KERR WOOD LEIDAL
consulting engineers

Vancouver Island
201 - 3045 Douglas Street
Victoria, BC V8T 4N2
T 250 595 4223
F 250 595 4224

City of Nanaimo Water Audit

Final Report

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KWL Project No. 0566.035-300

Prepared for:

City of Nanaimo

Prepared by:

Ryan Lesyshen, M.Sc., P.Eng.
Project Manager

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Executive Summary

Executive Summary

The City retained the services of Kerr Wood Leidal Associates Ltd. (KWL) to complete a water audit. The goal of this work was to gain an understanding of where and how water is being used and lost and make recommendations that will improve how water is delivered both operationally and financially.

The project was divided into two stages with a desktop water audit completed in Stage 1 and field works completed in Stage 2. The top down AWWA M36 water audit was completed on one year of data starting August 1, 2010 and ending July 31, 2011.

The audit revealed a low level of real losses 9.83% corresponding to an infrastructure leakage index (ILI) of 1.54 which means that losses are 1.54 times the lowest technically achievable loss rate. There is very little room for improvement to be made in real loss reductions.

72.6% of the water produced is billed to customers (revenue water). The remaining 27.4% non-revenue water comprises 14.7% un-billed authorized consumption, 2.9% apparent losses and 9.8% real losses.

Although unbilled authorized consumption and real losses make up the majority of non-revenue water, combined they represent only 4% of the total system operating costs ($117,000). The relatively small volume of apparent losses, on the other hand, represents 13% of the total system operating costs ($387,000). This point underpins the importance of managing the City's customer meter population.

Meter testing was completed to estimate the accuracy of the meter population and determine how accuracy is affected by meter age. The goal of this work was to determine an optimum replacement frequency to minimize yearly metering costs. A 24 year replacement frequency was found to be the most cost effective. The savings for increasing to a 24 year replacement frequency, from the current 33year replacement frequency is estimated at $37,000 to $57,000 per year.

A review of meters sized 50mm through 150mm indicated that these large meters are being over-sized by 1-2 pipe diameters in many instances. The apparent over-sizing appears to be due to a lack of adequate meter selection and sizing design standards. It is recommended that a meter selection and sizing specification be developed based on AWWA standards.

A meter replacement budget of $331,000 is recommended for the next twenty years. The budget can be reduced to $244,000 at the end of twenty years which coincides with a 24 year replacement frequency. The meter replacement budget should be allocated as follows:

- $230,000 for 19mm meter replacements
- 101,000 for large meter replacements

In the first 2-3 years the large meter replacement budget should be spent on "Right-Sizing" meters, giving priority to those meters that will offer the greatest recovery of apparent losses. Focussing first on meter re-sizing will not only recover lost revenues but will also decrease the future costs of replacements as smaller meters cost less.

A yearly budget of approximately $27,000 should be allocated to active leakage control. This budget should be split between the development of district metering areas and leak sounding in order to maintain the current low level of losses. The budget should be revised if annual real losses increase.

An annual budget of $8,000 should be allocated to update the water audit on a yearly basis. Audits should begin in the month of May. To aid in the water audit process, credits made to customer accounts due to leaks should be done without adjusting the consumption data within the database.

A disaggregated demand analysis (breaking demand into its individual components) was completed to determine the source of the City's water demands and to calculate unit rates that can be used for future demand predictions. The following points were noted:

- Nanaimo's indoor residential water use of 198 L/person/day is considered lower than average.
- Residential average day demand is estimated at 251 L/person/day which is also below the average 297 L/person/day for communities within the Capital Regional District and below the Canadian average of 274 L/person/day.
- The City's single family residential summer seasonal demands of 962 L/dwelling/day are lower than the average comparable community.
- It is suspected that the City's full cost accounting rate setting structure and the use of an inclining block rate structure may be a major contributor to low residential base and seasonal demands.
- On average ICI demands were found to be much lower than standard design values however the top consumers had demands much greater than would be predicted by design values.

Demands were calculated for future 2031 OCP based on the given OCP population and future land-use areas. An OCP base demand of 535 L/s and an OCP MDD of 1,153 L/s were estimated.

A summary of the budgets required to cover the recommended future works is given below:

Allocation of Funds for Recommendations

Project / Program	Required Budget Allocation	Reason(s)
Meter Replacements	$331,000/year for first 20 years; $244,000/year following; Note: Figures do not include for 1.6% per year increase in meter population.	A yearly savings of $37,000 to $57,000 can be gained increasing the meter replacement frequency from 33 years to 24 years.
Customer Demand Profiling and Sizing Calculations for Large Meter "Right-Sizing" Project	$30,000 per year for 3 years	To eliminate the estimated $36,000/year in lost revenue due to oversized meter under-reading.
Meter Selection and Sizing Specification	$15,000	See above.
Leak Detection	$27,000 per year	To manage the City's water losses and maintain current low levels.
Customer Meter Testing	$5,000 per year	To better understand accuracy as it relates to meter age and brand.
Yearly Update of Audit Spreadsheets	$8,000 per year	Accountability, improved efficiency, decision making.

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Section 1

Introduction

1. Introduction

The City has retained the services of Kerr Wood Leidal Associates Ltd. (KWL) to complete a top-down water audit, component analysis and field works to gain an understanding of where and how water is being used and what level of losses, both apparent and real are occurring.

The project has been divided into two stages with an AWWA M36 top down water audit and component analysis being completed in Stage 1 and field works being completed in Stage 2. The finding of the Stage 1 audit will form the basis of moving forward with recommended field works (bottom-up approach). The field works are meant to both increase the level of confidence in the audit and better understanding the quantity and nature of system losses.

This report provides the findings and data used to complete both the Stage 1 and 2 works. The objectives and deliverables are:

- Quantify the existing water uses by user type;
- compute the current level of water losses, both real and apparent and quantify the components of these losses;
- Determine a system infrastructure leakage index (ILI) and other performance indicators for the purpose of benchmarking the City's water losses against others and assessing the best steps for starting a water loss management program;
- Utilize a water auditing software to compile the data; and
- Review the current accounting measures for the billing and tracking of water use and identify where and how improvement can be made to reduce apparent losses (increase revenues) and reduce computational effort for future/ongoing water audits.

Also included in this report is a disaggregated demand analysis that separates demands by user type into base and seasonal components. *The definition of disaggregation is the division of an item into its constituent parts.* This analysis allows for:

- The effect of water conservation measures targeting base and/or seasonal demands to be quantified;
- More accurate forecasting of maximum day demands (MDD) in densifying areas; and
- Demand predictions to be updated easily since they are directly related to population and lot areas.

The above points are discussed as they related to an estimated OCP MDD demand prediction that is given in this report.

1.1 The AWWA Water Audit

The AWWA water audit methodology published in the M36 Water Audits and Loss Control Programs manual quantifies customer consumption and volumes of real and apparent losses. This method reveals the destinations of water supplied throughout the distribution system and quantifies volumes of consumption and losses. The audit process occurs at three levels, each adding increasing refinement:

- Top-down approach: the initial desktop process of gathering information from existing records, procedures, data, and other information systems;

- Component analysis: a technique that models leakage volumes based on the nature of leak occurrences and durations;
- Bottom-up approach: validating the top-down results with actual field measurements.

The top-down approach is the recommended starting point for water authorities that have 100% metered customers.

1.2 Background

Nanaimo is a growing community and the City is planning large capital works projects to increase source capacity to meet the growing needs of the community. The current water supply is estimated to have the capacity to supply approximately 100,000 people. It is expected that this population will be reached by 2020. As well, the City of Nanaimo is planning for a population of 118,000 by 2030 according to the Official Community Plan.

The City of Nanaimo has long been a proponent of water conservation and has adopted numerous demand management approaches to encourage the efficient use of water and delay large capital works projects. These measures include:

- Universal metering of all service connections (since 1983);
- Expanded block rate billing system (since 1983);
- Full cost pricing (since 1992);
- Regulation on permitted use and summer watering restrictions;
- Public education on the value of water and ways to conserve;
- Engineering standards and specifications that require stringent design and construction practices that aim to maintain an efficient water system (since 1978);
- Computerized water system monitoring using Supervisory Control and Data Acquisition (SCADA) system (since 1991); and
- Start of annual user rate increases to ensure funding sustainability for major capital and ongoing operations over a long term (since 2007).

The city wishes to better understand existing water use and unaccounted for water to quantify apparent and recoverable losses in the context of planning and providing resilient safe drinking water into the future.

1.3 Abbreviations Used

ADD = Average Day Demand
BD = Base Demand (Typical Winter Demands)
Ca = Capita (Person)
HGL = Hydraulic Grade Line
ILI = Infrastructure Leakage Index
MDD = Maximum Day Demand
MMCD = Master Municipal Contract Documents
PHD = Peak Hour Demand
PRV = Pressure Reducing Valve
SCADA = Supervisory Control and Data Acquisition
SD = Seasonal Demand (Typical Irrigation Demand)
ML/Yr = Unit of measure - Mega Litres of water per year
ML/d = Unit of measure - Mega Litres of water per day
mH = Unit of measure – System pressure expressed in meters (head)
km = Unit of measure – Length of mains in kilometers

1.4 Referenced Material

Preparation of this report has proceeded with the benefit of the following reference materials and software:

City of Nanaimo Reference Materials

1. City of Nanaimo AutoCAD drawing files which include pressure zone boundaries, PRV locations and water main information.
2. City of Nanaimo Official Community Plan (OCP).
3. Digital topographic, cadastral, contours, aerial orthophoto plans (LiDAR DEM).
4. Detail of water main breaks from 2007 – 2011.
5. Monthly and Daily Bulk water meter readings (from SCADA).
6. Customer meter readings (billed on a 4-month cycle) accessed from the City's Tempest database.
7. City's current tracking sheets characterising daily consumption, population and system characteristics.

Other Reference Materials

8. AWWARF. 2007. Evaluating Water Loss and Planning Loss Reduction Strategies. Denver, Colo.: AWWA Research Foundation.
9. CWWA March 2012 Bulletin Article "City's Future Water Supply Options Being Explored".
10. AWWA Manual of Water Supply Practices – M6 Water Meters - Selection, Installation, Testing, and Maintenance (1999).
11. AWWA Manual of Water Supply Practices – M36 Water Audits and Loss Control Programs, Third Edition (2009).

12. A.O. Lambert and Dr. R.D. Mckenzie, Paper: Practical Experience in Using the Infrastructure Leakage Index, IWA Leakage Management Conference – A Practical Approach, Cyprus, (November 2002), ISBN 9963-8759-0-4.
13. Ministry of Agriculture, Food and Fisheries, Evapotranspiration Rates for Turf Grass in British Columbia, January 2002.
14. Farmwest.com, Evapotranspiration Data for August 2011 North Cowichan.
15. Aquacraft Water Engineering and Management: Analysis of Water Use in New Single Family Homes (January 2011).
16. Dr. Hans D. Allender, P.E. Paper: Determining the Economical Optimal Life of Residential Water Meters, WATER/Engineering & Management (September 1996).
17. Endress + Hauser, Flow Handbook, 2nd Edition, 2004, ISBN 3-9520220-4-7
18. AWWA Manual of Water Supply Practices – M22 Sizing Water Service Lines and Meters, Second Edition (2004).

1.5 Acknowledgements

The project team for this study and contributors to this study are listed below. The project could not have been completed without timely contributions and assistance of all those listed.

City of Nanaimo

Euan Wilson	Project Manager
Scott Pamminger	Water Resources Specialist
Bill Sims	Manager of Water Resources
Ritchie Fulla	General Foreman of Waterworks
Brian Thomas	Water Distribution foreman
Al Rooseboom	Instrument & telemetry technologist
Sarah Peabody	Revenue Supervisor
Tanis Rinta	Revenue Services user rate department
Sylvia Gauthier	Revenue Services user rate department
Brad Currie	Waterworks Operations

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Section 2

Top-Down Water Audit

2. Top-Down Water Audit

The sub-sections included in this section reference the task numbers one (1) through eleven (11) outlined in Chapter 2 of the M36 manual. All references to a particular "Task" is done such that the reader may refer with ease to the appropriate section of the M36 manual.

2.1 Compiling the Top-Down Water Audit Data

An AWWA M36 water audit is an effective tool for quantifying consumption and losses that occur in the distribution system as well as apparent losses that occur within the management processes related to customer metering and billing practices.

The water balance summary sheet that summarizes the audit results is shown in Figure 2-1. The balance sheet shows the sources of non-revenue water, such that large sources of non-revenue water, including water losses, can be identified and managed.

<table>
<tr><td rowspan="11">System Input Volume</td><td rowspan="5">Authorized Consumption</td><td rowspan="3">Billed Authorized Consumption</td><td>Billed Water Exported</td><td rowspan="3">Revenue Water</td></tr>
<tr><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="8">Non-revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="6">Water Losses</td><td rowspan="3">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td>Systematic Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 2-1: AWWA M36 Water Balance

The accuracy of the top down water audit on assessing water losses relies on accurate source data, good record keeping, and a high percentage of metered customers in the network. The audit gathers all available records and places data in a water audit worksheet.

System Boundaries

The water audit was performed for the treated water transmission and distribution system as bounded by the City's source and customer meters. For the purpose of an AWWA water audit, source refers to the point where treated water enters the distributions system. The two locations where source water is metered are:

- The Water Process Centre that is supplied by the South Fork Reservoir; and
- Reservoir 1, a raw water reservoir that is supplied by the South Forks Reservoir. Water is treated at the reservoir outlet prior to distribution.

Raw water transmission mains from the South Forks reservoir are not included in the water audit as they are upstream of the above mentioned metering locations.

Time Period

A one year period is recommended for completing the audit as this allows for seasonal variations in demand and reduces the effects of lag time in customer meter reading.

At the start of the project, a complete set of meter data was not available to the end of 2011. Therefore the audit was performed on the most recent complete **one year data set which was August 1, 2010 through July 31, 2011.**

It is recommended that subsequent audits be performed following the second billing period of the succeeding year. For example, the 2012 audit should be completed in May 2013.

Units of Measure

The units of measure used in the water audit are **metric.** Water volume is given in mega-litres per year (ML/Yr), average operating pressures are given in metres head (mH) and length of water mains is expressed in kilometers (km).

2.2 Task 1 – Collect Distribution System Description Information

The physical characteristics of the water system are required in order to calculate key performance indicators. Pertinent characteristics of the City of Nanaimo's water system are listed below:

- 615 kilometers of water mains (excluding hydrant connections);
- 2922 fire hydrants;
- Estimated 29 kilometers of hydrant connections;
- 24,276 metered customers;
- 24,785 customer meters (*Note: some customers have multiple meters*);
- Average length of service connections from main to meter is approximately10 meters. Meters are located at property line and average City of Nanaimo Road allowance is 20 meters.
- 26 pressure zones with 51 pressure reducing stations and 10 surge release stations;
- 8 reservoirs; and
- 7 active (online) pump stations and 3 stand-by pump stations.

The AWWA audit method does not provide performance indicators as related to pipe material type and age; however, these physical characteristics are related to the mechanisms responsible for water losses. Pipe materials and age are characterized in Figures 2-2 and 2-3 respectively. Service connections were noted as being primarily copper with the exception of “tough tube” utilized in the Harewood community. It was noted that service connections are generally replaced at the same time as mains thus the age distribution of service connections will be similar to that of the mains.

The city has a service connection density of 102 connections per km of mains.

The system is operated at an average pressure of 71.5 meters head. This was calculated from the City’s water model using the 2008 average day demand (ADD) scenario.

It was noted by the General Foreman of Waterworks, Ritchie Fulla, that AC pipe has been the main source of break history in the past. The city has an active program to replace all AC mains.

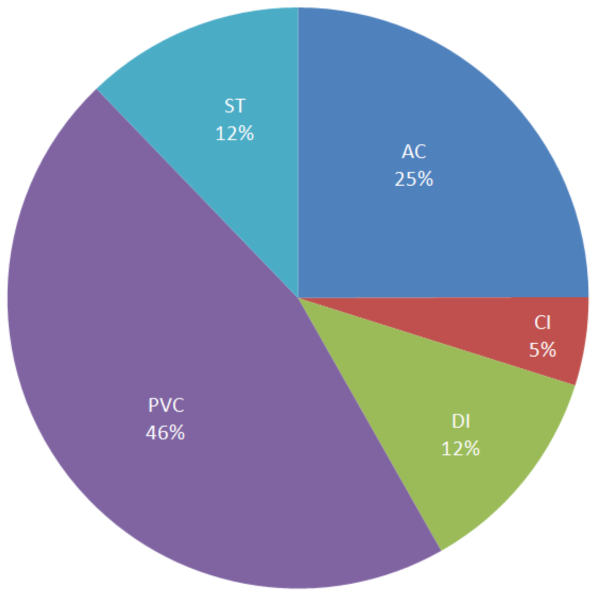


Figure 2-2: Pipe by Material Type [7]

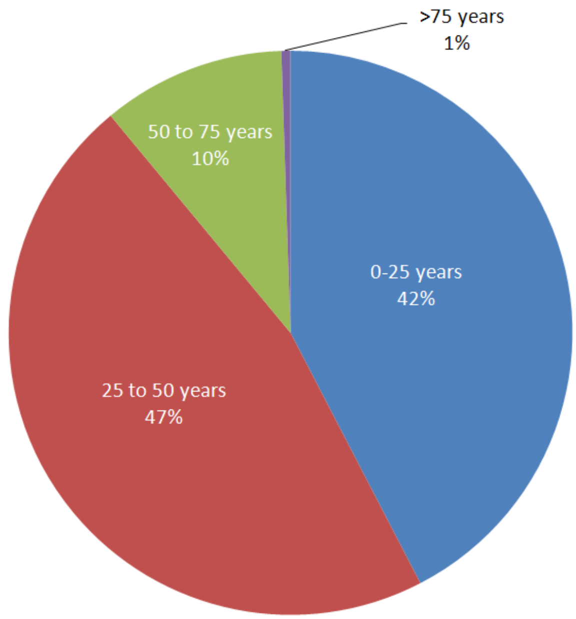


Figure 2-3: Pipe by Age [7]

2.3 Task 2 – Measure Water Supplied to the Distribution System (Source Flow Data)

Compile Source Volume Raw Data

The City has 5 bulk supply meters located at the two metering locations; three at the Water Process Centre (WPC) and two at Reservoir #1. Meters are NuSonics transit-time ultrasonic meters. The two at reservoir #1 are Model CM – 800 installed in 1997. The meters at WPC are Model 8400. Two were installed in the mid-1980s and one in 1993 when the third screening leg was commissioned.

The three meters at the WPC are located on the three 600 mm screening legs of the process. It has been noted that one of the three screening legs is isolated during low flows in the winter months. Figure 2-4 is a photo of the meters at WPC. It is noted that the upstream and downstream straight pipe lengths are approximately 3.5 and 0 respectively whereas the manufacturers recommends a minimum 10 straight pipe lengths upstream and 3 downstream. To compensate for the lack of straight pipe lengths manufacturer supplied flow straighteners are installed directly upstream of each meter.

The meters at Reservoir #1 are located downstream of the reservoir outlet with ample upstream and downstream pipe lengths. Figure 2-5 shows one of the meters at Reservoir #1. These meters have adequate upstream and downstream straight pipe lengths.

Table 2-1 displays two years of monthly source flow totals as provided by the City.

Table 2-1: 2010-2011 Monthly Source Flow Volumes

Month	2010			2011			% Change (2010 to 2011)
	Water Process Centre Volume (ML)	Reservoir #1 Volume (ML)	Cumulative Annual Volume (ML)	Water Process Centre Volume (ML)	Reservoir #1 Volume (ML)	Cumulative Annual Volume (ML)	
January	730	359	1,089	717	341	1,058	-2.9%
February	712	263	975	657	280	938	-4.0%
March	792	327	1,118	697	385	1,082	-3.4%
April	770	321	1,091	757	325	1,082	-0.8%
May	902	369	1,271	813	347	1,160	-9.6%
June	1,000	417	1,417	1,065	432	1,497	5.3%
July	1,621	601	2,222	1,250	555	1,805	-23.1%
August	1,534	531	2,065	1,403	588	1,990	-3.7%
September	935	382	1,317	1,119	510	1,629	19.2%
October	756	375	1,131	870	250	1,120	-1.0%
November	731	324	1,055	717	321	1,038	-1.6%
December	729	340	1,069	727	325	1,052	-1.6%
TOTALS	11,212	4,608	**15,820**	10,792	4,658	**15,450**	**-2.4%**
Note: Audit Period Data shaded in light blue.							

Table 2-1 shows a net decrease of 2.4% in total supplied volume from 2010 to 2011. For the audit period (August 2010 through July 2011) **the total metered source volume was 15,257 ML.**

Figure 2-4: Location of Three Source Meters at Water Process Centre

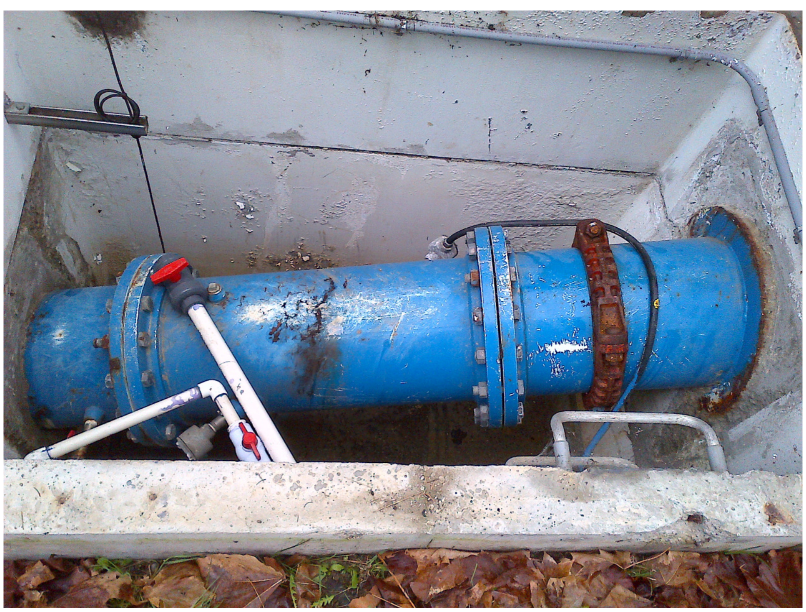


Figure 2-5: One of the Two Source Meters at Reservoir #1

Source Adjustments

Once the source volumes are established (raw data), the measured amounts need to be reviewed and corrected for known systematic or random errors that exist in the data. Factors to be considered in this adjustment include:

1. Meter inaccuracies;
2. Changes in reservoir and storage levels; and
3. Other adjustment such as losses occurring before water reaches the distribution system.

Given the duration of the audit and the diurnal fluctuations in tank volumes, changes in storage are considered negligible.

The blow-off of treated water to Reservoir #1 could be accounted for here; however it is instead accounted for as an authorized unbilled unmetered consumption. The Duke Point Reservoir blow-off is also treated in this manner. These blow-offs are discussed further in the section covering authorized unbilled unmetered consumption.

Source metering inaccuracy can be the largest source of error in a top down water audit. The two general sources of meter inaccuracy and the possible methods for quantifying them are:

1. **Mechanically Influenced Errors** – Quantifiable by calibrated validation meter located in pipe section with even flow profile (outside the influence of mechanical effects on flow profile). *A function of the physical location and age of a meter.*
2. **Low Flow Meter Inaccuracy** – Quantifiable by use of validation meter with better low flow characteristics, volumetric measurement or desktop error analysis (manufacturers literature). *Solely a function of the meters specified accuracy. Although labelled "Low Flow Metering Inaccuracy", meter error will occur over all flow rates. Low Flow inaccuracy is generally the greatest.*

Mechanically Influenced Errors

Flow profile at the meter location is very important, and the City's ultrasonic meters are particularly sensitive to this issue. These meters register fluid velocity along a single straight line and therefore significant variations in local velocity across the flow profile can result in large metering errors that are difficult or impossible to predict. Poor flow profiles are caused by changes in flow cross section, obstructions and where partial flows join.

The recommended industry standard for quantifying measurement error is to perform yearly verification testing (compare meter readings with readings of a calibrated meter installed in series). The results of a source meter verification exercise are given in the next section of the report.

Low Flow Meter Inaccuracy

Metering error associated with the typical flow rates that pass over the meters can be estimated by a desk top study. The current operating flow regime across each meter is compared with the meter manufacturers specified accuracy capabilities. Table 2-2 below gives the measurement capabilities of the supply meters as supplied by the meter manufacturer.

Table 2-2: Measurement Capabilities (Manufacturers Data)

Range	0.3 to 50 ft/sec
Pipe Diameter	2"-200" (50 mm to 5,080 mm
Accuracy	+/- 0.5 to 1% of flow reading above 0.3m/sec +/- 1 to 2% of flow reading from 0.09 to 0.3m/sec
Repeatability	0.20%
Linearity	0.10%
Turndown	167:01:00

Tables 2-3 and 2-4 give the estimated percentage accuracy at given flow rates and the metering accuracy analysis respectively. An *a*ccuracy of 10% is assumed for flows less than that of the stated capabilities of the meters (<0.09 m/s). It is estimated that flows drop to 0.08 m/s during base night flows at Reservoir #1, otherwise, flows are estimated to always be within the stated measurement capabilities of the meters.

It can be seen that the estimated overall metering accuracy is +/- 1.34% at base flow and +/- 1.07% during a summer flow regime. For the purpose of the audit, the meters are assumed to be under-registering**. The yearly average metering inaccuracy due to low flow under-registration is therefore estimated to be - 1.2% which equates to 183 ML/year.**

As noted previously, metering accuracy is also affected by mechanically influenced errors . These effects are quantified in the next section on source meter validations.

Table 2-3: Estimated Meter Accuracy

Accuracy Limits	Accuracy
0-0.09 m/s	10%
0.09-0.3 m/s	2%
>0.3 m/s	1%

Table 2-4: Total Source Meter Accuracy Calculation

Demand Type	Meter	Pipe Diameter (mm)	Estimated Flow (L/s)			Velocity (m/s)			Accuracy			% Time at Flow			% of Total Accuracy		
			Low Flow	Average Flow	High Flow	Low Velocity	Average Velocity	High Velocity	Low	Ave	High	Low	Ave	High	Low	Average	High
BASE DEMAND	WPC1	575	50	150	225	0.19	0.58	0.87	2%	1%	1%	0.15	0.65	0.2	0.037%	0.238%	0.110%
	WPC2	575	50	150	225	0.19	0.58	0.87	2%	1%	1%	0.15	0.65	0.2	0.037%	0.238%	0.110%
	WPC3	575	0	0	0	0.00	0.00	0.00	0%	0%	0%	0.15	0.65	0.2	0.000%	0.000%	0.000%
	RES#1-1	724	20	55	82.5	0.08	0.21	0.32	10%	2%	1%	0.15	0.65	0.2	0.073%	0.174%	0.040%
	RES#1-2	724	20	55	82.5	0.08	0.21	0.32	10%	2%	1%	0.15	0.65	0.2	0.073%	0.174%	0.040%
	TOTALS		**140**	**410**	**615**										**TOTAL ACCURACY**		**1.34%**
MAX MONTH	WPC1	575	76	190	285	0.29	0.73	1.10	2%	1%	1%	0.15	0.65	0.2	0.030%	0.160%	0.074%
	WPC2	575	76	190	285	0.29	0.73	1.10	2%	1%	1%	0.15	0.65	0.2	0.030%	0.160%	0.074%
	WPC3	575	76	190	285	0.29	0.73	1.10	2%	1%	1%	0.15	0.65	0.2	0.030%	0.160%	0.074%
	RES#1-1	724	40	100	150	0.15	0.39	0.58	2%	1%	1%	0.15	0.65	0.2	0.016%	0.084%	0.039%
	RES#1-2	724	40	100	150	0.15	0.39	0.58	2%	1%	1%	0.15	0.65	0.2	0.016%	0.084%	0.039%
	TOTALS		**308**	**770**	**1,155**										**TOTAL ACCURACY**		**1.07%**

2.4 Source Meter Validations

Source meter inaccuracy is the largest potential source of error in a top down water audit. Source meter testing was therefore carried out as a Stage 2 task and is reported in this section.

Both the Water Process Centre (WPC) and Reservoir #1 source meters were verified through comparison to a clamp on ultra-sonic flow meter installed in series at both metering locations. KWL's Controlotron Model 1010 clamp on meter was used.

The manufacturer recommends at least 10 upstream and 3 downstream straight pipe diameters for KWL's clamp on meter. Ensuring a uniform upstream profile is most important and this was taken into consideration for the placement of the clamp-on meter at both sites.

Water Process Centre Meter Validation

Figure 2-6 displays the location of the three WPC meters as well as where the clamp on meter was installed. The location that offered the most upstream straight pipe lengths was on the 900mm intake header as it enters the building. This location achieved greater than 10 straight pipe diameters upstream and 1.5 straight pipe diameters downstream. The influence of the downstream strainer leg on upstream flow profile is assumed to be negligible as there is little or no disturbance in the main flow resulting from a separating split in flow *[17]*.

The WPC source meters are located on the vertical section of the 600mm strainer legs three pipe diameters downstream of a 90 degree bend and mechanical strainer. It was reported by the City that flow straighters were installed directly upstream of the meters to improve measurement accuracy. The mechanical installation effects that are suspected to have influence on flow profile are:

- 90 degree bends will produce a range of distorted flow profiles which will vary with flow rate;
- The strainers assembly will induce swirl and profile distortions at the filter outlet; and
- Flow straighteners are designed to reduce swirl however tests have shown that immediately downstream of some designs, the flow is still unstable and considerable mixing is present. *[17]*

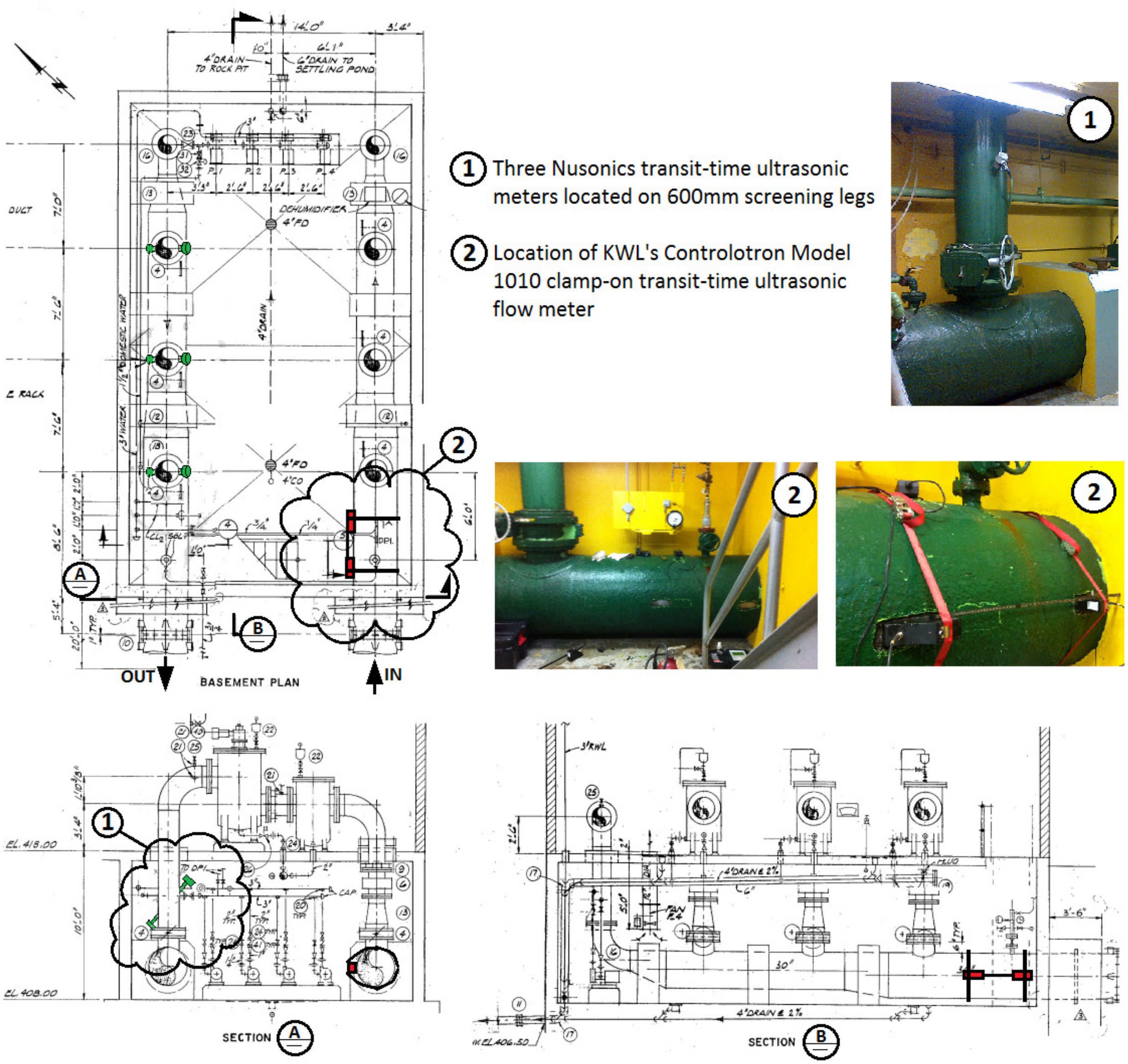
Manual meter readings were conducted from 20 July through 21 September 2012. Figure 2-7 displays the recorded difference between the summation of three source meters and KWL's clamp-on meter.

The measurements are in close agreement with each other, with less than 5% difference on all but one reading. The results display an apparent measurement bias that increases linearly with flow rate. The bias appears to begin at a flow rate of approximately 185 L/s (last assumed point of zero bias) and increase linearly to a 3% bias at flows around 650 L/s. The results also show 5 distinct bands of flow which are attributed to the combinations of different reservoirs filling.

The source of measurement bias could either be a positive bias associated with the configuration of the strainer legs or it could be a negative bias associated with the clamp-on meter installation. Assuming the bias is due to mechanical effects around the three source meters, an average positive bias (over registration of source flows) may be occurring.

The average measurement bias can be determined by comparing the average WPC source flows with the results shown on Figure 2-7. The average flow rate from WPC over the audit period was computed as 340 L/s. **A 1% over-registration can therefore be inferred from Figure 2-7.**

Figure 2-6: Water Process Centre Meter Locations



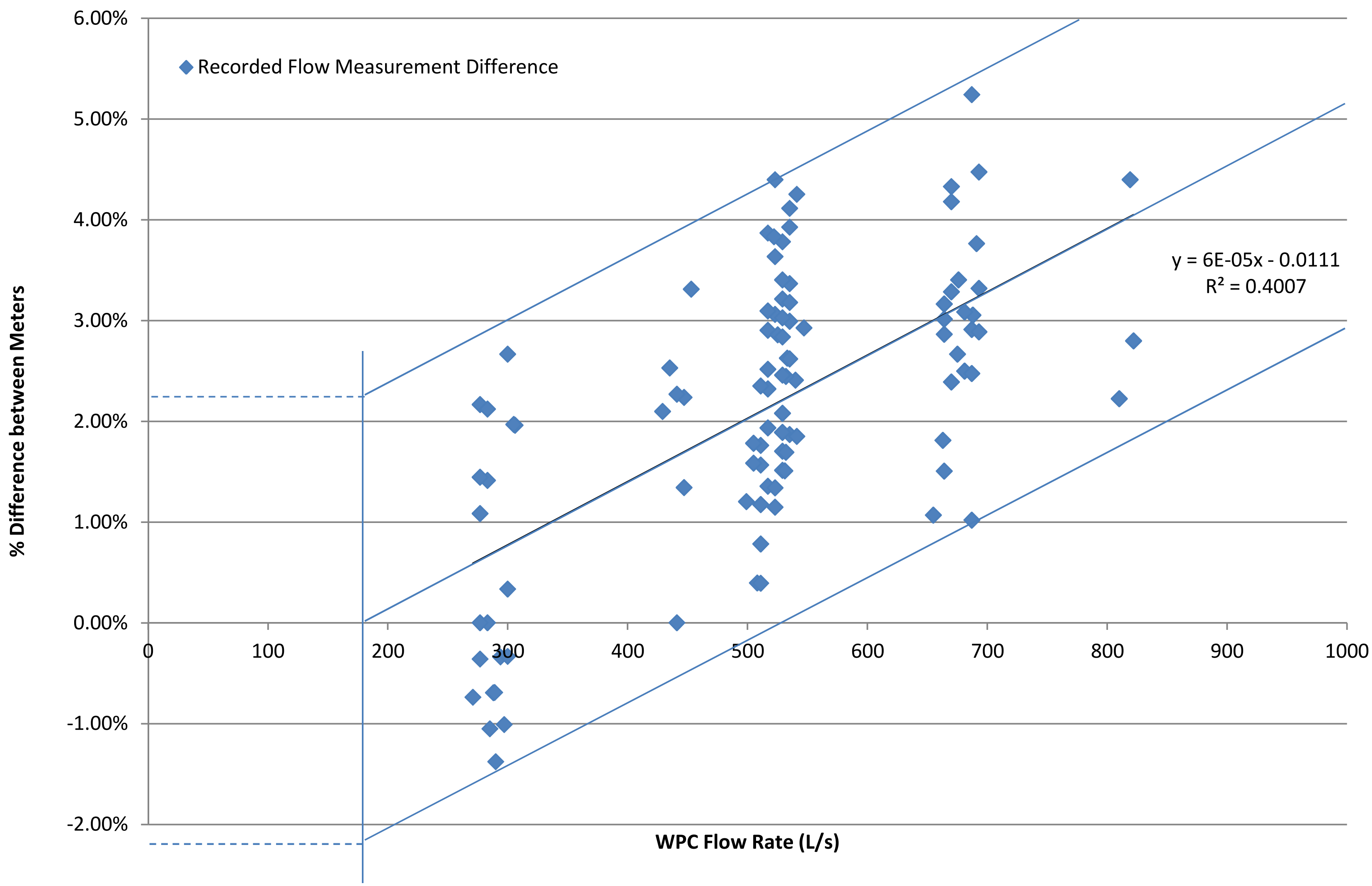


FIGURE 2-7: Water Process Centre Meter Validation Results Showing Percent Difference Between KWL Clamp-on Meter and Summation of Water Process Centre Meters

Reservoir #1 Meter Validation

Reservoir #1 outlet flows are metered by two NuSonics transit-time ultrasonic meters located in chambers on the North Side of the reservoir near the creek raw water overflow. These meters were validated by installing KWL's clamp on meter approximately 390 meters downstream on the 900mm diameter steel trunk main.

Figure 2-8 shows the location of the Reservoir #1 source meters and where KWL's clamp on meter was installed for the validation.

The validation meter was installed at the location of the new enclosed Reservoir #1 construction site. This location offered ample upstream and downstream straight pipe lengths and the site was recently cleared for the construction of the new reservoir. A fairly significant excavation was required in order to install the validation meter.

Figure 2-9 shows the results of the meter validation. **The validation and source meters have excellent agreement and therefore no measurement bias (error) is suspected.**

Source Meter Adjustments for the Water Audit

Calculations completed in Stage 1 of the audit estimated a source flow under-registration of1.2% due to meter inaccuracy. This apparent under-registration could not have been identified by the meter validations as both the validation meter and source meters would be affected by low flow inaccuracy.

The meter validation exercise showed an apparent 1% over-registration of average day WPC source flows. Adding the effects of this mechanically influenced error to the metering error approximation yields a 0.2% under-registration at WPC. Source meter adjustments at Reservoir #1 remain unchanged by the results of the validation and therefore 1.2% under-registration is assumed.

The total source meter adjustment is therefore 0.5% given that 70% of source flows are metered at WPC and 30% at Reservoir #1. **This equates to a 76 ML/yr adjustment and an adjusted source flow of 15,333 ML/yr.**

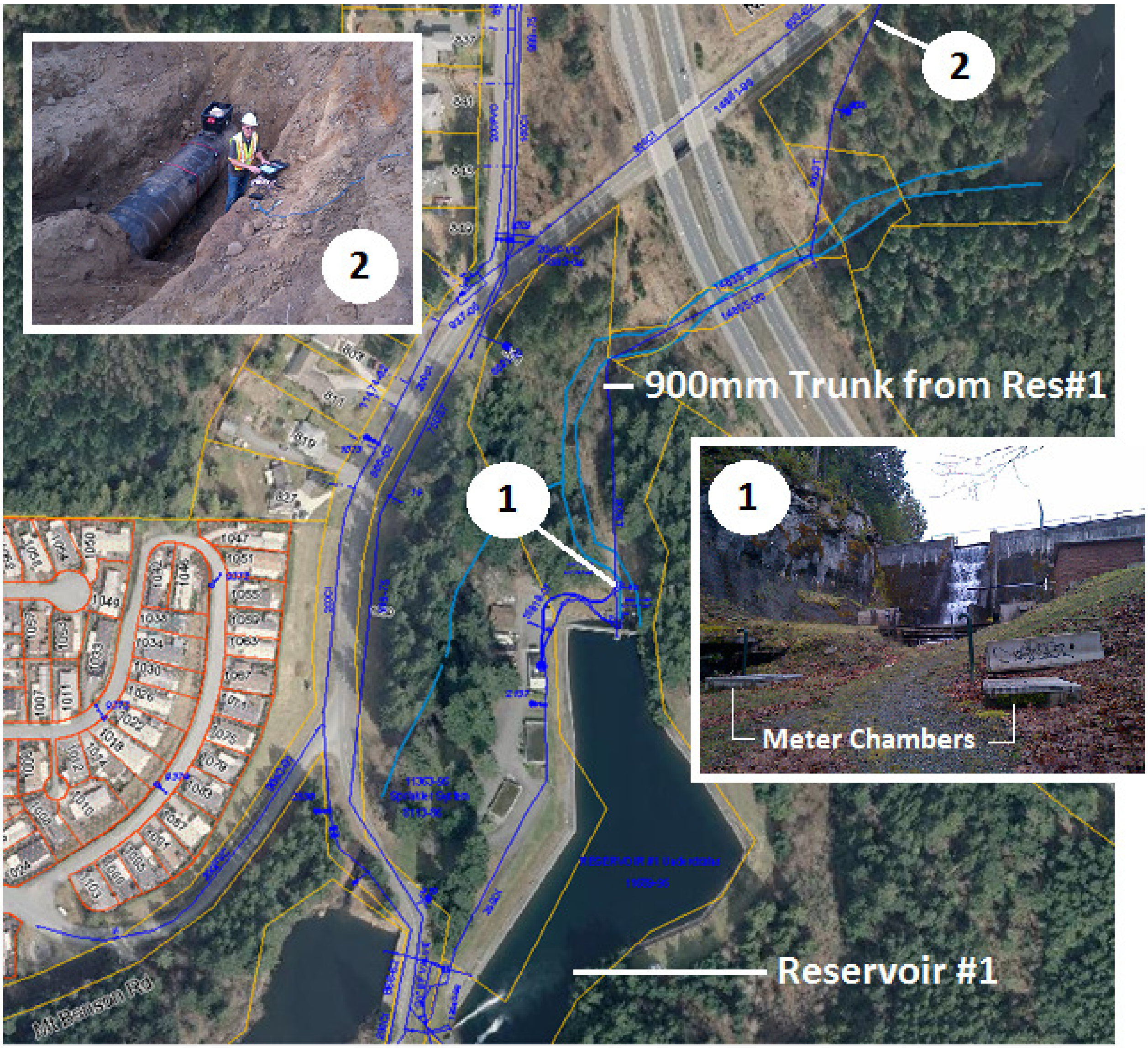
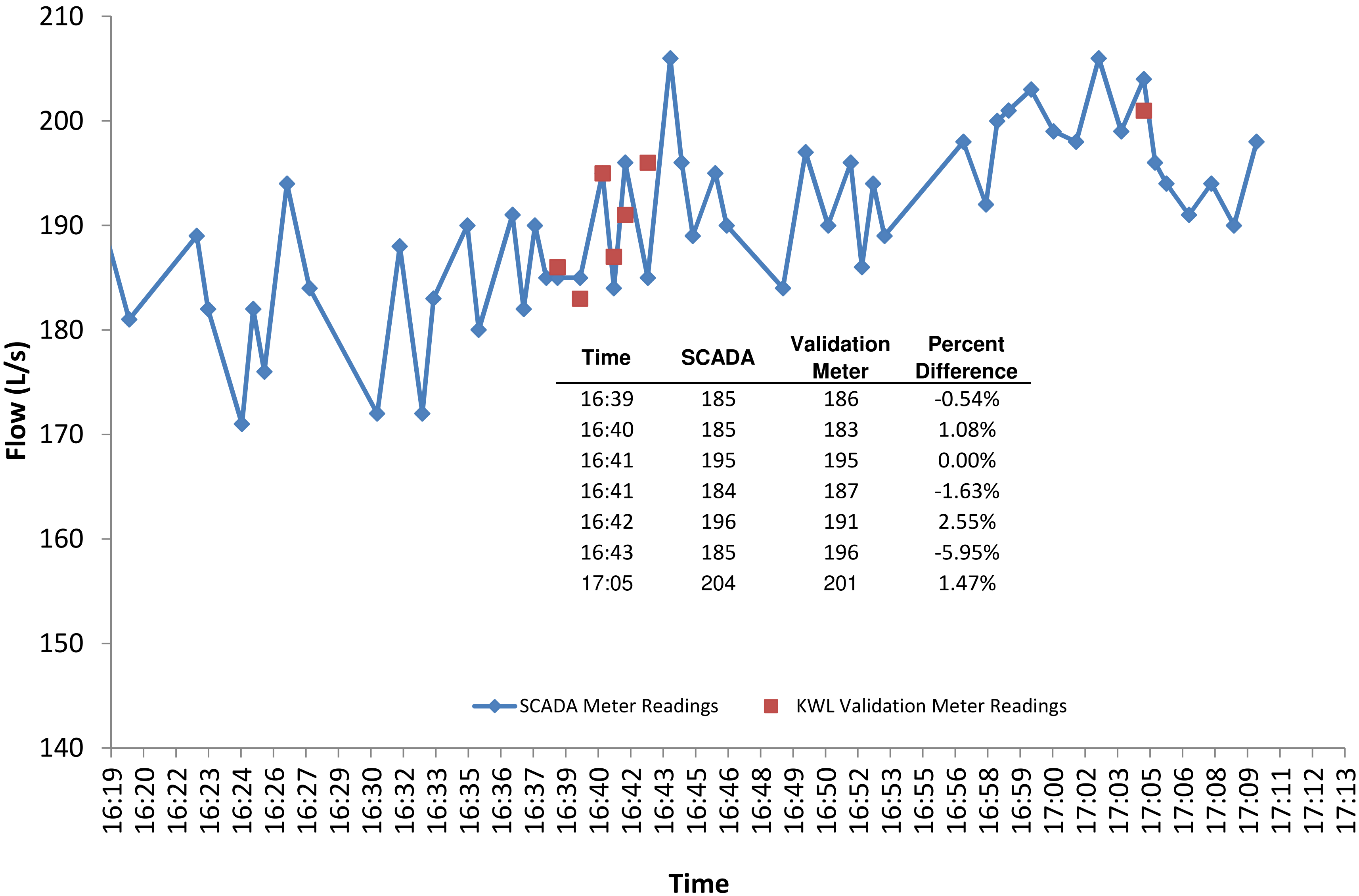


Figure 2-8: Reservoir #1 Meter Locations Showing Location of Verification Meter Installation



Time	SCADA	Validation Meter	Percent Difference
16:39	185	186	-0.54%
16:40	185	183	1.08%
16:41	195	195	0.00%
16:41	184	187	-1.63%
16:42	196	191	2.55%
16:43	185	196	-5.95%
17:05	204	201	1.47%

FIGURE 2-9: RESERVOIR #1 METER VALIDATION RESULTS

2.5 Tasks 3 & 5 – Quantify Authorized Consumption

Authorized consumption comprises:

TASK 3 – Quantify Billed Authorized Consumption
- Billed Water Exported.
- Billed Metered Consumption.
- Billed Unmetered Consumption.

TASK 5 – Quantify Unbilled Authorized Consumption
- Unbilled Metered.
- Unbilled Unmetered.

For the audit period, **authorized consumption was calculated as 13,387 ML.** The components of this figure are expanded upon below:

Billed Water Exported

In addition to its residents, the City also supplies water to the Village of Southwest Extension and Snuneymuxw Reserve No 1.

The City of Nanaimo has been supplying the Village of Southwest Extension with bulk water since 1998. Water is metered through a 50 mm Sensus touch read meter for low flow installed in 2008 and a 150 mm Sensus radio read meter for high flow installed within the audit period (2010). The total water exported to the village during the audit period was 16 ML.

The Snuneymuxw First Nation is supplied and billed for bulk water through a metering station containing two touch read Sensus meters. The current meters are 200 mm and 75 mm diameter and were installed in 2009. The total water exported to the Snuneymuxw Reserve No. 1 was 68 ML over the one year audit period.

The total water exported was therefore 84 ML over the audit period.

Billed Metered Consumption

The city has had universal metering of all service connections since 1983. It manages customer billing and meter reading using billing management software that stores meter readings and meter data including meter installation date, size and manufacturer.

There are 24,783 billing meters in the network for 24,275 metered customers (excluding bulk water export customers). Table 2-5 gives a summary of customer account types as defined in the meter database.

It is noted that the account type listed in the database contains limited information for defining ICI customers. The database does contain account descriptions that give detailed descriptions of each customer; however, the level of detail makes it difficult to easily categorize the database into a manageable list of land uses. The level of detailed data is still very informative and a breakdown of metered customers by account description is included in Appendix A.

Table 2-5: Metered Customers by Account Type

Account Type[1]	Number of Meters	Percent of Total Meters	Percent of Metered Consumption
COMMERCIAL/RES	179	0.7%	1.0%
GOVERNMENT	150	0.6%	7.0%
MUNICIPAL	160	0.6%	3.4%
OTHER	1,159	4.7%	17.8%
RESIDENTIAL-MLT	3,856	15.6%	27.4%
RESIDENTIAL-SFD	19,279	77.8%	43.4%
Grand Total	**24,783**	**100%**	**100%**

Notes: [1] COMMERCIAL/RES refers to commercial/residential mix use account types. MLT refers to multifamily. SFD refers to single family dwellings.

It is noted that 93.4% of accounts are residential and residential consumption is approximately 70.8% of the total.

A summary of average day consumption by account type, meter size and average installation year is given in Table 2-6. Single family dwellings registered an average day demand of 686 L/dwelling/day

The total billed-metered consumption over the audit period was 11,045 ML (excluding water exported).

(Note: an in-depth breakdown of water use by customer type is included within the disaggregated demand analysis section at the end of the report).

Table 2-6: Summary of ADD by Account Type, Meter Size and Average Installation Year

Account Type	Meter Size (mm)	Number of Meters	Ave. Installation Year	Ave. Demand (ML/year)	ADD (L/meter/day)
COMMERCIAL/RES		**179**	**2000**	**116.3**	**1,780**
	19	111	1999	37.5	926
	25-75	51	2001	55.8	2,998
	100	12	2003	23.0	5,251
	150-250	4	1998	0.0	0
	Blank	1	-	0.0	0
GOVERNMENT		**150**	**1998**	**780.8**	**1,426**
	19	32	1997	6.7	574
	25-75	94	1998	511.2	14,899
	100	4	1999	141.0	96,575
	150-250	20	1998	122.0	16,712
MUNICIPAL		**160**	**2000**	**372.8**	**6,384**
	19	39	2002	6.0	421
	25-75	110	1999	238.9	5,950
	100	8	1995	106.7	36,541
	150	3	1998	21.2	19,361
OTHER		**1,159**	**1998**	**1,894.6**	**4,479**
	19	570	1998	227.7	1,094
	25-75	515	1998	1,438.3	7,652
	100	26	1999	160.7	16,934
	150-200	48	2001	67.9	3,876
RESIDENTIAL-MLT		**3,856**	**1999**	**3,050.4**	**2,167**
	19	3,251	1999	1,096.9	924
	25-75	519	1999	1,754.4	9,261
	100	20	2001	91.9	12,589
	150-200	60	2002	97.9	4,470
	Blank	6	2007	9.2	4,201
RESIDENTIAL-SFD		**19,279**	**1997**	**4,830.2**	**686**
	19	19,129	1997	4,783.3	685
	25-75	122	2003	41.0	921
	150	9	2004	2.4	731
	Blank	19	2006	3.6	519
Grand Total		**24,783**	**1998**	**11,045.1**	**1,221**

Billed Un-metered Consumption

The city operates a bulk filling station where customers are charged for water based on the size of tank filled. Volumes are recorded for billing purposes but not metered.

Bulk water hauling spreadsheets were provided for the period of January through December 2011. The estimated volume of water bulk water hauling over the audit period was assumed to be approximately equal to the 2011 data. **This volume was 3.0 ML.**

Unbilled Metered Consumption

There are 16 accounts with meters that are not billed. Table 2-7 below gives a list of these accounts, and reasoning why consumption is not billed. **Unbilled metered consumption was 1.06 ML.**

Table 2-7: Unbilled Metered Consumption

Account Number	Volume (m^3)	Reason for Not Billing	Account Type	Account Description
101527	124.6	Nuisance Property	RES-SFD	SINGLE DWELLING RESIDENTIAL
101810	0.0	Nuisance Property	RES-SFD	OLD CITY MIXED USE
115536	483.6	Nuisance Property	RES-SFD	
117741	0.0	Nuisance Property	RES-MLT	
120190	326.3	Special Agreement not to bill	RES-SFD	OUTSIDE CITY
202788	0.0	Army Camp. Disconnect permit in Oct 2006. Meter moved to A/C 117013	RES-SFD	
205188	0.0	Nuisance Property	RES-SFD	
101817	0.0	Billing only for the A meter on this account	RES-MLT	2 SFDS PLUS CABIN
105072	0.0	Only charging for garbage on this account. On a well	GOVT	BC HYDRO
107051	0.0	Billing only for the C meter on this account	OTHER	OFFICE/HATCHERY/RESERVOIR
114093	17.3	?	RES-MLT	2 SFDS
117175	108.5	Billing only for the B meter on this account. A meter has been removed	OTHER	OFFICE/HALL
200160	0.0	Billing only for the C meter on this account	RES-MLT	TOWNHOUSE RESIDENTIAL
TOTAL	**1,060.3**			

Unbilled Un-Metered Consumption

Unbilled un-metered consumption includes water used by the City of Nanaimo for operational purposes. Components of unbilled un-metered consumption are given below in Table 2-8.

The largest components of unbilled un-metered consumption occur at Reservoir #1 and Duke Point Reservoir. Figures 2-10 and 2-11 are photos of the blow-offs at Duke Point and Reservoir #1.

At Reservoir #1 treated water is blown off into the untreated open water reservoir in order to maintain a minimum flow through the WPC. This operational decision is considered by the City to be a low cost method of maintaining control of dosing rates during low flows (winter night flows), however the blow off runs continuously year round.

The blow off at Duke Point reservoir was added to decrease water age as the Duke Point reservoir and distribution piping are sized for a much larger industrial demand than what currently exists.

The total unbilled un-metered consumption is estimated at 2254 ML/year.

Table 2-8: Estimated Unbilled Un-metered Consumption

Source	Volume (ML/Yr)	Data Source / Summary
Nanaimo Fire Training Centre	1.5	The Nanaimo Fire Hall's training centre water use was estimated from the average use at two metered fire halls (#8 Fire hall and Dorman Road Fire hall).
Yearly Flushing	14.5	Source Flows over flushing period were compared against 2 weeks of data prior and 2 weeks of data post flushing to estimate the volume of flushing water.
Un-metered Parks	16.5	Nanaimo Parks provided a spreadsheet listing 30 unmetered park sites. Usage per site was estimated as the average use for 33 park accounts that are metered.
Water Sampling Stations	55.5	The City has 12 sampling stations that run continuously. Flow rates were estimated based on average operating pressure and orifice size and then provided to Nanaimo Operations staff. The volume given is a revised estimated based on operations staff input.
PRV Sump Priming	157.7	The City has approximately 20 sumps in PRV stations that are primed with treated water. Operations staff estimates the total flow rate at these sites to be approximately 5 L/s.
Fire Fighting	2.8	The city estimates that 6-10 fires occur yearly. 350 m^3 is the estimated yearly firefighting volume.
Duke Point blow-off	1,040.7	The City continuously blows off water at the Duke point reservoir in order to maintain adequate water age. The Duke point industrial area currently has low demands. The City has previously estimated this flow rate at 33 L/s.
Reservoir #1 blow-off	965.0	The City adds water to Reservoir #1 continuously to maintain a minimum flow at the WPC for chlorine dosing. This flow rate is given as 30.6 L/s in the City's 2006 water model and was estimated by staff as being between 30-40 L/s.
TOTAL	**2,254**	

Table 2-8 shows that the total volume of water blown off at reservoirs is 2,006 ML. The cost associated with these operations is the variable production costs to treat and deliver water. These costs, derived later in the report, equate to $30.68/ML. Therefore the **costs associated with blow-off of water to maintain adequate treatment is estimated at $61,500/year.**

Figure 2-10: Photos of Duke Point Reservoir and Blow-Off

Figure 2-11: Photos of Reservoir #1 (Raw water) with Treated Water Blow-Off to Surface.

2.6 Task 4 – Calculate Non-revenue Water

Non-revenue water is the portion of water that the City treats and distributes that is not billed and therefore does not generate revenue for the City. Non-revenue water consists of unbilled authorized consumption (discussed above), apparent losses and real losses. In the top-down audit approach, non-revenue water is calculated as the remaining water into supply that is not accounted for within the billing records. This is shown as:

Non-Revenue Water = Adjusted Source Volume (Task 2) – Billed Authorized Consumption (Task 3) = 15,333 ML - (84ML + 11,045 ML + 3.0 ML) = **4201 ML**

2.7 Task 6 – Quantify Water Losses

Water losses are made up of apparent and real losses. In the AWWA water audit approach, water losses are determined as the adjusted source volume minus authorized consumption. Put in another way, water losses are non-revenue water minus unbilled authorized consumption. **Water losses are estimated as 1,946 ML (including both apparent and real losses).** This is given as:

Water Losses = Non-revenue water (Task 4) – Unbilled Authorized Consumption (Task 5) = 4,201 ML – (1 ML + 2254 ML) = 1946 ML

2.8 Task 7 – Quantify Apparent Losses

Apparent losses are those that are caused by incorrect meter reads, data handling errors, billing system accounting practices, meter under-registration and water taken without permission. **Apparent losses were calculated to be 437 ML**.

Apparent losses consist of three main components:

1. Customer metering inaccuracies;
2. Data-handling errors; and
3. Unauthorized consumption.

The components of apparent losses and calculation assumptions are given below.

Customer Metering Inaccuracies

The extent of customer metering inaccuracy can be established by performing testing on a representative sample of meters. Residential meter testing was completed as a Stage 2 task and is reported in Section 3 – Service Meters and Managing Apparent Losses. The reader is referred to this section for a detailed analysis of customer metering inaccuracy.

The following meter accuracies were calculated:

- 98% for the 19mm meter population.
- 97.2% for the large meter population (25mm – 250mm)
- 97.8% overall meter accuracy.

Apparent losses due to metering inaccuracies were therefore estimated at 250 ML/year.

Systematic Data Handling Errors

Systematic data handling errors are apparent losses associated with the City's meter reading and billing system. The City's billing system was reviewed through interviews and conversations with the City's Revenue Services Department. Two customer billing policies that create errors for the audit are:

1. Customers are offered adjustments to their water bill to remove the volume of water lost through a service pipe breaks. The policy requires the customer to submit plumber receipts showing that service pipe repairs have been made.
2. Customers are also allowed a once only bill adjustment with no explanation required.

The data handling errors occur due to how the adjustments are made. Adjustments are made by changing the billing period consumption. It is recommended that credits be given without the adjustment of consumption data within the database.

The volume of systematic data handling errors was calculated by calculating the yearly consumption from the raw meter register readings and comparing these values with the consumption figures provided. Most adjustments were negative, reducing the customer's water bill; however some positive adjustments were noted. Possible explanations given for positive adjustments are:

1. Discovery of bypassed consumption meters (a source of unauthorized consumption);
2. Meter reading error adjustments;
3. Meter not running; and
4. Correction of estimated meter readings.

Systematic data handling errors were estimated at 149 ML/year.

Unauthorized Consumption

The main causes of unauthorized consumption are:

1. Illegal connections;
2. Misuse of fire hydrants and firefighting systems; and
3. Vandalized or bypassed consumption meters.

Improper use of fire hydrants, such as unauthorized filling of tanker trucks is difficult to account for and control.

The City's billing department stated that they encounter a number of bypassed consumption meters. When found these accounts are adjusted based on average previous use over the billing period or an estimated use based on population (for meters found to be bypassed prior to occupancy). This usage is accounted for above; however, other sources of unauthorized consumption will exist and should be estimated.

AWWA recommends that unauthorized consumption be estimated as 0.25% of source flows. For the City of Nanaimo, un-authorized consumption is therefore estimated to be 38 ML/year.

2.9 Task 8 – Quantify Real Losses

Real losses include water that has been extracted from a water source, treated, and transported a distance before being lost from the distribution system.

Real losses are calculated as the system input volume minus authorized consumption and apparent losses. **Real losses are therefore estimated to be 1,508 ML/year.**

2.10 Task 9 – Assign Costs of Apparent and Real Losses

Determining the cost impacts associated with apparent and real losses is equally as important as the tracing of the volume of each component of the water balance.

The unit cost implications of apparent and real losses are not equal. Apparent losses are losses associated with real consumption that would otherwise produce revenue, whereas, real losses, due to such things as main breaks, don't affect customer revenues but do affect operational costs such as the costs to chlorinate water and pump it as required. Apparent losses are therefore valued at the retail cost that is charged to the customer and real losses are valued at the variable production costs to treat and deliver water.

The city utilizes a fixed daily rate plus volumetric inclining block rate structure for water billing. The 2011 water rate structure is given below in Table 2-9:

Table 2-9: City of Nanaimo 2011 Water Billing Rate Structure

FIXED DAY RATE = $0.427656 / day	
Rate Block (m^3)	**Step Rate ($/$m^3$)**
0-0.659	0.0008933
0.660-0.999	0.0041351
1.000 – 1.499	0.0043521
1.500-2.494	0.00453083
2.495-4.985	0.0046839
>4.985	0.00482433

The costs associated with the supply and distribution of water are given in Table 2-10.

Table 2-10: Annual System Operating Costs (as Provided by the City)

Supply and Distribution Costs	**Costs $**	**Total Unit Cost $/ML**
Materials (chemicals & replacement parts)	$361,268	$23.40
Labour (internal & external staff)	$2,082,426	$134.87
Energy (heating & electricity for pump stations at treatment facilities)	$112,428	$7.28
Other (vehicles, office equipment, pc software licences & telemetry equipment telephone line rentals)	$ 379,982	$24.61
Total	**$2,936,104**	**$190.16**
Note: Capital upgrade and replacement costs not included.		

The cost of real losses includes the unit cost for treatment (chemicals, power) and delivery (pumping power costs). These costs are approximated as the Materials and Energy costs provided in Table 2-10. **The unit cost attributed to real losses is therefore estimated at $30.68/ML.**

The cost of real losses for the audit period is approximately $46,000.

The cost of apparent losses is estimated as the unit rate of average day demand charged to customers. The average day demand across all customer types is calculated to be 1.248 m^3/day. **Given the Cities 2011 rate structure the unit cost attributed to apparent losses is $0.8851/$m^3$ or $885.1/ML.**

The cost of apparent losses is significant. Table 2-11 gives the costs associated with each source of apparent losses. It can be seen that even at the relatively low estimate of meter under-registration, 2.2%, the cost implications are significant.

Table 2-11: Cost of Apparent Losses by Source

Source of Apparent Loss	Yearly Volume (ML)	Yearly Cost ($)
2.2 % customer metering under-registration	250	$221,000
Systematic data handling errors (includes customer credits for leak repairs)	149	$132,000
Un-Authorized Consumption (estimated as 0.25% of source flows	38	$34,000
Total	**437**	**$387,000**

2.11 Task 10 – Calculate Performance Indicators

The M36 water audit includes a useful array of performance indicators, which are described and presented in this section. These indicators display a water system's performance in terms of water losses. The performance indicators are given below in Table 2-12.

Non-revenue water represents 27.4% of the total yearly system input volume and 17.1% of the total system operating costs. These figures can be broken down as follows:

- Unbilled Authorized Consumption = 14.7% of volume, 2.4% of operating costs;
- Apparent Losses = 2.9% of volume, 13.1% of operating costs; and
- Real Losses = 9.8% of volume, 1.6% of operating costs.

These indicators show the significance of reducing errors in apparent losses.

The real loss estimate is quite low. This equates to an ILI of 1.54 which is excellent.

Table 2-12: AWWA M36 Performance Indicators

Performance Indicator	Description	Formula (Units of measure)	Calculated Value
Nonrevenue Water by Volume	Volume of nonrevenue water as a percentage of system input volume.	Nonrevenue Water / System Input Volume **(%)**	**27.4%**
Nonrevenue Water by Cost	Value of non-revenue water as a percentage of the annual cost of running the system	((Unbilled Metered Consumption + Apparent Losses) x Customer Water Rate + (Unbilled Unmetered Consumption + Real Losses) x Variable Production Costs) / Total Annual System Operating Costs **(%)**	**17.1%**
Apparent Losses per connection	Daily Apparent Loss Volume per service connection	**(litres/service connection / day)**	**48.39**
Real Losses per connection	Daily Real Loss Volume per service connection	**(litres/service connection / day)**	**166.72**
Unavoidable Annual Real Losses	A theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied to reducing losses.	UARL **(Ml/day)** = (18xLm + 0.8xNc + 25xLp) x P / 1,000,000 where: Lm = Total length of mains and hydrant leads (km), Nc = number of service connections, Lp = Total length of service connections (km), and P = average operating pressure (meters head).	**2.69**
Infrastructure Leakage Index	Ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL).	ILI **(dimensionless)** = CARL / UARL = 4.49 (Ml/day) / 2.65 (Ml/day)	**1.54**

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2.12 Task 11 – Compile the Water Balance

A summary of the water balance results is presented below in Table 2-13.

Table 2-13: Water Audit Results

System Input Volume **15,333 ML**	Authorized Consumption **13,387 ML**	Billed Authorized Consumption **11,132 ML**	Billed Water Exported **84 ML**	Revenue Water **11,132 ML**
			Billed Metered Consumption **11,045 ML**	
			Billed Unmetered Consumption **3 ML**	
		Unbilled Authorized Consumption **2,255 ML**	Unbilled Metered Consumption **1 ML**	Non-revenue Water **4,201 ML**
			Unbilled Unmetered Consumption **2,254 ML**	
	Water Losses **1,946 ML**	Apparent Losses **438 ML**	Unauthorized Consumption **38.3 ML**	
			Customer Metering Inaccuracies **250.4 ML**	
			Systematic Data Handling Errors **149.1 ML**	
		Real Losses **1508 ML**	Leakage on Transmission and Distribution Mains **498 ML**	
			Leakage and Overflows at Utility's Storage Tanks **0 ML**	
			Leakage on Service Connections up to point of Customer metering **1010 ML**	

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Section 3

Service Meters and Managing Apparent Losses

3. Service Meters and Managing Apparent Losses

3.1 Overview

This section of the report provides an analysis of the customer meter population. Estimates of customer metering in-accuracy are calculated based on the results of residential meter testing, a desktop review of large meters (50mm through 150mm), and large ICI customer meter profiling.

A financial analysis was completed to determine the replacement frequency that minimizes yearly metering costs.

It appears large meters are being oversized, due to a lack of adequate meter selection and sizing design standards. A separate financial analysis was completed for a large meter “right-sizing” program.

Financially justified recommendations are presented for changes in the way meters are sized and replaced. A meter replacement strategy is presented that sets the annual budget for yearly meter replacements.

3.2 Sources of Apparent Metering Losses

Meters are subject to wear and loss of accuracy with continued use. Another common source of meter inaccuracy occurs when meters are oversized for the flow profile that they encounter. Many meter types fail to accurately measure low flow rates, therefore meters frequently experiencing low flows will be less accurate than appropriately sized meters.

The degree of inaccuracy in the meter population depends on:

1. The amount of cumulative flow that meters have registered;
2. Appropriate sizing and installation of meters (changes in customer use, is a reason for meter under registration);
3. The aggressiveness of the water in creating internal corrosion (meter age based deterioration); and
4. The degree of upkeep and renewal of the population.

3.3 Meter Population Statistics

The first step in quantifying and effectively managing service meter accuracy is to understand the demographics of the meter population. gives the basic statistics of the City’s metering infrastructure. This table is organized by size of meter, giving the total number of meters, average age and percentage of the metered consumption.

Table 3-1: Meter Statistics by Size

Meter Size (mm)	Number of Meters	Percent of Total Meters	Average Age (years)[1]	Percent of Total Consumption	Percent of Total Consumption per Meter	Average Yearly Revenue/Meter (Based on $0.885/m^3)
19	23132	93.33%	13.4	55.33%	0.00%	$232.95
25	397	1.60%	10.8	2.18%	0.01%	$534.78
38	294	1.19%	12.7	3.50%	0.01%	$1,159.40
50	626	2.53%	11.6	22.66%	0.04%	$3,525.30
75	94	0.38%	14.3	8.54%	0.09%	$8,847.92
100	70	0.28%	11.1	4.70%	0.07%	$6,539.00
150	121	0.49%	9.8	2.30%	0.02%	$1,851.20
200	17	0.07%	8.9	0.66%	0.04%	$3,781.00
250	6	0.02%	15.3	0.01%	0.00%	$162.31
Blank	26	0.10%	-	0.13%	0.01%	$486.95
TOTALS	**24,783**	**100.00%**	**13.2**	**100.00%**		

Notes: [1] Average Age may be greater than stated. Meters with an installation date of 1989 were reporting installed on or before 1989. This table does not take this into account.

The following observations are made from Table 3-1:

- The largest total percentage of the meter population and consumption are 19 mm residential meters.
- 75 mm meters make up only 0.38% of the population but meter 8.54% of the total consumption. These meters represent the highest volume sold per meter and are also on average the oldest meters in the population at an average age of 14.3 years.
- 50 mm meters are the second largest population at 2.53% and register the second highest total consumption; however, on a per meter basis they measure just slightly more than a third of that which 75 mm meters register.
- 100 mm meters register the second highest per meter flows in the meter population.
- The relatively low per meter volumes registered on 150 mm – 250 mm meters is attributed to these meters being largely used on building fire suppression systems.

Because of the vast number of meters within the population, it is not practical to inspect all meters on a yearly basis. Instead, it is recommended that a sample of meters be tested yearly and that the meters serving the largest users are regularly maintained and checked to ensure that they are still adequately specified for the customer's current usage patterns.

Table 3-2 gives the number of meters in the population by manufacturer.

Table 3-2: Meter Manufacturers

Manufacturer	Number of Meters
Neptune	1,806
Rockwell	3
Schlumberger	1,270
Sensus	7,380
Unknown	14,326
Total	**24,785**

Approximately 58% of the population has an unknown meter manufacturer. The vast majority of these were installed prior to 2001. Since 2001, the city has kept better records of the meter population. Approximately 3% of meters installed from 2001 to 2005 are missing meter make information. In the last 3 years however only 0.2% of meters did not have meter information registered in the data base.

Table 3-3 gives the number of meters installed by date as reported in the City of Nanaimo's Tempest Database[6]. It can be seen that the vast majority of the meter population appears to have been installed in 1989 (30%). This date (1989), was the default date used when the City changed it's computer software. It is reported that meters with this date were installed on or before1989.

Given the above and that the average distribution of the meter population is 3-4% per year, a revised population distribution is presented in Table 3-3. The average meter age would therefore be 14.4 years instead of 13.2 as reported in Table 3-1**.**

Table 3-3: Number of Meter Installations by Year

Tempest Database			Adjusted Database		
Meter Installation Year	Number of Meters	Percent of Population	Meter Installation Year	Number of Meters	Percent of Population
1981	1	0%	1981	821	3%
1982			1982	821	3%
1983			1983	821	3%
1984			1984	821	3%
1985			1985	821	3%
1986			1986	821	3%
1987	49	0%	1987	821	3%
1988	29	0%	1988	821	3%
1989	**7,314**	**30%**	**1989**	**825**	**3%**
1990	589	2%	1990	589	2%
1991	649	3%	1991	649	3%
1992	705	3%	1992	705	3%
1993	1,183	5%	1993	1,183	5%
1994	669	3%	1994	669	3%
1995	535	2%	1995	535	2%
1996	724	3%	1996	724	3%
1997	668	3%	1997	668	3%
1998	572	2%	1998	572	2%
1999	634	3%	1999	634	3%
2000	621	3%	2000	621	3%
2001	610	2%	2001	610	2%
2002	579	2%	2002	579	2%
2003	702	3%	2003	702	3%
2004	791	3%	2004	791	3%
2005	857	3%	2005	857	3%
2006	886	4%	2006	886	4%
2007	915	4%	2007	915	4%
2008	1,150	5%	2008	1,150	5%
2009	1,352	5%	2009	1,352	5%
2010	1,096	4%	2010	1,096	4%
2011	880	4%	2011	880	4%
2012	25	0%	2012	25	0%
Ave Age (as of 2011)		13.2 Years	Ave Age (as of 2011)		14.4 Years

Since 2003 the City has been recording whether a meter is a replacement or new installation. Table 3-4 displays the number of new meter installations and replacements from 2003-2011.

Table 3-4: Meter Renewal and Population Growth

Year	New Meter Installations	Increase in Population	Replacement Meter Installations	Population Replaced
2003	248	1.5%	454	2.7%
2004	373	2.1%	418	2.4%
2005	427	2.3%	430	2.3%
2006	359	1.9%	527	2.7%
2007	393	1.9%	522	2.6%
2008	318	1.5%	832	3.9%
2009	258	1.1%	1094	4.8%
2010	319	1.3%	777	3.3%
2011	220	0.9%	660	2.7%
Averages	**324**	**1.6%**	**635**	**3.0%**

On average, 324 meters are installed yearly for new customers. This represents an average yearly growth rate of 1.6%. On average the city replaces 3.0% of its meters or 635 meters annually. This rate of replacement represents a 33 year replacement cycle. This replacement cycle is noted as being quite long.

3.4 Calculating the Optimum Meter Replacement Frequency – Theory

According to the AWWA M6 “Water Meters - Selection, Installation, Testing, and Maintenance" manual, a water supplier should develop a meter replacement program based on testing of a representative sample of residential meters that establishes an accuracy versus age relationship. It is noted that the likely lowest cost replacement frequency will be less than 15 years, however local factors such as water chemistry and soil conditions will affect the mechanical decline and therefore optimum replacement frequency.

Figure 3-1 shows a typical cost curve for meter replacement. It can be seen that replacing meters at a high frequency results in less apparent loss as a result of meter inaccuracy. However, a high replacement frequency means higher replacement costs. Figure 3-2 overlays this typical cost curve with the value of recoverable apparent losses. The third curve shown is the addition of the two costs curves, known as the total cost curve. The economic level of apparent losses is the level of losses at the minimum point on this curve which determines the optimum meter replacement frequency.

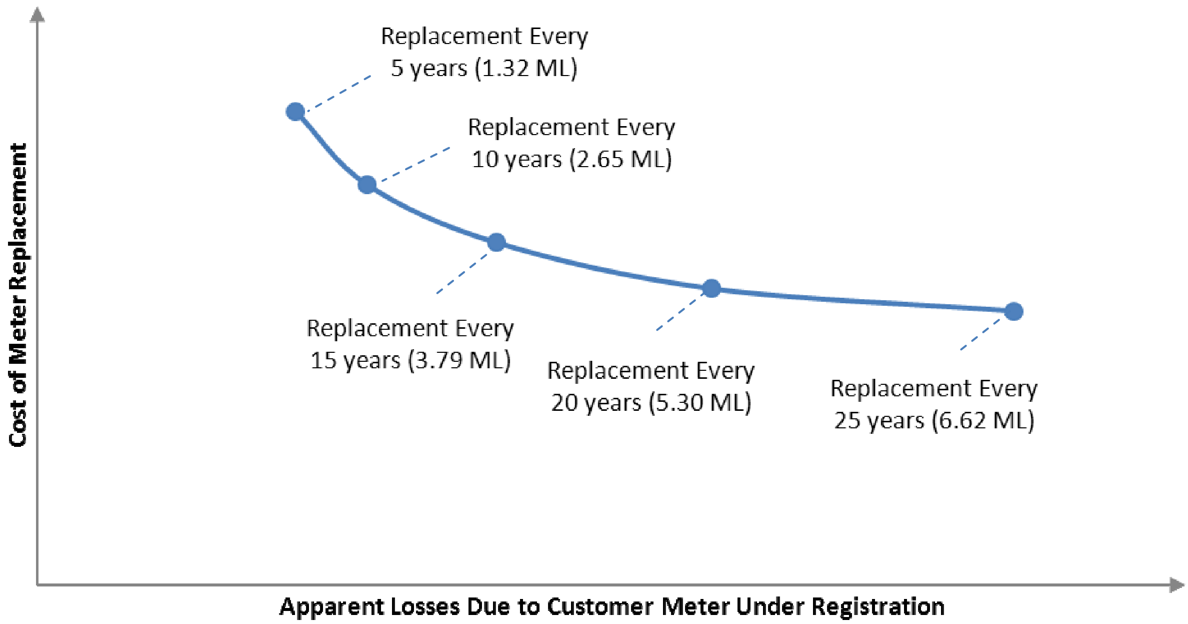


Figure 3-1: Theoretical Cost Curve for Meter Replacement from AWWA M36 Manual (2007)

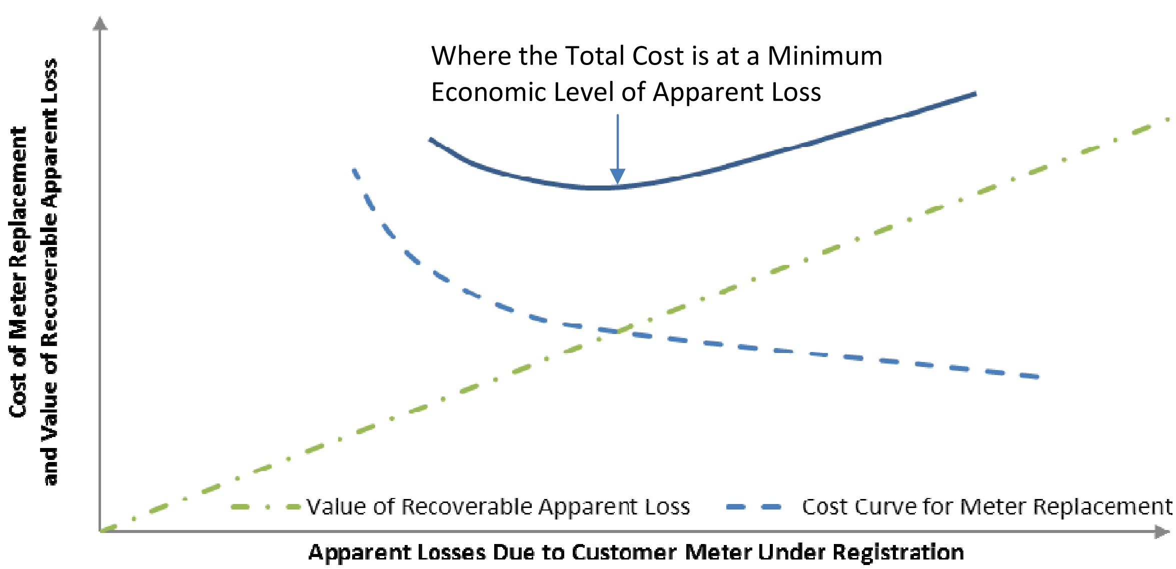


Figure 3-2: Economic Balance for Reduction of Apparent Losses through Meter Replacement (Theoretical - AWWA M36)

3.5 Residential Meter Testing Procedure

A sample population of residential water meters were tested to gain an understanding of the meter populations overall accuracy as well as determine an appropriate replacement protocol. A total of 45 meters were identified as candidates for testing given the following selection criteria:

- Half of the meters to have above average demands (ADD) and half having lower than average demands;
- All meters to be 19mm residential;
- 40% installed prior to 1990;
- 40% installed between 1990 – 2000; and
- 20% installed after 2000

Figure 3-3 is displays the locations of the 45 residential meters chosen for testing along with the year of installation and average day demand in L/property/day. Of the 45 meters identified, 27 were removed for testing. The locations of the meters that were tested are highlighted in yellow on Figure 3-3.

Meters were tested by running water through them in series with a calibrated test meter. The calibrated meter was a Sensus 5/8" x 3/4" SRII, factory tested on April 30, 2012 and supplied with calibration test results showing percent accuracy as a function of flow rate.

Meters were tested at low (0.25 GPM), medium (2 GPM) and high (12 GPM) flow rates in accordance with the AWWA M6 Manual of Water Supply Practices testing procedures. Figure 3-4 is a photo of the setup for meter testing.

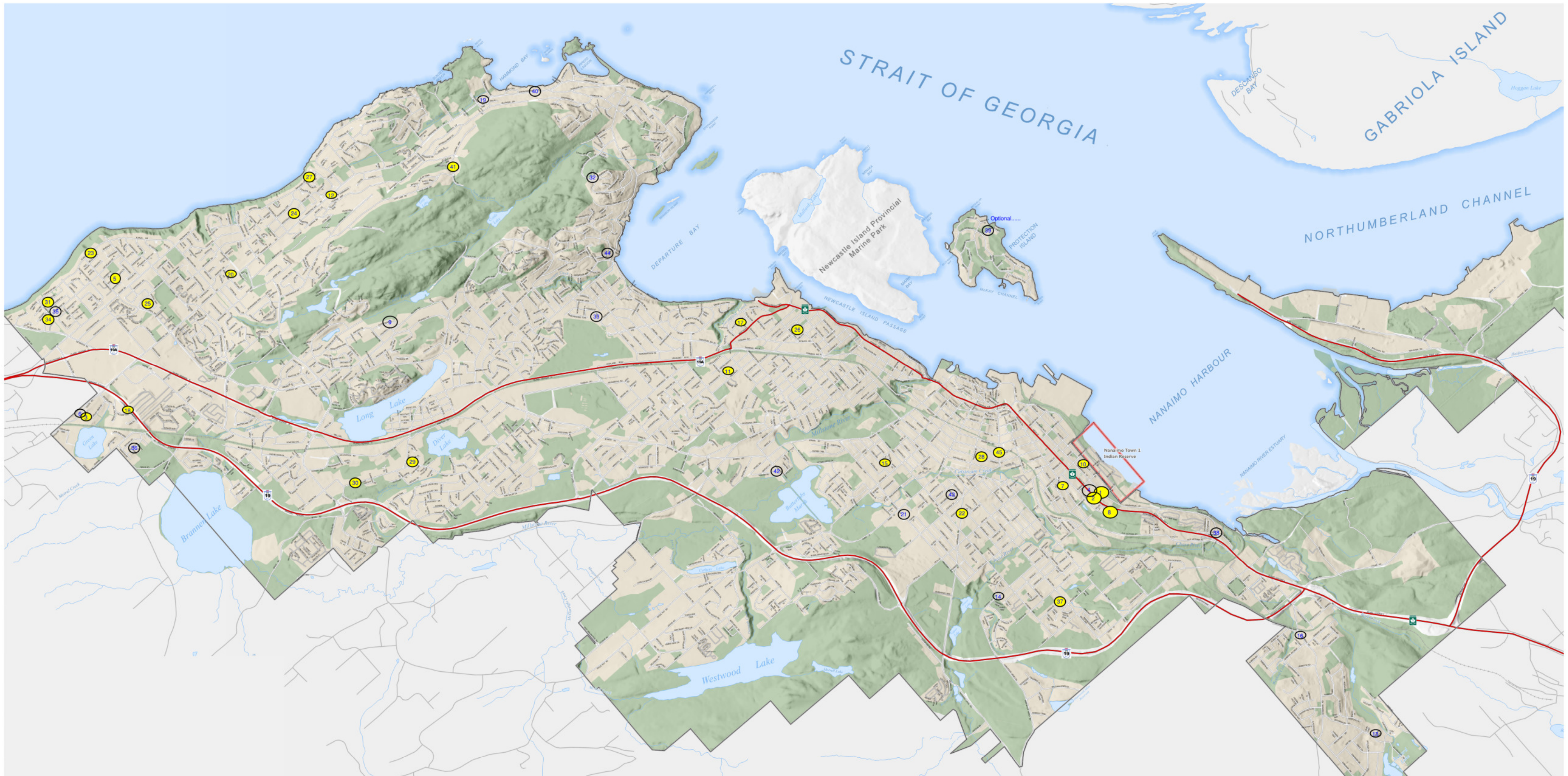
Testing of 27 meters was completed over the course of two days. Six to eight meters were connected in series and tested together.

The following minimum test volumes were used for each flow rate:

- Low Flow = 40 L
- Medium Flow = 100 L
- High Flow = 500 L

Test volumes were confirmed by filling 20 litre buckets.

Figure 3-4: Residential Meter Testing



Map #	Year	Account Number	Civic Address	Totalized Volume (Gallons)	ADD (L/account/day)
1	1987	102321	739 NICOL STREET	11922	172
2	1987	100026	729 HALIBURTON STREET	9205	292
3	1987	110687	6649 VALLEY VIEW DRIVE	9186	566
4	1987	100004	723 NICOL STREET	9124	458
5	1987	116304	236 KINGFISHER PLACE	14727	622
6	1987	110682	6659 VALLEY VIEW DRIVE	14172	693
7	1987	101953	616 VICTORIA ROAD	14056	472
8	1988	100375	828 HARBOUR VIEW STREET	8787	372
9	1988	114240	3695 COTTLEVIEW DRIVE	8559	229
10	1988	101071	18 GILLESPIE STREET	7661	422
11	1989	103331	1173 STRATHMORE STREET	7932	95
12	1989	115547	5321 HAMMOND BAY ROAD	5707	95
13	1989	104430	14 TORKKO CRESCENT	2779	97
14	1989	117887	614 SEVENTH STREET	10397	144
15	1989	118094	186 O'HARA PLACE	12582	164
16	1989	104992	1540 EXTENSION ROAD	26378	591
17	1989	103521	88 VALDES PLACE	25074	1113
18	1990	110732	6017 MT VIEW ROAD	28799	1788
19	1990	115022	4250 HAMMOND BAY ROAD	20368	828
20	1990	112994	5934 BEACON PLACE	14412	575
21	1990	119201	308 WAKESIAH AVENUE	14387	881
22	1990	119659	208 HAREWOOD ROAD	14227	434

Map #	Year	Account Number	Civic Address	Totalized Volume (Gallons)	ADD (L/account/day)
23	1992	116225	6276 ICARUS DRIVE	21713	3605
24	1992	115261	5580 LESLIE CRESCENT	13534	2113
25	1992	115509	6135 JANELLE PLACE	12351	1145
26	1992	102330	563 POPLAR STREET	11574	560
27	1994	115075	5386 BAYSHORE DRIVE	12117	1138
28	1994	101491	421 KENNEDY STREET	12085	298
29	1994	109248	217 ARDOON PLACE	7230	300
30	1994	109571	4151 JINGLE POT ROAD	6952	721
31	1994	116040	6542 RAVEN ROAD	6948	1034
32	1994	111277	100 CANTERBURY CRESCENT	6245	745
33	1994	108604	2720 COSGROVE CRESCENT	5584	1243
34	1994	116019	6576 GROVELAND DRIVE	5582	401
35	1997	200666	6541 GROVELAND DRIVE	6107	927
36	1997	200669	6650 EVEREST DRIVE	5511	616
37	2002	119397	538 WEBER STREET	1100	147
38	2002	118815	1074 CHASE RIVER ROAD	1639	187
39	2002	201987	45 CUTLASS LOOKOUT	673	265
40	2004	114583	3852 HAMMOND BAY ROAD	1946	299
41	2004	202955	4663 LOST LAKE ROAD	13835	1643
42	2000	107393	1602 VENLAW ROAD	1404	104
43	2000	119728	370 GEORGIA AVENUE	2692	230
44	2000	108852	1441 SHERWOOD DRIVE	11211	468
45	2000	101125	736 ALBERT STREET	4023	720

CITY OF NANAIMO
THE HARBOUR CITY

Legend

1 Tested Meter Location

1 Potential Meter Location – Not Tested

KERR WOOD LEIDAL
consulting engineers

NTS

Project No.	Date
566.035	December 2012

Residential Meter Testing – Proposed and Tested Locations (Highlighted)

Figure 3-3

Meter accuracy was assessed by comparing the totalized volume of water with that of the calibrated meter and making adjustments for each flow rate based on the calibrated meters calibration chart. Results are presented for each flow rate.

Actual meter accuracy is a function of how much water is used at each test flow rate. The statistical distribution of residential end uses of water has been studied by others for similar meter testing exercises. The portions of water use at each flow rate given in the below formula was derived by Hans & Allender in a similar study [16]:

$$Overall\ Accuracy\ (\%) = 0.12 \times (Low\ Flow\ \%) + 0.86 \times (Medium\ Flow\ \%) + 0.02 \times (High\ Flow\ \%)$$

3.6 Residential Meter Test Results

The test results for each meter are given in Table 3-5 along with the meters installation year, make and model. It can be seen that the overall accuracy of the meters tested was acceptable, at 96.5%. The results show that overall accuracy drops as age increases and is a function of a decline in low flow accuracy with age.

Figure 3-5 displays metering accuracy by flow rate, installation year and model type. It can be seen for the meters tested that the only age related effect on metering accuracy is low flow under-registration.

Medium and high flow recording capability did not diminish with age however it is expected that accuracy will begin to diminish over all flows given enough time. In similar works, medium and high flow accuracy only begins to diminish after 25 years of use. The oldest meters tested for Nanaimo were 25 years old. Figure 3-5 also shows how accuracy varies by model type.

Table 3-5 Residential Meter Individual Test Results

				Accuracy			
Meter Map #	Install Year	Make	Model	Low Flow %	Medium Flow %	High Flow %	Overall Weighted Average
1	1987	Rockwell	S-21	0.2%	97.0%	98.4%	82.7%
2	1987	Rockwell	S-21	84.5%	101.8%	98.5%	98.7%
3	1987	Rockwell	S-21	87.0%	101.8%	99.0%	99.2%
5	1987	Rockwell	S-21	78.1%	100.7%	100.3%	97.3%
7	1987	Rockwell	S-21	75.7%	103.4%	99.8%	98.7%
8	1988	Rockwell	S-21	90.2%	101.6%	100.4%	99.7%
10	1988	Rockwell	S-21	41.0%	101.3%	99.5%	92.0%
11	1989	Rockwell	S-21	2.2%	98.1%	97.2%	83.6%
12	1989	Rockwell	S-21	82.8%	101.6%	99.5%	98.5%
15	1989	Rockwell	S-21	84.5%	101.8%	100.1%	99.0%
17	1989	Rockwell	S-21	19.4%	101.7%	100.3%	89.2%
18	1990	Rockwell	S-21	74.2%	103.5%	99.8%	98.5%
20	1990	Rockwell	SRII	89.2%	99.5%	98.4%	97.8%
22	1990	Rockwell	S-21	88.0%	100.9%	99.2%	98.7%

				Accuracy			
Meter Map #	Install Year	Make	Model	Low Flow %	Medium Flow %	High Flow %	Overall Weighted Average
23	1992	Rockwell	SRII	81.4%	97.8%	97.5%	95.3%
24	1992	Rockwell	SRII	96.4%	98.9%	98.7%	98.5%
25	1992	Sensus	SRII	95.2%	100.4%	99.3%	99.4%
26	1992	Rockwell	S-21	72.3%	100.8%	99.1%	96.3%
27	1994	Sensus	SRII	94.0%	99.4%	98.3%	98.4%
28	1994	Rockwell	S-21	86.0%	101.9%	100.6%	99.3%
29	1994	Rockwell	SRII	81.5%	99.1%	98.5%	96.4%
30	1994	Sensus	SRII	93.2%	98.7%	77.9%	94.8%
31	1994	Sensus	SRII	95.7%	99.1%	98.2%	98.5%
34	1994	Sensus	SRII	90.8%	98.8%	98.5%	97.6%
37	2002	Neptune	T-10	97.9%	100.2%	99.1%	99.7%
41	2004	Sensus	1" SRII	86.4%	101.0%	100.3%	98.7%
45	2000	Neptune	T-10	95.6%	100.9%	99.3%	99.9%
			Mean Values	**76.4%**	**100.4%**	**98.4%**	**96.5%**

Table 3-6 gives metering accuracy by model. It is noted that the SRII meter was sold under both the Sensus and Rockwell names.

Table 3-6: Meter Accuracy Results by Model

MODEL	# Tested	Average Low Flow %	Average Medium Flow %	Average High Flow %	Average Overall %
S-21	15	64.4%	101.2%	99.4%	95.4%
SRII	9	90.8%	99.1%	96.1%	97.4%
T-10	2	96.8%	100.6%	99.2%	99.8%
1" SRII	1	86.4%	101.0%	100.3%	98.7%
Totals / Mean Values	**27**	**76.4%**	**100.4%**	**98.4%**	**96.5%**

The following points are noted for each model type:

Rockwell S-21

- Oldest of the meter population. The average age of S-21 meters tested was 23 years;
- Poor low flow accuracy (64.4%);
- Low flow accuracy decreases with age;
- Highest over-registration of medium flows (101.2%)

- Highest registration of high flows (99.4%)
- Lowest overall accuracy, due to poor low flow registration.

19mm Sensus & Rockwell SRII

- Better low flow (90.8%) and overall performance (97.4%);
- Accuracy was not noted as decreasing with age however the age span of those meters tested was only 1990-1994. Newer SRII meters may perform better than those tested and age related degradation may increase later in life.
- Average age of SRII meters tested was 19 years;
- With the exception of one, 19mm SRII meters did not over-register medium flow rates.

Neptune T-10

- Newest of the meter population tested. Average age of T-10 was 11 years;
- Most accurate of the meters tested.

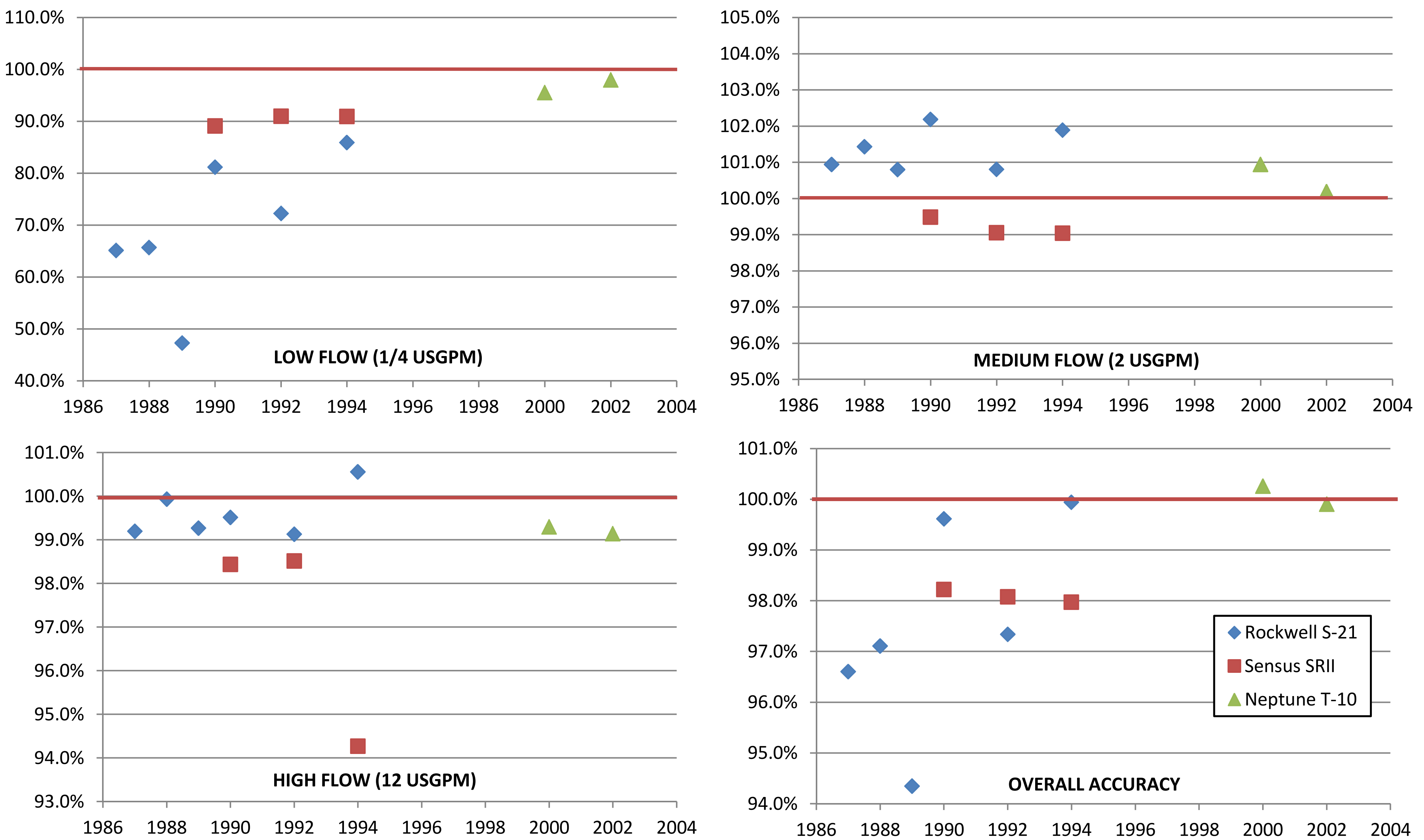


FIGURE 3-5: RESIDENTIAL METER TESTING RESULTS BY AGE AND MODEL

3.7 19mm Meter Replacement Financial Analysis

The following financial analysis is done to determine the replacement frequency that offers the lowest average cost per year of use. The volume of yearly unregistered water use can be estimated given the accuracy of the meters and the average yearly flow rate through the meter population. The analysis is based on the annual distribution of both capital meter replacement costs and meter inaccuracy costs (apparent losses). The capital replacement costs per year of use will decrease as the number of years increases, however as meter accuracy declines the cost of lost revenues increases. See Figure 3-2 for a graphical representation.

To determine the optimal meter replacement frequency, age versus metering accuracy relationships must first be approximated. Figure 3-6 shows the assumed best fit approximations for metering accuracy versus age for the three test flow rates and resulting overall meter accuracy. The curves follow the average test results for the first 25 years and assume linear projections to a maximum meter age of 48 years.

The low flow curve follows a linear projection past the last set of data points (25 year old meters) with the average low flow metering accuracy reaching 0% at 42 years of use. The medium and high flow curves are assumed to have no decline for the first 28 years of use. It is assumed that meters will begin to under-register medium and high flows after 28 years of use at a decline of 0.2% to 1% per year.

Although there is no data to support a linear decline past 28 years of use, the envelope is a reasonable method of capturing the effects of mechanical breakdown. The lower end of the decline approximation assumes a 48 year old meter will still register 96% of medium flows and 95% of high flows. The high end of the decline envelope assumes the 48 year old meter will register 80% of medium flows and 79% of high flows. The results presented by Hans & Allender fall within this envelope, close to the high decline boundary [16].

The cost of lost revenues for metering inaccuracies is assumed as the average unit cost charged to customers, \$0.885/m^3 (See Section 2.9).

The supply and installation costs for 19mm residential meters is estimated as \$176 per meter. This includes \$84 for the meter, and \$92in labour. Meter costs were provided by City of Nanaimo equipment purchasing or Stores as it is known. Labour costs were estimated based on data provided by the General Foreman of Water Works. A high and low estimate was made and the average installation cost of \$92/meter assumes 75% of installations can be completed without the use of a vactor truck. Table 3-7 provides the high and low estimated installation costs.

Table 3-7: Labour Cost Assumptions for Meter Installations

		Low Estimate (75% of Installs)		High Estimate (25% of Installs)	
Unit	**Cost / hour**	**hours / meter**	**Cost**	**hours / meter**	**Cost**
Labourer	$40	0.5	$20	0.75	$30
Labourer	$40	0.5	$20	0.75	$30
Forman	$60	0.07	$4	0.1	$6
Truck	$20	0.5	$10	0.75	$15
Vactor	$165	0.0	-	0.75	124
		TOTAL	**$54**	**TOTAL**	**$205**

Table 3-8 gives the annual average cost of water meters for each year of use from installation to 48 years of use. The goal is to find the replacement frequency that offers the minimum yearly cost, with replacement being required due to decreasing meter accuracy and increasing lost revenues.

Replacement at 24 years offers the lowest annual cost per year at $10.28. It is noted that at 24 years the accuracy/age curve assumes full registration of medium and high flow rates (meter decline is due solely to low flow inaccuracy). It is also noted that there is a reasonable level of confidence in the lost revenue estimate as just over half the meters tested were in service for 22 to 25 years.

Despite the fact that the accuracy of a 24 year old meter is estimated at 95.8%, replacement at this age is economically justified. The justification for replacement hinges on the prevention of further apparent losses. The City's current replacement frequency is 33 years. The savings for increasing to a 24 year replacement frequency is estimated at $1.61 to $2.45 / meter / year. This equates to an annual savings of $37,000 to $57,000 given the current meter population of 23,132.

3.8 Current Level of Residential Customer Metering Inaccuracy

The meter accuracy versus age relationship developed from the residential meter testing results can be used to estimate the current level of metering inaccuracy due to age related effects. The average meter age of 14.4 years corresponds to a meter accuracy of approximately 99%.

The effects of low flow under-registration are estimated at 1% for the 19mm meter population. **The total overall accuracy estimate for 19mm meters is therefore 98% or 2% under-registration.**

Table 3-8: Financial Analysis - Annual Average Cost of Water Meters to 48 Years of Use

Meter Age	Meter Cost	Slower Rate of Decline: Cost of Use	Slower Rate of Decline: Accumulative Cost	Slower Rate of Decline: Average Cost / Year	Higher Rate of Decline: Cost of Use	Higher Rate of Decline: Accumulative Cost	Higher Rate of Decline: Average Cost / Year
0	$176.00	$0.65	$176.65	$176.65	$0.65	$176.65	$176.65
2		$0.65	$177.30	$88.65	$0.65	$177.30	$88.65
4		$0.65	$177.96	$44.49	$0.65	$177.96	$44.49
6		$0.65	$178.61	$29.77	$0.65	$178.61	$29.77
8		$1.21	$179.82	$22.48	$1.21	$179.82	$22.48
10		$1.77	$181.59	$18.16	$1.77	$181.59	$18.16
12		$3.03	$184.62	$15.38	$3.03	$184.62	$15.38
14		$4.29	$188.91	$13.49	$4.29	$188.91	$13.49
16		$5.54	$194.45	$12.15	$5.54	$194.45	$12.15
18		$6.80	$201.25	$11.18	$6.80	$201.25	$11.18
20		$11.00	$212.25	$10.61	$11.00	$212.25	$10.61
22		$15.19	$227.44	$10.34	$15.19	$227.44	$10.34
24		$19.38	$246.82	**$10.28**	$19.38	$246.82	**$10.28**
26		$23.58	$270.39	$10.40	$23.58	$270.39	$10.40
28		$27.77	$298.16	$10.65	$27.77	$298.16	$10.65
30		$33.60	$331.76	$11.06	$40.16	$338.32	$11.28
32		$39.43	$371.20	$11.60	$52.55	$390.88	$12.21
33		$21.18	$392.37	$11.89	$29.38	$420.25	$12.73
34		*$45.27*	$416.47	$12.25	$64.95	$455.83	$13.41
36		$51.10	$467.57	$12.99	$77.34	$533.17	$14.81
38		$56.93	$524.50	$13.80	$89.73	$622.90	$16.39
40		$62.77	$587.27	$14.68	$102.13	$725.03	$18.13
42		$67.48	$654.75	$15.59	$113.40	$838.43	$19.96
44		$69.12	$723.88	$16.45	$121.60	$960.04	$21.82
46		$70.76	$794.64	$17.27	$129.80	$1,089.84	$23.69
48		$72.40	$867.04	$18.06	$138.00	$1,227.84	$25.58

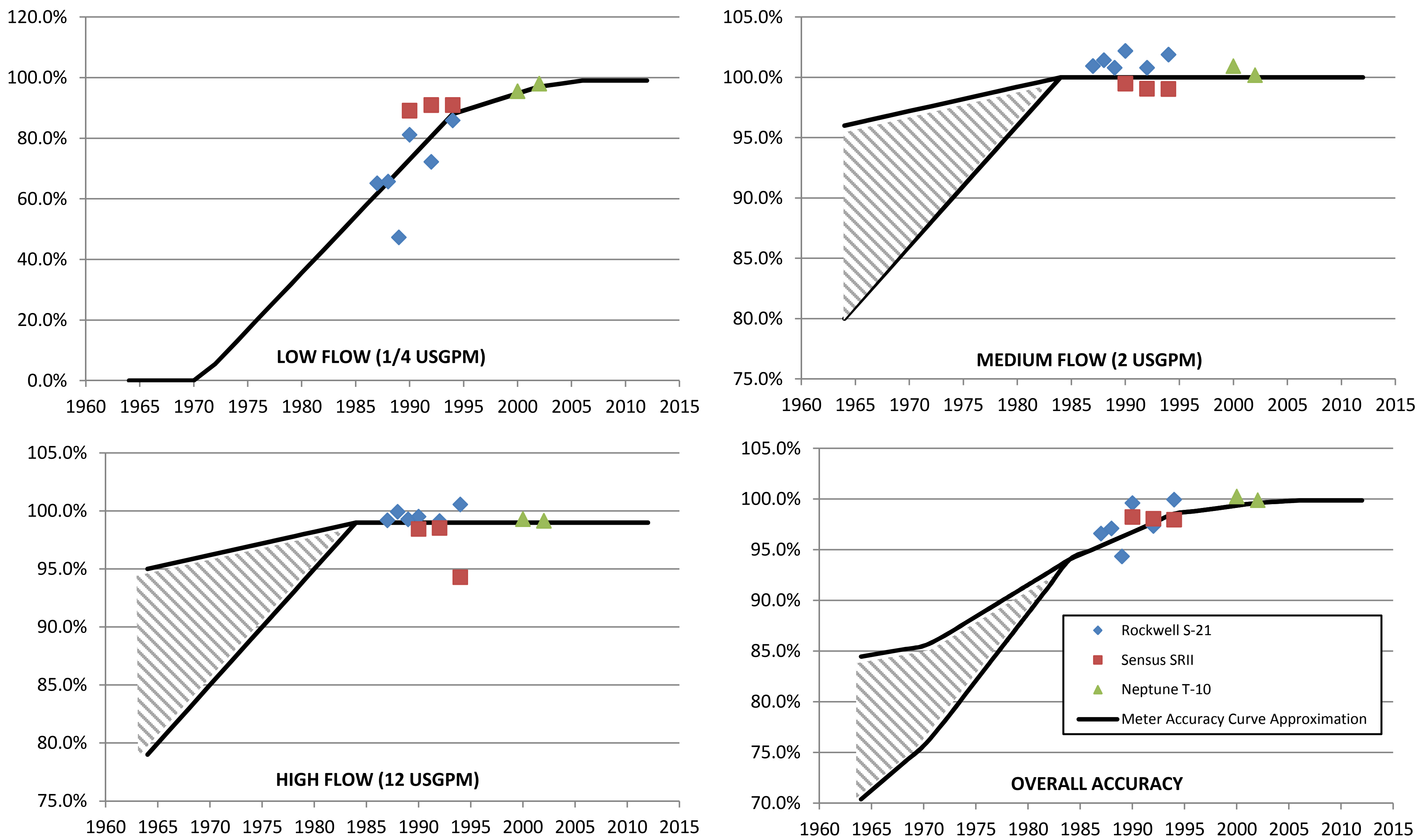


FIGURE 3-6: RESIDENTIAL METER REGISTRATION DECLINE APPROXIMATIONS

3.9 Large Meter Analysis - Overview

A desktop review of 50mm through 150mm meters was completed. This review compared average customer demands to the minimum operating range of accurate measurement. This was done to assess the level of apparent losses in the ICI population as well as to determine if there is a business case for changes to the City of Nanaimo's current practices for meter replacement as well as selection of meters for new customers/developments. A weighted decision matrix is presented that prioritizes a list of meter replacements based on total yearly demand, apparent level of over-sizing and meter age.

It appears large meters are being oversized, due to a lack of adequate meter selection and sizing design standards. The estimated savings for implementing a demand based large meter replacement program as well as changing the current new meter sizing protocol to match AWWA standards is significant.

ICI flow profiling was also completed for seven large ICI customers to gain an understanding of how these customers use water and to determine if their existing meter size and type are appropriate for their water use pattern. Flow profiling is often completed prior and post meter replacement to assess whether the new meter registers flow more accurately.

3.10 Meter Selection and Sizing

Customer meters are the "weight scales" for which an equitable full cost accounting (use pay) system is based. They are the most important meters in the distribution system and therefore **it is paramount the City of Nanaimo ensure the sizing, reading, maintaining and monitoring of customer meters is correct and equitable to all customers.** Choosing the correct meter type and size is particularly important for large ICI and multi-family customers.

Meters that are too large for the customer will operate below the meters minimum flow rate and will consistently under-register flow. Customer use pattern is also important in the selection of meters. Different meters types are designed for a different flow regimes, with some, such as turbine meters, having poor low flow characteristics (under-registering).

Meters can be sized or become improperly sized for a number of reasons. Some examples include:

- Change in customer and therefore customer use pattern;
- Change in customer use pattern such as a change in the technology used or products being produced by an industrial customer (market forces);
- Improperly sized meter due to difficulty in sizing (unknown commercial or industrial customer at design);
- Meter sized for infrequent or incorrect demand assumptions (matching meter size to service line size).

To address the root causes of improper meter sizing the following fundamental practices should always be followed:

- The utility (not the customer) should own the water meter;
- **The selection and sizing of the water meter should be determined by the utility** and not by the property owners (developers) agent. Meters must be sized for expected minimum and maximum flow rates. It is suggested that selection and sizing of larger meters should be done

in consultation with the property owner and utilizing the AWWA M22 Sizing Service Lines and Meters Manual;

- Meter replacement should consider recent historical usage;
- Changes in use patterns should be periodically reviewed and used for the prioritization of meter replacements.

3.11 Current City of Nanaimo Meter Selection and Replacement Practices

Selection and Sizing of New Customer Meters

The City of Nanaimo's Manual of Engineering Standards and Specifications, Section 5, states the following regarding sizing of new customer meters:

"5.30.8 Meters:

*(c) For **single family servicing, meters shall be 19 mm x 16 mm positive displacement meters**.*

*(d) For **duplex servicing, meters shall be 25 mm positive displacement meters.***

*(e) **All meters larger than 25 mm require approval from the City Engineer**. All meters larger than 38 mm shall be equipped with test ports.*

It was reported by City's Design Services department that the correct sizing of meters is the responsibility of the developers design consultant and is done in accordance with the BC Building Code. That is to say that meters are sized based on the size of the service, calculated by the fixture unit method.

It is highly recommended that meters be sized based on the AWWA M22 Sizing Service Lines and Meters **fixture value method** and not the fixture unit method employed by the BC Building Code for piping within buildings. It is noted that the M22 fixture value method will generally result in a meter size that is 1 to 2 pipe diameters smaller than the service.

Replacement Protocol

The City does not currently have a large ICI meter replacement protocol. Meters are replaced when they stop working or can no longer be read by the City's meter reading staff. Meters replacements are like for like (meter sizing is not revisited upon replacement).

3.12 Assumptions Made for Large Meter Analysis

A number of assumptions were made in the desk top analysis of large meter sizing. The following criteria and assumptions were used:

- *Review of 50mm through 150mm meters;*
- *Average day demand used for assessment of meter size;*
- *Meters identified as fire flow meters were removed from the analysis;*
- *Meters for "Municipal" Customer Class were removed from the analysis. This customer class is largely comprised of municipal parks which have highly seasonal water use.*

- *All meters are assumed to be turbine meters. This was the case for the meters investigated for the customer flow profiling exercise discussed later in this section.*
- *The following minimum normal operating ranges were used for each meter size:*

Meter Size (mm)	*Minimum Normal Operating Flow (L/s)*
50	*0.252*
75	*0.305*
100	*0.946*
150	*1.893*

- *Meter accuracy drops significantly below the meters minimum flow rate. Meters with average day demands less than one quarter (25%) of the minimum normal operating flow were assumed to be under-registering. The following flow rate related meter accuracies were assumed:*
    - *100% for meters having ADD > 0.25 x Minimum Operation Flow;*
    - *85% for meters having ADD < 0.25 x Minimum Operating Flow;*
    - *80% for meters having ADD < 0.10 x Minimum Operating Flow; and*
    - *70% for meters having ADD < 0.05 x Minimum Operating Flow.*

  These accuracy estimates are considered conservative*; they may under-estimate under-registration. Turbine meters need enough flow related forces to break static friction and begin turning. The turbine will stop turning and thus the meters will stop registering flow below a minimum threshold flow.*
- *Meter accuracy versus age relationship was assumed to be equal to that of the 19mm meters (Figure 3-6).*

3.13 Accuracy of the Large Meter Population

A total of 747 meters, sizes 50mm through 150mm were reviewed. Table 3-9 gives the number of meters in each customer class and percentage of the total.

Table 3-9: Large Meter Population Studied (By Customer Class)

Customer Class	# of Meters	% of Total
COMMERCIAL/RES	32	4%
GOVERNMENT	85	11%
OTHER	302	40%
RESIDENTIAL-MLT	292	39%
RESIDENTIAL-SFD	36	5%
TOTAL	747	100%

A comparison of average day demands and meter minimum operating ranges is given below in Table 3-10 by meter size. It can be seen that the average day demand for almost all meters falls below the minimum operating range for the meter, 71% of demands fall below half the minimum operating range, 57% fall below a quarter, 42% fall below a tenth and still 32% fall shy of one twentieth of the meters normal minimum operating range.

Table 3-10: Average Day Demand as a Function of Minimum Operating Flow for 50-150mm Meters (Showing % of Meter Population below a Threshold Flow)

Meter Size (mm)	# of Meters	Sum of ADD (L/s)	Ave ADD per Meter (L/s)	% of Total # Meters			
				(ADD < 0.5*Min Flow)	(ADD < 0.25*Min Flow)	(ADD < 0.1*Min Flow)	(ADD < 0.05*Min Flow)
50	533	70.56	0.13	69%	53%	35%	24%
75	70	23.57	0.34	34%	21%	14%	11%
100	49	10.73	0.22	86%	76%	63%	47%
150	95	7.21	0.08	99%	94%	93%	83%
TOTALS	**747**	**112.07**	**0.15**	**71%**	**57%**	**42%**	**32%**
NOTES: Excludes fire flow and municipal customer class meters							

The total number of meters under-registering flow is significant. The total volume of flow passing through these meters, shown as a percentage, is presented in Table 3-11. This table does not consider age related accuracy decline. A weighted total accuracy is calculated as 98.2% for meters 50mm to 150mm in size.

Taking the average age of the meter population into account, the actual meter accuracy for this segment of the meter population would be approximately 1% lower or 97.2%.

Table 3-11: Average Day Demand as a Function of Minimum Operating Flow for 50-150mm Meters (Showing % of Total ADD within a Discrete Flow Range and Overall Meter Accuracy)

Meter Size (mm)	% of Total ADD				Overall Meter Accuracy
	>25% Min Flow	< 25% Min Flow >10% Min Flow	< 10% Min Flow >5% Min Flow(	<5% Min Flow	
50	92.0%	5.7%	1.5%	0.8%	98.6%
75	98.5%	1.1%	0.2%	0.2%	99.8%
100	83.7%	8.6%	5.0%	2.7%	97.0%
150	58.9%	6.0%	17.0%	18.2%	91.2%
				Average	98.2%

Tables 3-10 and 3-11 indicate that the large meter population is over-sized by 1-2 pipe diameters. This is expected given that large meters are currently sized to the same size as internal building plumbing (BC Building Code Fixture Unit Method) and not to standard meter sizing literature such as the AWWA M22 manual.

3.14 Apparent Losses due to Customer Meter Inaccuracy

A combined or total meter accuracy estimate is required in order to estimate apparent losses due to customer meter inaccuracy.

For each meter size, the estimated accuracy was multiplied by the total flow to determine the level of apparent losses in the system. **Apparent losses were calculated as 250 ML/year which equates to an overall meter accuracy of 97.8%.**

3.15 Large Meter Replacement Financial Analysis

A financial analysis for meter replacement was conducted. The following assumption is in addition to those listed in Section 3.12:

- *Meters that were not the smallest meter on an account were excluded from the meter replacement financial analysis. These meters are assumed to be installed in parallel with a smaller meter (compound meter arrangement) and not metering a separate customer demand.*

This assumption is considered conservative for building a financial business case as it removes approximately 50% of the meters from the analysis. In some instances this assumption will not hold true and therefore the top 10 meters in this list (financially) should be considered for replacement after checking this assumption.

The assumed costs for meter replacements are given below in Table 3-12. Meter costs were provided by the City of Nanaimo:

Table 3-12: Assumed Meter Replacement Costs

Meter Size	Meter Cost	Replacement Meter Cost	Parts/Labour	Total Replacement Cost
25	$183	-	-	-
50	$879	$183	$500	$683
75	$1,096	$183	$500	$683
100	$2,133	$879	$600	$1,479
150	$3,840	$1,096	$600	$1,696

A total of 277 meters were identified for replacement which is 37% of the population studied. A meter accuracy was calculated for each meter based on age and average flow rate.

Table 3-13 and 3-14 give the estimated yearly losses in terms of volume and revenue, the cost of meter replacement and the saving per year assuming a 10 year period (amortizing meter replacement costs and yearly recovered revenues over a 10 year period). Table 3-13 is given in terms of customer class and Table 3-14 is given in terms of meter size.

Table 3-13: Meter Replacement Financial Analysis (By Customer Class)

Customer Class	# of Meters	Average Accuracy Estimate	Volume of Apparent Yearly Losses (m^3)	Estimated Yearly Lost Revenue	Cost of Meter Replacement	Savings Per Year (10 Year Analysis)
COMMERCIAL/RES	21	77%	4,016	$3,555	$18,332	$1,721
GOVERNMENT	23	78%	3,599	$3,186	$15,720	$1,614
OTHER	120	76%	16,606	$14,698	$88,237	$5,874
RESIDENTIAL-MLT	79	77%	14,651	$12,968	$66,218	$6,346
RESIDENTIAL-SFD	34	70%	2,234	$1,977	$32,349	-$1,257
TOTALS	**277**	**76%**	**41,107**	**$36,383**	**$220,855**	**$14,298**

Table 3-14: Meter Replacement Financial Analysis (By Meter Size)

Meter Size	# of Meters	Average Accuracy Estimate	Volume of Apparent Yearly Losses (m^3)	Estimated Yearly Lost Revenue	Cost of Meter Replacement	Savings Per Year (10 Year Analysis)
50	235	76%	26,993	$23,891	$160,615	$7,830
75	7	77%	1,167	$1,033	$4,784	$554
100	18	76%	7,348	$6,504	$26,627	$3,841
150	17	72%	5,599	$4,955	$28,828	$2,073
TOTALS	**277**	**76%**	**41,107**	**$36,383**	**$220,855**	**$14,298**

A meter replacement program should be prioritized to maximize the return on investment. The program should be adjusted on a yearly basis to account for changes in customer use patterns, refined cost estimates, and refined meter accuracy estimates given the customer billing data for meters replaced in the last year.

Tables 3-13 and 3-14 provide a general business case for replacing over-sized meters. What is not shown in these tables is the variation in annual savings per year among the population. A prioritized list of meter replacements was created and could be used to begin a meter replacement project. Figure 3-7 displays graphically the yearly cost savings versus replacement priority for the 277 meters. It can be seen that the savings varies from $1,698/year to negative $148/year. The negative values simply indicate that the costs of meter replacement have not yet been recovered in a 10 year period.

The top 20 customer meters are listed on Figure 3-7. The following points are noted:

- Over half of the total estimated yearly savings, $8,052, is associated with these top 20 meter replacements.
- Although the majority of meters in the study population are 50mm, only two of these meters were in the top twenty.
- Multifamily residential meters make up 55% of the top 20 replacements; this could be attributed in part to multi-family developments (apartments) not being at full occupancy or full build-out of a multi-phased development.
- The meters have an average age of 12 years.

3.16 Recommendations for Large Meter Selection and Replacement

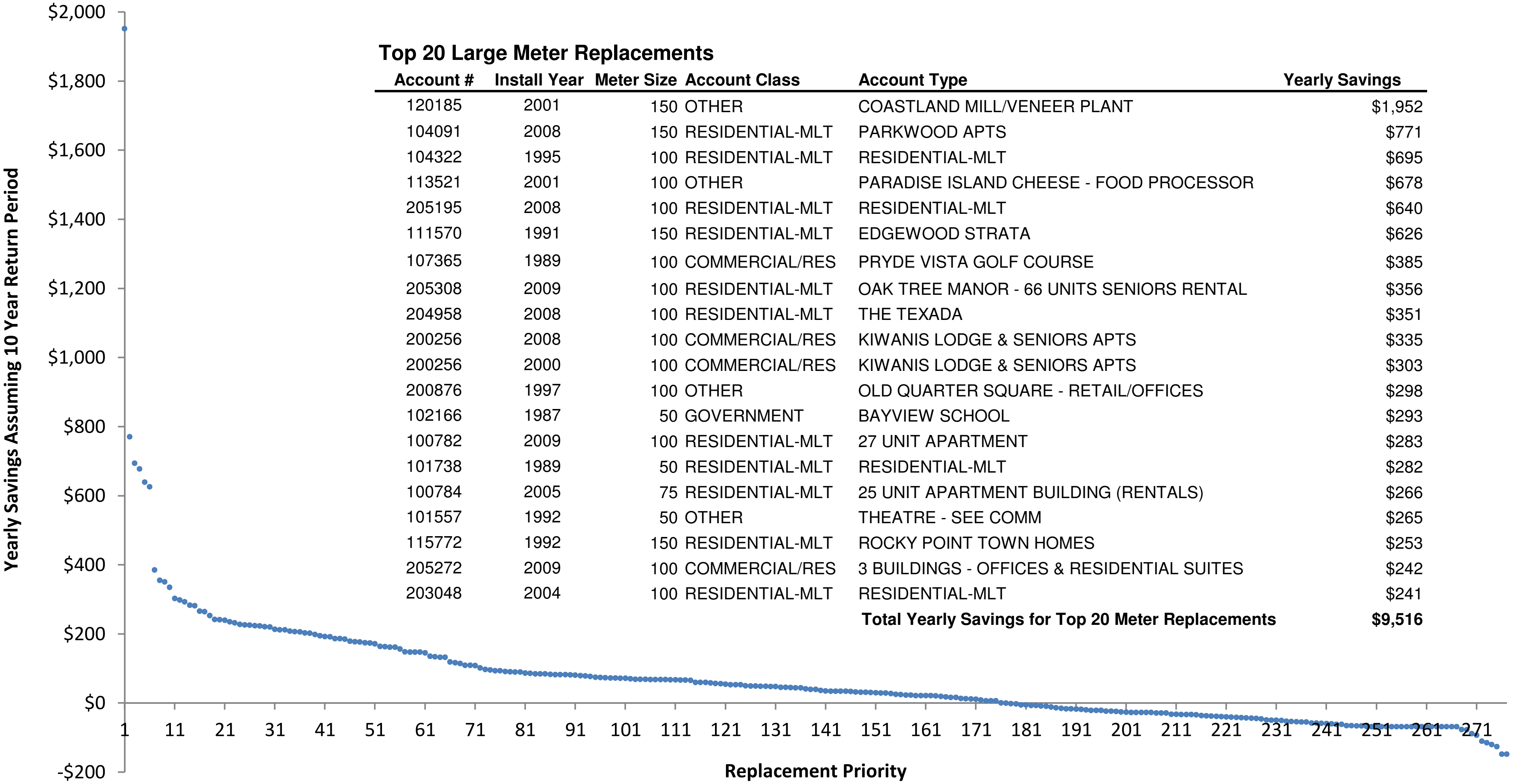
The following recommendations are made with regards to specifying meters for new developments:

- Create new section in Manual of Engineering Standards and Specifications for meter selection and sizing. This section should be based on AWWA M22 methodology.
- Provide a spreadsheet in Manual of Engineering Standards and Specifications for the right sizing of meters. This will make both the calculation and review by city staff easier.
- Specify that multi-phased developments have meter chamber sized for full build-out but size meter to match each phase of the development (replace meter as necessary).

The following recommendations are made with regards to replacement of existing meters:

- A meter sizing calculation should be done at the time of all replacements. This is particularly important given the likely over-sizing of meters within the network.
- Begin a large meter replacement project / program.
- Review and track changes in registered consumption for meters being replaced. This is best done by flow profiling but could also be accomplished less accurately through yearly billing records.
- For a multi-year replacement program, adjusted replacement priorities on a yearly basis to account for changes in customer use patterns, refined cost estimates, and refined meter accuracy estimates given the customer billing data for meters replaced in the last year.

A large meter replacement project is discussed in the context of an overall meter replacement strategy later in this section.



Top 20 Large Meter Replacements

Account #	Install Year	Meter Size	Account Class	Account Type	Yearly Savings
120185	2001	150	OTHER	COASTLAND MILL/VENEER PLANT	$1,952
104091	2008	150	RESIDENTIAL-MLT	PARKWOOD APTS	$771
104322	1995	100	RESIDENTIAL-MLT	RESIDENTIAL-MLT	$695
113521	2001	100	OTHER	PARADISE ISLAND CHEESE - FOOD PROCESSOR	$678
205195	2008	100	RESIDENTIAL-MLT	RESIDENTIAL-MLT	$640
111570	1991	150	RESIDENTIAL-MLT	EDGEWOOD STRATA	$626
107365	1989	100	COMMERCIAL/RES	PRYDE VISTA GOLF COURSE	$385
205308	2009	100	RESIDENTIAL-MLT	OAK TREE MANOR - 66 UNITS SENIORS RENTAL	$356
204958	2008	100	RESIDENTIAL-MLT	THE TEXADA	$351
200256	2008	100	COMMERCIAL/RES	KIWANIS LODGE & SENIORS APTS	$335
200256	2000	100	COMMERCIAL/RES	KIWANIS LODGE & SENIORS APTS	$303
200876	1997	100	OTHER	OLD QUARTER SQUARE - RETAIL/OFFICES	$298
102166	1987	50	GOVERNMENT	BAYVIEW SCHOOL	$293
100782	2009	100	RESIDENTIAL-MLT	27 UNIT APARTMENT	$283
101738	1989	50	RESIDENTIAL-MLT	RESIDENTIAL-MLT	$282
100784	2005	75	RESIDENTIAL-MLT	25 UNIT APARTMENT BUILDING (RENTALS)	$266
101557	1992	50	OTHER	THEATRE - SEE COMM	$265
115772	1992	150	RESIDENTIAL-MLT	ROCKY POINT TOWN HOMES	$253
205272	2009	100	COMMERCIAL/RES	3 BUILDINGS - OFFICES & RESIDENTIAL SUITES	$242
203048	2004	100	RESIDENTIAL-MLT	RESIDENTIAL-MLT	$241
				Total Yearly Savings for Top 20 Meter Replacements	**$9,516**

FIGURE 3-7: Large Meter Replacement Prioritization Showing Top 20 Replacements

3.17 Large Meter Demand Profiling

Demand profiling is the gathering of sub-minute diurnal water use through the use of a data logger installed on a customer meter. Demand profiling provides data essential for making a variety of decisions such as:

- checking whether existing meters are properly sized as part of maintenance and replacement programs;
- performing water use audits and leak detection programs for customers or district metered areas that are not actively data logged;
- collecting peak demand information for cost of service studies;
- collecting customer type / class use patterns to better estimate meter under-registration from average day demand data;
- collecting peak instantaneous demand data for creation of demand curves used for sizing new and existing service lines and meters as a supplemental to BC Building Code and AWWA M22 sizing guidelines.

Flow profiling was completed on seven large meters. Each meter was selected for one of the following reasons which are listed in order of priority:

- Large water user with old water meter;
- Largest water user in population;
- Meter appears too large for average consumption.

It is noted that priority was given to the gathering of flow profiles for the largest customers as opposed to assessing meters that appear to be oversized. The meter selected as highest priority for replacement was however tested.

Flow profiling cannot determine meter accuracy, but it can help determine the accurate meter type and size. It is noted that because most meter inaccuracy involves under-registration of usage, a flow record on an under-registering meter can result in the selection of an undersized meter. It is recommended that a meter resizing program based on current registered demand patterns be coupled with either existing meter testing or a customer use audit (M22 meter sizing exercise).

Meter under-registration was estimated by determine the volume of water passing through the meter at discrete intervals (low, normal and high flows). Manufacturer's literature was used to set these target flow intervals and estimate accuracy. The following intervals and accuracies were generally used.

- Below low flow = 65% (assumed – not given by manufacturers literature);
- At low flow but below the normal operating range = 95%;
- Within the normal operating range = 100%; and
- At or above the meters intermittent flow = 100-101%.

A summary of the results from the large meter flow profiling is given below in Table 3-15.

Table 3-15: Flow Profiling Summary of Results

Customer	Install Year	Meter Size (mm)	ADD (L/s)	Recorded Demand (L/s)	Est. Meter Accuracy	Meter Size Correct?
Hub City Fisheries	1989	75	1.07	1.66	99.58%	YES
BC Ferries	1996	150	1.06	1.64	99.42%	YES
501 6th Street Townhouses	1989	75	0.82	0.68	98.74%	YES
Vancouver Island University	2007	200	2.16	39.65	99.30%[1]	??
Vancouver Island University	1991	75	0.99	-0.74[2]	100.00%	YES
Coastland Mill Veneer Plant	2001	150	0.43	0.71	79.61%[3]	NO[4]
Western Forest Products	1989	100	0.26	0.12	91.87%[5]	NO[4]

Notes:
[1] Large flow during test due to re-direction of zone flows through University. Accuracy not indicative of normal operating conditions.
[2] Meter installed backwards.
[3] 58% of flow through meter below low flow minimum, 5% in shoulder between minimum and minimum operating range.
[4] 50mm meter recommended.
[5] 15% of flow through meter below low flow minimum, 61% in shoulder between minimum and minimum operating range.

Detailed flow profiling results are included on Figures 3-8 through 3-14. These figures include the following useful customer data:

- recorded flow pattern;
- Normal ADD demand and average demand during test;
- Meter manufacturer's accuracy data;
- Estimated meter accuracy based on usage pattern;
- Photo of the data logger installation; and
- Recommended meter size and estimated lost revenue where applicable.

The top three meters were selected because they represent some of Nanaimo's largest commercial, government and multi-family residential water users respectively. It can be seen that customer usage is registered well by these meters.

The University meters were selected in order to determine a usage pattern for one of the largest institutional customers. The University has 4 customer meters. It was reported during the project that the University may have a significant water leak however this would have been difficult to verify without isolating one of the two sources of supply as well as the smaller meter in the compound meter arrangement.

The results at the University cannot be used for the intended purpose as a large flow was bypassed through the University during the flow profiling exercise as part of the new Reservoir #1 construction project. The results could however be utilized to correct the Universities water bill as a result of the large flow diversion.

The Coastland Mill Veneer Plant and Western Forests Products meters were both found to be improperly sized. Yearly lost revenues were estimated at $2,408 and $565 respectively and the recommended meter sizes were both 2 pipe diameters smaller than existing.

KERR WOOD LEIDAL
consulting engineers

POTENTIAL LOST REVENUE =	$642 / year

METER DATA

Customer	Western Forest Products
Address	500 DUKE POINT HIGHWAY
Installation Year	1989 (???)
Meter Type	Neptune
Meter Model	W2000 Class II Turbo
Meter Size (mm)	100
2010/2011 ADD (L/s)	0.265
Recommended Meter	**50 mm**

TEST DATA

Start Test	05/12/2012 10:26
Start Meter Register (m^3)	684845.38
End Test	10/12/2012 13:12
End Meter Register (m^3)	684896.25
Totalized Volume (m^3)	50.87
Average Flow (L/s)	0.115

FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.0151	14.53%	7.4	65%
0.0151 - 0.0379	60.92%	31.0	95%
0.0379 - 4.5425	24.56%	12.5	100%
4.5425 - 5.68	0.00%	0.0	101%
TOTALS	**100.01%**	**50.9**	**91.87%**

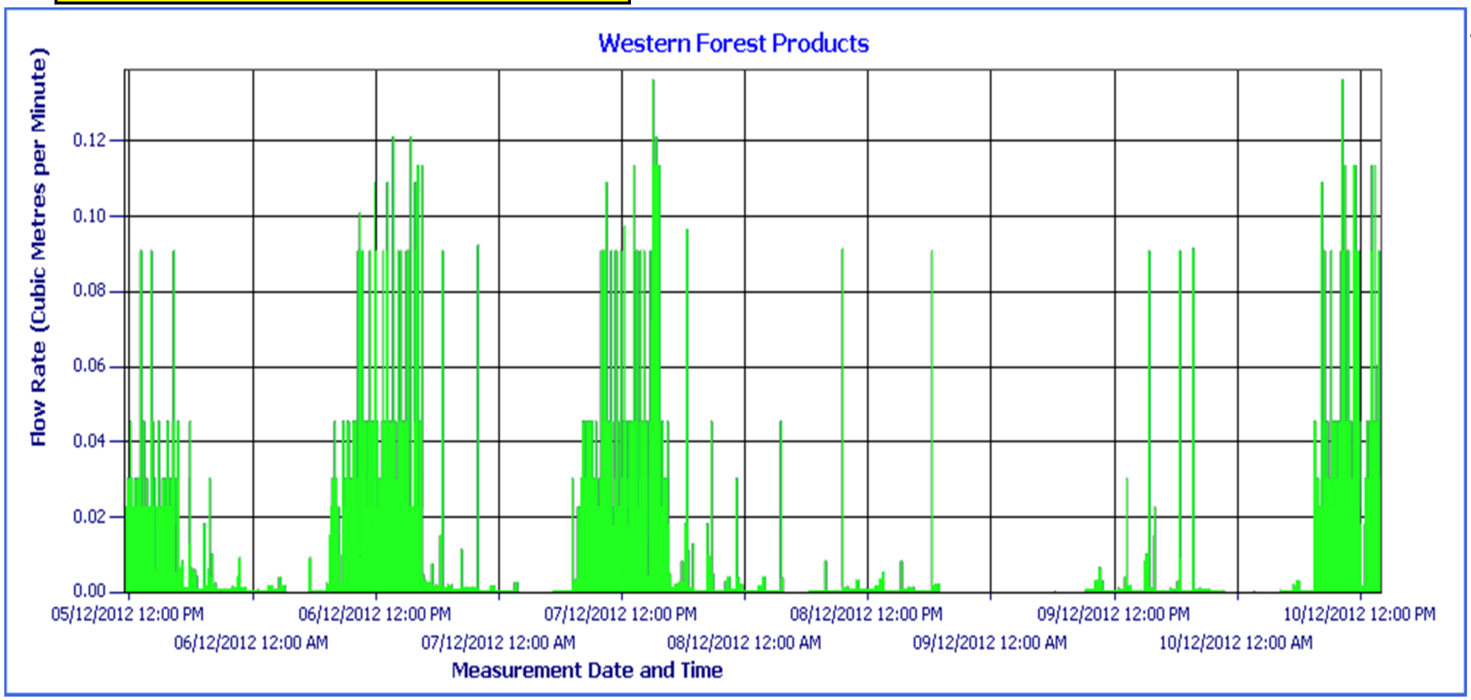
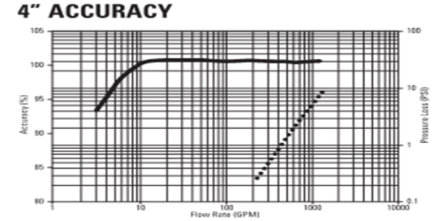


FIGURE 3-14: WESTERN FOREST PRODUCTS FLOW PROFILING

METER ACCURACY DATA

Low Flow (m^3/min)	0.0151
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.0379 to 4.5425
Intermittent Flow (m^3/min)	5.68
Accuracy for Operating Range	100% ± 1.5% of actual thruput

4" ACCURACY



METER DATA

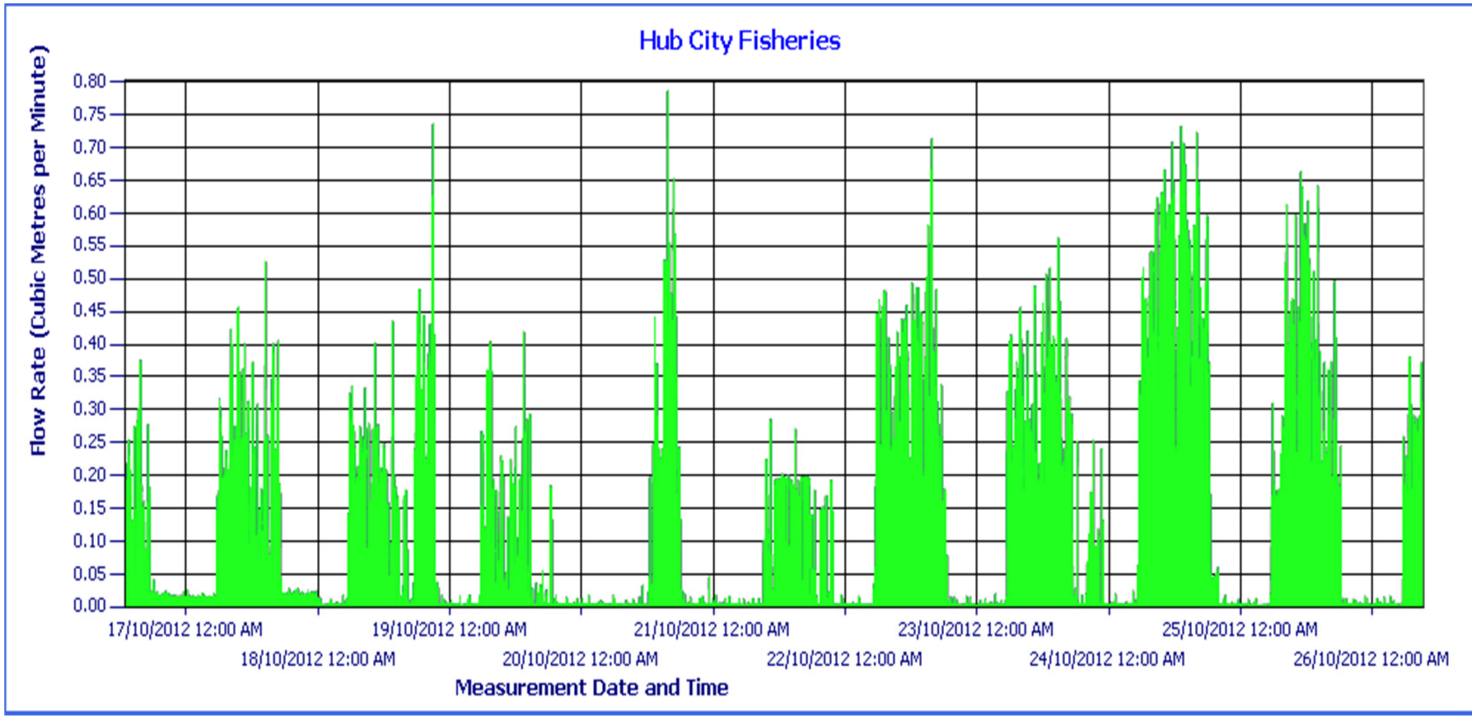
Customer	Hub City Fisheries
Address	262 SOUTHSIDE DRIVE
Installation Year	1989 (???)
Meter Type	Rockwell
Meter Model	W350
Meter Size (mm)	75
2010/2011 ADD (L/s)	1.07

TEST DATA

Start Test	16/10/2012 12:30
Start Meter Register (m^3)	677334.6
End Test	26/10/2012 9:15
End Meter Register (m^3)	678745.2
Totalized Volume (m^3)	1410.6
Average Flow (L/s)	1.655

FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.015	1.13%	15.9	65%
0.015 - 0.0183	0.41%	5.8	95%
0.0183 - 1.333	98.46%	1388.9	100%
1.333 - 1.667	0.00%	0.0	100%
TOTALS	**100.00%**	**1410.6**	**99.58%**



METER ACCURACY DATA

Low Flow (m^3/min)	0.015
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.0183 to 1.333
Intermittent Flow (m^3/min)	1.667
Accuracy for Operating Range	100% ± 1.5% of actual thruput

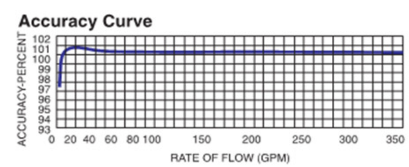


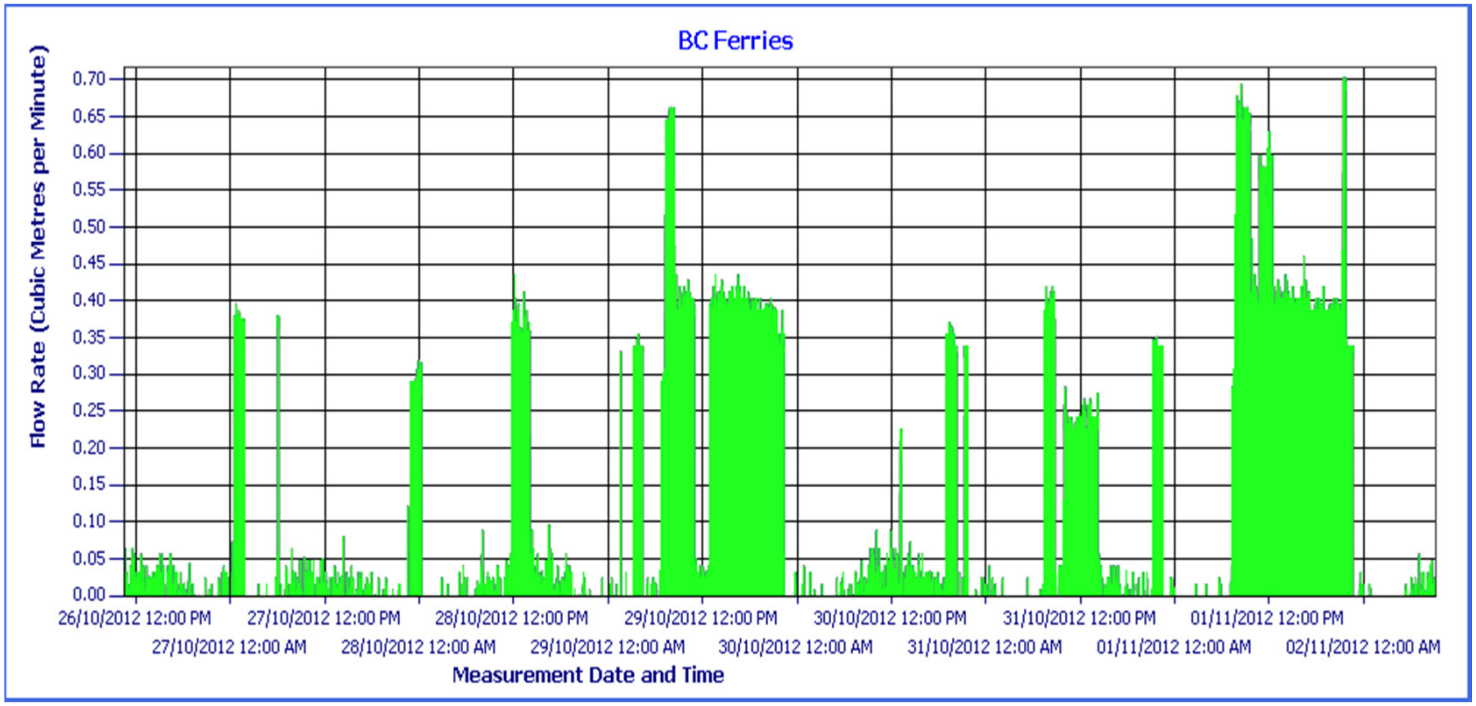
FIGURE 3-8: HUB CITY FISHERIES FLOW PROFILING

METER DATA	
Customer	BC Ferries
Address	Stewart Avenue
Installation Year	1996
Meter Type	Sensus (Touch Read)
Meter Model	W2000 Class II Turbo
Meter Size (mm)	150
2010/2011 ADD (L/s)	1.06

TEST DATA	
Start Test	26/10/2012 10:22
Start Meter Register (m^3)	615628.04
End Test	02/11/2012 9:10
End Meter Register (m^3)	616611.8
Totalized Volume (m^3)	983.76
Average Flow (L/s)	1.638

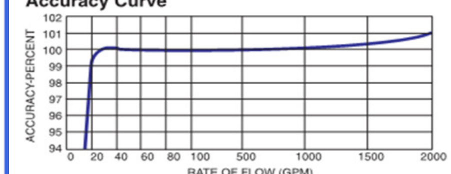
FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.0757	1.65%	16.2	65%
0.0757 - 0.1136	0.06%	0.6	95%
0.1136 - 7.57	98.29%	966.9	100%
7.57 - 9.46	0.00%	0.0	101%
TOTALS	**100.00%**	**983.8**	**99.42%**



METER ACCURACY DATA

Low Flow (m^3/min)	0.0757
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.1136 to 7.57
Intermittent Flow (m^3/min)	9.46
Accuracy for Operating Range	100% ± 1.5% of actual thruput



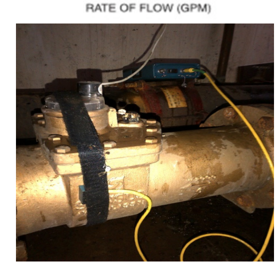


FIGURE 3-9: BC FERRIES FLOW PROFILING

METER DATA

Customer	501 6th Street Townhouses
Address	501 Sixth Street
Installation Year	1989 (???)
Meter Type	Rockwell
Meter Model	W350
Meter Size (mm)	75
2010/2011 ADD (L/s)	0.8195

TEST DATA

Start Test	02/11/2012 11:26
Start Meter Register (m^3)	788575.7
End Test	06/11/2012 10:48
End Meter Register (m^3)	788808.8
Totalized Volume (m^3)	233.1
Average Flow (L/s)	0.679

FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.015	3.39%	7.9	65%
0.015 - 0.0183	1.55%	3.6	95%
0.0183 - 1.333	95.06%	221.6	100%
1.333 - 1.667	0.00%	0.0	101%
TOTALS	**100.00%**	**233.1**	**98.74%**

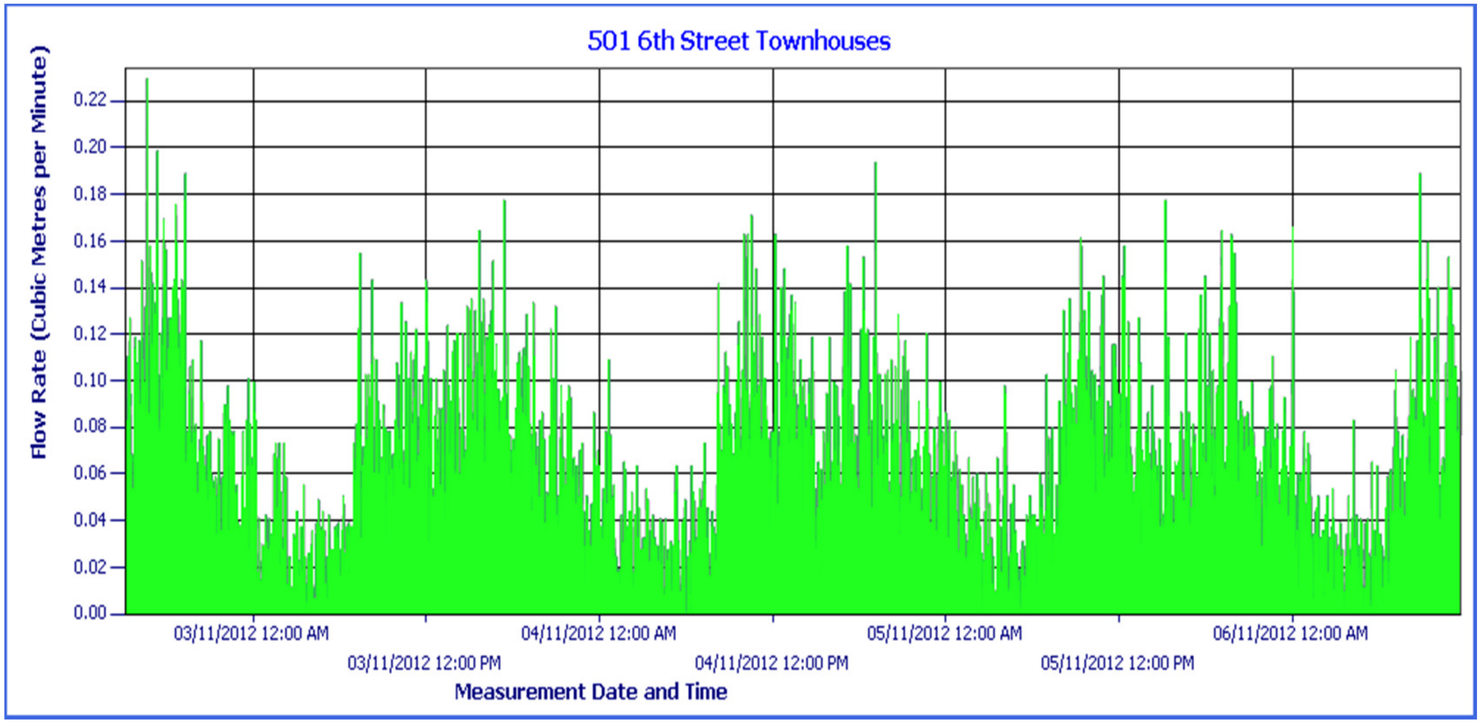
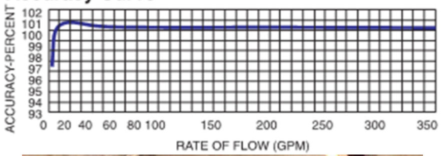


FIGURE 3-10: 501 6th STREET TOWNHOUSES FLOW PROFILING

METER ACCURACY DATA

Low Flow (m^3/min)	0.015
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.0183 to 1.333
Intermittent Flow (m^3/min)	1.667
Accuracy for Operating Range	100% ± 1.5% of actual thruput

Accuracy Curve



METER DATA

Customer	Vancouver Island University
Address	Addison Road
Installation Year	2007
Meter Type	Sensus (Touch Read)
Meter Model	W-3500
Meter Size (mm)	200
2010/2011 ADD (L/s)	2.1630

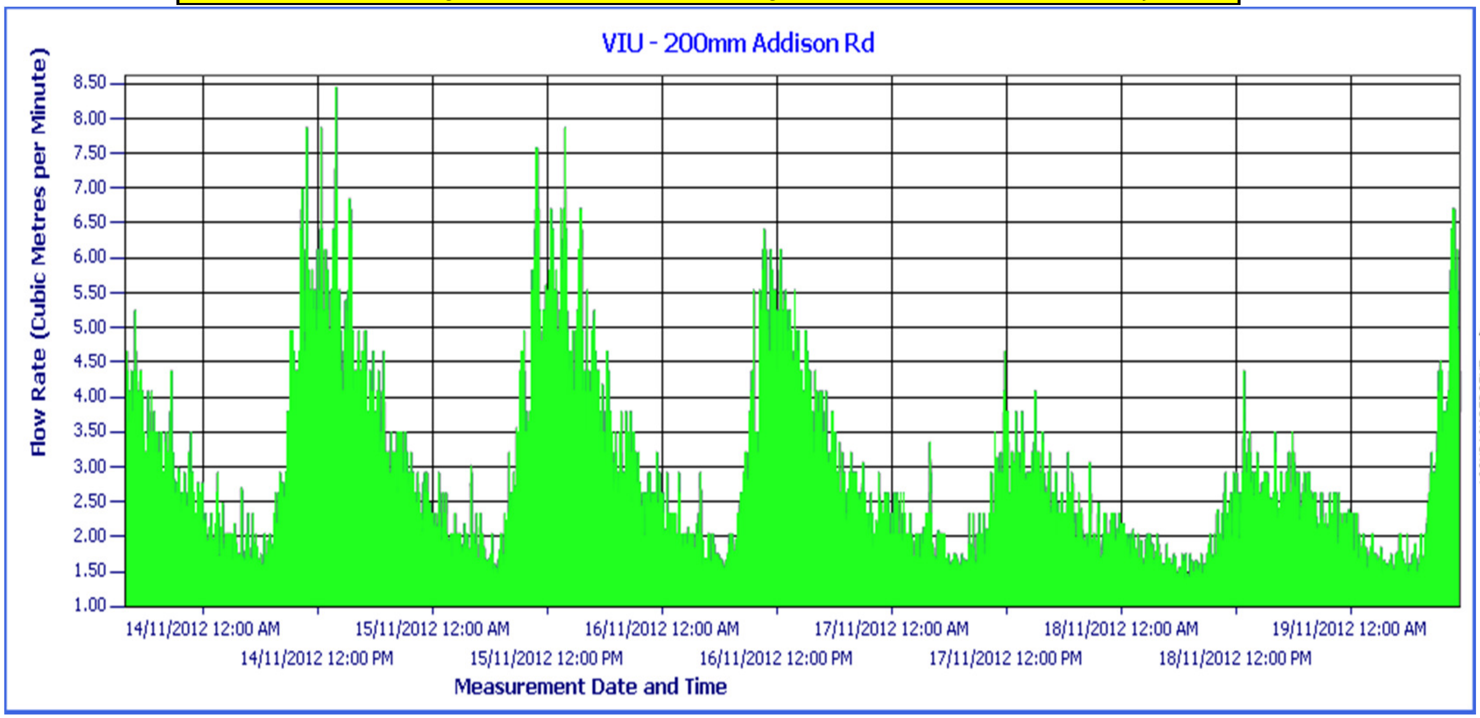
TEST DATA

Start Test	13/11/2012 14:45
Start Meter Register (m^3)	3741232
End Test	19/11/2012 10:34
End Meter Register (m^3)	3761187.1
Totalized Volume (m^3)	19955.1
Average Flow (L/s)	39.645

Flow Redirected through Meter to feed zone during Reservoir #1 Construction Project

FLOW STATISTICS/CALCULATED ACCURACY

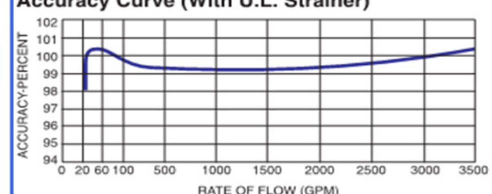
FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.114	0.00%	0.0	65%
0.114 - 0.132	0.00%	0.0	95%
0.132 - 13.249	100.00%	19955.1	99.3%
13.249 - 16.656	0.00%	0.0	100%
TOTALS	**100.00%**	**19955.1**	**99.30%**



METER ACCURACY DATA

Low Flow (m^3/min)	0.114
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.132 to 13.249
Intermittent Flow (m^3/min)	16.656
Accuracy for Operating Range	100% ± 1.5% of actual thruput

Accuracy Curve (With U.L. Strainer)



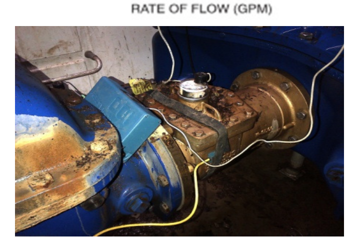


FIGURE 3-11: VANCOUVER ISLAND UNIVERSITY - 200mm ADDISON RD FLOW PROFILING

METER DATA

Customer	Vancouver Island University
Address	College Park
Installation Year	1991
Meter Type	Hersey
Meter Model	MVR 350
Meter Size (mm)	75
2010/2011 ADD (L/s)	0.9873

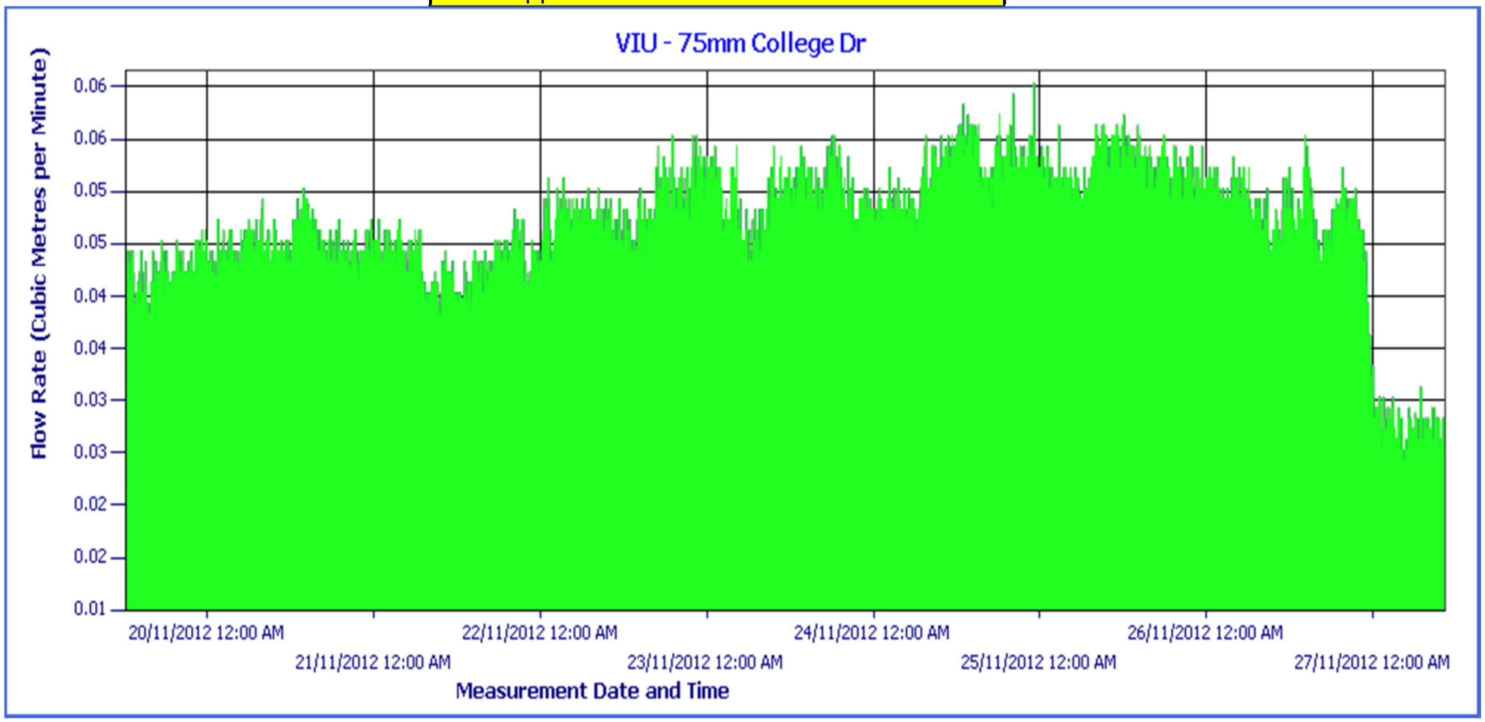
TEST DATA

Start Test	19/11/2012 11:12
Start Meter Register (m^3)	97814.8
End Test	27/11/2012 9:34
End Meter Register (m^3)	97304.35
Totalized Volume (m^3)	-510.45
Average Flow (L/s)	-0.745

Meter appears to be installed backwards

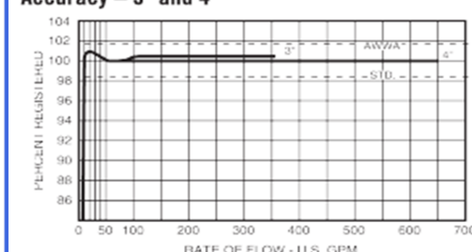
FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.009	0.00%	0.0	65%
0.009 - 0.015	0.00%	0.0	95%
0.015 - 1.325	100.00%	-510.4	100.0%
1.325 - 1.476	0.00%	0.0	100%
TOTALS	**100.00%**	**-510.4**	**100.00%**



METER ACCURACY DATA

Low Flow (m^3/min)	0.009
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.015 to 1.325
Intermittent Flow (m^3/min)	1.476
Accuracy for Operating Range	100% ± 2% of actual thruput



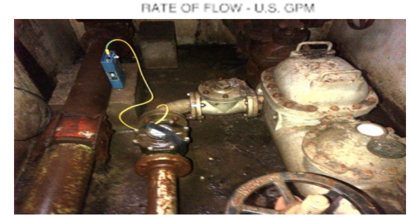


FIGURE 3-12: VANCOUVER ISLAND UNIVERSITY - 75mm COLLEGE PARK FLOW PROFILING

POTENTIAL LOST REVENUE =	**$2,735 / year**

METER DATA

Customer	Coastland Mill Veneer Plant
Address	942 HALIBURTON STREET
Installation Year	2001
Meter Type	Sensus (Touch Read)
Meter Model	W2000 Class II Turbo
Meter Size (mm)	150
2010/2011 ADD (L/s)	0.434
Recommended Meter	**75 mm**

TEST DATA

Start Test	27/11/2012 12:10
Start Meter Register (m^3)	284839
End Test	05/12/2012 9:36
End Meter Register (m^3)	285324
Totalized Volume (m^3)	485
Average Flow (L/s)	0.711

FLOW STATISTICS/CALCULATED ACCURACY

FLOW RANGE	Flow Percentage	Volume (m^3)	Est. Accuracy
0 - 0.0757	57.51%	278.9	65%
0.0757 - 0.1136	5.10%	24.7	95%
0.1136 - 7.57	37.38%	181.3	100%
7.57 - 9.46	0.00%	0.0	101%
TOTALS	**99.99%**	**485.0**	**79.61%**

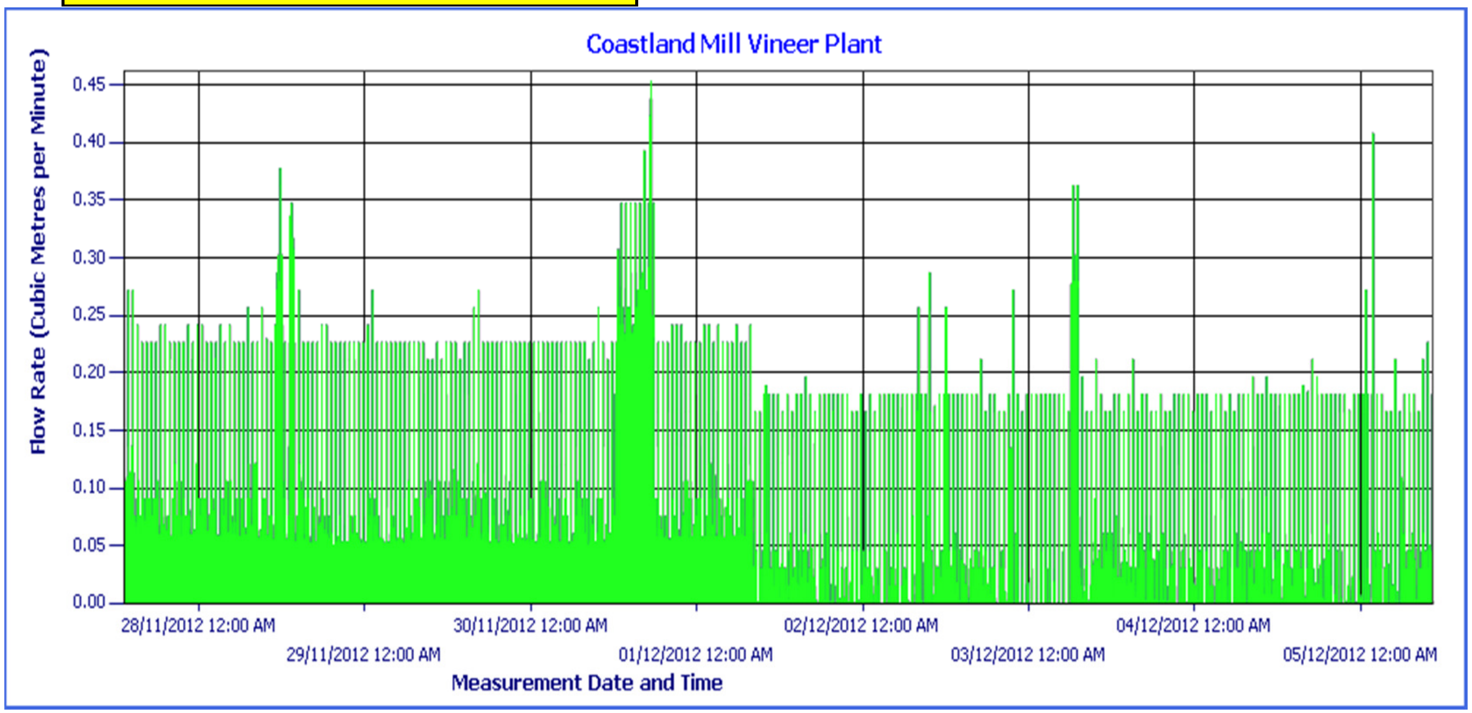
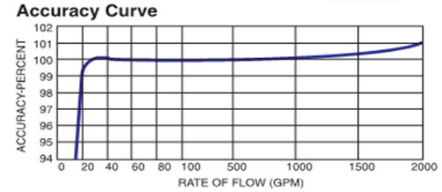


FIGURE 3-13: COASTLAND MILL VENEER PLANT FLOW PROFILING

METER ACCURACY DATA

Low Flow (m^3/min)	0.0757
Low Flow Accuracy	95%
Operating Range (m^3/min)	0.1136 to 7.57
Intermittent Flow (m^3/min)	9.46
Accuracy for Operating Range	100% ± 1.5% of actual throughput

Accuracy Curve



3.18 Proposed Meter Replacement Strategy

The financial analysis completed for both residential 19mm meters and large meters for ICI and multi-family customers are used to develop a meter replacement strategy. The total cost of replacement of the meter population and a yearly replacement budget, assuming a 24 year renewal frequency, are given below in Table 3-16. The yearly replacement budget is estimated as $244,000 which equates roughly to 1,000 meter replacements per year.

Table 3-16: Calculating a Meter Replacement Budget (based on a 24 year renewal frequency)

Meter Size (mm)	# of Meters	Cost of Meter	Labour / Parts	Replacement Cost	Total Replacement Cost	Yearly Replacement Budget
19	23132	$84	$92	$176	$4,071,200	$169,635
25	397	$183	$125	$308	$122,300	$5,095
38	294	$300	$125	$425	$125,000	$5,206
50	626	$879	$150	$1,029	$644,200	$26,840
75	94	$1,096	$150	$1,246	$117,100	$4,880
100	70	$2,133	$200	$2,333	$163,300	$6,805
150	121	$3,840	$200	$4,040	$488,800	$20,368
200	17	$4,500	$300	$4,800	$81,600	$3,400
250	6	$6,000	$300	$6,300	$37,800	$1,575
TOTALS	24757				$5,851,000	**$244,000**

Given a 24 year replacement frequency the average age of meters would be 12 years and there would be no meters in the network installed prior to 1990. The current average meter age is estimated at 14.4 years and there are approximately 7,400 meters in the network installed prior to 1990. The yearly budget should therefore allow for this meter deficit to be removed. The current meter deficit is estimated at $1.75 million.

A 20 year period for deficit removal would set the yearly **meter replacement budget at $331,000.** This is broken down into:

- **$230,000 for residential 19mm meter replacements** (approximately 1,300 per year); and
- **$101,000 for large meter replacements.**

It is recommended that the large meter replacement budget be used for a “right-sizing” replacement project for the first 2-3 years. Right sizing large customer meters as a first priority will decrease the required replacement budget moving forward.

The budget figures given above should be increased annually to account for growth in the meter population. The current and projected growth rate to 2030 is approximately 1.6% per year.

An annual meter testing program and large meter profiling/maintenance program are recommended to re-calibrate the replacement strategy moving forward (replacement frequency).

KERR WOOD LEIDAL
consulting engineers

Section 4

Component Analysis

4. Component Analysis

Component analysis is a method used to broadly quantify the different components of leakage to understand which components are the greatest portion of the current annual real losses (CARL) and how these losses occur.

The component analysis includes 3 steps, namely:

Step 1: Quantify current reported leakage (CRL)

Step 2: Quantify economic unreported leakage (EUL)

Step 3: Estimate the unavoidable background leakage (UBL) and target background leakage (TBL)

Step 4: Estimate the potentially recoverable leakage (PRL)

Having an estimate of the individual components of CARL helps identify which leak reduction strategies will be most beneficial. As an example, if a system has high background leakage, which by definition is not detectible by leak detection equipment, then leak detection surveys should not be recommended.

4.1 Step 1 – Quantify Current Reported Leakage (CRL)

During the audit period, the city encountered 14 reported main breaks and approximately 161 service breaks. These events are detailed below in Table 4-1 along with estimated flow rates and leak running times. Flow rates and average run times are estimated from values presented in the AWWA M36 manual.

Table 4-1: Reported Break History for Audit Period

Location	Type of Break	Date Break Reported	Pipe Diameter (mm)	Material	Flow Rate (m^3/day)	Leak duration (days)	Annual Leakage Volume (ML/yr)
161 Locations	161 Service Leaks		25		45.2	9	65.5
Friar Tuck	Longitudinal	14/08/2010	200	AC	1,228.1	3	3.7
Sherwood Dr.	Longitudinal	25/09/2010	150	AC	909.3	3	2.7
Opal Rd.	Longitudinal	30/11/2010	150	AC	909.3	3	2.7
Thetis Pl.	Circumferential	17/12/2010	100	CI	727.3	3	2.2
Poplar St.	Circumferential	22/12/2010	150	CI	727.3	3	2.2
Cadogan St.	Circumferential	16/01/2011	150	CI	727.3	3	2.2
Forest Dr.	Longitudinal	28/01/2011	150	AC	909.3	3	2.7
Tom's Turnabout	Longitudinal	21/05/2011	150	AC	909.3	3	2.7
Terminal Ave.	Leaking Joint	30/05/2011	200	CI	113.3	3	0.3
Nanaimo Lakes Rd.	Corrosion Hole	15/06/2011	900	ST	462.4	3	1.4
Skinner St.	Joint Failure	08/07/2011	150	CI	727.3	3	2.2
Sheriff Way	Leaking Joint	10/07/2011	200	AC	113.3	3	0.3
Laguna Way	Circumferential	27/07/2011	200	AC	999.0	3	3.0
Glen Eagle Cres.	Service blowout	29/07/2011	150	AC	1,440.2	3	4.3
TOTAL (Current Reported Leakage)							**98**

Note that the largest volume of leakage was from customer service connection breaks. Also note that reported leakage 98 ML/year, is only a small fraction (6.5%) of the CARL of 1,508 ML/year. This illustrates that, while reported leaks can be disruptive and result in damage to private property and municipal assets, overall they are typically addressed quickly and normally do not account for a major portion of the annual volume of real losses. Hidden unreported leaks that are left to run continuously, and undetectable background leakage, often account for a major portion of the CARL in a water system.

4.2 Step 2 – Quantify Economic Unreported Leakage (EUL)

The City of Nanaimo does not operate an ongoing active leakage control program (daily flow monitoring and ongoing leak sounding activities). Unreported leaks will remain until increased failure at the leak location causes leaks to surface or significant loss of system pressure.

To determine the economic unreported leakage, knowledge on the rate of rise of unreported leakage and the cost of leak sounding is required. Without historical data from active leakage control works, estimates are required.

The economic intervention frequency is given as:

Economic intervention frequency (EIF) (months) = $[0.789*(CI/CV)/RR]^{0.5}$

where:

CI = cost of leak detection survey ($/km/year);

CV = Variable cost of real losses ($/ML) = $30.68 / ML (calculated above); and

RR = Average Rate of Rise of unreported leakage (ML/km/day)

The cost of conducting leak detection surveys is approximated as $650 / km, based on recent quotes provided to KWL for leak correlation works. The average rate of rise of unreported leakage for Nanaimo is assumed to be relatively low due to the shallow depth of cover of mains (1-1.2 meters on average) and favourable ground conditions which are reported to cause most leaks to surface. The RR is therefore estimated to be 0.0005 ML/km/day which equates to 117.5 ML/year for the Nanaimo water system.

EIF is therefore estimated to be 183 months or approximately 6.5% of the system inspected annually. An estimate of the appropriate budget to be spent on leak detection yearly is therefore given as:

Average annual budget for active leakage control = $650/km x 644 km of pipe in system x 6.5% **= $27,000.**

EUL is then the average annual budget for active leakage control divided by CV. Therefore EUL = 895.4 ML/year.

4.3 Step 3 - Estimate Unavoidable Background Leakage (UBL) and Target Background Leakage (TBL)

Unavoidable background losses (UBL) are the portion of unavoidable annual real losses (UARL) attributed strictly to background leaks. It is a function of the length of mains, number of service connections, estimated total length of service connections and average system pressure. The equation is expressed as:

$$UBL\ (litres/day) = \left(470.4 \times L_m + 30.3 \times N_c + 800 \times L_c\right) \times \left(\frac{P}{49.26}\right)^{1.5}$$

Where:

L_m = mains length (km)

N_c = # of service connections

L_c = total length of service connections (km)

P = average system pressure (meters water column)

Given a total main length of 644 km, 24,276 service connections at an assumed average length of 10 meters/connection and an average system pressure of 71.8 meters, the UBL was calculated as 2.17 ML/day or 792 ML/year.

Target background leakage is the actual level of background leakage for a particular system. It is equal to the UBL multiplied by the infrastructure condition factor (ICF). The ICF therefore gives how much more a system's background losses are compared to the estimated lowest achievable level for an average system (UBL).

Unfortunately, the ICF is a mostly unknown factor that without detailed measurement is difficult to know. For this reason a sensitivity analysis approach is recommended for determining the TBL.

The best case is to assume that an ICF of 1 is achievable and the worst case is to assume that after deducting the reported losses and calculated economic unreported leakage (EUL) from the current annual real losses (CARL), all remaining real losses are attributable to background leakage. The worst case gives:

TBL = CARL – CRL – EUL = 1,508 - 98.2 – 895.4 = 514.4 ML/year

This equates to an ICF < 1 which again illustrates that the estimated CARL are quite low. Given as ICF = 1, the TBL would equate to UBL or 792 ML/year. Therefore a TBL of 792 ML/year is assumed.

4.4 Step 4: Estimate the Potentially Recoverable Leakage (PRL)

Potential recoverable leakage is calculated as the CARL minus the three components of target real losses given above, namely:

PRL = CARL – CRL – EUL – TBL

The potential recoverable leakage is estimated to be negligible, past that which is recommended for yearly active leakage control to reduce EUL. Again, this is due to the low estimate of CARL.

4.5 Components of Real Losses

The last component of the water audit is to estimate the distribution of real losses from transmission mains, service connection and reservoirs. No field data on reservoir leakage has been completed and no historical reports of uncontrolled reservoir leakage. Reservoir leakage is therefore assumed to be negligible.

The distribution of real losses between transmission mains and service connections is assumed to be equal to that of reported leakage. Service connection leakage is estimated as 67% of reported leakage and therefore the total leakage from service connection is estimated as 1010 ML/year. Transmission main leakage is therefore estimated at 498 ML/year. Refer to Table 2-13 (given earlier) for reference of how these values fit into the water audit results.

KERR WOOD LEIDAL
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Section 5

Disaggregated Demand Analysis

(Use by Customer Type)

5. Disaggregated Demand Analysis (Use by Customer Type)

A disaggregated demand analysis was completed to determine how different customers use water. In a disaggregated demand formulation, demands are separated into base and seasonal demand components for each land use.

Base demands are defined as those demands that are generally constant throughout the year, such as residential internal water use, industrial processes and leakage. Seasonal demands are defined as the additional demands that are present in the summer months due primarily to irrigation. These demands reach a maximum during periods of high soil moisture deficit and evapotranspiration.

This formulation of demand is useful for the development of an accurate representation of existing and future demands. As growing metropolitan areas densify, seasonal demands will generally decrease as irrigatable areas decrease. The best way to estimate future demands in a densifying city is to use a disaggregated base and seasonal demand formulation.

Residential water use is the focus of many demand management strategies and thus assessing the per-capita indoor consumption and seasonal water use is useful for gauging the success of these programs as well as recommending areas for improved efficiency.

This section gives the results of the disaggregated demand analysis. Specifically, average day, base and seasonal usage figures are given in terms of per account, per dwelling unit and per hectare for different customer types. These figures are then used to predict 2031 OCP demands.

5.1 Base and Seasonal Demand Formulation

Base demands are formulated by looking at winter billing period data when outdoor use or seasonal demands are minimal. Base demand for each customer was calculated from the billing period prior to June 15th 2011. Therefore if a particular meter is scheduled to be read on June 16th then base demand is calculated from the billing period from October 7th 2010 to February 17th 2011.

This formulation was chosen as it represents the minimum total base demand over all customers. It minimizes the effects of seasonal demands for meters that do not have a truly base demand reading period within the framework of City's meter reading cycle. Therefore the billing periods used to establish base demand ranged between:

- October 6th 2010 – February 16th 2011, and
- February 15th 2011 – June 14th 2011.

Seasonal demands are the additional components of metered demand that are not associated with base demand. They are largely comprised of irrigation demands occurring primarily in the months of July and August with shoulder periods beginning in mid-May and ending in early October. It can be seen from the 2010-2011 source flow data that the maximum seasonal demand over the audit period occurred in the month of August 2010.

Due to the short duration of seasonal demands and the rolling 4 month billing cycle (3 annual meter reads), seasonal demands are not easily discerned from the customer meter records. The approach used to establish seasonal demands is presented below.

Figure 5-1 displays the number of customers with maximum billing periods ending in each calendar month.

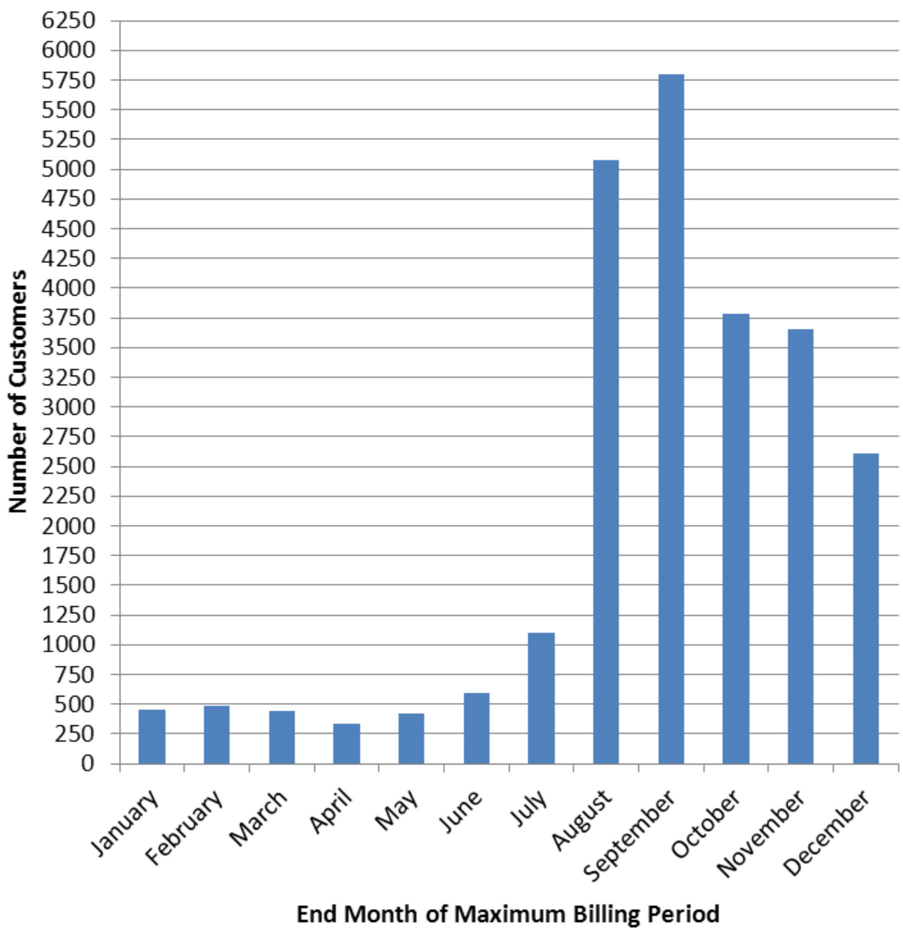

Figure 5-1: Number of Customers with Maximum Billing Period by Month

Demand estimates for the maximum month (August 2010) were formulated by multiplying each customer's maximum billing period by the peaking factor curve displayed in Figure 5-2. The peaking factors were calculated as the peak monthly source flow (August 2010) divided by the average source flow over the billing period. Linear interpolation was used to arrive at peaking factors for each calendar day. No peaking factor was added for customers with maximum billing periods falling in the range of:

- September 2nd, 2010 – January 1st, 2011; and
- February 1st 2011 – May 31st, 2011.

2,133 customers (8.8%) had maximum billing periods in this range. The maximum month demand for these customers was therefore assumed to be equal to the maximum billing period demand. These customers represent 7.6% of maximum day demands.

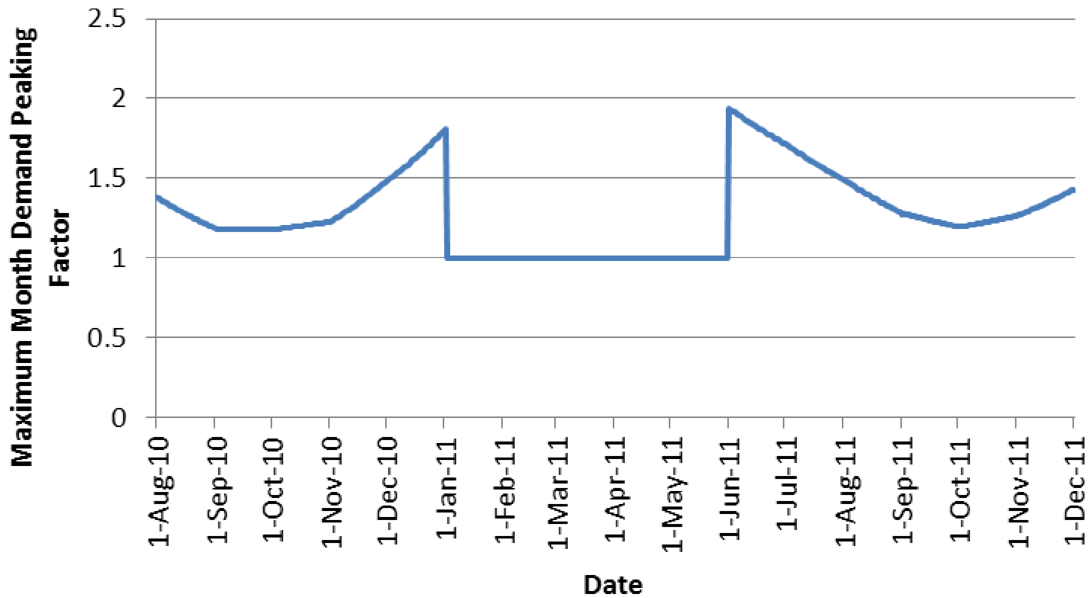

Figure 5-2: Peaking Factor Curve for Estimation of Customer Seasonal Demands

Seasonal demands are calculated as the maximum month demand minus base demand.

Maximum day, MDD, seasonal demand predictions can be made by multiplying the maximum month figures by a ratio of observed source flow MDD to maximum month. 2011 Daily source flow data was provided for the months of July and August. For this period, the maximum month demand was observed as 743 L/s (August) and the MDD was 812 L/s (July 6, 2011). Seasonal demands represent approximately 47% of the maximum month source flow. Therefore the 9% difference in demand between MDD and Maximum Month can be attributed to a 20% difference in the seasonal demand component. MDD seasonal demands are therefore approximated as being 1.2 times the maximum month seasonal demands.

5.2 Per Account and Per Dwelling Unit Demand Estimates

The customer meter database categorizes customer account types as given in Table 2-5. A secondary account description is also given. This account description provides much more data on the property, such as the name of the business or whether a residential multifamily dwelling is a single family home with a secondary suite, a duplex or a mobile home park. Also provided in the meter database is the number of units on each account. This data is useful for calculating per capita base demands for customer meters with more than one residence.

Demands expressed as per account and per dwelling unit for each customer type are given in Table 5-1. Also given are the top account description water users under each customer type. A complete list of demands for each customer description is given in Appendix A

Table 5-1: Demands by Customer Type (with Top ADD Consumers Descriptions)

Customer Type / Description	Number of Accounts	Total Number of Units	ADD (L/s)	Base Demand (L/s)	MDD (L/s)	MDD-SEAS (L/s)	Per Account Demand (L/Account/day)			Per Dwelling Unit Demand (L/Dwelling/day)		
							ADD	BD	MDD-SEAS	ADD	BD	MDD-SEAS
COMMERCIAL/RES	**153**	**777**	**3.69**	**3.16**	**7.28**	**4.12**	**2083**	**1786**	**2327**	**410**	**352**	**458**
COMMERCIAL/RES	54	111	0.62	0.50	1.37	0.87	985	801	1387	479	389	675
CHANNEL VIEW CONDOS	1	43	0.34	0.46	0.46	0.00	29489	39412	0	686	917	0
WOODGROVE PINES (RES - UP/COMM - DOWN)	1	41	0.24	0.23	0.41	0.19	20493	19499	16321	500	476	398
COMMERCIAL/RESIDENTAL STRATA	1	75	0.16	0.11	0.36	0.25	13944	9245	22012	186	123	293
HARBOURVIEW MANOR	1	18	0.16	0.22	0.22	0.00	13916	18702	0	773	1039	0
MEREDITH BUSINESS CENTRE (BAKERY & APTS)	1	1	0.12	0.09	0.25	0.16	10599	7909	13525	10599	7909	13525
KIWANIS LODGE & SENIORS APTS	1	165	0.12	0.07	0.23	0.16	10579	6121	13457	64	37	82
LAKE SIDE CENTRE (COM)/ WATERDOWN QUAY (RES)	1	46	0.10	0.09	0.16	0.07	8636	7514	6140	188	163	133
MOSTAR CENTRE - RETAIL DOWN & RES. UP	1	1	0.09	0.03	0.19	0.15	7890	3000	13314	7890	3000	13314
PRIDEAUX GARDENS	1	8	0.09	0.06	0.22	0.17	7625	4879	14365	953	610	1796
YACHT CLUB	1	7	0.09	0.06	0.19	0.14	7511	4804	11820	1073	686	1689
RESTAURANT - RESIDENTIAL	1	4	0.09	0.05	0.25	0.20	7375	4370	17618	1844	1093	4405
PRYDE VISTA GOLF COURSE	1	3	0.07	0.04	0.21	0.17	6326	3164	15118	2109	1055	5039
APT BLDG & COMM BLDG	1	8	0.06	0.04	0.14	0.10	5018	3448	8779	627	431	1097
6 OFFICE SUITES/7 RESIDENTIAL UNITS	1	7	0.06	0.05	0.08	0.04	4914	4059	3245	702	580	464
GOVERNMENT	**91**	**304**	**24.76**	**18.70**	**44.68**	**25.98**	**23507**	**17758**	**24663**	**7037**	**5316**	**7383**
VANCOUVER ISLAND UNIVERSITY	1	15	6.49	5.02	9.05	4.03	560515	433733	348327	37368	28916	23222
NRGH/EXTENDED CARE/DAYCARE	1	1	4.30	3.71	6.19	2.47	371521	320737	213728	371521	320737	213728
BIOLOGICAL STATION	1	21	2.81	2.95	3.88	0.94	243047	254487	81101	11574	12118	3862
BC FERRIES	1	1	1.06	0.52	2.31	1.79	91473	44922	154646	91473	44922	154646
BRANNEN LAKE INSTITUTE	1	1	1.01	0.99	1.67	0.68	87349	85838	58676	87349	85838	58676
SEWER TREATMENT PLANT	1	3	0.75	0.70	1.10	0.40	64454	60379	34553	21485	20126	11518
N.D.S.S./BOARD OFFICE/ROTARY BOWL/ STADIUM	1	6	0.52	0.44	0.79	0.35	44987	38140	29977	7498	6357	4996
WELLINGTON SECONDARY SCHOOL	1	11	0.41	0.09	1.30	1.21	35022	7858	104535	3184	714	9503
PROVINCIAL RENTAL HOUSING CORP	1	34	0.40	0.37	0.44	0.08	34397	31836	6554	1012	936	193
JOHN BARSBY SCHOOL	1	3	0.40	0.21	1.22	1.00	34311	18544	86472	11437	6181	28824
DUKE POINT ASSEMBLY WHARF	1	1	0.36	0.09	1.10	1.01	31461	7881	87358	31461	7881	87358
SEAPLANE TERMINAL & LIGHTHOUSE BISTRO	1	1	0.31	0.22	0.61	0.39	26711	18643	33905	26711	18643	33905
FEDERAL BLDG	1	1	0.30	0.28	0.40	0.12	25866	24273	10273	25866	24273	10273
BULK WATER DUKE POINT VALVE STATION	1	1	0.27	0.18	0.56	0.38	23639	15554	33189	23639	15554	33189
BULK WATER	2	2	0.27	0.20	0.54	0.34	11539	8541	14878	11539	8541	14878

Customer Type / Description	Number of Accounts	Total Number of Units	ADD (L/s)	Base Demand (L/s)	MDD (L/s)	MDD-SEAS (L/s)	Per Account Demand (L/Account/day)			Per Dwelling Unit Demand (L/Dwelling/day)		
							ADD	BD	MDD-SEAS	ADD	BD	MDD-SEAS
MUNICIPAL	**122**	**190**	**11.82**	**4.97**	**35.39**	**30.42**	**8372**	**3522**	**21543**	**5376**	**2261**	**13833**
BEBAN PARK	1	7	3.18	2.11	8.63	6.52	274615	182139	563532	39231	26020	80505
NANAIMO AQUATIC CENTRE	1	1	1.30	1.29	1.59	0.30	112744	111831	25613	112744	111831	25613
BOWEN PARK	1	15	0.72	0.06	1.98	1.92	62024	4761	166314	4135	317	11088
CEMETERY	1	1	0.69	0.00	2.51	2.51	59927	151	216854	59927	151	216854
BALL FIELD ON JINGLEPOT/ROTARY FIELD HOUSE	1	1	0.64	0.22	2.86	2.64	54962	18919	228206	54962	18919	228206
NANAIMO ICE CENTRE	1	1	0.44	0.31	0.83	0.52	38193	27189	44871	38193	27189	44871
COMOX ROAD PARK	1	2	0.42	0.35	1.07	0.73	36133	29940	62890	18066	14970	31445
FIRE HALL /BALL FIELD/WATER PARK	1	2	0.36	0.00	1.53	1.53	31417	319	131852	15708	160	65926
HAREWOOD WATER PARK	1	1	0.35	0.10	1.34	1.24	30546	8573	106840	30546	8573	106840
HALIBURTON PARK & WATER PARK	1	1	0.30	0.00	0.98	0.98	25736	0	84804	25736	0	84804
MAY BENNETT/PIONEER PARK	1	1	0.28	0.00	1.01	1.01	24543	106	87120	24543	106	87120
HARRY WIPPER PARK	1	1	0.21	0.02	0.59	0.57	17894	1543	49190	17894	1543	49190
GROVELAND PARK	1	1	0.19	0.00	0.69	0.69	16664	17	59715	16664	17	59715
PARK	15	15	0.17	0.02	0.69	0.67	966	108	3872	966	108	3872
TROFTON PARK	1	1	0.16	0.00	0.57	0.57	13996	61	49135	13996	61	49135
OTHER	**948**	**2159**	**62.69**	**52.39**	**120.70**	**68.31**	**5714**	**4775**	**6225**	**2509**	**2097**	**2733**
OTHER	259	264	3.19	2.57	6.83	4.26	1064	857	1422	1044	841	1395
OFFICE/HATCHERY/RESERVOIR	1	1	2.48	2.27	3.38	1.11	214057	195935	95761	214057	195935	95761
SNUNEYMUXM FIRST NATIONS	1	121	2.22	2.96	3.06	0.10	192137	256045	8371	1588	2116	69
WOODGROVE MALL & SERVICE STN	1	5	1.72	1.42	3.15	1.73	148184	123001	149335	29637	24600	29867
NAN. SENIORS VILLAGE (NURSING HOME)	1	142	1.45	1.32	2.35	1.03	124976	114032	88983	880	803	627
GREEN THUMB NURSERY	1	1	1.23	0.25	3.67	3.43	105924	21364	296035	105924	21364	296035
HUB CITY FISHERIES	1	1	1.07	0.64	2.04	1.40	92460	55349	120983	92460	55349	120983
SEA DRIFT FISH CO LTD	1	1	1.00	0.60	1.72	1.12	86642	52250	96589	86642	52250	96589
ROCK CITY CENTRE	1	1	1.00	0.83	1.99	1.17	86284	71481	100730	86284	71481	100730
LONGWOOD STATION - SHOPPING CENTRE	1	8	0.83	0.56	1.59	1.03	72115	48673	88717	9014	6084	11090
COUNTRY CLUB MALL	1	3	0.83	0.83	1.28	0.45	71908	71585	39197	23969	23862	13066
MALASPINA GARDENS - NURSING HOME	1	162	0.76	0.75	1.33	0.58	65432	64724	50072	404	400	309
TALLY HO HOTEL/BUS DEPOT	1	1	0.75	0.62	1.26	0.64	64770	53543	55247	64770	53543	55247
ST JEANS CANNERY	1	1	0.74	0.80	1.33	0.53	64181	69146	45360	64181	69146	45360
PORT PLACE MALL/WENDY'S/MEDICAL ARTS CENTRE	1	3	0.70	0.48	1.88	1.40	60447	41313	120883	20149	13771	40294

Customer Type / Description	Number of Accounts	Total Number of Units	ADD (L/s)	Base Demand (L/s)	MDD (L/s)	MDD-SEAS (L/s)	Per Account Demand (L/Account/day)			Per Dwelling Unit Demand (L/Dwelling/day)		
							ADD	BD	MDD-SEAS	ADD	BD	MDD-SEAS
RESIDENTIAL-MLT	**3684**	**18544**	**96.72**	**81.87**	**175.37**	**93.50**	**2269**	**1920**	**2193**	**451**	**381**	**436**
SFD W/SUITE	2279	4555	22.86	19.61	44.76	25.14	867	744	953	434	372	477
RESIDENTIAL-MLT	489	3348	17.22	15.02	29.50	14.48	3043	2654	2559	444	388	374
DUPLEX	429	631	4.38	4.05	8.15	4.09	882	817	824	600	555	560
BARE LAND STRATA	9	278	2.09	1.25	4.42	3.18	20043	11952	30512	649	387	988
DEERWOOD PLACE ESTATES	1	298	1.68	1.06	3.81	2.75	145254	91600	237201	487	307	796
SEABREEZE MOBILE HOME PARK	1	154	1.47	1.34	2.82	1.48	126858	115472	127764	824	750	830
SHARMAN MOBILE HOME PARK	1	146	1.02	0.86	1.74	0.89	87816	73994	76773	601	507	526
LONG LAKE HEIGHTS (SP830, 762 & 1703)	1	232	0.97	0.77	1.64	0.87	84098	66496	75471	362	287	325
SEA CREST TOWERS	1	107	0.82	0.83	1.19	0.36	70664	72050	30852	660	673	288
WILLOW MOBILE HOME PARK	1	113	0.78	0.59	1.54	0.95	67362	50839	82494	596	450	730
THE TERRACES (TOWNHOUSES)	1	89	0.76	0.36	1.70	1.33	66071	31438	115260	742	353	1295
LONGWOOD MULTI BLDG CONDOS	1	229	0.73	0.45	1.56	1.11	63262	38839	95891	276	170	419
MALASPINA ESTATES - ALL UNITS SFD'S	1	86	0.71	0.65	1.24	0.59	61169	56059	51311	711	652	597
DARUMA GARDEN APTS - 5 BLDGS	1	121	0.70	0.72	1.13	0.42	60335	61783	36087	499	511	298
CEDAR GROVE VILLA	1	94	0.68	0.43	1.37	0.94	58957	37422	80926	627	398	861
RESIDENTIAL-SFD	**19268**	**19282**	**153.16**	**114.68**	**329.36**	**214.68**	**687**	**514**	**963**	**686**	**514**	**962**
RESIDENTIAL-SFD	18464	18472	146.47	109.31	315.56	206.25	685	511	965	685	511	965
SFD W/SUITE	745	748	6.10	4.89	12.67	7.78	707	567	902	704	565	899
OUTSIDE CITY	1	1	0.16	0.14	0.24	0.09	14004	12455	8036	14004	12455	8036
DUPLEX	5	5	0.04	0.04	0.07	0.04	726	645	621	726	645	621
SFD AND FARM	1	1	0.03	0.04	0.05	0.02	2965	3119	1604	2965	3119	1604
SANDS FUNERAL CHAPEL	1	1	0.03	0.01	0.06	0.05	2494	675	4727	2494	675	4727
SFD W/HAIR SALON	2	2	0.03	0.02	0.07	0.05	1111	650	2340	1111	650	2340
SFD W/DAYCARE	2	2	0.02	0.02	0.04	0.01	1068	1080	458	1068	1080	458
SFD W/HOME BUSINESS	1	1	0.02	0.01	0.07	0.06	2005	563	5208	2005	563	5208
LICENCED CARE FACILITY	1	1	0.02	0.02	0.04	0.02	1983	1934	1902	1983	1934	1902
2 SFDS	2	3	0.02	0.02	0.03	0.01	885	884	474	590	589	316
SFD W/ SUITE	14	15	0.02	0.01	0.03	0.02	108	86	118	101	80	110
SFD WITH SUITE	1	1	0.02	0.01	0.04	0.03	1393	1076	2480	1393	1076	2480
BRIDAL SHOP	1	1	0.02	0.00	0.07	0.07	1336	135	5774	1336	135	5774
DAYCARE	1	1	0.02	0.01	0.03	0.02	1332	942	1529	1332	942	1529
Grand Total	**24266**	**41256**	**352.90**	**275.82**	**712.86**	**437.04**	**9859**	**7813**	**11067**	**4333**	**3224**	**5738**

Per account single family seasonal demand, 962 L/dwelling/day, is another “benchmark” figure to note from Table 5-1. Seasonal demands however are better represented on a volume per land area basis. Institutional, Commercial and Industrial (ICI) base demands are also best described on a land area basis for the purpose of predicting future demands. Per hectare demands are provided in Table 5-2. A complete list of per hectare demands for all customer descriptions is provided in Appendix B.

Table 5-2: Per Hectare Demands

Customer Type / Description	Number of Accounts	Average Lot Area (m^2)	ADD (m^3/Ha/day)	Base Demand (m^3/Ha/day)	MDD-SEAS (m^3/ha/day)
COMMERCIAL/RES	**141**	**3640**	**5.23**	**4.20**	**6.58**
COMMERCIAL/RES	50	1579	6.49	5.25	9.37
WOODGROVE PINES (RES - UP/COMM - DOWN)	1	5403	37.93	36.09	30.20
COMMERCIAL/RESIDENTAL STRATA	1	9982	13.97	9.26	22.05
HARBOURVIEW MANOR	1	1623	85.72	115.20	0.00
MEREDITH BUSINESS CENTRE (BAKERY & APTS)	1	4234	25.03	18.68	31.95
KIWANIS LODGE & SENIORS APTS	1	8007	13.21	7.64	16.81
MOSTAR CENTRE - RETAIL DOWN & RES. UP	1	3286	24.01	9.13	40.51
PRIDEAUX GARDENS	1	2425	31.44	20.12	59.24
YACHT CLUB	1	36316	2.07	1.32	3.25
RESTAURANT - RESIDENTIAL	1	1332	55.38	32.82	132.30
PRYDE VISTA GOLF COURSE	1	175661	0.36	0.18	0.86
APT BLDG & COMM BLDG	1	829	60.52	41.57	105.86
6 OFFICE SUITES/7 RESIDENTIAL UNITS	1	2153	22.83	18.86	15.07
DINGHY DOCK PUB & SFD	1	1148	42.57	33.92	50.18
STUDIO NA	1	2775	15.23	12.73	15.60
GOVERNMENT	**80**	**29032**	**7.01**	**5.24**	**7.66**
VANCOUVER ISLAND UNIVERSITY	1	317138	17.67	13.68	10.98
BIOLOGICAL STATION	1	55755	43.59	45.64	14.55
BC FERRIES	1	53264	17.17	8.43	29.03
BRANNEN LAKE INSTITUTE	1	469699	1.86	1.83	1.25
SEWER TREATMENT PLANT	1	50561	12.75	11.94	6.83
WELLINGTON SECONDARY SCHOOL	1	46249	7.57	1.70	22.60
PROVINCIAL RENTAL HOUSING CORP	1	9684	35.52	32.88	6.77
JOHN BARSBY SCHOOL	1	19414	17.67	9.55	44.54
FEDERAL BLDG	1	371	696.39	653.52	276.59
BULK WATER DUKE POINT VALVE STATION	1	3670	64.41	42.38	90.43
BULK WATER	2	3670	31.44	23.27	40.54
ROCK CITY SCHOOL	1	29616	7.28	1.16	28.32
NHC - COMMERCIAL BOAT BASIN	1	442	486.15	621.56	91.34
MCGIRR ELEMENTARY SCHOOL	1	28751	7.11	0.80	16.71
GEORGIA AVENUE SCHOOL	1	31394	5.91	1.41	12.67

Customer Type / Description	Number of Accounts	Average Lot Area (m^2)	ADD (m^3/Ha/day)	Base Demand (m^3/Ha/day)	MDD-SEAS (m^3/ha/day)
MUNICIPAL	**91**	**28748**	**3.72**	**1.59**	**9.42**
BEBAN PARK	1	516523	5.32	3.53	10.91
NANAIMO AQUATIC CENTRE	1	19201	58.72	58.24	13.34
BOWEN PARK	1	392680	1.58	0.12	4.24
CEMETERY	1	5983	100.16	0.25	362.46
BALL FIELD ON JINGLEPOT/ROTARY FIELD HOUSE	1	163444	3.36	1.16	13.96
NANAIMO ICE CENTRE	1	32373	11.80	8.40	13.86
COMOX ROAD PARK	1	21993	16.43	13.61	28.59
FIRE HALL /BALL FIELD/WATER PARK	1	6848	45.88	0.47	192.55
HAREWOOD WATER PARK	1	16203	18.85	5.29	65.94
HALIBURTON PARK & WATER PARK (DEVERILL SQUARE) & SOCCER FIELD	1	8147	31.59	0.00	104.10
MAY BENNETT/PIONEER PARK	1	80496	3.05	0.01	10.82
HARRY WIPPER PARK	1	26560	6.74	0.58	18.52
GROVELAND PARK	1	7285	22.87	0.02	81.97
TROFTON PARK	1	29571	4.73	0.02	16.62
CALEDONIA PARK	1	21088	6.37	0.02	17.52
OTHER	**825**	**6496**	**7.61**	**6.29**	**8.19**
OTHER	229	2719	3.69	3.08	4.68
OFFICE/HATCHERY/RESERVOIR	1	119152	17.97	16.44	8.04
NAN. SENIORS VILLAGE (NURSING HOME)	1	3974	314.51	286.97	223.94
GREEN THUMB NURSERY	1	177406	5.97	1.20	16.69
HUB CITY FISHERIES	1	10756	85.96	51.46	112.48
SEA DRIFT FISH CO LTD	1	3657	236.95	142.90	264.16
MALASPINA GARDENS - NURSING HOME	1	11578	56.51	55.90	43.25
TALLY HO HOTEL/BUS DEPOT	1	21458	30.18	24.95	25.75
ST JEANS CANNERY	1	3564	180.06	193.99	127.26
PORT PLACE MALL/WENDY'S/MEDICAL ARTS CENTRE	1	40884	14.78	10.10	29.57
COAST BASTION HOTEL/PURE SPA	1	1275	471.80	394.14	274.17
ALSCO	1	813	723.67	681.35	200.09
BEBAN PLAZA MALL	1	5935	86.81	69.04	82.93
SPORTS PLEX - PLAYING FIELDS	1	36124	13.06	0.06	43.04
FERRY TERMINAL	1	104399	4.24	3.84	2.71
Customer Type / Description	**Number of Accounts**	**Average Lot Area (m^2)**	**ADD (m^3/ha/day)**	**Base Demand (m^3/ha/day)**	**MDD-SEAS (m^3/ha/day)**
RESIDENTIAL-MLT	**3462**	**1596**	**12.34**	**10.71**	**11.19**

SFD W/SUITE	2259	952	9.12	7.82	10.04
RESIDENTIAL-MLT	431	1853	15.81	14.10	12.29
DUPLEX	364	554	14.63	13.13	13.72
DEERWOOD PLACE ESTATES	1	199983	7.26	4.58	11.86
SEABREEZE MOBILE HOME PARK	1	76	16644.59	15150.62	16763.44
SHARMAN MOBILE HOME PARK	1	92023	9.54	8.04	8.34
SEA CREST TOWERS	1	3089	228.75	233.24	99.87
WILLOW MOBILE HOME PARK	1	125502	5.37	4.05	6.57
CREST MOBILE HOME PARK - PARK #2	1	94550	5.97	4.15	6.55
PARKLANE MOBILE HOME PARK	1	20193	27.26	26.76	8.92
THE HIGHLANDS	1	39312	13.65	8.08	18.31
WOODGROVE ESTATES - MOBILE HOME PARK W/CLUBHOUSE	1	67761	7.91	6.46	6.80
MILLSTONE CREEK	1	248	2116.93	1794.17	1972.47
PINE RIDGE ESTATE APTS	1	2939	177.94	172.42	75.84
BRECHIN VIEW CONDOS	1	10172	48.25	43.32	28.50
RESIDENTIAL-SFD	**19130**	**1155**	**5.95**	**4.45**	**8.34**
RESIDENTIAL-SFD	18329	1149	5.97	4.46	8.40
SFD W/SUITE	743	905	7.81	6.26	9.97
DUPLEX	5	266	27.28	24.23	23.33
SFD AND FARM	1	79923	0.37	0.39	0.20
SANDS FUNERAL CHAPEL	1	540	46.20	12.50	87.55
SFD W/HAIR SALON	2	1244	8.93	5.22	18.82
SFD W/DAYCARE	2	723	14.76	14.92	6.33
SFD W/HOME BUSINESS	1	1262	15.89	4.46	41.26
LICENCED CARE FACILITY	1	799	24.80	24.19	23.79
2 SFDS	2	990	8.94	8.92	4.79
SFD W/ SUITE	14	611	1.77	1.40	1.92
SFD WITH SUITE	1	8151	1.71	1.32	3.04
BRIDAL SHOP	1	808	16.54	1.67	71.44
DAYCARE	1	624	21.36	15.10	24.52
DUPLEX - METER SHARED 50%	2	97	60.46	55.77	33.25
Grand Total	**23729**	**1619**	**7.00**	**5.46**	**8.74**

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Table 5-3 below gives a summary of base and seasonal-MDD per hectare demands.

Table 5-3: Estimating Seasonal Demands by Land Area

Account Type	Base Demand per Hectare (m^3/ha/day)	ADD per Hectare (m^3/ha/day)	MDD Seasonal Demand per Hectare (m^3/ha/day)
RESIDENTIAL-SFD	4.45	5.95	8.34
SFD W/SUITE	7.80	9.10	10.02
DUPLEX	13.13	14.63	13.72
RESIDENTIAL-MLT	10.71	12.34	11.19
Other (ICI)	6.29	7.61	8.19
Municipal	1.59	3.72	9.42
Government	5.24	7.01	7.66
Commercial/Residential	4.20	5.23	6.58

MMCD provides design population equivalents for industrial, commercial and institutional demands. These equivalents are:

Land Use	Equivalent Population / Hectare (gross)	ADD (m^3/ha/day)
Commercial:	90 people/ha	54
Institutional:	50 people/ha	30
Industrial:	90 people/ha	54

A comparison of City of Nanaimo Industrial/Commercial/Institutional (ICI) customers to the Master Municipal Contract Documents (MMCD) design values will give some indication of how intensive ICI water use is in Nanaimo. Per hectare water use will be related to both the usage patterns of Nanaimo's ICI sector and the density of ICI customers on the land. It can be seen that the ADD values calculated for the City are on average 5 to 8 times lower than the MMCD design values however a number of the top consumers use much more than MMCD values.

5.3 Per Capita Demand Estimates (Base and Average Day)

Base and average day per capita demand estimates are useful benchmarks for comparing water use with other municipalities.

Estimating Population Density across Meter Population

The City provided a 2011 serviced population estimate of 87,517 (Source: BC Stats 2011 adjusted population). This population is made up of:

- City of Nanaimo = 86,961 persons
- Snuneymuxw First Nation = 335 persons
- Village of South West Extension = 221 persons

The City records the total number of dwelling units on each account. The serviced population within the City of Nanaimo is distributed between the 19,282 single family dwellings, 18,544 multi-family dwellings and a portion of the 777 commercial/residential units. It is assumed that 50-70% of the commercial/residential units are residential dwelling units and the remainder are commercial units. The estimated number of dwelling units is therefore between 38,215 and 38,370. The Snuneymuxw First Nation and Village of South West Extension accounts are registered as “Other” account type and therefore their populations will not be within the City of Nanaimo dwelling units.

The overall population density is calculated as 2.27 persons/dwelling. Population densities for single family and multi-family are not equal. Table 5-4 presents 2006 Statistics Canada figures of population densities by dwelling types across BC.

Table 5-4: Statistics Canada Private Households by Structural Type of Dwelling

Type of Dwelling	SURVEYED AREA OCCUPANCY PER DWELLING				
	B.C.	Kelowna	Abbotsford	Vancouver	Victoria
Single Detached House	2.8	2.7	3.2	3.1	2.6
Apartment, five or more storeys	1.7	1.7	1.5	1.7	1.4
Movable Home	2.0	2.0	1.9	1.9	1.9
Other Dwellings	2.3	2.0	2.5	2.4	2.0
AVERAGE	**2.5**	**2.4**	**2.8**	**2.6**	**2.2**

Taking into consideration the population densities presented in Table 5-4, Table 5-5 gives estimated population densities across the three residential account types in Nanaimo.

Table 5-5: Estimated Nanaimo Population Densities

Account Type	# of Units	Pop Density	Population Estimate
COMMERCIAL/RESIDENTIAL	500	1.93	965
RESIDENTIAL-MLT	18,544	1.93	35,790
RESIDENTIAL-SFD	19,282	2.6	50,133
TOTAL	**38,326**	**2.27**	**86,888**

Per Capita Demand Estimates

Table 5-6 gives the per-capita base and average day demand estimates for the three residential account types.

Table 5-6: Per-Capita Base and Average Day Demands

Account Type	Population Estimate	ADD (L/s)	BD (L/s)	ADD (L/person/day)	BD (L/person/day)
COMMERCIAL/RESIDENTIAL	965	2.58	2.21	231	198
RESIDENTIAL-MLT	35,790	96.72	81.87	233	198
RESIDENTIAL-SFD	50,133	153.16	114.68	264	198
TOTAL	**86,888**	**252.46**	**198.76**	**251**	**198**

Per capita base demand is estimated to be 198 L/person/day across all account types. Overall per-capita average day demand is 251 L/person/day.

5.4 Residential Water Use Efficiency

Residential water use is the focus of many demand management strategies and thus assessing the per-capita indoor consumption and seasonal water use is useful for gauging the success of these programs as well as recommending areas for improved efficiency.

Per-capita indoor or base water demand is approximately 198 L/capita/day. Most, if not all, of the metered communities KWL's worked with have had base demands less than 230 L/ capita/day. Nanaimo's residential base demand estimate is lower than average. As a comparison, KWL recently calculated a per capita base demand of 203 L/capita /day for a municipality in the Capital Regional District (CRD).

A 2011 study completed by Aquacraft Water Engineering & Management for the Salt Lake City Corporation and US EPA estimates indoor water demand of approximately 170 L/capita/day for average new construction and 136 L/capita/day for homes utilizing the most water efficient fixtures available.

Nanaimo's per capita indoor water use is lower than average and will continue to decline with continued new construction and home renovation.

Residential seasonal demands that make up the largest portion of summer demand are largely considered discretional. For this reason, there are a number demand management measures aimed at lowering this component of demand. These include sprinklering bylaws, public education, expanded block rate billing and promotion of native plants in landscaping to name a few.

Single family residential seasonal demands were noted to be on average 962 L/lot/day at MDD.

The average single family lot size is approximately 1,155 m^2. Irrigated area (green space) for single family lots is typically between 30-40% of the total lot size. Single family lots therefore use between 20.8-27.8 m^3/ha/day on the irrigated portion of their properties on maximum day.

This value can be checked by comparing it to theoretical "required" irrigation rates based on crops and weather conditions. The theoretical irrigation rate is given as:

$$IrrigationRate\ (mm/day) = \frac{Et \times Crop\,Coefficient \times Allowable\,Stress}{Irigation\ Efficiency}$$

Where:

$$Et = Evapotranspriation\,rate\ (mm/day)$$

$$Crop\,Coefficient = 1\ for\,turf$$

$$Allowable\,Stress = 0.7\,(Default\ for\,turf\ grass\,in\,B.C.\,conditions)$$

$$Irrigation\,Efficiency = 70\%\ for\,metered\,irrigation, 50\%\ for\,un-metered$$

Environment Canada's farmwest.com web site gives the average August 2011 evapotranspiration rate for North Cowichan (closest site) as 4.5 mm/day or 45 m^3/ha/day. Using the above formula, (with a 70% irrigation efficiency), the theoretical expected irrigation rate for Nanaimo is 45 m^3/ha/day. The observed irrigation rate is approximately half this amount.

The City's residential seasonal demands are also lower than the average communities we've worked with. The CRD community noted above with base demands of 203 L/capita/day had an average single family irrigation rate between 31.1-41.5 m^3/ha/day.

Given the lower than average base and seasonal usage, it is not surprising that the City's average per capita demand of 251 L/person/day is lower than the CRD which has an average per capita demand of approximately 296 L/person/day.

It is suspected that the City's inclining block rate structure may be a major contributor to low residential demands, and that this rate structure has the largest effect on discretional seasonal water use.

5.5 2031 OCP Demands

The unit rates derived in the disaggregated demand analysis are used to predict future 2031 MDD demands in this section.

Existing and Future Land-Use

The City of Nanaimo occupies a land mass of about 8900 ha (Statistics Canada, 2006 Census land area 89.3 km^2). Nanaimo's urban land base is largely made up of low density single family neighbourhoods, punctuated by areas of commercial activity along the primary transportation corridors.

Table 5-7 gives the OCP future land uses and associated land areas. It is noted that the total area for all land use types is 7800 ha which is less than the total land mass given by Statistics Canada. The difference in these figures is attributed to the area of roads which is not included in the land use areas.

Table 5-7: City of Nanaimo Future Land-use Descriptions and Areas

Future Land-Use	Brief Description	Parcel Area (ha)
Commercial Centre	Existing concentrations of commercial uses distributed across the city.	81
Industrial	Range of industrial uses within industrial parks.	387
Light Industrial	Mix of technology, research and development, and warehousing and distribution.	227
Neighbourhood	Mix of housing types including single family homes and ground-oriented multiple family units.	3,627
Parks and Open Space	Including a range of park sizes, applies to lands that serve as parks, plazas, open spaces and recreation areas.	1,294
Resort Centre	A primary recreational facility with supporting residential neighbourhoods and accommodations in close proximity to small-scale commercial uses.	189
Resource Protection	Addresses the protection and preservation of environmentally sensitive areas and agricultural lands located adjacent to existing urban areas.	647
Corridor	Multi-unit residential development, public amenities and commercial services in mixed use developments.	526
Urban Node	The commercial, service, and high density focal points for Nanaimo.	347
Urban Reserve	Recognized for future growth, Area Plans will be required prior to development to address timing and servicing of development, land use and densities, and environmental protection issues.	334
Waterfront	Applied to ocean and foreshore areas and providing for marinas, ocean-focused industrial uses, as well as commercial, residential, recreation, open space, and pedestrian activity.	98
Total		**7,757**

The City of Nanaimo Land Inventory & Residential Capacity Analysis, January 2007, prepared by the Sheltair Group, concluded that while there is sufficient capacity to accommodate projected growth for ground-oriented dwellings (e.g., townhouses) and ample capacity to accommodate projected demand for apartments, there is insufficient capacity to accommodate projected demand for single family dwelling units.

Table 5-8 gives the breakdown of residentially zoned land.

Table 5-8: Residentially Zone Land Areas

Residential Land-Use	Area (ha)
Single-family	2,848
Multi-family	589
Rural Agricultural	190
Total	**3,627**

According to the Sheltair Group report, that taking into account setbacks and slopes of 30% or greater (considered undevelopable in this study due to cost of servicing, building costs, and potential risk of slope failures), 17% of the residentially zoned land is constrained and therefore can't be developed easily.

The study also found that approximately 28% of land zoned industrial is constrained by water feature setbacks and slopes that are 10% or greater and therefore defined as unsuitable for industrial use.

Population and Housing Projections

An Urban Futures Inc. report, "Population and Housing Projections for the City of Nanaimo, 2006 to 2031" (November 2006) concluded the following:

- Nanaimo's population is projected to grow by almost 50% to 118,000 by 2031. Future growth will be driven largely by people moving to Nanaimo rather than natural increase, and the aging of the City's population will be a dominant theme with the 65 plus age groups experiencing the greatest increase.
- Based on projections for growth and change within the city, the report suggests that housing demand in the City will increase the City's 2006 housing stock of approximately 33,000 by about 16,800 units. These additional housing units are predicted to be made up of 9,000 single detached family homes, 4,000 ground-oriented homes, and 3,800 apartment units.

OCP Demand Estimation

Table 5-9 uses the above data to estimate OCP demands. This should be considered a high level analysis of future demand. The same exercise could be completed on a Neighbourhood plan level to refine the estimate as well as assess infrastructure constraints within the City's hydraulic model. The estimated OCP base demand is 535 L/s and OCP MDD is 1,153 L/s.

Table 5-9: 2031 OCP Demand Predictions

Future Land Use	Total Land Area (ha)	Est. % Constrained	Developable Land Area (ha)	ICI-BD		Res-BD			NRW	Total BD	ICI-SEAS		RES-SEAS		MDD
				(m3/ha/day)	(L/s)	(Pop.)	(L/person/day)	(L/s)	(L/s)	(L/s)	(m3/ha/day)	(L/s)	(m3/ha/day)	(L/s)	(L/s)
Commercial Centre	81	0%	81	4.2	3.9				1.6	5.6	6.58	6.2			11.7
Industrial	387	28%	279	6.29	20.3				5.5	25.8	8.19	26.4			52.2
Light Industrial	227	28%	163	6.29	11.9				3.3	15.2	8.19	15.5			30.6
Neighbourhood															
- Single Family	2848	17%	2364			70000	198	160.4	47.1	207.5			8.34	228.2	435.7
- Multi Family	589	17%	489			32000	198	73.3	9.7	83.1			11.19	63.3	146.4
- Rural Agricultural	190	17%	158			1000	198	2.3	3.1	5.4			8.34	15.2	20.7
Parks and Open Space	1294	0%	1294	1.59	23.8				25.8	49.6	9.42	141.1			190.7
Resort Centre	189	0%	189	4.2	9.2				3.8	13.0	6.58	14.4			27.3
Resource Protection	647	0%	647	0					12.9	12.9					12.9
Corridor	526	0%	526	6.29	38.3				10.5	48.8	8.19	49.9			98.6
Urban Node	347	0%	347	4.2	16.9	10000	198	22.9	6.9	46.7	6.58	26.4			73.1
Urban Reserve	334	17%	277			5000	198	11.5	5.5	17.0			8.34	26.8	43.7
Waterfront	98	50%	49	6.29	3.6				1.0	4.5	8.19	4.6			9.2
TOTAL	**7757**		**6863**		**128**	**118000**		**270**	**137**	**535**		**284**		**333**	**1153**

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KERR WOOD LEIDAL
consulting engineers

Section 6

Summary and Recommendations of Water Audit

6. Summary and Recommendations of Water Audit

6.1 Summary of Key Points

A break-down of how water is consumed is shown in Figure 6-1:

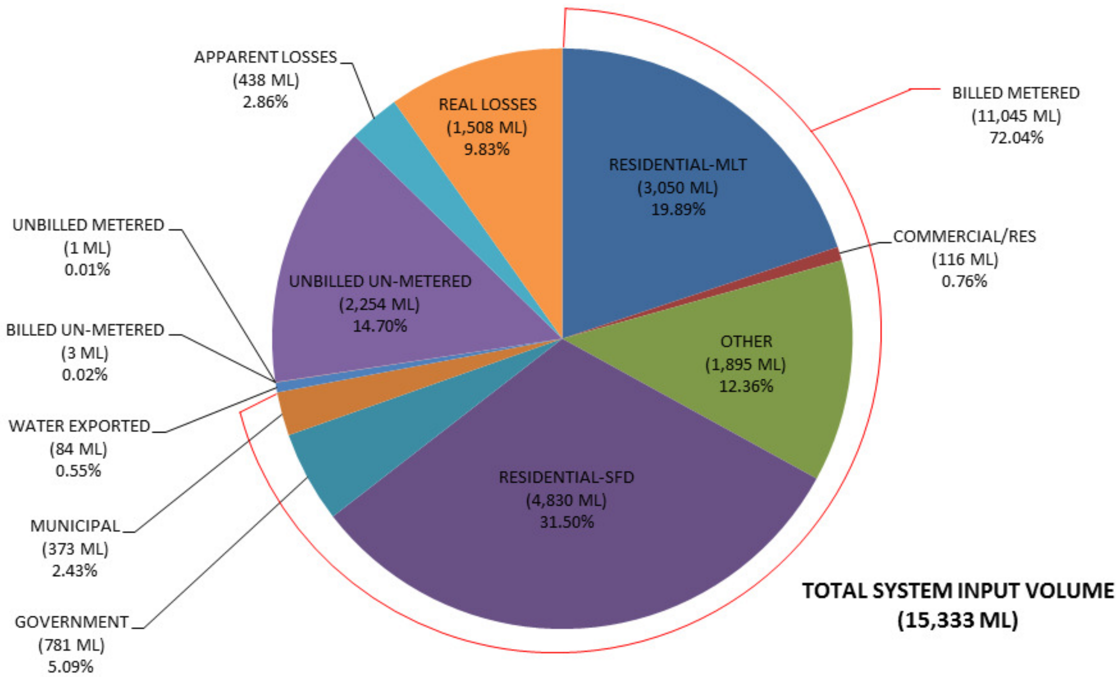

Figure 6-1: A Summary of Consumption

The following is a summary of key findings:

Non-Revenue Water

- The current level of annual real losses is very low at 1,508ML (9.83% of total system input volume). Given that 982 ML of losses cannot be avoided (known as UARL) there is very little room from improvements to be made in real loss reductions. The infrastructure leakage index is non-dimensional value used to compare the losses of water systems. It is the ratio of real losses to unavoidable losses and is calculated as 1.54 which is excellent.
- At $30.68/ML, the cost of real losses for the audit period is approximately $46,000 of which only $30,000 is technically recoverable. Given the low ILI value, these losses are not financially recoverable. An annual budget of $27,000 for loss management is however still recommended to control leakage levels.

- The total unbilled un-metered consumption of 2,254.2 ML/year is high. The large volume of unbilled un-metered consumption is due to blow-offs at Reservoir #1 and Duke Point Reservoirs. The purpose of dumping water at these two sites is to maintain adequate control of chlorine levels. The costs associated with these blow-offs is $61,500 per year.
- The cost of apparent losses is significant. The total yearly cost attributed to apparent losses is $387,000 and can be broken out as follows:
  - 2.2% Meter under-registration is estimated at $221,000;
  - Customer credits associated with leak repairs are estimated at $132,000; and
  - Un-authorized consumption is estimated at $34,000.

The non-revenue water discussed above represents 27.4% of the total yearly system input volume and 17.1% of the total system operating costs which are approximately $2.94 million annually.

Meter Verifications and Testing

- Both the Water Process Centre (WPC) and Reservoir #1 source meters were verified through comparison to a clamp on ultra-sonic flow meter installed in series at both metering locations. The results showed that the meters are accurately registering flows. A source adjustment of 0.5% (under-registration) was made. This value accounts for minor high flow over-register at the WPC and the estimated low-flow under-registration at all sites.
- Twenty seven residential water meters were tested to gain an understanding of the meter populations overall accuracy as well as determine an appropriate replacement protocol. The overall accuracy of the meters tested was acceptable, at 96.5%. The results show that overall accuracy drops as age increases and is largely function of a decline in low flow accuracy with age.
- Meter testing was used to develop an accuracy versus age relationship. This was done to determine the replacement frequency that minimizes yearly metering costs. A 24 year replacement frequency was found to be the most cost effective.
- The savings for increasing to a 24 year replacement frequency is estimated at $1.61 to $2.45 / meter / year. This equates to an annual savings of $37,000 to $57,000.
- An analysis of 747 meters sized 50mm through 150mm indicate that the large meter population is being over-sized by 1-2 pipe diameters.
- The apparent over-sizing appears to be due to a lack of adequate meter selection and sizing design standards. Meters are currently being sized using the fixture unit method employed by the BC Building Code for piping within buildings. This may be due to a misguided assumption that the BC Building Code is applicable to customer meter sizing, which it is not.
- A desktop study identified 277 to 550 meters as being oversized. The lower number excludes meters for properties with multiple meters as they may be set up in a compound metering arrangement.
- A “Right-Sizing” meter replacement project was analyzed for 277 over-sized meters. The estimated lost revenue from these meters is $36,000 per year.
- The total cost of the “Right Sizing” project is estimated at $221,000. This gives an estimated yearly cost savings of $14,000 assuming a 10 year amortization period. The following additional points are noted:

- The yearly cost savings would be greater if replacement costs were amortize over a longer period.
- Over half of the total estimated yearly savings, $8,052, is associated with the top 20 meter replacements.
- Although the majority of meters studied were 50mm, only two of these meters were in the top twenty.
- Multifamily residential meters make up 55% of the top 20 replacements; this could be attributed in part to multi-family developments (apartments) not being at full occupancy or full build-out of a multi-phased development.

- The average age of the meter population is 14.4 years. Given the accuracy versus age relationship and estimates of low flow under-registration, the current accuracy of the meter population is 97.8%.

Disaggregated Demand Analysis

The following points summarize the results of the disaggregated demand analysis:

- Per-capita base demand residential use was calculated as 198 L/person/day which is considered below average for the Island and Lower Mainland communities KWL has worked with;
- Per-capita average day demand residential use was calculated as 251 L/person/day which is also below average. As a comparison, residential average day demand within the communities of the Capital Regional District is estimated at 297 L/person/day.
- Base demands are expected to decrease with new construction and continued home renovations.
- Per account single family seasonal demand was calculated as 962 L/dwelling/day which relates to an application rate of 20.8-27.8 m^3/ha/day for irrigated areas (not including hard surfaces). These seasonal demands are lower than the average communities KWL has worked with;
- Lower than average residential base and seasonal demands may be attributed to the City's inclining block rate structure. Increased pricing will have a greater effect on discretional water use than on base usage.
- Per hectare Base, Average Day and Maximum day demands were calculated for each customer type. It was noted that on average these demands are lower than MMCD values however, the largest consumers used more than the MMCD design values.
- A high level OCP demand prediction was completed using the calculated unit rate demands, both per capita and per hectare, in conjunction with future land use and population projections. OCP base demand was estimated as 535 L/s and OCP maximum day demand was estimated as 1,153 L/s.

6.2 Recommendations

The following recommendations are made:

Selection and Sizing of Large Meters

- Create new section in Manual of Engineering Standards and Specifications for meter selection and sizing. This section should be based on AWWA M22 methodology.
- Provide a spreadsheet in Manual of Engineering Standards and Specifications for the right sizing of meters. This will make both the calculation and review by city staff easier.
- Specify that multi-phased developments have meter chamber sized for full build-out but size meter to match each phase of the development (replace meter as necessary).

Meter Replacements

- A meter sizing calculation should be done at the time of all replacements. This is particularly important given the likely over-sizing of meters within the network.
- A meter replacement budget of $331,000 is recommended for the next twenty years. The budget can be reduced to $244,000 at the end of twenty years which coincides with a 24 year replacement frequency and the average age of meters reaching 12 years respectively (from the current value of 14.4 years). The budget should be increased by 1.6% per year to account for the current and forecasted increase in meter population.
- The meter replacement budget should be allocated as follows:
    - $230,000 for 19mm meter replacements
    - $101,000 for large meter replacements

  In the first 2-3 years the large meter replacement budget should be spent on a "Right-Sizing" meter replacement project giving priority to those meters that will offer the greatest recovery of apparent losses. Focussing first on meter re-sizing will not only recover lost revenues but will also decrease the future costs of replacements as smaller meters cost less.
- Review and track changes in registered consumption for meter replacements. This is best done by flow profiling but could also be accomplished less accurately through yearly billing records.
- Continue annual testing of a sample of residential meters. Test 50 meters per year with 25 randomly selected meters and 25 meters that are being removed and replaced due to high cumulative consumption or age. Keep a record of which meters were randomly selected and which were removed as part of the prioritized replacement project. All meters can be tested at the same time over the course of 2 days. Build a data base of age and consumption volume versus apparent losses and use this data to refine the meter replacement frequency and budget.

Water Loss Management

- It is recommended that approximately 6.5% of the system be inspected annually by means of leakage surveys and flow monitoring. This equates to a yearly budget of approximately $27,000 for active leakage control. This budget should be split between the development of district metering areas and leak sounding. Revise this budget if annual real losses increase (See Component Analysis).

Future Water Auditing Considerations

- Subsequent audits should be performed following the second billing period of the succeeding year. For example, the 2012 audit should be completed in May 2013. This will ensure that audits are completed for a regular calendar year. An annual budget of $8,000 would cover the costs of updating the water audit annually.
- Credits made to customer accounts should be done without adjusting the consumption data within the database. This applies to both the one time no questions asked credit as well as the credit given to those who have had plumbing repairs made on their service connection.

A summary of the budgets required to cover the recommended future works is given in Table 6-1 below:

Table 6-1: Allocation of Funds for Recommendations

Project / Program	Required Budget Allocation	Reason(s)
Meter Replacements	$331,000/year for first 20 years; $244,000/year following; Note: Figures do not include for 1.6% per year increase in meter population.	A yearly savings of $37,000 to $57,000 can be gained increasing the meter replacement frequency from 33 years to 24 years.
Customer Demand Profiling and Sizing Calculations for Large Meter "Right-Sizing" Project	$30,000 per year for 3 years	To eliminate the estimated $36,000/year in lost revenue due to oversized meter under-reading.
Meter Selection and Sizing Specification	$15,000	See above.
Leak Detection	$27,000 per year	To manage the City's water losses and maintain current low levels.
Customer Meter Testing	$5,000 per year	To better understand accuracy as it relates to meter age and brand.
Yearly Update of Audit Spreadsheets	$8,000 per year	Accountability, improved efficiency, decision making.

Report Submission

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

PROFESSIONAL
PROVINCE OF BRITISH COLUMBIA
R.M. LESYSHEN
34702
ENGINEER
11 MARCH, 2013

Ryan Lesyshen, M.Sc., P.Eng
Project Manager

Reviewed by:

Christine Norquist, P.Eng
Technical Reviewer

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Revision History

Revision #	Date	Status	Revision	Author
0	May 24, 2012	Draft Stage 1 Report	-	RYL
1	July 10, 2012	Final Stage 1 Report	City of Nanaimo review comments received July 9, 2012 addressed.	RYL
2	December 20, 2012	Draft Final Report	Included findings of Stage 2 Field Tasks	RYL
3	March 11, 2013	Final Report	Revisions made based on City of Nanaimo review comments received February 6, 2013	RYL