 1995, average daily makeup required to operate HSCs chilled water loop was 2010 imperial gallons. These losses are a result of 31 chilled water pumps using packing seals. These seals are not water-tight and require periodic maintenance and/or replacement to minimize losses. Due to chemical treatment, these losses are significant as the cost per 1000 imperial gallons of makeup water is $66.38. Currently, a program is in place to replace these seals with water-tight mechanical seals resulting in savings of approximately 0.2% or 530 CCF/yr[23].

### 4.8 X-Ray Processing

Eighteen out of twenty of HSCs x-ray processors have stand-by switches to shut the water off approximately 2-3 minutes after a film has been processed. The two units that do not have stand-by switches (M6AN in GG-187 and Rehab) consume water whenever the machine is on, whether or not a film is being processed. Current restructuring and renovation plans will see these units replaced with new water efficient processors (Popoff, 1995a). The amount of water saved will depend on the number of hard copies processed and the exact nature of the restructuring.

### 4.9 Medical Vacuum & Medical Air Pumps

All of HSCs medical vacuum and medical air pumps use a liquid ring to seal the pump chamber, as well as to dissipate waste heat. Ninety percent water-saving retrofit kits are available, for medical vacuum pumps. The CSA code prevents their use with medical air compressors (Miller, 1995a). Potentially three vacuum units; CS-008, GG-

[23] Based on 165 days of chilled water service (Lehmann, 1995).

048, and GH-014; can be retrofitted with 90% water saving retrofit kits. Retrofitting CS-008 and GG-048 would reduce consumption by 2.2% or 5819 CCF/yr. Currently, a study is underway to determine whether the vacuum unit in CS-008 can assume GH-014's load, as this unit is very old and inefficient. If the option of converting GH-014's load proves feasible, an additional 4736 CCF/yr or 1.8% (slightly less than this due to the increased load on CS-008) can be realized. If not, then a 90% retrofit kit is available and would only save 1.6% not 1.8% of total consumption.

## 4.10 Domestic

Domestic consumption represents the single largest water use at HSC (33.3%), however, the extent of the savings are limited by the existing plumbing infrastructure, plumbing code requirements, and health concerns.

Tankless toilets with flushometers flush valves are almost exclusively used throughout HSC. These flush valves can be adjusted to consume less water, however, present bowl geometry limits the amount of savings available (Berg, 1995). Also, there are health concerns, bacteria and infections, associated with inadequate flushing.

Another option is to change to new ultra-low volume (ULV) toilet bowls. This option is expensive because, in addition to the bowl costs, ULV bowls require different piping runs and fittings. The option to convert to ULVs is limited to new developments and renovation zones.

In order to prevent air borne bacteria from entering the water supply, the Plumbing Code does not permit aerated flow restricting devices in hospitals. As a result, laminar flow devices, using a series of screens, have been developed to reduce consumption. These devices are much more expensive than aerated models (approximately $6 per compared to $2) and have higher flow rates of 2.0 US gpm (33% savings) compared to 0.5 US gpm (83% savings) for aerated models.

### 4.11 Hot Water

Savings associated with hot water are linked to savings elsewhere. Savings may be realized by technical improvements (e.g. flow restricting devices), improving general operating procedures (e.g. full loads in dish and clotheswashers), and/or employee education (e.g. eliminating unnecessary flows -- only running water when required). Due to the linkages elsewhere, cost savings associated with these measures are difficult to quantify, and in the case of improving general operating procedures and employee education difficult to verify.

### 4.12 Water-Cooled Condensers

Water-cooled condensers represent the second largest water use (29.9%) at HSC. This use has increased over the years to meet localized space cooling or refrigeration needs. The problem with these units is that water is only used in a single-pass capacity to dissipate waste heat. One option is to convert these units from water to air-cooled. However, due to the large number of units (~92) and finite space (roof tops) to locate the air conditioning units, this option is only preferred for a limited number of condensers, which will be identified later. As a result, the Health Sciences Centre commissioned a preliminary engineering study (HSC Project No. 95-20-SP) to evaluate the possibility of operating the existing chilled water loop year round. The study was based on the premise that "winter chilled water would be provided by a process fluid cooler and a plate heat exchanger located in the Central Energy Plant" (SMS, 1996, p.1). SMS (1996) identified the cost of the fluid cooler and associated distributional hardware, piping requirements, and operating expenses; as well as identifying condensers that were not included in the study. By operating the chilled water loop year-round, HSC can reduce its present water consumption by approximately 25.5% or 66,711 CCF/yr. Additional savings of 1.9% or 4938 CCF/yr can be realized by converting three existing water-cooled condensers, excluded[24] from the year round study (BA-001, GF-632, and GC-420), to air-cooled units.

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[24] Excluded condensers include: FE-018, BA-001, GC-420, GD-725, GE-708, GF-632 (SMS, 1996).

## 4.13 Economic Evaluation and Prioritization of Water Saving Measures

Sections 4.2 to 4.12 identified a number of water saving measures available to HSC. However, two questions still needed answering: i) Are these measures feasible? And if so, ii) What is its relative priority in relation to other measures? Table 4.1 answers the first question by evaluating each option based on their capital and operating costs, cost savings, and payback period[25]. Using a payback period of 5 years or less to determine the feasibility of a conservation option, it was not feasible to replace dishwashers based on energy and water savings alone.

Table 4.2 answers the second question by conducting a negative bias sensitivity analysis. Measures that could effect feasibility and/or priority, such as capital cost increases, consumption overestimation, and differences in water rate increases, were selected to identify the range of probable outcomes (high and low sensitivity estimates).

Since the Health Sciences Centre is a public institution, the criteria for choosing among competing investment opportunities (Projects) should be the project that has the highest net present value as it contributes the most to the welfare of society (Treasury Board, 1976). Such an approach to decision-making complements the Provincial government's position on Sustainable Development: "employees and organizations at all levels must identify what they do that has an impact on the environment and economy and they must isolate and correct the causes of and activities which are unsustainable" (Manitoba Round Table on Environment & Economy, 1992, p.iii). The average five year net present value, in Table 4.2, was used to prioritize the various water saving measures. This value was used as it indicates the foregone benefits or opportunities of the various projects over a short-term planning horizon. Also, included in table 4.2 is the net present value over 20 years reflecting the foregone opportunity or benefits over the life of the equipment.

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[25] Payback periods were calculated using the following formula: Capital Cost/(CCF Saved/yr*Cost/CCF - Operating Costs). The Cost/CCF used was $3.74 (combined water and sewer rate for 1996). The proposed ten to twelve percent per year increase in the water and sewer rate were not included in the calculations. Thus, the payback periods did not change when the water and sewer rates changed in Table 4.2.

## Table 4.1 Economic Evaluation of Water Conservation Options

| Use Category | Type of Saving | Cost Data Source | Capital Cost[1] | Operating Cost | Cost Savings | Payback Period[2] | CCF/YR Saved | Status |
|---|---|---|---|---|---|---|---|---|
| Sterilizers | Retrofit sterilizers (WT-069 & GG-049)3 | Koslowsky, 1994 | $ 22,504 | $ 1,000 | $ 8,950 | 2.5 years | 3,555 | Completed |
| | Replace EtO sterilizers | Statutory Requirement | | | | | 6,812 | Completed |
| | Install New Steam sterilizer | To Meet Demand due to Statutory Requirement | | | | | (1,542) | Completed |
| | | | | | | | | |
| Kitchen/Cafeteria | Replace Tunnel Dishwasher | Walker, 1996 | $ 22,640 | Undetermined | $ 3,422 | >6 years | - | Not Feasible |
| | Replace Cafe on 2 Dishwasher | Walker, 1996 | $ 65,000 | Undetermined | $ 2,500 | >10 years | - | Not Feasible |
| | Eliminate Oasis Cafeteria Dishwasher | | | | | | 1,165 | |
| | | | | | | | | |
| Air Compressor | Install Recirculating Cooling Loop | Lehmann, 1996 | $ 31,155 | $ 12,000 | $ 24,418 | 2.5 years | 6,529 | Completed |
| | | | | | | | | |
| Chilled Water | Replace Packing Seals with Mechanical Seals[4] | Cruickshank, 1996 | $44,082 | N/A | $ 21,916 | 2.0 years | 530 | On-Going |
| | | | | | | | | |
| X-Ray Processing | Department Restructuring | Unknown, Not Based on Energy or Water Savings | | | | | N/A | On-Going |
| | | | | | | | | |
| Medical Vacuum | Retrofit Vacuum Pump in CS-008 | Miller, 1995 | $ 17,100 | $ 800 | $ 11,284 | 1.6 years | 3,017 | See Table 4.2 |
| | Retrofit Vacuum Pump in GG-048 | Miller, 1995 | $ 11,400 | $ 800 | $ 10,479 | 1.2 years | 2,802 | See Table 4.2 |
| | Put GH-014 Vacuum Pump's Load on CS-008 | | Currently Under Review | | | | 4,736 | |
| | | | | | | | | |
| Domestic | Install Faucet Moderators | | Requires Further Study, See Section 5.2 | | | | | |
| | Adjust Flush Valves | | Requires Further Study, See Section 5.2 | | | | | |
| | | | | | | | | |
| Condensers | Install Year Round Cooling Loop | SMS, 1996 | $ 784,206 | $ 18,200 | $ 249,499 | 3.4 years | 66,711 | See Table 4.2 |
| | Convert BA-001Condenser to Air Cooled | Bettencourt, 1996 | $ 12,612 | Unchanged | $ 4,155 | 3.0 years | 1,111 | See Table 4.2 |
| | Convert GF-632 Condenser to Air Cooled | Bettencourt, 1996 | $ 16,577 | Unchanged | $ 9,376 | 1.8 years | 2,507 | See Table 4.2 |
| | Convert GC-420 Condenser to Air Cooled | Bettencourt, 1996 | $ 16,480 | Unchanged | $ 4,937 | 3.3 years | 1,320 | See Table 4.2 |

[1]Including installation costs and appropriate taxes.

[2]Based on 1996 water rate at $3.74/CCF. Payback Period = Capital Costs/(CCF/yr saved*$3.74/CCF-Operating Costs).

[3]Based on 1994 costing data ($2.80/CCF), not adjusted for inflation.

[4]Cost savings based on $41.35/CCF.

## Table 4.2 Sensitivity Analysis and Prioritization of Water Conservation Options

| Use Category | Type of Saving | | Capital Costs | | Consumption | | | Water & Sewer Rate | | | Summary Statistics | | | Priority[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Discount Rate[1] = 4.775% | +25% | +50% | -10% | -25% | -50% | 0%/yr | +5.3%/yr | +10.6%/yr | Mean | Sensitivity | | |
| | | | | | | | | | | Present Condition | | High | Low | |
| Medical Vacuum | Retrofit Vacuum Pump in CS-008 | Net Present Value (5 years) | $ 33,706 | $ 29,626 | $ 32,043 | $ 23,428 | $ 9,070 | $ 27,270 | $ 32,263 | $ 37,787 | $ 28,149 | $ 9,070 | $ 37,787 | 4 |
| | | Net Present Value (20 years) | $ 330,578 | $ 326,498 | $ 97,157 | $ 244,489 | $ 154,319 | $ 110,787 | $ 189,637 | $ 334,658 | $ 223,515 | $ 97,157 | $ 334,658 | |
| | | Simple Payback Period[3] | 2.0 | 2.4 | 1.8 | 2.2 | 3.5 | 1.6 | 1.6 | 1.6 | 2.1 | 3.5 | 1.6 | |
| | Retrofit Vacuum Pump in GG-048 | Net Present Value (5 years) | $ 36,414 | $ 33,694 | $ 33,785 | $ 33,785 | $ 12,464 | $ 29,367 | $ 34,004 | $ 39,134 | $ 31,581 | $ 12,464 | $ 39,134 | 3 |
| | | Net Present Value (20 years) | $ 311,675 | $ 308,955 | $ 280,802 | $ 280,802 | $ 146,908 | $ 106,478 | $ 179,709 | $ 314,395 | $ 241,216 | $ 106,478 | $ 314,395 | |
| | | Simple Payback Period | 1.5 | 1.8 | 1.3 | 1.6 | 2.6 | 1.2 | 1.2 | 1.2 | 1.5 | 2.6 | 1.2 | |
| Condensers | Install Year Round Cooling Loop | Net Present Value (5 years) | $ 258,699 | $ 71,582 | $ 318,819 | $ 128,326 | - | $ 213,274 | $ 323,684 | $ 445,815 | $ 251,457 | $ 71,582 | $ 445,815 | 1 |
| | | Net Present Value (20 years) | $ 6,818,966 | $ 6,631,849 | $ 6,208,561 | $ 5,012,279 | - | $ 2,055,917 | $ 3,799,411 | $ 7,006,082 | $ 5,361,866 | $ 2,055,917 | $ 7,006,082 | |
| | | Simple Payback Period | 3.7 | 4.5 | 3.8 | 4.6 | - | 3.4 | 3.4 | 3.4 | 3.8 | 4.6 | 3.4 | |
| | Convert BA-001Condenser to Air Cooled | Net Present Value (5 years) | $ 6,103 | $ 3,094 | $ 6,998 | $ 3,825 | $ (1,462) | $ 5,240 | $ 7,079 | $ 9,113 | $ 4,999 | $ (1,462) | $ 9,113 | 5 |
| | | Net Present Value (20 years) | $ 133,879 | $ 133,879 | $ 120,491 | $ 100,409 | $ 66,939 | $ 51,439 | $ 80,475 | $ 133,879 | $ 102,674 | $ 51,439 | $ 133,879 | |
| | | Simple Payback Period | 3.8 | 4.6 | 3.4 | 4.0 | 6.1 | 3.0 | 3.0 | 3.0 | 3.9 | 6.1 | 3.0 | |
| | Convert GF-632 Condenser to Air Cooled | Net Present Value (5 years) | $ 67,502 | $ 71,457 | $ 27,131 | $ 19,972 | $ 8,041 | $ 23,165 | $ 27,314 | $ 31,903 | $ 34,561 | $ 8,041 | $ 71,457 | 2 |
| | | Net Present Value (20 years) | $ 319,486 | $ 323,441 | $ 253,916 | $ 208,960 | $ 134,033 | $ 97,860 | $ 163,380 | $ 283,887 | $ 223,120 | $ 97,860 | $ 323,441 | |
| | | Simple Payback Period | 2.2 | 2.7 | 2.0 | 2.4 | 3.5 | 1.8 | 1.8 | 1.8 | 2.3 | 3.5 | 1.8 | |
| | Convert GC-420 Condenser to Air Cooled | Net Present Value (5 years) | $ 5,467 | $ 1,535 | $ 6,887 | $ 3,117 | $ (3,165) | $ 4,798 | $ 6,983 | $ 9,400 | $ 4,378 | $ (3,165) | $ 9,400 | 6 |
| | | Net Present Value (20 years) | $ 138,143 | $ 134,211 | $ 126,295 | $ 102,624 | $ 63,173 | $ 44,127 | $ 78,625 | $ 142,075 | $ 103,659 | $ 44,127 | $ 142,075 | |
| | | Simple Payback Period | 4.2 | 5.0 | 3.7 | 4.5 | 6.7 | 3.3 | 3.3 | 3.3 | 4.3 | 6.7 | 3.3 | |

[1]Discount rate = 6.875% (5 year GIC return as of 5/6/1996) - 2.1% (Inflation rate 1995).

[2]Based on Net Present Value over 5 years.

[3]Simple Payback Period does not account for increases in the water & sewer rate. Payback Period = Capital Costs/(CCF/yr. saved*$3.74/CCF-Operating Costs).

With the exception of the GF-632 condenser, there is a clear hierarchy with respect to 'like' options. HSC should pursue year round cooling first, as it clearly has the largest net present value; followed by vacuum pump retrofits; and finally, converting individual water-cooled condensers to air-cooled. This hierarchy should be followed instead of the priority ratings in table 4.2 for two reasons: i) the average net present values for GF-632 and vacuum pumps are quite close, and ii) potential cost savings may be realized by grouping 'like' projects (e.g. travel and per diem expenses for vacuum pumps and crane rental for air-cooled condensers).

## 4.14 Summary

Chapter 4 identified a number of water saving initiatives available to HSC. Some have recently been completed or are currently on-going, whereas others have potential for future installation. At present, the only potential option that was not feasible, based on a payback period of five years or less, was installing new dishwashers based on their energy and water savings alone. The remaining options were feasible and were prioritized according to their net present value over five years, resulting in the following implementation hierarchy:

1. Provide Year Round Chilled Water
2. Retrofit CS-008 and GG-048 Vacuum Pumps with 90% Recirculation Retrofit Kits
3. Convert BA-001, GF-632, and GC-420 Water-Cooled Condensers to Air-Cooled.

These changes, in conjunction with recently completed and on-going projects or programs over the past year, will result in an overall reduction of 99,253 CCF/yr or 37.9% resulting in annual savings of approximately $390,000 (based on 1996 costs).

## Chapter 5 Conclusion and Recommendations

### 5.1 Conclusion

HSC has seen water-related expenditures increase by 10.6% per year over the past four years due to water and sewer rate increases. These increases have created an incentive to reduce consumption. As a result, research was undertaken to identify and evaluate potential water saving measures available to HSC, as well as other large scale tertiary care hospitals, in order to reduce present and future water-related expenditures.

This was accomplished by systematically identifying consumption estimates for HSCs major water uses (see figure 5.1). From which, potential water minimization options were identified and economically evaluated according to capital and operating costs, cost savings, simple payback period, and five year net present value. The five year net present value was then used to prioritize the potential minimization options which have not been completed or are currently on-going. The result is HSC can reduce present consumption by approximately 99,250 CCF/yr. or 37.9% and realize savings close to $387,000/yr (see table 5.1).

### 5.2 Recommendations

Currently, a portion of these savings are being realized as some projects have been completed or are currently on-going (see table 5.1). However, they only account for 17,049 CCF/yr or 17.2% of identified savings while the remaining savings are contingent upon future installations, retrofits, or replacements. Thus, the following recommendations:

1. HSC should adopt the following water minimization implementation hierarchy:

    i. Provide Year Round Chilled Water (NPV = $251,457),
    ii. Retrofit CS-008 (NPV = $28,149) and GG-048 (NPV = $31,581) Vacuum Pumps with 90% Recirculation Retrofit Kits, and

**Figure 5.1 HSCs Major Water Use Consumption Estimates**

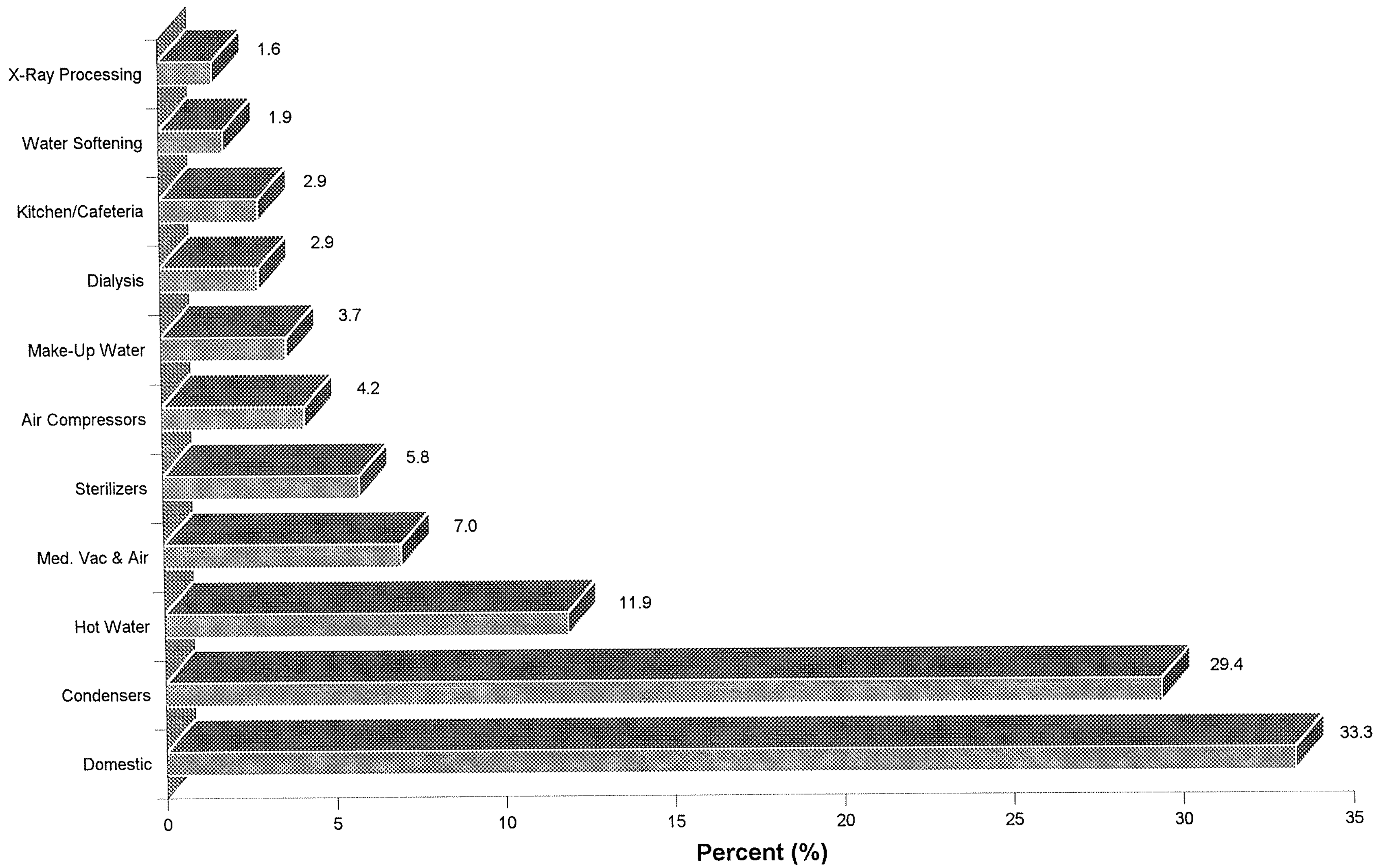

**Table 5.1 Summary of Water Conservation Options Available to HSC**

| Use Category | Type of Saving | Capital Cost[1] | Operating Cost | Cost Savings | CCF/YR Saved | Percent | Payback Period[2] | Net Present Value (5 yr)[3] | Implementation Status |
|---|---|---|---|---|---|---|---|---|---|
| Sterilizers | Retrofit sterilizers (WT-069 & GG-049)4 | $ 22,504 | $ 1,000 | $ 8,950 | 3,555 | 1.4% | | | Completed |
| | Replace EtO sterilizers | Statutory Requirement | | $ 25,477 | 6,812 | 2.6% | | | Completed |
| | Install New Steam sterilizer | Required to meet Demand | | $ (5,767) | (1,542) | -0.6% | | | Completed |
| | | | | | | | | | |
| Kitchen/Cafeteria | Eliminate Oasis Cafeteria Dishwasher | | | $ 4,357 | 1,165 | 0.4% | | | On-Going |
| | | | | | | | | | |
| Air Compressor | Install Recirculating Cooling Loop | $ 31,155 | $ 12,000 | $ 24,418 | 6,529 | 2.5% | | | Completed |
| | | | | | | | | | |
| Chilled Water | Replace Packing Seals with Mechanical Seals[5] | | | $ 21,916 | 530 | 0.2% | | | On-Going |
| | | | | | | | | | |
| X-Ray Processing | Department Restructuring | Not based on Energy or Water savings | | | N/A | | | | On-Going |
| | | | | | | | | | |
| Medical Vacuum | Retrofit Vacuum Pump in CS-008 | $ 17,100 | $ 800 | $ 11,284 | 3,017 | 1.2% | 1.7 - 2.6 years | $22,557 - $33,742 | Second Priority |
| | Retrofit Vacuum Pump in GG-048 | $ 11,400 | $ 800 | $ 10,479 | 2,802 | 1.1% | 1.2 - 1.9 years | $26,385 - $36,777 | Second Priority |
| | Put GH-014 Vacuum Pump's Load on CS-008 | Currently Under Review | | $ 17,713 | 4,736 | 1.8% | N/A | N/A | |
| | | | | | | | | | |
| Domestic | | Requires Further Study, See Section 5.2 | | | | | | | |
| | | | | | | | | | |
| Condensers | Install Year Round Cooling Loop | $ 784,206 | $ 18,200 | $ 249,499 | 66,711 | 25.5% | 3.4 - 4.2 years | $174,181 - $328,733 | First Priority |
| | Convert BA-001Condenser to Air Cooled | $ 12,612 | Unchanged | $ 4,155 | 1,111 | 0.4% | 3.1 - 4.6 years | $2921 - $7077 | Third Priority |
| | Convert GF-632 Condenser to Air Cooled | $ 16,577 | Unchanged | $ 9,376 | 2,507 | 1.0% | 1.8 - 2.7 years | $19,428 - $49,694 | Third Priority |
| | Convert GC-420 Condenser to Air Cooled | $ 16,480 | Unchanged | $ 4,937 | 1,320 | 0.5% | 3.5 - 5.1 years | $1866 - $6890 | Third Priority |
| | **Total** | | | **$ 386,794** | **99,253** | **37.9%** | | | |

[1]Including installation costs and appropriate taxes.

[2]Based on 1996 water rate at $3.74/CCF.

[3]From Table 4.2

[4]Based on 1994 costing data ($2.80/CCF), not adjusted for inflation.

[5]Cost savings based on $41.35/CCF.

iii. Convert BA-001 (NPV = $4999), GF-632 (NPV = $34,561), and GC-420 (NPV = $4378) Water-Cooled Condensers to Air-Cooled.

This implementation hierarchy does not follow the priority scheme in table 4.2 for two reasons. First, the net present values for the GF-632 water-cooled condenser and vacuum pumps in CS-008, and GG-048 are quite close. Secondly, by grouping minimization options into similar classes, potential cost savings may be realized with respect to crane rental (water-cooled condensers) and per diem and travel expenses (medical vacuum pumps).

By following the implementation hierarchy, HSC will maximize its return on investment while eliminating unsustainable water use at the hospital.

2. HSC proceed with the installation of the winter chilled water supply as described by SMS (1996) so as to provide year round chilled water.

With year round chilled water available, almost all of the water-cooled condensing units can be converted from a single-pass domestic water supply to the existing recirculating chilled water loop. The project costs approximately $800,000 with annual cost savings, net of operating costs, of approximately $230,000, translating into a payback period between 3.4 to 4.6 years. It is the most significant of all the water minimization options, identified in table 5.1, as it represents 67% of the identified potential savings (25.5% overall reduction) and has the largest net present value over twenty years ($174,181 - $328,733).

3. HSC proceed with the technical assessment required to operate the medical vacuum pumps in CS-008 and GG-048 at 90% recirculation.

Retrofitting these units is second on the implementation hierarchy. Potential cost savings (travel and per diem expenses) can be realized by combining the installation of the two units since a technical assessment by the vacuum pump's manufacturer is required.

These kits are available in either air or water-cooled models. Since the mechanical rooms, in question, are not vented and are warm to begin with, the water-cooled option was chosen for costing purposes. However, it requires year round chilled water. For CS-008, the retrofit costs approximately $17,000 producing annual cost savings, net of operating costs, of $10,000 and translating into a payback period of 1.6 to 3.5 years. While GG-048 will cost $11,400 with annual savings, net of operating costs, of approximately $9500 or a payback period of 1.2 to 2.6 years.

Currently, a study is underway to determine whether the GH-014 vacuum pump's load can be assumed by the CS-008 vacuum pump unit (Berg, 1996). If so, converting GH-014s load to the CS-008 will positively affect the annual cost savings and payback period associated with the CS-008 vacuum pump unit.

Retrofitting CS-008 and GG-048 will reduce overall consumption by 5819 CCF/yr or 3.3%.

4. HSC convert three of the water-cooled condenser units not feasible in the SMS (1996) proposal (BA-001, GC-420, and GF-632) to air-cooled units.

Seven water-cooled condensers were not feasible in the SMS (1996) proposal. Three of the units (BA-001, GC-420, and GF-632) can be converted from the existing single pass water supply to air-cooled eliminating water use. Converting these units is last on the implementation priority list (recommendation 1) as the net present values are low compared to the other options (see table 5.1). The exception is the GF-632 condenser. This condenser, ranked second in table 4.2, is in the third classification due to potential cost savings (crane rental) by grouping 'like' options together. Converting the three units will reduce overall consumption by 4938 CCF/yr or 1.9%.

5. HSC should conduct a separate study on Domestic water minimization for hospitals.

Domestic consumption represents a third of HSCs water use. The potential exists to reduce consumption, but there are a number of obstacles preventing implementation. Little published information coupled with infection control concerns with commonly used devices in the residential and commercial setting have limited their use. Recently, products have been designed specifically for hospitals, however they are expensive and only offer limited savings. Also, due to the number of fixtures throughout the hospital, it is important to install a reliable product that is endorsed by all players in order to prevent unforeseen operating and maintenance expenses.

Before any retrofits are recommended, with respect to domestic consumption, these obstacles need to be overcome. The focus of this research was on initiatives that were benign or transparent to patient care, therefore those issues were not addressed. HSC should conduct a separate study specific to domestic consumption. Such a study should include:

i. a detailed literature search and survey of existing practices,
ii. a controlled trial or case study in a metered building primarily comprised of domestic consumption,
iii. a test of the devices, and
iv. an economic analysis of retrofits and renovations based on capital and operating costs, annual cost savings, and payback periods.

Most importantly, it should include input from all players or stakeholders in order to ensure effective implementation.

In conclusion, the proposed 35% reduction in the sewer rate for large water users by the City of Winnipeg will result in a 33% increase in the payback periods associated with potential conservation options. Even with this increase, the payback periods are still quite favorable, approximately five years or less. However, as the mid to long term trend is toward higher water and sewer rates, HSC has an opportunity to significantly reduce the impact associated with price rate increases by eliminating all unsustainable practices. By doing so, HSC will be seen as an environmentally (promoting sustainable resource use) and economically responsible public institution.

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# Appendix A List of Abbreviations

## List of Abbreviations

| Abbreviation | Description |
|---|---|
| °F | Degrees Fahrenheit |
| 12/88 | 12% Ethylene Oxide and 88% Freon |
| 3ph | Three Phase |
| AAC | Adult Ambulatory Care |
| AC | Accelerated Current |
| ACR | Accelerated Current Recorder |
| AD | Intern's Residence |
| Ave. | Average |
| BA | Financial Services Building |
| CB | Concentration of Bleed-Off |
| CBA | Cost - Benefit Analysis |
| CCF | Hundred Cubic Feet |
| CDU | Central Dialysis Unit |
| CE | Children's Hospital - E Wing |
| CEP | Central Energy Plant |
| CFC | Chloroflourocarbon |
| CH | Children's Hospital - H Wing |
| CK | Children's Hospital - K Wing |
| CM | Concentration of Makeup Water |
| CN | Children's Hospital - N Wing |
| $CO_2$ | Carbon Dioxide |
| CR | Concentration Ratio |
| CS | Children's Hospital - S Wing |

| **Abbreviation** | **Description** |
|---|---|
| CSA | Canadian Standards Association |
| e.g. | Example |
| EO | Ethylene Oxide |
| EPA | Environmental Protection Agency |
| etc. | Etcetera |
| EtO | Ethylene Oxide |
| FE | Community Services Building - E Wing |
| FW | Community Services Building - W Wing |
| GA | General Hospital - A Wing |
| GB | General Hospital - B Wing |
| GC | General Hospital - C Wing |
| GD | General Hospital - D Wing |
| GE | General Hospital - E Wing |
| GF | General Hospital - F Wing |
| GG | General Hospital - G Wing |
| GH | General Hospital - H Wing |
| GPD | Gallons per Day |
| gpm | Gallons per Minute |
| HCFC | Hydrochloroflourocarbons |
| HP | Horsepower |
| hr | Hour(s) |
| HSC | Health Sciences Centre |
| Imp. | Imperial |
| L | Liter |
| LA | Laundry Building |
| LB | Lennox Bell Lodge |
| MA | Maintenance Building |

| Abbreviation | Description |
|---|---|
| Med. | Medicine |
| MH | Materials Handling Building |
| min | Minute(s) |
| MS | Thorlakson Medical Support |
| n.d. | No Date |
| NA | School of Nursing |
| O.R. | Operating Room(s) |
| ON | Cancer Building |
| PX | PsycHealth Building - X Wing |
| PY | PsycHealth Building - Y Wing |
| PZ | PsycHealth Building - Z Wing |
| rla | Rotor Locked Amps |
| RR | Rehabilitation Hospital |
| RS | Respiratory Hospital |
| SCD | Self-Care Dialysis Building |
| SMS | Scouten Mitchell Sigurdson |
| sq.ft | Square Feet |
| TW | Tunnel |
| ULV | Ultra Low Volume |
| UNEP | United Nations Environmental Programme |
| US | United States |
| V | Volts |
| Wk | Week |
| WR | Women's Hospital - R Wing |
| WS | Women's Hospital - S Wing |
| WT | Women's Hospital - T Wing |
| yr | Year |

# Appendix B HSC Water Meter Information

**Water Consumption - Health Sciences Centre**

| QUARTER | CONSUMPTION (CCF) 91/92 | 92/93 | 93/94 | 94/95 |
|---|---|---|---|---|
| APR-JUNE | 69,616 | 59,692 | 58,227 | 60,067 |
| JULY-SEPT | 85,039 | 73,279 | 67,597 | 72,823 |
| OCT-DEC | 70,403 | 64,183 | 62,900 | 62,446 |
| JAN-MARCH | 61,408 | 71,176 | 68,333 | 60,872 |
| PsycHealth Adjustment | - | 1,049 | 5,156 | 5,662 |
| **TOTALS** | **286,467** | **269,379** | **262,213** | **261,869** |
| | | | | |
| **Cost/CCF** | **2.44** | **2.64** | **2.96** | **3.27** |
| **% Change** | **12%** | **8%** | **12%** | **10%** |

**Two Year Average (CCF/yr) = 262,041**

**Average Cost/CCF Increase 10.6%**

# Appendix C Theoretical vs. Actual Flow Rates for HSC Condensers

**Theoretical vs. Actual Flow Rates for HSC Condensers**

| Room | Month Observed | HP | Delta T° (°F) | Actual US GPM | Calc. US GPM | Actual/ Calc |
|---|---|---|---|---|---|---|
| GH-195A (cu-7) | July | 1.8 | 18 | 1.0 | 3.2 | .31 |
| GH-195A (cu-8) | July | 7.6 | 15 | 2.3 | 14.6 | .16 |
| ON-302 | July | 1.7 | 20 | .7 | 2.2 | .32 |
| CS-006 | July | 6.1 | 32 | 1.2 | 2.7 | .44 |
| MS-444 | July | 1.58 | 11 | .8 | 1.5 | .53 |
| MS-635E | July | 1.8 | 12 | 1 | 3.7 | .27 |
| MS-449 | July | 4.8 | 12 | 1.7 | 7.3 | .23 |
| RR-044B | July | 3.1 | 12 | 1.1 | 8 | .14 |
| MS-055B | July | 2 | 9 | 1.8 | 2.9 | .62 |
| ON-040 | July | 2.4 | 14 | 2.6 | 6.3 | .41 |
| Plumbing | November | 3 | 49 | 2.2 | 1.8 | 1.24 |
| CCMS | November | 3 | 41 | 2.2 | 2.1 | 1.01 |
| BA-001 | July | 12 | 20 | 12 | 30.7 | .39 |
| GH-014 | November | 10 | 41 | 6 | 7.1 | .85 |
| ON-302 | November | 1.7 | 49 | 0.7 | 1.0 | .66 |
| NA-154 | November | 5 | 49 | 1.2 | 3 | .40 |
| GF-120 | November | 5 | 49 | 2.1 | 3 | .71 |
| CS-006 | November | 6.1 | 61 | .9 | 2.9 | .29 |
| | | | | | **Average** | **.50** |

# Appendix D HSC Condenser Loads

## HSCs Condenser Loads

| Room | Cooling Type | % ON |
|---|---|---|
| CS-111 | Computer | 24 |
| ON-040 | Space | 44 |
| MA-005A | Space | 52 |
| GH-195A (Garbage Rm.) | Process | 52 |
| MA-002 | Space | 53 |
| GH-195A (#7) | Process | 55 |
| GC-420 | Space | 59 |
| TW-37B | Space | 68 |
| GH-195A (CU-5) | Process | 88 |
| GG-347B | Space | 98 |
| GD-043 (F-37) | Space | 100 |
| GD-043 (F-38) | Space | 99 |
| WT-561 | Space | 14 |
| CS-231 | Space | 1 |
| NA-154 | Space | 81 |
| | **Average** | **59%** |

# Appendix E Water-Cooled Condensers Summer and Winter Consumption

## HSCs Water-Cooled Condensers Summer Consumption

| Room # | Unit # | Horsepower & Usage: All Year | Spooled | Summer | (A) Delta T °F | (B) GPM US | (C) Adjustment | (D) Summer Days | (E) Load | (F) % Theory | Consumption |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GE-426 | | | | 5 | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| GE-708 | | 5 | | | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| GE-122A | | 2 | | | 20 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| GE-118 | | 6.1 | | | 20 | 8.8 | 1 | 165 | 0.59 | 0.5 | 616810 |
| GH-014 | #1 | 2.4 | | | 18 | 4.1 | 1 | 165 | 0.59 | 0.5 | 287377 |
| | #2 | 2.4 | | | 26 | 2.8 | 1 | 165 | 0.59 | 0.5 | 196258 |
| | #3 | 2.4 | | | 11 | 6.6 | 1 | 165 | 0.59 | 0.5 | 462607 |
| GH-195A | CU-7 | 1.8 | | | 18 | 3.2 | 1 | 165 | 0.59 | 0.5 | 224294 |
| | CU-8 | 7.6 | | | 15 | 14.6 | 1 | 165 | 0.59 | 0.5 | 1023343 |
| | CU-11 | NOT OPERATIONAL | | | 20 | | 1 | 165 | 0.59 | 0.5 | 0 |
| | no. 10 | 7.2 | | | 13 | 15.7 | 1 | 165 | 0.59 | 0.5 | 1100444 |
| | Dairy | 7.5 | | | 34 | 6.4 | 1 | 165 | 0.59 | 0.5 | 448589 |
| | no. 5 | 13.5 | | | 11 | 35.8 | 1 | 165 | 0.59 | 0.5 | 2509294 |
| | Garbage | 7.4 | | | 5 | 43.8 | 1 | 165 | 0.59 | 0.5 | 3070030 |
| | Copeland | 5.2 | | | 18 | 8.1 | 1 | 165 | 0.59 | 0.5 | 567745 |
| | Salad | 2 | | | 19 | 3.1 | 1 | 165 | 0.59 | 0.5 | 217285 |
| | no. 7 | 2 | | | 23 | 2.5 | 1 | 165 | 0.59 | 0.5 | 175230 |
| GG-158 | FC-111 | Included with GG-038 | | | 20 | | 0 | 165 | 0.59 | 0.5 | 0 |
| GG-169 | FC-114 | Included with GG-038 | | | 20 | | 0 | 165 | 0.59 | 0.5 | 0 |
| GG-639 | | 5 | | | 21 | 7 | 1 | 165 | 0.59 | 0.5 | 490644 |
| GG-346 | | | 6.3 | | 20 | 7.3 | 0 | 165 | 0.59 | 0.5 | 0 |
| GG-347B | | 3.6 | | | 17 | 5.2 | 1 | 165 | 0.59 | 0.5 | 364478 |
| GG-038 | SPOOLED | | 25 | | 20 | 36.5 | 0 | 165 | 0.59 | 0.5 | 0 |
| GF-632 | | 20 | | | 22 | 26.5 | 1 | 165 | 0.59 | 0.5 | 1857438 |
| GF-120 | | 5 | | | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| GD-043 | Supply Fan (F-37) | | 4.5 | | 20 | 5.8 | 1 | 165 | 0.59 | 0.5 | 406534 |
| | Supply Fan (F-38) | | 4.5 | | 18 | 6.5 | 1 | 165 | 0.59 | 0.5 | 455598 |
| | CR-1 | | 2 | | 19 | 3.1 | 1 | 165 | 0.59 | 0.5 | 217285 |
| | CR-2 | | 1.5 | | 19 | 2.3 | 1 | 165 | 0.59 | 0.5 | 161212 |
| GD-725 | | 3 | | | 20 | 4.4 | 1 | 165 | 0.59 | 0.5 | 308405 |
| GC-420 | | 7.5 | | | 24 | 9.1 | 1 | 165 | 0.59 | 0.5 | 637837 |
| GC-107 | | 3 | | | 13 | 6.7 | 1 | 165 | 0.59 | 0.5 | 469616 |
| GC-112 | | 1.5 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| GA-150 | | 3 | | | 20 | 4.35 | 1 | 165 | 0.59 | 0.5 | 304900 |
| NA-017 | | | | 5 | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| NA-154 | | 5 | | | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| NA-029A | | | | 7.3 | 20 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| TW37B | Supply Fan (F-13) & (F-14) | | 10 | | 20 | 14.6 | 1 | 165 | 0.59 | 0.5 | 1023343 |
| TW39D | CR-1 | 1 | | | 5 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| | CR-2 | 0.8 | | | 12 | 1.2 | 1 | 165 | 0.59 | 0.5 | 84110 |
| | CR-3 | 0.8 | | | 7 | 2.1 | 1 | 165 | 0.59 | 0.5 | 147193 |
| | CR-4 | 2.2 | | | 15 | 3.9 | 1 | 165 | 0.59 | 0.5 | 273359 |
| | CR-5 | 2.9 | | | 16 | 5.5 | 1 | 165 | 0.59 | 0.5 | 385506 |
| | CR-6 | 0.8 | | | 2 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| RS-303 | | | 1.5 | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| RS-307 | | | 1.5 | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| RR-029A | #2 | 0.33 | | | 20 | 0.5 | 1 | 165 | 0.59 | 0.5 | 35046 |
| | #3 | 1 | | | 27 | 1.1 | 1 | 165 | 0.59 | 0.5 | 77101 |
| | #4 | 2 | | | 10 | 5.8 | 1 | 165 | 0.59 | 0.5 | 406534 |
| | #5 | 1 | | | 18 | 1.6 | 1 | 165 | 0.59 | 0.5 | 112147 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| RR-044B | | 3.1 | | | 11 | 8 | 1 | 165 | 0.59 | 0.5 | 560736 |
| WS-002 | | 12.9 | | | 22 | 13.3 | 1 | 165 | 0.59 | 0.5 | 932224 |
| WR-206 | | | | 10 | 26 | 11.2 | 1 | 165 | 0.59 | 0.5 | 785030 |
| WS-202A | | 1.5 | | | 14 | 3.1 | 1 | 165 | 0.59 | 0.5 | 217285 |
| WR-506A | | | | 10 | 11 | 26.5 | 1 | 165 | 0.59 | 0.5 | 1857438 |
| WT-563 | | 8 | | | 8 | 18.3 | 1 | 165 | 0.59 | 0.5 | 1282684 |
| BA-001 | | | | 20.7 | 19 | 30.7 | 1 | 165 | 0.59 | 0.5 | 2151824 |
| ON-040 | | 2.4 | | | 14 | 6.3 | 1 | 165 | 0.59 | 0.5 | 441580 |
| ON-048 | | | 3 | | 9 | 9.7 | 0 | 165 | 0.59 | 0.5 | 0 |
| ON-059 | | | 5 | | 9 | 16.2 | 0 | 165 | 0.59 | 0.5 | 0 |
| ON-231 | | 1.4 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| ON-245 | | 1.4 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| ON-302 | | 1.7 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| ON-174A | | 2 | | | 22 | 2.7 | 1 | 165 | 0.59 | 0.5 | 189248 |
| CS-006 | | 6.1 | | | 32 | 2.7 | 1 | 165 | 0.59 | 0.5 | 189248 |
| CS-105 | Climate Master #1 | 2 | | | 17 | 3.4 | 1 | 165 | 0.59 | 0.5 | 238313 |
| | Climate Master #2 | 5.5 | | | 32 | 2.3 | 1 | 165 | 0.59 | 0.5 | 161212 |
| CS-111 | Supply Fan F-95 (AC-1) | 6.2 | | | 11 | 13.3 | 1 | 165 | 0.59 | 0.5 | 932224 |
| | Supply Fan F-96 (AC-4) | 4.7 | | | 12 | 12.2 | 1 | 165 | 0.59 | 0.5 | 855122 |
| CS-116 | | 5 | | | 13 | 11.2 | 1 | 165 | 0.59 | 0.5 | 785030 |
| CS-231 | | | 4 | | 9 | 9.7 | 1 | 165 | 0.59 | 0.5 | 679892 |
| CCMS | AC Unit F-148 | | 3 | | 20 | 4.4 | 0 | 165 | 0.59 | 0.5 | 0 |
| Plumbing | | 3 | | | 20 | 4.4 | 1 | 165 | 0.59 | 0.5 | 308405 |
| MH-009B | | 2 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| MH-009C | | 1.5 | | | 20 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| MH-114 | | 2 | | | 20 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| MS-444 | | 4.8 | | | 20 | 1.5 | 1 | 165 | 0.59 | 0.5 | 105138 |
| MS-449 | | 4.8 | | | 12 | 7.3 | 1 | 165 | 0.59 | 0.5 | 511672 |
| MS-458A | | | 4.1 | | 16 | 1.8 | 1 | 165 | 0.59 | 0.5 | 126166 |
| MS-543R | | 1.8 | | | 20 | 1.5 | 1 | 165 | 0.59 | 0.5 | 105138 |
| MS-551E | Conviron #1 | 2.4 | | | 20 | 1.5 | 1 | 165 | 0.59 | 0.5 | 105138 |
| | Conviron #2 | 3.4 | | | 20 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| MS-635E | | 1.8 | | | 12 | 3.7 | 1 | 165 | 0.59 | 0.5 | 259340 |
| MS-655A | | 2.4 | | | 20 | 2.2 | 1 | 165 | 0.59 | 0.5 | 154202 |
| MS-655D | | 2.5 | | | 20 | 4.4 | 1 | 165 | 0.59 | 0.5 | 308405 |
| MS-773 | | 4.1 | | | 20 | 1.5 | 1 | 165 | 0.59 | 0.5 | 105138 |
| MS-055B | | 2 | | | 20 | 2.9 | 1 | 165 | 0.59 | 0.5 | 203267 |
| AD-202A | | 3 | | | 20 | 4.4 | 1 | 165 | 0.59 | 0.5 | 308405 |
| FE-018 | Copeland #1 | | | 10.2 | 20 | 14.6 | 1 | 165 | 0.59 | 0.5 | 1023343 |
| | Copeland #2 | | | 7.7 | 23 | 6.9 | 1 | 165 | 0.59 | 0.5 | 483635 |
| PX-077 | | | 3 | | 20 | 4.4 | 0 | 165 | 0.59 | 0.5 | 0 |
| PX-049 | | | 3 | | 20 | 4.4 | 0 | 165 | 0.59 | 0.5 | 0 |
| PX-056A | | | 3 | | 20 | 4.4 | 0 | 165 | 0.59 | 0.5 | 0 |
| PY-204 | | | 3 | | 20 | 4.4 | 0 | 165 | 0.59 | 0.5 | 0 |
| | **Total Horsepower** | **249.33** | **87.9** | **75.9** | | | | | | | |

| | |
|---|---|
| **US Gallons/Summer** | **41,161,527** |
| **CCF/Summer** | **55,029** |
| **% of Total** | **21.0%** |
| **Cost ($)** | **$ 182,696** |

Consumption = A*B*C*D*E*F*24hrs/day*60min/hr
Gallons per Minute (GPM) = 14,544/(500*(A))
Adjustment: 0 = Summer Unit Only 1 = Operational

## HSCs Water-Cooled Condensers Winter Consumption

| Room # | Unit # | Horsepower & Usage All Year | Spooled | Summer | (A) Delta T °F | (B) GPM US | (C) Winter Days | (D) Adjustment | (E) Load | (F) % Theory | GPWinter |
|---|---|---|---|---|---|---|---|---|---|---|---|
| GE-426 | | | | 5 | 49 | 3.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| GE-708 | | 5 | | | 49 | 3.0 | 200 | 1 | 0.59 | 0.5 | 254880 |
| GE-122A | | 2 | | | 49 | 1.2 | 200 | 1 | 0.59 | 0.5 | 101952 |
| GE-118 | | 6.1 | | | 49 | 3.6 | 200 | 1 | 0.59 | 0.5 | 305856 |
| GH-014 | #1 | 2.4 | | | 47 | 1.5 | 200 | 1 | 0.59 | 0.5 | 127440 |
| | #2 | 2.4 | | | 55 | 1.3 | 200 | 1 | 0.59 | 0.5 | 110448 |
| | #3 | 2.4 | | | 40 | 1.7 | 200 | 1 | 0.59 | 0.5 | 144432 |
| GH-195A | CU-7 | 1.8 | | | 47 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| | CU-8 | 7.6 | | | 44 | 5.0 | 200 | 1 | 0.59 | 0.5 | 424800 |
| | no. 10 | 7.2 | | | 42 | 5.0 | 200 | 1 | 0.59 | 0.5 | 424800 |
| | Dairy | 7.5 | | | 63 | 3.5 | 200 | 1 | 0.59 | 0.5 | 297360 |
| | no 5 | 13.5 | | | 40 | 9.8 | 200 | 1 | 0.59 | 0.5 | 832608 |
| | Garbage | 7.4 | | | 34 | 6.3 | 200 | 1 | 0.59 | 0.5 | 535248 |
| | Copeland | 5.2 | | | 47 | 3.2 | 200 | 1 | 0.59 | 0.5 | 271872 |
| | Salad | 2 | | | 48 | 1.2 | 200 | 1 | 0.59 | 0.5 | 101952 |
| | no. 7 | 2 | | | 52 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| GG-158 | | Included with GG-038 | | | 49 | 0.0 | 200 | 1 | 0.59 | 0.5 | 0 |
| GG-169 | | Included with GG-038 | | | 49 | 0.0 | 200 | 1 | 0.59 | 0.5 | 0 |
| GG-639 | | 5 | | | 50 | 2.9 | 200 | 1 | 0.59 | 0.5 | 246384 |
| GG-346 | | | 6.3 | | 49 | 3.7 | 200 | 1 | 0.59 | 0.5 | 314352 |
| GG-347B | | 3.6 | | | 46 | 2.3 | 200 | 1 | 0.59 | 0.5 | 195408 |
| GG-038 | | | 25 | | 49 | 14.8 | 200 | 1 | 0.59 | 0.5 | 1257408 |
| GF-632 | | 20 | | | 51 | 11.4 | 200 | 0 | 0.59 | 0.5 | 0 |
| GF-120 | | 5 | | | 49 | 3.0 | 200 | 1 | 0.59 | 0.5 | 254880 |
| GD-043 | Supply Fan (F-37) | | 4.5 | | 49 | 2.7 | 200 | 1 | 0.59 | 0.5 | 229392 |
| | Supply Fan (F-38) | | 4.5 | | 47 | 2.8 | 200 | 1 | 0.59 | 0.5 | 237888 |
| | CR-1 | | 2 | | 48 | 1.2 | 200 | 1 | 0.59 | 0.5 | 101952 |
| | CR-2 | | 1.5 | | 48 | 0.9 | 200 | 1 | 0.59 | 0.5 | 76464 |
| GD-725 | | 3 | | | 49 | 1.8 | 200 | 1 | 0.59 | 0.5 | 152928 |
| GC-420 | | 7.5 | | | 53 | 4.1 | 200 | 1 | 0.59 | 0.5 | 348336 |
| GC-107 | | 3 | | | 42 | 2.1 | 200 | 1 | 0.59 | 0.5 | 178416 |
| GC-112 | | 1.5 | | | 49 | 0.9 | 200 | 1 | 0.59 | 0.5 | 76464 |
| GA-150 | | 3 | | | 49 | 1.8 | 200 | 1 | 0.59 | 0.5 | 152928 |
| NA-017 | | | | 5 | 49 | 3.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| NA-154 | | 5 | | | 49 | 3.0 | 200 | 1 | 0.59 | 0.5 | 254880 |
| NA-029A | | | | 7.3 | 50 | 4.2 | 200 | 0 | 0.59 | 0.5 | 0 |
| TW37B | Supply Fan (F-13) & (F-14) | | 10 | | 49 | 5.9 | 200 | 1 | 0.59 | 0.5 | 501264 |
| TW39D | CR-1 | 1 | | | 34 | 0.9 | 200 | 1 | 0.59 | 0.5 | 76464 |
| | CR-2 | 0.8 | | | 41 | 0.6 | 200 | 1 | 0.59 | 0.5 | 50976 |
| | CR-3 | 0.8 | | | 36 | 0.6 | 200 | 1 | 0.59 | 0.5 | 50976 |
| | CR-4 | 2.2 | | | 44 | 1.5 | 200 | 1 | 0.59 | 0.5 | 127440 |
| | CR-5 | 2.9 | | | 45 | 1.9 | 200 | 1 | 0.59 | 0.5 | 161424 |
| | CR-6 | 0.8 | | | 31 | 0.8 | 200 | 1 | 0.59 | 0.5 | 67968 |
| RS-303 | | | 1.5 | | 39 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| RS-307 | | | 1.5 | | 39 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| RR-029A | #2 | 0.33 | | | 49 | 0.2 | 200 | 1 | 0.59 | 0.5 | 16992 |
| | #3 | 1 | | | 56 | 0.5 | 200 | 1 | 0.59 | 0.5 | 42480 |
| | #4 | 2 | | | 39 | 1.5 | 200 | 1 | 0.59 | 0.5 | 127440 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | #5 | 1 | | | 47 | 0.6 | 200 | 1 | 0.59 | 0.5 | 50976 |
| RR-044B | | 3.1 | | | 40 | 2.3 | 200 | 1 | 0.59 | 0.5 | 195408 |
| WS-002 | | 12.9 | | | 51 | 7.4 | 200 | 1 | 0.59 | 0.5 | 628704 |
| WR-206 | | | | 10 | 55 | 5.3 | 200 | 0 | 0.59 | 0.5 | 0 |
| WS-202A | | 1.5 | | | 43 | 1.0 | 200 | 1 | 0.59 | 0.5 | 84960 |
| WR-506A | | | | 10 | 40 | 7.3 | 200 | 0 | 0.59 | 0.5 | 0 |
| WT-563 | | 8 | | | 37 | 6.3 | 200 | 1 | 0.59 | 0.5 | 535248 |
| BA-001 | | | | 20.7 | 48 | 12.5 | 200 | 0 | 0.59 | 0.5 | 0 |
| ON-040 | | 2.4 | | | 43 | 1.6 | 200 | 1 | 0.59 | 0.5 | 135936 |
| ON-048 | | | 3 | | 38 | 2.3 | 200 | 1 | 0.59 | 0.5 | 195408 |
| ON-059 | | | 5 | | 38 | 3.8 | 200 | 1 | 0.59 | 0.5 | 322848 |
| ON-231 | | 1.4 | | | 49 | 0.8 | 200 | 1 | 0.59 | 0.5 | 67968 |
| ON-245 | | 1.4 | | | 49 | 0.8 | 200 | 1 | 0.59 | 0.5 | 67968 |
| ON-302 | | 1.7 | | | 49 | 1.0 | 200 | 1 | 0.59 | 0.5 | 84960 |
| ON-174A | | 2 | | | 51 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| CS-006 | | 6.1 | | | 61 | 2.9 | 200 | 1 | 0.59 | 0.5 | 246384 |
| CS-105 | | 2 | | | 46 | 1.3 | 200 | 1 | 0.59 | 0.5 | 110448 |
| | | 5.5 | | | 61 | 2.6 | 200 | 1 | 0.59 | 0.5 | 220896 |
| CS-111 | Supply Fan F-95 (AC-1) | 6.2 | | | 40 | 4.5 | 200 | 1 | 0.59 | 0.5 | 382320 |
| | Supply Fan F-96 (AC-4) | 4.7 | | | 41 | 3.3 | 200 | 1 | 0.59 | 0.5 | 280368 |
| CS-116 | | 5 | | | 42 | 3.5 | 200 | 1 | 0.59 | 0.5 | 297360 |
| CS-231 | | | 4 | | 38 | 3.1 | 200 | 1 | 0.59 | 0.5 | 263376 |
| CCMS | | | 3 | | 41 | 2.1 | 200 | 1 | 0.59 | 0.5 | 178416 |
| Plumbing | | 3 | | | 49 | 1.8 | 200 | 1 | 0.59 | 0.5 | 152928 |
| MH-009B | | 2 | | | 35 | 1.7 | 200 | 1 | 0.59 | 0.5 | 144432 |
| MH-009C | | 1.5 | | | 31 | 1.4 | 200 | 1 | 0.59 | 0.5 | 118944 |
| MH-114 | | 2 | | | 49 | 1.2 | 200 | 1 | 0.59 | 0.5 | 101952 |
| MS-444 | | 4.8 | | | 41 | 3.4 | 200 | 1 | 0.59 | 0.5 | 288864 |
| MS-449 | | 4.8 | | | 41 | 3.4 | 200 | 1 | 0.59 | 0.5 | 288864 |
| MS-458A | | | 4.1 | | 45 | 2.7 | 200 | 1 | 0.59 | 0.5 | 229392 |
| MS-543R | | 1.8 | | | 49 | 1.1 | 200 | 1 | 0.59 | 0.5 | 93456 |
| MS-551E | Conviron #1 | 2.4 | | | 45 | 1.6 | 200 | 1 | 0.59 | 0.5 | 135936 |
| | Conviron #2 | 3.4 | | | 45 | 2.2 | 200 | 1 | 0.59 | 0.5 | 186912 |
| MS-635E | | 1.8 | | | 41 | 1.3 | 200 | 1 | 0.59 | 0.5 | 110448 |
| MS-655A | | 2.4 | | | 49 | 1.4 | 200 | 1 | 0.59 | 0.5 | 118944 |
| MS-655D | | 2.5 | | | 49 | 1.5 | 200 | 1 | 0.59 | 0.5 | 127440 |
| MS-773 | | 4.1 | | | 49 | 2.4 | 200 | 1 | 0.59 | 0.5 | 203904 |
| MS-055B | | 2 | | | 38 | 1.5 | 200 | 1 | 0.59 | 0.5 | 127440 |
| AD-202A | | 3 | | | 49 | 1.8 | 200 | 0 | 0.59 | 0.5 | 0 |
| FE-018 | Copeland #1 | | | 10.2 | 49 | 6.1 | 200 | 0 | 0.59 | 0.5 | 0 |
| | Copeland #2 | | | 7.7 | 52 | 4.3 | 200 | 0 | 0.59 | 0.5 | 0 |
| PX-077 | | | 3 | | 49 | 0.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| PX-049 | | | 3 | | 49 | 0.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| PX-056A | | | 3 | | 49 | 0.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| PY-204 | | | 3 | | 49 | 0.0 | 200 | 0 | 0.59 | 0.5 | 0 |
| | **Total Horsepower** | **249.33** | **87.9** | **75.9** | | | | | | | |

| | |
|---|---|
| **US Gallons/Winter** | **16,482,240** |
| **CCF/Winter** | **22,035** |
| **% of Total** | **8.4%** |
| **Cost ($)** | **$ 73,156** |

Consumption = A*B*C*D*E*F*24hrs/day*60min/hr
Gallons per Minute (GPM) = 14,544/(500*(A))
Adjustment 0 = Summer Only 1 = Operational

# Appendix F Water Balance Accuracy Assessment

## Water Balance Accuracy Assessment

### Financial Services

| | |
|---|---|
| Average CCF/yr | 1,172 |
| Square Footage | 15,186 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 653 |
| Hot Water | 243 |
| Condenser | 2,877 |
| Total CCF | 3,773 |
| Percent | 322% |

### PsycHealth Building

| | |
|---|---|
| Average CCF/yr | 5,409 |
| Square Footage | 179,073 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 7,700 |
| Hot Water | 2,865 |
| Condenser | - |
| Total CCF | 10,565 |
| Percent | 195% |

### Womens Hospital

| | |
|---|---|
| Average CCF/yr | 14,844 |
| Square Footage | 95,029 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 4,086 |
| Hot Water | 1,520 |
| Condenser | 8,454 |
| Medical Vacuum & Air | 1,475 |
| Sterilizer | 1,690 |
| Total CCF | 17,225 |
| Percent | 116% |

### Cancer Building

| | |
|---|---|
| Average CCF/yr | 15,579 |
| Square Footage | 99,941 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 4,297 |
| Hot Water | 1,599 |
| Condenser | 2,757 |
| Medical Vacuum & Air | 1,763 |
| Total CCF | 10,416 |
| Percent | 67% |

### School of Nursing

| | |
|---|---|
| Average CCF/yr | 2,699 |
| Square Footage | 89,324 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 3,841 |
| Hot Water | 1,429 |
| Condenser | 2,393 |
| Total CCF | 7,663 |
| Percent | 284% |

### Childrens Hospital (CE/CS/CN)

| | |
|---|---|
| Average CCF/yr | 20,001 |
| Square Footage | 119,728 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 5,148 |
| Hot Water | 1,916 |
| Condenser | 7,543 |
| Medical Vacuum & Air | 5,232 |
| X-Ray Processing | 155 |
| Sterilizers | 201 |
| Total CCF | 20,194 |
| Percent | 101% |

### Internes Residence

| | |
|---|---|
| Average CCF/yr | 1,316 |
| Square Footage | 27,190 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 1,169 |
| Hot Water | 435 |
| Condenser | 412 |
| Total CCF | 2,017 |
| Percent | 153% |

### Lennox Bell Lodge

| | |
|---|---|
| Average CCF/yr | 1,530 |
| Square Footage | 36,214 |

| Consumption Estimates | CCF |
|---|---|
| Domestic Consumption | 1,557 |
| Hot Water | 579 |
| Total CCF | 2,137 |
| Percent | 140% |

**Respiratory/Rehabilitation Hospital (RR/RS)**

| | |
|---|---|
| Average CCF/yr | 11,386 |
| Square Footage | 200,825 |

| **Consumption Estimates** | **CCF** |
|---|---|
| Domestic Consumption | 8,635 |
| Hot Water | 3,213 |
| Condenser | 2,834 |
| Medical Vacuum & Air | 257 |
| X-Ray Processing | 482 |
| Total CCF | 15,422 |
| Percent | 135% |

**General Hospital Service (GA to GH, AD, MA, LB, WR/WS/WT, LA2&3, MH)**

| | |
|---|---|
| Average CCF/yr | 133,108 |
| Square Footage | 884,240 |

| **Consumption Estimates** | **CCF** |
|---|---|
| Domestic Consumption | 38,022 |
| Hot Water | 14,148 |
| Condenser | 46,266 |
| Medical Vacuum & Air | 10,371 |
| X-Ray Processing | 3,478 |
| Kitchen & Cafeteria | 4,187 |
| Sterilizers | 14,267 |
| Total CCF | 130,740 |
| Percent | 98% |

**Sherbrook Parkade Service (CE/CS/CN/CK/CH, MS, RR/RS, ON, NA)**

| | |
|---|---|
| Average CCF/yr | 77,502 |
| Square Footage | 885,016 |

| **Consumption Estimates** | **CCF** |
|---|---|
| Domestic Consumption | 38,056 |
| Hot Water | 14,160 |
| Condenser | 23,883 |
| Medical Vacuum & Air | 8,008 |
| X-Ray Processing | 637 |
| Kitchen & Cafeteria | 2,209 |
| Sterilizers | 975 |
| Total CCF | 87,928 |
| Percent | 113% |

| | |
|---|---|
| **Weighted Average Based on Square Footage** | **121%** |
| **Weighted Average Based on CCF** | **108%** |

## Appendix G Financial Services Condenser's Consumption Methodology

Methodology to determine water consumption associated with the water-cooled condenser in the Financial Services Building.

**CONSUMPTION (CCF)**

| **Fiscal Year** | **88/89** | **89/90** | **90/91** | **91/92** | **92/93** | **93/94** | **94/95** |
|---|---|---|---|---|---|---|---|
| April | 29 | 62 | 41 | 42 | 31 | 38 | 29 |
| May | 149 | 225 | 89 | 166 | 67 | 73 | 109 |
| June | 332 | 215 | 194 | 226 | 95 | 164 | 258 |
| July | 304 | 435 | 376 | 172 | 61 | 123 | 292 |
| August | 504 | 649 | 298 | 295 | 118 | 207 | 327 |
| September | 202 | 564 | 112 | 80 | 44 | 78 | 209 |
| October | 112 | 357 | 26 | 45 | 52 | 125 | 65 |
| November | 35 | 24 | 29 | 45 | 26 | 35 | 26 |
| December | 22 | 19 | 20 | 37 | 20 | 20 | 19 |
| January | 23 | 21 | 27 | 50 | 46 | 24 | 21 |
| February | 25 | 26 | 41 | 36 | 44 | 23 | 30 |
| March | 27 | 27 | 88 | 37 | 56 | 25 | 22 |
| **CCF/yr** | **1764** | **2623** | **1341** | **1230** | **659** | **936** | **1407** |

Since this building is affected by outside temperatures, year-round consumption was estimated using data from 1988 to present.

Financial Services Building Average Annual Consumption (CCF/yr) = 1423

Since the condenser is not operational during winter, the original two-year methodology was used.

Non-Summer Average Monthly Consumption Nov. to April (CCF/yr) = 26

**Average Condenser Consumption = 1423 - (26*12) = 1111 CCF/yr**