WATER EFFICIENCY STRATEGY UPDATE, GUELPH, APRIL 2016
TECHNICAL MEMORANDUM –EVALUATION OF WCE MEASURES, FINAL

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Overview

This technical note documents an economic evaluation completed for water conservation and efficiency (WCE) measures that have been investigated for the 2015 Guelph Water Efficiency Strategy Update project. Methodology, input data and results are presented below.

Approach

A discounted cash flow analysis is completed to compare individual WCE measures and WCE programs which combine measures to each other and to a do nothing alternative. The approach encompasses both water supply (WS) and wastewater (WW) operations since both are impacted by WCE measures and estimates the total cost—capital and operating—of these operations under alternative WCE scenarios.

The basic measure of cost in a discounted cash flow analysis is the present value of annual operating and maintenance costs incurred over the period of a common planning horizon applied to each scenario. The net present value calculation expresses all costs incurred over the planning horizon in terms of present day costs by discounting future costs to account for the time value of money.[1]

Each scenario that we consider below is distinguished by the amount of expenditure for WCE measures, the resulting demand for water and generation of wastewater and the incremental changes in capital and operating costs required to produce water and treat wastewater. In these scenarios higher costs for WCE measures are being traded off against lower costs to produce water and treat wastewater. A WCE measure or program is beneficial from a financial perspective if the present value of aggregate costs with that measure or program in place are lower than the present value of costs without the measure or program.

A financial model was developed using an EXCEL software platform to facilitate the discounted cash flow analysis. The following table describes key features of the model as well as assumptions and data sources:

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[1] The discount rate calculation is analogous to an interest rate calculation. For the interest rate calculation, the FUTURE value (FV) of a PRESENT value (PV) amount, say Y dollars, is calculated as:
$FV_{(\text{next year})} = Y \times (1+\text{interest rate})$;
$FV_{(\text{in two years})} = FV_{(\text{next year})} \times (1+\text{interest rate}) = Y \times (1+\text{interest rate}) \times (1+\text{interest rate}) = Y \times (1+\text{interest rate})^2$
$FV_{(\text{in year T})} = Y \times (1+\text{interest rate})^T$
Since Y is the PV, we can write this as: $FV_{(\text{in year T})} = PV \times (1+\text{interest rate})^T$
With a bit of algebra, we can then estimate PV for a known value of FV as: $PV_{(\text{in year 1})} = FV_{(\text{in year T})} \div (1+\text{interest rate})^T$
This is the basic calculation in a discounted cash flow analysis.

Table 1 Key features of the Financial Analysis

ITEM	DESCRIPTION	COMMENT
A. Planning horizon	Annual time steps from 2017 to 2038 and from 2017 to 2076	The shorter time frame is consistent with the water supply maser plan. The longer planning horizon was also used to allow consideration of the full range of WS and WW capacity expansion options, some of which are not needed until near the end of this period.
B. Financial assumptions	Discount rate = 2.91%	Representative of the cost of capital for the City and based on Infrastructure Ontario Indicative Lending Rates on 19/03/2016. This is the rate for a 15 year amortized loan.
	Future inflation = 1.7%	Average rate of inflation from 2007 to 2014 for 'final consumption expenditure' from Statistics Canada, CANSIM Table 384-0039 Implicit price indexes, gross domestic product, provincial and territorial annual (2007=100), http://www5.statcan.gc.ca/cansim/a26)
C. Base case water supply assumptions (lpcd)	Residential (RES) Consumption = 171.0	Per capita demands averaged over 2012-14 using metered water use records grouped by MPAC land use codes into residential and ICI categories. Data provided by W. Gauley originally from City of Guelph. Note ICI consumption is based on total population, not equivalent employment population.
	ICI Consumption = 125.8	
	Non revenue water (NRW) = 43.2	Water Supply Master Plan Update Draft Final Report, 2014, Table ES-2 Projected Average Day Water Demand (2013-2038). NRW for 2016 estimated by interpolation of values for 2013 and 2018. Total value divided by 2016 population.
	Total = 340.0	Summation
	Natural decline in residential water use/year = 2.7	Personal communication, W. Gauley, 18 March 2016.
D. Maximum day loading factor for water supply	= 1.50	Water Supply Master Plan Update Draft Final Report, 2014, pg 62, sec 4.2.2.
E. Base case wastewater assumptions (lpcd)	Total plant influent = 478.0	2009 Guelph Wastewater Treatment Master Plan, section 3.1.2, pg. 3-5
	Inflow/Infiltration (I/I) = 181.2	Total less sum of residential and ICI water use (all assumed to go to WW plant)
F. Population	Year Total Growth / year 2013 130,670 2018 143,480 1.89% 2023 156,290 1.73% 2028 168,190 1.48% 2033 178,464 1.19% 2038 186,299 0.86%	Water Supply Master Plan Update Draft Final Report, 2014, Table ES-1 Guelph Population Projections. Within interval population values are estimated using the indicated growth rates. Population beyond 2038 is assumed to grow at a rate of 0.86%.
G. Existing water supply capacity	Existing = 83,836 cubic meters/day (m3/d) Available = 85% of existing capacity	Water Supply Master Plan Update Draft Final Report, 2014, section 4.1, pg 31 and section 3.2.2.2, pg 27

Table 1 Key features of the Financial Analysis

ITEM	DESCRIPTION	COMMENT
	Required capacity = population X (RES + ICI + NRW per capita rates) X maximum day loading factor	Assumed based on approach used in Water Supply Master Plan Update Draft Final Report, 2014 (See item C above for per capita rates)
H. Existing wastewater treatment capacity	Existing = 73,300 m3/d	2009 Guelph Wastewater Treatment Master Plan, Table 9.6
	Required capacity = population X (RES + ICI + I/I per capita rates)	Assumed based on approach used in 2009 Guelph Wastewater Treatment Master Plan (See item E above for per capita rates)
I. New capacity projects	Water supply - See Table 3 Wastewater - See Table 4	Capacity costs are updated to 2016 prices using the price index for 'General governments gross fixed capital formation' from Statistics Canada, CANSIM, Table 384-0039 Implicit price indexes, gross domestic product, provincial and territorial annual (http://www5.statcan.gc.ca/cansim/a26) Forecast costs are assumed to increase with inflation at the rate noted above (see Item B).
J. Operating and Maintenance (OM) costs	See Table 2 for OM costs for existing facilities.	Budget figures for future years are assumed to be in inflating prices.
	WS OM costs for new capacity – see Table 3	WS OM costs in Table 3 are assumed to represent 'Supply, Treatment and Protection' costs in Table 2. Other OM costs for WS and all OM costs for WW are assumed to increase in proportion to increases in volume and numbers of customers. The proportional increase is modelled as a power function with a coefficient of 0.8 indicating economies of scale in service provision: (% change in cost) = (% change in volume or customers)$^{0.8}$ Forecast costs are also assumed to increase with inflation at the rate noted above (see Item B).
	WW OM costs for new capacity are estimated based on existing 'Plant Operations and Maintenance' costs.	
K. WCE Measures	See Table 5, Table 6, and Figure 1 below	Consulting team estimates.

Table 2 Operating and Maintenance Costs for Existing Facilities

	2016	2017	2018	2019
WATERWORKS				
Customer Service and Conservation	$7,324	$7,481	$7,650	$7,949
Supply, Treatment and Protection	$3,930	$4,015	$4,105	$4,266
Distribution and Metering	$4,489	$4,585	$4,689	$4,872
WASTEWATER				
Customer Service and Conservation	$5,745	$5,868	$6,005	$6,225
Plant Operations and Maintenance	$9,759	$9,969	$10,201	$10,575
Spills Response, Sewer Use, Wastewater Collections	$1,430	$1,461	$1,495	$1,550

Source: City of Guelph 2016 Proposed Non-tax-supported Budget.
Note: The functional cost classification for years 2017 to 2019 is based on reported functional costs for 2016.

Table 3 New Water Supply Capacity Projects

Supply Project	Total capital cost ($2014)	Annual operating and maintenance cost ($2014)	Capacity, m3/d
Ironwood	$4,036	$111,250	8,000
Clythe	$4,809	$154,400	3,395
Logan	$4,735	$92,150	4,714
Sacco	$4,135	$22,275	1,150
Smallfield	$3,820	$23,440	1,408
Lower Collector	$9,161	$80,229	3,000
Sunny Acre	$4,522	$25,070	1,500
Scout Camp	$4,702	$79,170	5,789
Hauser	$3,691	$19,950	900
Arkell Collector ASR	$8,954	$12,628	3,342
Guelph South	$5,185	$80,230	5,281
Guelph North	$5,289	$92,900	6,291
Guelph Lake WTP	$36,708	$490,543	12,312
Guelph Lake WTP + ASR	$78,905	$1,150,000	27,184

Source: 2009 Guelph Wastewater Treatment Master Plan, Table 8-7 Capital Cost Forecast – Enhanced Conservation Scenario Project.

Table 4 New Wastewater Capacity Projects

Supply Project	Total capital cost ($2008)	Capacity, m3/d
Design and Construction of 85 MLD Expansion	$60,000,000	20,000
Long Term Expansion - 105 MLD WWTP	$60,000,000	20,000
Long Term Expansion - 125 MLD WWTP	$60,000,000	20,000
Long Term Expansion - 144 MLD WWTP	$60,000,000	20,000

Source: 2009 Guelph Wastewater Treatment Master Plan, Table 9.6

Table 5 Accumulated Water Savings for WCE Measures – cubic meters per day

Water Efficiency Measure	2018	2019	2020	2021	2022	2023	2024	2025	2026
Water Loss Management	431	718	1,052	1,433	1,861	2,336	2,861	3,386	3,962
Water Smart Business	300	450	600	750	900	1,050	1,200	1,350	1,500
Municipal Facility Upgrades	44	66	88	110	132	154	176	198	220
Royal Flush Toilet Rebate Program	58	83	107	129	149	167	183	197	209
Distribution System Pressure Management	0	0	0	0	20	40	60	80	100
Automated Meter Reading Installation	0	0	0	0	20	40	60	80	100
Home Visits/Audits	32	49	65	81	81	81	81	81	81
Sub-metering Program	13	18	23	27	30	33	35	37	37
Multi- Residential Rebate Program*	13	18	23	27	30	33	35	36	37
Irrigation Audit (Water Smart Irrigation Professional) *	0	0	0	0	10	20	30	30	30
Cooling Tower Audit Research Program*	0	0	0	0	5	10	14	17	16
Blue Built Home Water Efficiency Standards and Rebate Program 2.0*	5	7	9	10	11	12	13	14	14
Healthy Landscapes Home Visit*	1	2	2	3	4	4	5	5	6
Irrigation System Rebates*	0	0	0	0	2	4	6	6	6
Water Softener Rebate*	0	0	0	0	1	1	2	3	4
Hot Water Recirculation Systems Rebate*	0	0	0	0	1	1	2	2	3
Total	897	1,411	1,969	2,570	3,257	3,987	4,762	5,521	6,323

* Included in '8 Other Measures' plotted in Figure 1.

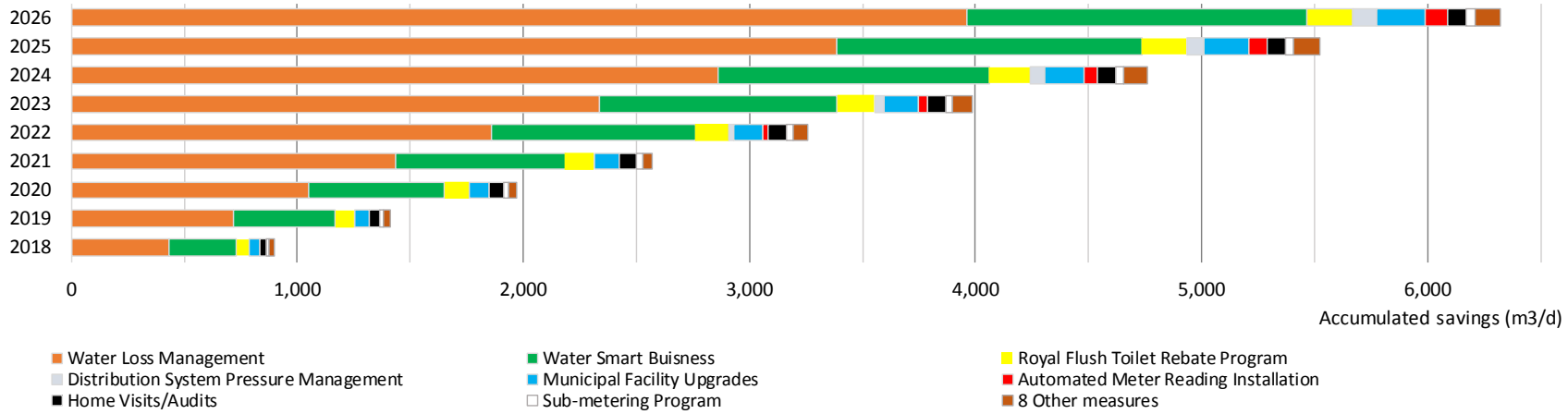


Figure 1 Water Savings

Table 6 WCE Implementation Costs – 2016 $1000s

Water Efficiency Measure	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Direct Water Saving Measures (included in Table 5 above)										
Water Loss Management	225.6	225.6	225.6	225.6	225.6	225.6	225.6	225.6	225.6	225.6
Water Smart Business	297.5	297.5	197.5	197.5	197.5	197.5	197.5	197.5	197.5	197.5
Municipal Facility Upgrades	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3	60.3
Royal Flush Toilet Rebate Program	85.0	80.0	75.0	70.0	65.0	60.0	55.0	50.0	45.0	40.0
Distribution System Pressure Management	0.0	0.0	0.0	0.0	0.0	12.0	2.0	2.0	2.0	2.0
Automated Meter Reading Installation	0.0	0.0	0.0	0.0	0.0	160.0	160.0	160.0	160.0	160.0
Home Visits/Audits	23.5	23.5	23.5	23.5	23.5	0.0	0.0	0.0	0.0	0.0
Sub-metering Program	25.0	24.0	13.0	12.0	11.0	10.0	9.0	8.0	7.0	6.0
Multi- Residential Rebate Program	40.0	28.5	27.0	25.5	24.0	22.5	21.0	19.5	18.0	16.5
Irrigation Audit (Water Smart Irrigation Professional)	0.0	0.0	0.0	0.0	0.0	9.0	9.0	9.0	0.0	0.0
Cooling Tower Audit Research Program	0.0	0.0	0.0	0.0	30.0	40.0	40.0	38.0	36.0	34.0
Blue Built Home WE Standards and Rebate Program 2.0	39.0	38.1	37.2	26.3	25.4	24.5	23.6	22.7	21.8	20.9
Healthy Landscapes Home Visit	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1	39.1
Irrigation System Rebates	0.0	0.0	0.0	0.0	0.0	6.0	6.0	6.0	0.0	0.0
Water Softener Rebate	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0
Hot Water Recirculation Systems Rebate	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	2.0	2.0
Sub-total	835.0	816.6	698.2	679.8	701.4	878.5	860.1	849.7	824.3	813.9
Education, Promotion and Regulation (no direct savings)										
Public Outreach and Education	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0	115.0
Water Reuse and Demand Management	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0	110.0
Water Efficient Landscaping Incentives	0.0	0.0	0.0	0.0	40.0	70.0	70.0	70.0	70.0	70.0
Outdoor Water Use Programs	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Mobile Applications (water)	50.0	30.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Drinking Water Promotion	20.0	20.0	20.0	70.0	20.0	20.0	20.0	20.0	20.0	20.0
Water Conservation and Rebound Effects Study	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Water/Energy Nexus	0.0	0.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0
Water Softening Pilot Study	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Best Practices for Municipal Upgrades Document	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AMR Study	0.0	0.0	60.0	60.0	60.0	0.0	0.0	0.0	0.0	0.0
Irrigation System Design and Const. Standard for New Construction	0.0	0.0	0.0	0.0	0.0	30.0	0.0	0.0	0.0	0.0
Rainwater Collection Network Regulations	0.0	0.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0
Sub-total	455.0	405.0	385.0	435.0	395.0	535.0	455.0	455.0	455.0	455.0
Total	1,290.0	1,221.6	1,083.2	1,114.8	1,096.4	1,413.5	1,315.1	1,304.7	1,279.3	1,268.9

Results and Discussion

Unit Costs for Water Supply and Wastewater Services

Unit costs for supply expansion and water efficiency measures are shown in Table 7. The unit cost for supply expansion captures both operating and capital costs required to provide additional water and treat additional wastewater as demand for service grow over the period 2017 to 2038. It is measured as the total incremental costs incurred annually over the period divided by the total incremental demand.[2] The figure comprises a cost of $1.90 for water and $2.47 for wastewater.

The unit costs for water saving measures represent the cost of reducing water demand by a cubic meter. As with the supply cost, these costs are measured over the period 2017 to 2038 and are the total incremental costs incurred annually for each measure divided by the total of annual reductions in demand that are achieved by the measure. The first five water saving measures cost less on a unit basis than the cost of supply expansion.

Table 7 Average Unit Costs for Supply Expansion and Water Efficiency

	Unit cost ($s/m3)
Supply expansion (water and wastewater)	$4.37
Direct Water Saving Measures	
Distribution System Pressure Management	$0.56
Water Loss Management	$1.60
Irrigation Audit (Water Smart Irrigation Professional)	$2.50
Home Visits/Audits	$3.97
Water Smart business	$4.02
Municipal Facility Upgrades	$7.52
Royal Flush Toilet Rebate Program	$8.18
Irrigation System Rebates	$8.33
Hot Water Recirculation Systems Rebate	$9.13
Sub-metering Program	$9.15
Multi- Residential Rebate Program	$17.50
Automated Meter Reading Installation	$21.92
Cooling Tower Audit Research Program	$31.51
Water Softener Rebate	$39.14
Blue Built Home Water Efficiency Standards and Rebate Program 2.0	$54.39
Healthy Landscapes Home Visit	$178.78

NOTE: These unit costs are referred to as 'average incremental costs' and are measured as: (net present value of incremental costs) ÷ (net present value of change in water demand).

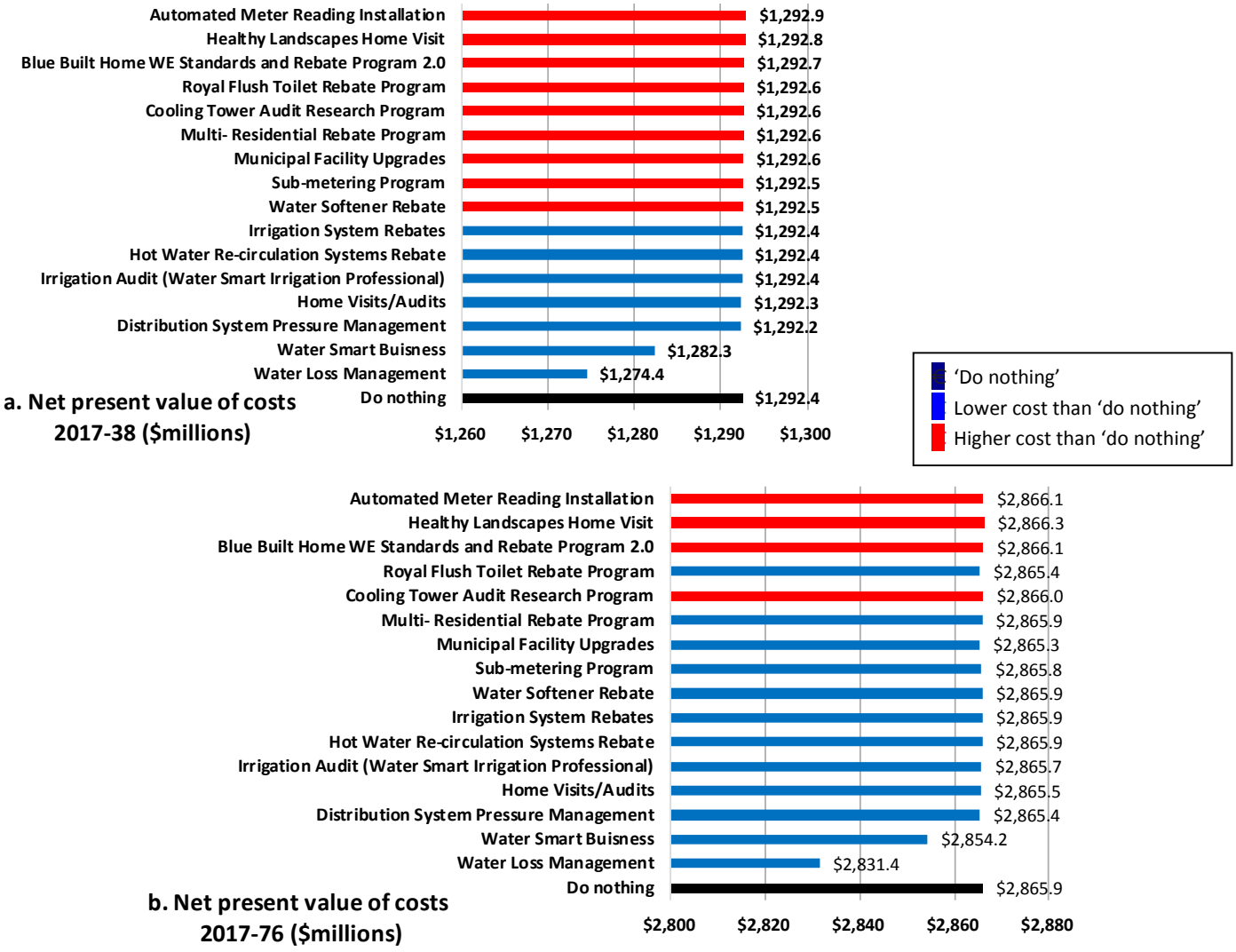
Financial Benefits

Financial benefits accrue to the City from implementation of WCE measures in the form of reduced OM costs and delays in the need for investments in WS and WW capacity expansions to supply increased volumes of water and treat increased volumes of wastewater. Against this benefit we must weigh the costs of the WCE measures.

[2] Totals for costs and volume are estimated using a net present value calculation.

Total system costs for WS and WW services are shown in Figure 2 for the 'do nothing' option which has no WCE programming, and for the system with added WCE measures. The benefit of a WCE measure is represented by the difference between the 'do nothing' cost and the total system cost with the measure in place, thus the 'water loss management' measure confers an overall benefit of $18.0 million ($1,292.4 less $1,274.4). This amount is the difference between the cost savings from reduced demand minus the cost of implementing the measure. The measures in part 'a' of Figure 2 are ordered from most beneficial to least beneficial. The first four measures generate a positive benefit. Other measures have a neutral or negative impact on overall costs.

Figure 2 Net Financial Benefits of WCE Measures



Part 'a' of this figure shows the net present value of total OM and capital costs over the period 2017 to 2038 and part 'b', with measures ordered as in part 'a', covers the longer period to 2076. In all cases, the performance of measures in part 'b' has improved over the performance shown in part 'a' of Figure 2 because cost savings are incurred over a longer period of time. The savings from implementation of the 'water loss management' option jumps from $18.0 million to $34.5 million. And some of the measures

that had a negative impact on overall costs have a beneficial impact when a longer time period is considered.

The implementation of combinations of measures has a cumulative impact on cost savings as the combined reductions in demand allow ever greater deferrals in capacity expansions. This is evident in Table 8 showing the timing of investments in capacity expansions under alternative WCE scenarios.

Table 8 Timing of Capacity Expansions with Alternative WCE Measures

	WS Capacity			WW Treatment capacity	
	1st New Well - Ironwood	Last New Well - Guelph North	Guelph Lake WTP	1st Expansion to 85 Megalitres/day	Last Expansion to 125 Megalitres/day
Do nothing	2018	2063	2070	2025	2072
A. Water Loss Management	2026	2069	2076	2029	2076
B. Water Smart Business	2018	2066	2072	2027	2073
Both A. and B.	2028	2072	not needed	2031	not needed
All Direct Saving Measures	2029	2073	not needed	2031	not needed

The financial benefit of an increasingly comprehensive WCE program with multiple measures is shown in Figure 3. Looking at part 'a' of Figure 3, after the first five measures are included in the program there is little additional benefit to be gained by adding additional measures. With the longer time frame of part 'b', the combination of the first six most cost effective measures leads to lower overall costs.

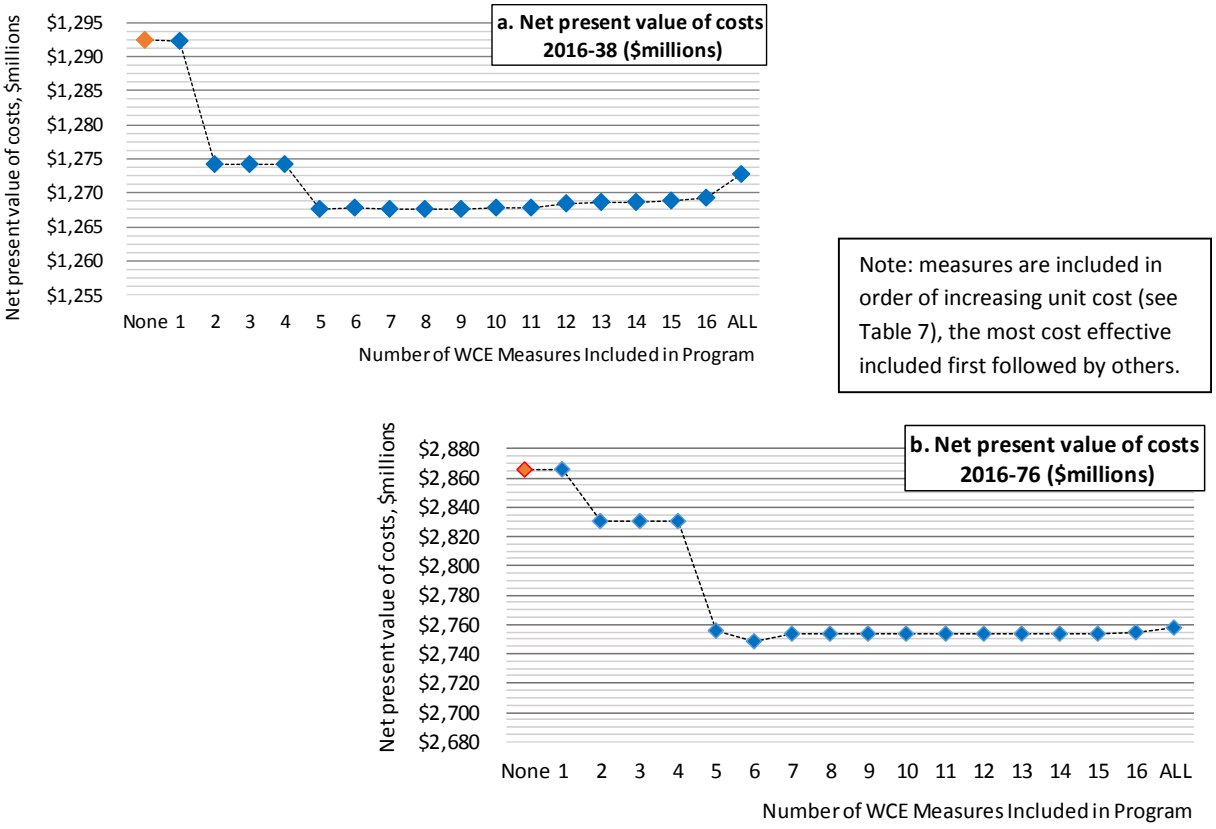


Figure 3 Benefit of Increasing the Number of Measures in a WCE Program

The fact that cost increases are minimal beyond the first five or six WCE measures suggest that many of the measures are coming close to paying for themselves in terms of OM cost savings that accrue over time. For this reason, the selection of WCE measures beyond those that are known to yield a significant beneficial impact should be based on criteria other than costs; a topic which is briefly discussed in the following section.

Non-Financial Benefits

The preceding section addresses financial benefits to the City of Guelph arising from the implementation of WCE measures. There are however other factors that bear consideration in deciding which measures to include in a comprehensive WCE program. Some of these considerations are discussed in

Table 9 Non-Financial Factors Bearing on the Selection of WCE Measures

ITEM	Description / comment
Awareness of WCE program	The analysis of the preceding section focusses on WCE measures that have a direct impact on water use. There are a number of measures that involve education, promotion, research and regulation; measures which have an indirect impact on water use. By raising awareness, these measures may serve to assure the uptake of the direct savings measures and may therefore be needed to achieve the estimated financial gains.
Innovation	The research oriented measures, while not yielding immediate savings, may serve to expand the potential for water savings beyond the limits that can be achieved using proven measures.
Carbon emissions	WCE measures reduce the use of energy used in water supply and wastewater systems. One estimate made in 2009 for the City of Guelph indicates an aggregate reduction in CO_2 emissions of about 0.5 tonnes per year for every cubic meter of daily demand that can be avoided.[3] The total reduction in CO_2 emissions associated with implementation of all WCE measures is about 2,800 tonnes per year by 2025. The social worth in present value terms of this emission reduction is conservatively estimated to be $4 million.[4] Additional carbon reductions are achieved through carbon sequestration by the trees planted under the Healthy Landscapes program.
Ecological values	Certain WCE programs address outdoor water use by promoting drought tolerant herbaceous and woody plants. These programs provide benefits beyond water conservation such as expansion of the urban tree canopy, increase in biodiversity of the urban ecosystem and protection of pollinators.

[3] Carol Maas. Greenhouse Gas and Energy Co-Benefits of Water Conservation POLIS Research Report 09-01 March 2009

[4] Based on R. Clarkson and K. Deyes, 2002. Estimating the Social Cost of Carbon Emissions. Environment Protection Economics Division, Department of Environment, Food and Rural Affairs: London. The estimate of damages caused by CO2 emissions in this report was £70/tC. This translates to $58/tCO2 at 2016 prices.