

# **City of Victoria**

## **Water Distribution System Model**

### **Calibration Report**



prepared by

Expertware Development Corporation

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# INTRODUCTION

This report details the procedures used to calibrate the pipe network model of the City of Victoria's water distribution system. It also documents some of the sources used for compiling the data.

The work that went into building the model included detailing every watermain in the system. Consumption demands were derived from five years of recorded water meter readings from individual properties. Over 55 field flow tests were performed for comparison during the calibration process.

Roughness calibration for cast iron pipes was performed using both conventional methods and experimental methods to try to determine whether it can be shown that flow velocities influence the roughness coefficients over the history of the distribution system.

With pipe materials, installation dates, diameters, lengths and other details stored, the WATSYS modeling software can be used to extract useful pipe inventory statistics and information, in addition to the more complex pressure and flow calculations.

Over 75 model configurations were tested and compared to the field records. Future calibrating could refer to these configurations to see the effects of various data changes and whether they improved the accuracy of the model.

Possible improvements to the data, software, field testing and sampling are suggested at the end of this report as further refinements which could make the model more accurate.

# PIPE NETWORK

The City of Victoria water network model has approximately 3150 pipes including those of the Township of Esquimalt which is also managed by the City. The Capital Regional District (CRD) water mains from Sooke Lake supply the Victoria-Esquimalt distribution system generally on its northern side. Victoria has two high pressure zones for elevated areas that directly connect to the higher pressure CRD mains and two lower-elevation zones which are pressure regulated with valves. Esquimalt has one directly connected high pressure zone, one regulated higher pressure zone and one regulated zone. In addition, Victoria has high pressure pipes in its downtown core for fire-fighting and a small pumped zone.

## Numbering

The model's pipes and nodes were assigned numbers to identify the pressure zones they belong to as follows:

<1000, 1000s, 2000s	Victoria Regulated Pressure
4000s	Victoria High Pressure # 1
5000s	Victoria High Pressure #2
6399 - 6473	Victoria Downtown High Pressure
6800 - 6814	Victoria Fairfield High Pressure (Pumped)
7169 - 8000	Victoria West Regulated Pressure
8001 - 8451	Esquimalt Regulated Pressure
8800 - 8856	Esquimalt High Pressure #1
8901 - 8946	Esquimalt Regulated Higher Pressure #2
9000 - 9064	CRD mains
9097 - 9134	Closed pipes

## Pipe Data Source

Pipe diameter, material and installation date data came from the City waterworks offset book and AutoCAD base maps. Pipe and node locations were digitized on top of the existing pipe line-work on the drawings. Pipe lengths were calculated from node coordinates. Pipe roughness coefficients and minor losses are described in the **Calibration** section of this report.

## Node Data Source

Ground elevations were derived from contour base maps and sometimes from monuments and surveys. Node elevations were calculated by assuming the pipe was installed 1 metre deep. Nodal demands are described in the **Water Consumption** section of this report.

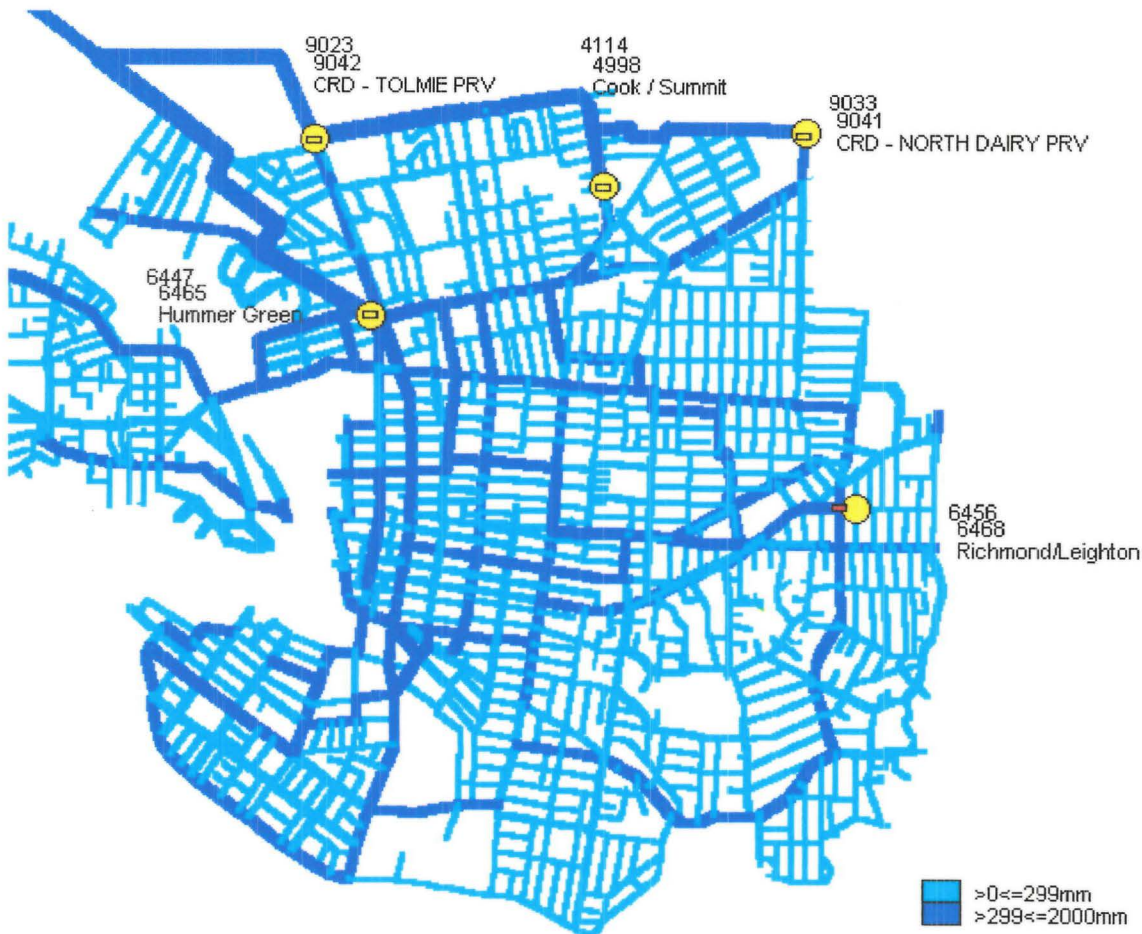
## Pressure Regulating Valves

The following list describes the water model's pressure regulating valves, zones and locations.

PRV	Node	Setting	Location	Pressure Zone
20001	9007	85.3m	Burleith / Craigflower	Victoria West & Esquimalt Regulated Pressure
20002	9013	85.3	Tyee / Bay	Victoria West & Esquimalt Regulated Pressure
20003*9034	112		Cook / Summit	Victoria High Pressure #1
20004	9033	72.3	Shelbourne / North Dairy	Victoria Regulated Pressure
20005	4114	72.3	Cook / Mallek	Victoria Regulated Pressure
20006	6456	72.3	Richmond / Leighton	Victoria Regulated Pressure
20007	6447	72.3	Humber Green	Victoria Regulated Pressure
20008	9023	72.3	Tolmie Douglas	Victoria Regulated Pressure
20009*8910	114		Maplebank / Admirals	Esquimalt High Pressure #1
20010	8146	85.3	Lampson / Craigflower	Esquimalt Regulated Pressure
20011	8146	92	Lampson / Craigflower	Esquimalt Regulated Higher Pressure #2
20012	8919	85.3	Admirals / Parklands	Esquimalt Regulated Pressure
20013	8800	85.3	Park Place	Esquimalt Regulated Pressure
20014*6448	114		Humber Green	Victoria High Pressure #2 and Downtown
20015*9036	112		Tolmie / Somerset	Victoria High Pressure #1

\* These PRVs are for modeling purposes only to adjust hydraulic grades.

No physical PRV is in the system as the pipes are directly connected to the higher pressure CRD mains.



**Key Plan of Victoria Regulated Pressure Zone PRVs**

# WATER CONSUMPTION

Nodal demands for the model were derived from water meter readings. Meters are connected to water services of individual properties throughout the City. Staff read and record from these meters three times a year for water and sewer utility billing purposes. The data was stored in the AS400 tax and utility billing software (which was subsequently phased out in 2002 and replaced by Tempest). This data was converted by city staff to produce compatible text files. The readings were then processed by custom-made VicMeter software and stored in the CivilSystems Property Connector software for extraction to WATSYS. Approximately 300,000 meter readings from 5 years were processed to produce 4 sets of consumption demands for the model's 2400 nodes. Details of the files used in this process are shown in **Appendix A**.

## Property Identifiers

Compilation and processing of water meter data began in the year 2000. At that time, staff had not completed assignments of Victoria property identifiers (VIDs) for GIS purposes and so new identifiers had to be generated for unassigned properties. Property identifiers (PIDs) as used in the CivilSystems data files were assigned a single character prefix as shown in the following examples:

V00601014	Victoria property identifier (VID)	12799 counted
01046009	Victoria tax roll number	428 counted
n00000028	Victoria new number (no VID or roll number available)	272 counted
m00000169	Victoria new number (LROLNO= 'VARIOUS')	" included
o00000271	Victoria new number (LROLNO= 'OAK BAY...')	" included
E008530025	Esquimalt roll number with dashes '-' removed	3582 counted
e00000053	Esquimalt new number (LROLNO= 'ESQUIMALT')	559 counted

When available, tax roll numbers were added as a prefix to the property description for possible future use as a cross-reference.

Property coordinates were already available for both VIDs and Esquimalt roll numbers and so were simply read in and matched using the CivilSystems import facility. New PID numbers had their coordinates digitized individually from a base map using the CivilSystems AutoCAD facilities.

## Meter Reading Data

Data from the 5 years, 1996 to 2000, was compiled and processed by VicMeter to produce four consumption scenarios for average, low and high and higher-high periods. These are stored as meter units (623 Imperial gallons or 2832 liters per unit) of a 4 month period in the CivilSystems property file, Victoria-Esquimalt.PPT. All individual property consumptions were assigned 'meter' as a zoning name. Detailed processing notes and statistics can be found in VicMeter.DOC.

If more than 3 meter readings were found for a year on a property, then 3 were used to total the number of readings; otherwise the number of readings found (3 or less) were used. The readings were summed for all the years on each property, then divided by the total number of readings to determine the average 4 month reading.

To find the lowest and highest consumption periods, Victoria properties with exactly 3 meter readings per year were examined for all 5 years. The highest and lowest readings for each of these properties and the month of those readings were determined. A sum was made to find the number of highest and lowest readings in each month. The table showing the results of this process is included in **Appendix A** and shows that on average:

Months 2 to 5 had lowest readings (Feb-May)  
Months 8 to 11 had highest readings (Aug-Nov)  
Months 12, 1, 6, 7 had highs and lows in some years and may be considered shoulder periods (Dec, Jan, Jun, Jul)

The 4 month periods prior to the readings' months have a correlation with the Victoria total monthly consumption records (rev 01/15/02) shown in **Appendix A**.

The scenarios assigned to the processed readings are as follows:

**Scenario 1:** Average readings taken from all years and months.

**Scenario 2:** Average low readings taken from readings in months 2 to 5 (Feb-May)

**Scenario 3:** Average high readings taken from readings in months 8 to 11 (Aug-Nov)

**Scenario 4:** Average higher-highs: Only months 9 & 10 used for highs with 2/3 of the 6 month (months 11,12, 1, 6, 7,8) shoulder readings substituted for properties without readings in 9 & 10 over the 5 year period.

The high consumptions of Scenario 3 were 35% more than lows of Scenario 2. The higher-high consumptions of Scenario 4 were 40% more than lows of Scenario 2 which is closer to what City staff have experienced.

## Leakage and Irrigation

Unaccounted flows due to leakage, park and boulevard irrigation, hydrant flushing and other factors were calculated using the City of Victoria Water Consumption Analysis which compares City water meter reading data to CRD bulk water volumes. Averages for years 1996 to 2000 were calculated as 4,320,000,000 Imperial gallons bulk and 3,886,000,000 Imperial gallons read from individual property meters. Dividing the numbers, the CRD bulk is **1.112** times more. The average (CivilSystems Scenario 1) flow extracted for the entire Victoria-Esquimalt system was **560** litres per second = 3,884,769,028 Imperial gallons per year which is very close to the Consumption Analysis figure above.

The unaccounted volume was accounted for in the model by distributing it fairly evenly throughout the system by assigning a default pipe leakage (WATSYS Loads|Design criteria) of **83** litres/mm/km/day. Assignments of 0 leakage codes and rates (WATSYS System|Pipe network, Loads|Leakage rates) were made to CRD pipes to exclude them from leakage calculations. The procedure was to enter a default leakage value of 1.0 litres/mm/km/day to determine how much leakage the average (CivilSystems

Scenario 1) flow extraction will produce for the whole network, which in this case was **0.755** lps as shown in the WATSYS statistics produced below:

**TOTALS:**

Properties= 19520  
Population= 0  
Area= 606  
Leakage= **0.755 lps**  
Irrigation= 0 lps  
Industrial= **560 lps**  
Residential= 0 lps  
Total Flow= 561 lps

The leakage rate is calculated with the above figures as follows:

$560 \text{ lps} \times (1.112 - 1.0) / 0.755 \text{ lps (leakage per 1.0 litres/mm/km/day)} = 83 \text{ litres/mm/km/day}$   
 $560 \text{ lps} \times 1.112 = 623 \text{ lps total}$

Once the **83** litres/mm/km/day default leakage rate is entered, a second extraction is performed which produces the required results:

**TOTALS:**

Properties= 19520  
Population= 0  
Area= 606  
Leakage= **62.647 lps**  
Irrigation= 0 lps  
Industrial= **560 lps**  
Residential= 0 lps  
Total Flow= **623 lps**

## **Connecting to Pipe Network**

Once the PIDs, meter readings, property coordinates and descriptions were imported and stored, the CivilSystems Property Connector was used to plot all of the property symbols on an AutoCAD base plan drawing. The pipe network and nodes were also plotted with WATSYS. The CivilSystems AutoCAD tools were then used to connect properties to the nearest nodes. Once the data set was complete, each of the 4 loading scenarios could be extracted (CivilSystems: File|Extract to WATSYS) to the water model as cumulative nodal demands.

# CALIBRATION

The water model built for this project has well detailed data. Every watermain in the system was modeled with all available data and each nodal demand was accurately determined as described in the **Water Consumption** section above. During the calibration process some fine tuning of the pipe network portion of the model was investigated by adjusting for pipe minor losses, hydrant losses and pipe sizing. The main unknowns of the calibration process were the pipe roughness coefficients.

Over 75 different model configurations were compared to the 55 flow tests performed on hydrants in the field. This entailed performing over 10,000 steady-state model analyses. Automated facilities were developed in WATSYS to make this process more efficient.

One of the main aspects of this project was to try to determine a more accurate method of assigning roughness coefficients to cast iron (CI) pipes which entailed using flow velocities as a refinement to conventional methods. About 80% of the model configurations were tested to investigate this relationship. The Victoria water distribution system is fed by CRD mains generally on its northern side. This means that the water generally flows southward. City engineering staff have made field observations over many years finding that many CI pipes were unusually clean inside for their age. A majority of those were north-south pipes. It was thought that a detailed computer model could be used to determine a velocity-based formula to best fit their field observations and flow tests.

## Flow Tests

City staff performed field-tests throughout the system using their flow test standard procedures. These tests were performed in low demand months when irrigation was unlikely and outside of the summer periods. 55 flow tests in the Victoria regulated system were used for comparison to model results. The flow test record list is shown in **Appendix B**.

In general, four hydrants were monitored: the flow hydrant and three other hydrants. The static pressure on the flow hydrant was measured and recorded. The flow hydrant was then opened to release flow through a Pitot gauge. Once pressures had stabilized, the flow hydrant's Pitot pressure and the residual pressures for all four hydrants were measured at the same time and recorded.



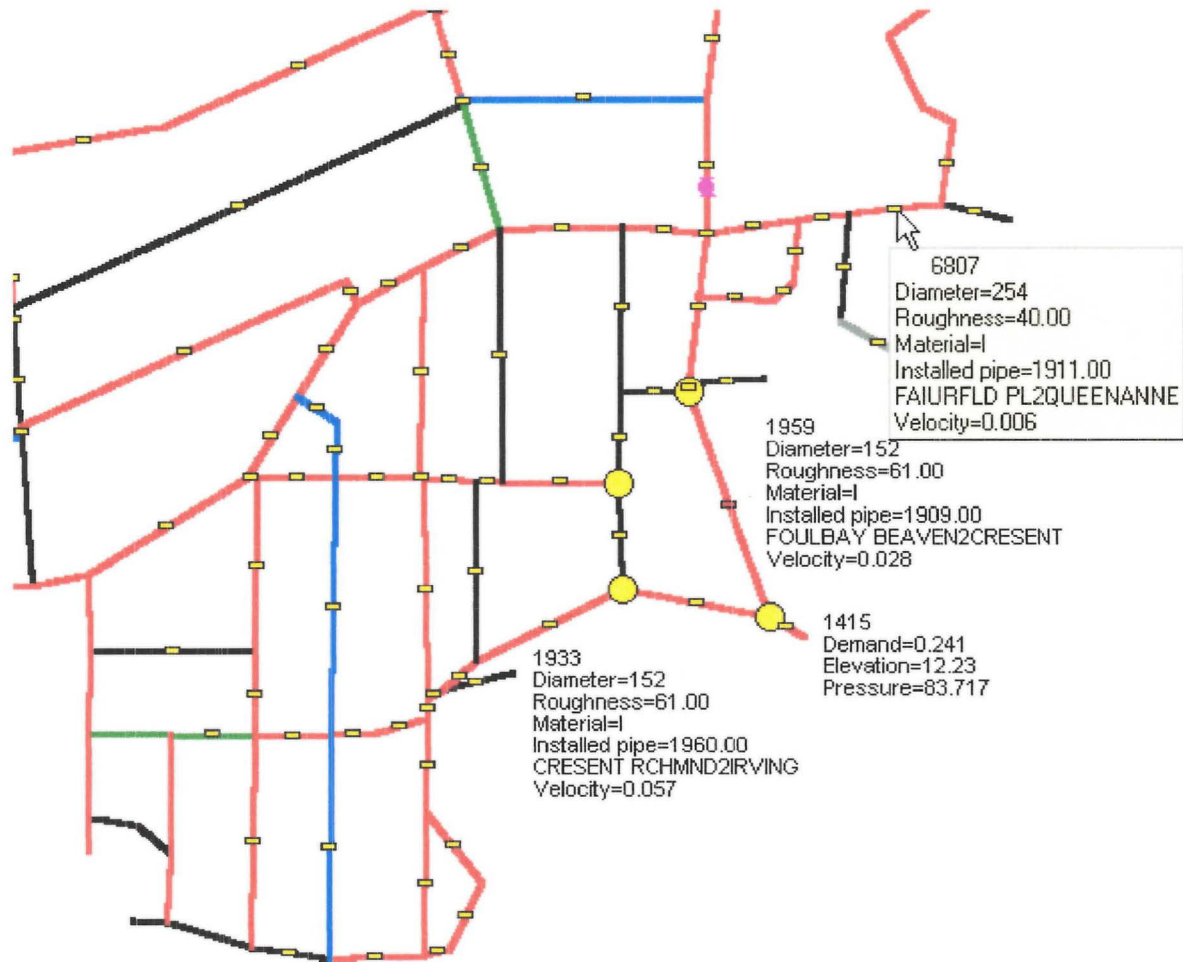
**Key Plan of Flow Test Locations**

## Model Comparison Procedure

The water model was compared to flow tests and adjusted using a number of methods. In most of the comparisons the flow velocity was considered and so the following general procedure was used (in comparisons without flow velocity considerations, step 1 and the analysis in 3 are omitted):

1. The average demands are loaded from import files (WATSYS: File|Import|Nodes, VdemandAv.TXT) or extracted from the property database (CivilSystems Scenario 1: File|Extract to WATSYS).
2. The roughness coefficients are adjusted (WATSYS: System|Calibrate|Roughness) or other data is adjusted.
3. An evolution analysis is performed or the C-factors are calibrated (WATSYS: System|Calibrate|Roughness) before an analysis and then after a steady-state analysis.
4. The low demands are loaded from import files (WATSYS: File|Import|Nodes, VdemandLo.TXT) or extracted from the property database (CivilSystems Scenario 2: File|Extract to WATSYS). As noted earlier, the flow tests were performed in low demand months.
5. The files are saved as a new configuration set (WATSYS: File|Save as VicCal\*.WAT, VicCal\*.DCT).
6. Each of the 55 flow tests are compared to the model by:

- adjusting the hydraulic grades of the pressure regulating valves for the area (WATSYS: System|Calibrate|Set valve analysis) so that the pressure calculated at the model's flow node matches the static pressure measured at the flow hydrant.
- analyzing with the recorded flow (WATSYS: System|Calibrate|Flow test analysis)
- comparing the pressures at each of the four test hydrants to the pressures at their associated nodes. This can be done by either using the scoring tables produced as shown in **Appendix B** or by plotting a key plan of the selected keyed nodes and their surrounding selected keyed pipes (WATSYS: Keys|Options, Keys|Material plan). The latter method is more useful when trying to decide which data to adjust for the next calibration trials.



**Key Plan of Flow Test Site**

## Pipe Installation Dates

The oldest pipes in the system were installed in 1885. In general, unlined cast iron and steel pipes were installed until about 1965, after which cement-lined ductile iron pipes and plastic pipes were introduced. Of the 335 km of pipe in the model, 177 km are 100mm to 300mm diameter cast iron which means that over 53% of the system is about 40 years old or older.

## Pipe Materials

As noted above, there are 335 km of pipe in the model excluding CRD pipes. The following table is a general breakdown of the pipe materials in the system:

<u>Total</u>	<u>% of Total</u>	<u>Material</u>
177 km	53%	Cast Iron, 100mm to 300mm, unlined, about 40 years or older
112 km	33%	Ductile Iron, cement-lined
22 km	7%	Steel, unlined, about 40 years or older
17 km	5%	PVC
8 km	2%	Galvanized iron, copper, AC, HDPE, epoxy-lined CI



**Key Plan of Pipe Materials**

### Cast Iron

It is well known that unlined cast iron (CI) pipe can deteriorate significantly inside over time. The problems occur as a result of oxidation, other chemical reactions and accretion inside the pipes. Over many years, this can result in tuberculations and significant head loss due to increased roughness and flow turbulence. In some of the worst cases, it is not possible to see through a small section of pipe due to the incrustations.

As more than half of the City's water distribution system is unlined cast iron and over 40 years old, the calibration process paid most attention to the roughness coefficients of this type of pipe.

## **Roughness Coefficients**

The basic Hazen-Williams C-factors for various pipe materials and ages came from a number of sources.

Cast iron pipe C-factors can vary based on water quality and other factors, so local information was obtained. The District of Saanich provided results from local field tests for C-factors (derived from the report, Saanich Water Infrastructure Analysis Study, with field tests by Willis Cunliffe Tait, Heath Consultants and Saanich Public Works staff). Saanich is a municipality which is adjacent to Victoria and uses the same CRD supply system and Sooke Lake water source. The report's table of "Computed C Factor Results - Cast Iron Pipe, Phase 1- Gorge-Douglas Area, C Factor Testing - Nov 24 1995" was used as a starting point to assign C values to 150 mm diameter CI pipes.

Sources generally indicate that C-factors for old CI pipes are higher for larger diameter pipes than for smaller, given the same pipe age and water quality. Four sets of C-factor assignments were made based on CI pipe diameter ranges. Each of the four sets had various assignments made based on pipe age. Using tables in "Analysis of Water Distribution Systems, Walaski, Thomas M., New York, New York, Van Nostrand Reinhold Company Inc, 1984" as a general guide, higher C-factor assignments were made for CI pipes with larger diameters.

The roughness coefficients of unlined steel pipe was treated as similar to cast iron as very little documentation could be found on the subject. As steel pipe makes up only a small portion (7%) of the City's system, only one set of C-factor assignments was made based on 150 mm CI.

Cement-lined ductile iron, PVC, galvanized iron, copper, AC, HDPE, and epoxy-lined CI pipes were assigned average C-factors with little variation for pipe age.

## **Minor Losses**

Specific minor losses for individual pipes were not determined because of the changeable flow directions for differing flow test locations. A globally applied minor loss coefficient (MI) was investigated and assigned because it was thought that flow would often go around bends and through side outlets of Tee fittings, etc. As an example, a minor loss coefficient of 1.8 is often assigned to a pipe with flow entering through a Tee side outlet. MI values of 0.0, 0.8, 1.0, 1.5 and 2.0 were modeled and compared to the 55 flow tests. The best fit in configurations with flow velocity considerations was with MI = 1.0 applied globally to all pipes. The scoring matrix for this investigation is shown in **Appendix B**.

## **Hydrant Losses**

Flow test locations were simulated at the nodes nearest the hydrants. These nodes were often at watermain intersections and so may not have been entirely accurate. More significantly, the pipes

connecting the watermains through Tees and bends to the tests' flow hydrants' Pitot gauge outlets were not modeled for specific flow hydrant configurations.

Several typical configurations were calculated to approximate the losses associated with these test flow hydrants all of which used a 150 mm diameter pipe 3.5 metres long (2.5 metre offset + 1.0 metre watermain depth). The two test locations were chosen for their high (node 140) and low (node 1472) recorded flows and residual pressures. Hazen-Williams C-factors of 50 and 100 were calculated with minor losses of 1, 3 and 5. Losses of between 1 and 14 PSI were calculated as shown in the following table:

<b>Node</b>	<b>C</b>	<b>MI</b>	<b>PSI loss</b>
140	50	5	14
140	100	5	11
140	50	3	10
140	100	3	7
140	50	1	6
140	100	1	3
1472	50	5	5
1472	100	5	4
1472	50	3	4
1472	100	3	3
1472	50	1	3
1472	100	1	1

For configurations with flow velocity considerations, it was decided to subtract 5 PSI from the modeled pressure at each flow hydrant when comparing them to the field tests to approximate this loss. The scoring matrix for this investigation is shown in **Appendix B**.

## **Metric Pipe Sizing**

Pipes are generally manufactured with nominal sizes given in inches. Initially, all of the pipe diameters in the model were entered to the nearest 25 mm giving sizes of 100, 150, 250, 300 mm etc. Most of the first calibration comparisons were made using these rounded sizes. Later comparisons to flow tests were made with pipe sizes using a 25.4 mm/inch conversion factor (102, 152, 254, 305 mm etc.). This provided a better fit for calibration and so the more accurate pipe diameters were assigned. It must be noted that the better fit was partly due to the assignment of larger C-factors from the roughness table (WATSYS: System|Calibrate|Roughness) because some the increased diameters fell within the next set of C-factor assignments made based on CI pipe diameter ranges.

## **Abating Velocities**

Facilities were developed in WATSYS to investigate the possibility that flow velocities might be a factor in determining pipe roughness coefficients. The roughness table (WATSYS: System|Calibrate|Roughness) now has the option to enter a velocity above which a different C-factor is assigned. It was thought that, over many years, the pipes with higher average flow velocities might not tuberculate as much or at all. For reference purposes this report refers to these as **abating velocities**. The decisions to adjust various model configurations were made by looking at specific test locations and surrounding pipes

and comparing them to the flow tests recorded. Two types of abating velocity were investigated: a higher abating velocity which might keep a pipe fairly clean inside (a high C-factor) and a lower abating velocity which might keep a pipe from tuberculating too much and closing off entirely. Higher abating velocities of 0.10 to 0.35 metres per second (mps) and lower abating velocities of 0.01 to 0.03 mps were investigated. A higher abating velocity of 0.20 mps and a lower abating velocity of 0.02 mps provided the best fit. Values of 0.25 mps and 0.01 mps respectively also provided a good fit. The scoring matrix for this investigation is shown in **Appendix B** (VicCal9 to VicCal26).

## Evolution Analysis

As noted earlier, parts of the pipe network were installed in 1885. To accurately model how the network evolved over time would require a great deal of effort and investigation of historical records. Changes in flow in the network as it evolved might effect the determination of possible abating velocities. As an approximation of this, an Evolution analysis facility was developed in WATSYS. At the time of this writing, this produced a small improvement in fitting modeled results to measured readings when compared to the procedure of assigning the C-factors before an analysis and then after a steady-state analysis. The scoring matrix for this investigation is shown in **Appendix B** (VicCalib1 to VicCalib6a).

## Accuracy and Margins of Error

As with any data, that used for this project has inaccuracies and errors due to limitations of instrument measurement, mapping, human error in recording techniques and data entry and other factors. It is interesting to note that during calibration, once the model became more accurate, some of the recording and data entry errors became apparent and were fixed.

Some of the other possible errors and estimated accuracies that were identified are:

In the model:

- Flow test locations which were simulated at the nodes nearest the hydrants. These nodes were often at watermain intersections and so may not have been entirely accurate.
- Node elevations  $\pm 1$  to 2 m
- Flow hydrant losses  $\pm 5$  PSI or more. The pipes connecting the watermain to the flow hydrants were not modeled individually.
- Pipe minor losses on specific pipes.

With field tests:

- Pitot gauge reading  $\pm 2$  PSI  $\sim \pm 1$  to 4 lps
- Residual pressure gauge reading at flow hydrant  $\pm 2$  PSI
- Residual pressure gauge reading at other hydrants  $\pm 2$  PSI
- Possible partially closed valves
- Possible air pockets in watermain, pressure gauges
- Possible pressure surges from customer demands
- Possible uncalibrated gauges

## Closest Configurations

Of over 75 configurations investigated, two were identified as having the closest fit to the flow tests. One uses the abating velocity theory and the other uses more conventional methods of assigning roughness coefficients. The scoring sheets for these configurations are shown in **Appendix B**.

### Abating Velocity Configuration

The closest abating velocity configuration found was VicCal 36 which has the following:

- a minor loss of 1.0 applied globally to all pipes.
- a hydrant loss of 5 PSI taken from the flow node when comparing to the flow hydrant.
- abating velocities where CI pipes:
  - with flow of 0.20 mps or more are assigned a C-factor of 121.
  - up to 200 mm diameter are not assigned a C-factor of less than 61 if the flow is 0.02 mps or more.
  - over 200 mm diameter are not assigned a C-factor of less than 66 if the flow is 0.02 mps or more.
- changes from the CI pipe C-factors assigned in the first configurations:
  - 152 mm diameter C +5 (was 150 mm)
  - 203 mm diameter C +5 (was 200 mm)
  - 203 mm diameter minimum C of 66 for lower abating velocities (was 200 mm with 61)

### Conventional Configuration

The closest conventional method configuration found was VicCal 1j which has the following:

- no minor losses for pipes.
- no flow hydrant losses
- changes from the CI pipe C-factors assigned in the first configurations:
  - $\leq 200$  mm diameter C +5
  - 203 mm diameter C +10 (was 200 mm)
  - $> 203$  mm diameter C +5

Though VicCal1j shows some higher scoring results compared to VicCal36, it does not account for minor losses in pipes or for hydrant losses at the flow test location. VicCal1a is the same configuration as VicCal36 but using conventional methods and no abating velocities.

## Possible Improvements

There are several possibilities for improving the comparison of the model's results to flow tests. Below are some suggestions for improving the accuracy of future calibrations.

## **Hydrant Connections**

The model could have additional nodes added to more accurately represent the locations of the flow test hydrants. Flow hydrant losses could be modeled by adding short pipes with minor losses representing the tee, bend, Pitot outlet etc. That pipe's size, material and age could be used to assign a C-factor if appropriate.

## **Flow Tests**

Some of the flow test results could be checked by re-testing. This might also give a better idea of the accuracy of the flow testing procedure.

As noted above, the 55 flow tests that were used for this calibration were located in the Victoria regulated portion of the model (excluding downtown). Flow tests in other areas such as Esquimalt, VicWest and the high pressure zones should also be performed and compared.

## **Pipe Samples and Testing**

A comparison of the similarity between CI and steel pipe roughness could be investigated by digging up some sections of recently abandoned old steel pipes such as on Quamichan Street.

It would also be useful to know if older hydrant CI connecting pipes tuberculate similarly to watermains.

The model configurations that use abating velocities attempt to predict which older CI pipes will stay clean retaining high C-factors. Flow tests could be performed on those predicted pipes to determine their actual C-factors for comparison.

## **C-Factor Source Data**

As noted above, the initial C-factors used for 150 mm CI pipe came from the Saanich Water Infrastructure Analysis Study. It would be useful to know if the calculations from the testing results accounted for hydrant connection losses.

## **Pipe Network Evolution**

The evolution of the pipe network during the last 120 years could be more accurately represented if it proves useful to model with abating velocities. Though the amount of data needed to model this accurately may require a prohibitive amount of work, better modeling algorithms might be developed to estimate this evolution to more accurately predict C-factors from flow velocities and directions over the history of the system.

# Appendix A - Consumption Data

## Victoria Water Consumption Record - Rev 01/15/02

IMP. GAL. IN 1,000,000s

2001	284	286	286	350	289	302	412	318	387	295	286	281
------	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

4 highs highlighted:

Year	1	2	3	4	5	6	7	8	9	10	11	12
2000	351	285	286	<u>382</u>	380	356	<u>539</u>	<u>437</u>	376	<u>400</u>	293	350
1999	280	274	337	<u>293</u>	317	<u>438</u>	<u>403</u>	<u>512</u>	379	<u>401</u>	297	279
1998	298	279	280	368	<u>425</u>	367	<u>410</u>	<u>540</u>	<u>375</u>	310	369	256
1997	392	292	275	<u>386</u>	337	352	<u>497</u>	<u>433</u>	<u>420</u>	308	290	322
1996	355	293	288	364	312	<u>482</u>	<u>468</u>	<u>451</u>	<u>440</u>	309	302	279

4 lows highlighted:

Year	1	2	3	4	5	6	7	8	9	10	11	12
2000	351	<u>285</u>	<u>286</u>	382	380	356	539	437	376	400	<u>293</u>	<u>350</u>
1999	<u>280</u>	<u>274</u>	337	<u>293</u>	317	438	403	512	379	401	297	<u>279</u>
1998	<u>298</u>	<u>279</u>	<u>280</u>	368	425	367	410	540	375	310	369	<u>256</u>
1997	<u>392</u>	<u>292</u>	<u>275</u>	386	337	352	497	433	420	<u>308</u>	<u>290</u>	322
1996	355	<u>293</u>	<u>288</u>	364	312	482	468	451	440	309	<u>302</u>	<u>279</u>

Totals IMP. GAL.

2001	3,781,578,593
2000	4,440,826,676
1999	4,217,739,000
1998	4,282,503,000
1997	4,308,896,000
1996	4,348,626,000

## Low and High Reading Counts by Month

Properties with exactly 3 meter readings per year were examined for all 5 years. The highest and lowest readings for each of these properties and the month of those readings were determined. A sum was made to find the number of highest and lowest readings in each month.

2000	1999	1998	1997	1996
Lows (3/yr) in month:	Lows (3/yr) in month:	Lows (3/yr) in month:	Lows (3/yr) in month:	Lows (3/yr) in month:
0= 13	0= 41	0= 28	0= 37	0= 32
<b>1= 1076</b>	1= 1363	1= 828	1= 656	<b>1= 2555</b>
<b>2= 2079</b>	<b>2= 1905</b>	<b>2= 1948</b>	<b>2= 1437</b>	<b>2= 2133</b>
3= 325	<b>3= 1971</b>	<b>3= 2376</b>	<b>3= 1277</b>	<b>3= 2146</b>
4= 66	<b>4= 1374</b>	<b>4= 919</b>	<b>4= 1703</b>	<b>4= 1059</b>
<b>5= 1985</b>	<b>5= 1654</b>	<b>5= 1806</b>	<b>5= 2325</b>	5= 726
<b>6= 615</b>	6= 364	6= 527	6= 1156	6= 252
7= 140	7= 393	7= 256	7= 636	7= 293
8= 39	8= 183	8= 71	8= 142	8= 144
9= 274	9= 206	9= 161	9= 211	9= 137
10= 274	10= 180	10= 87	10= 209	10= 139
11= 102	11= 291	11= 349	11= 228	11= 171
12= 0	12= 515	12= 125	12= 520	12= 102
Highs (3/yr) in month:	Highs (3/yr) in month:	Highs (3/yr) in month:	Highs (3/yr) in month:	Highs (3/yr) in month:
0= 13	0= 41	0= 28	0= 37	0= 32
<b>1= 506</b>	1= 450	1= 257	1= 548	1= 405
2= 242	2= 161	2= 211	2= 513	2= 106
3= 122	3= 392	3= 249	3= 308	3= 178
4= 57	4= 174	4= 76	4= 287	4= 162
5= 201	5= 172	5= 111	5= 160	5= 320
6= 398	6= 263	6= 98	6= 159	6= 146
7= 127	7= 980	<b>7= 1107</b>	7= 519	7= 895
8= 80	<b>8= 1241</b>	8= 809	8= 331	<b>8= 1263</b>
<b>9= 2463</b>	<b>9= 2272</b>	<b>9= 2562</b>	<b>9= 2552</b>	<b>9= 2041</b>
<b>10= 2085</b>	<b>10= 2196</b>	<b>10= 2250</b>	<b>10= 2205</b>	<b>10= 2653</b>
<b>11= 694</b>	<b>11= 1244</b>	<b>11= 1487</b>	<b>11= 1847</b>	<b>11= 1303</b>
12= 0	12= 854	12= 236	<b>12= 1071</b>	12= 385

## **File Names**

### **Used as input to VicMeter.EXE**

Consumption 2000.TXT	PC compatible ASCII files from billing data
Consumption 1999. TXT	
Consumption 1998. TXT	
Consumption 1997. TXT	
Consumption 1996. TXT	

### **Output from VicMeter.EXE, import to CivilSystems**

#### **Average, low, high scenarios 1 to 3:**

Vid5YearALH.txt	Victoria VID number already assigned
Rid5YearALH.txt	Victoria Roll numbers used as IDs
Nid5YearALH.txt	Victoria New ID numbers assigned
Eid5YearALH.txt	Esquimalt Roll numbers used as IDs
NEid5YearALH.txt	Esquimalt New ID numbers assigned

#### **Higher-high scenario 4:**

Vid5YearHsc4.txt	Victoria VID number already assigned
Rid5YearHsc4.txt	Victoria Roll numbers used as IDs
Nid5YearHsc4.txt	Victoria New ID numbers assigned
Eid5YearHsc4.txt	Esquimalt Roll numbers used as IDs
NEid5YearHsc4.txt	Esquimalt New ID numbers assigned

### **Import to CivilSystems (possible future use)**

EsquimaltZones.txt	Esquimalt Roll#s, Zone1, Description from Esquimalt Autocad map DB
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### **Stored and used by CivilSystems and extracted to WATSYS**

Victoria-Esquimalt.PPT	Property and meter consumption data for all of Victoria and Esquimalt
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## Appendix B - Calibration Data

The data and tables in this appendix were produced by WATSYS during the calibration process when simulating flow tests.

### Summary of Flow Test Analyses

Each time that the roughness coefficient table or other data was adjusted, a new model configuration was established and stored in numbered WAT and DCT files with a VicCalib or VicCal prefix. For instance, VicCal17 is stored in VicCal17.WAT and VicCal17.DCT with C-factors assigned to all pipes and average low demands stored for each node. The list of configurations below gives a brief description of the changes made.

#### Abbreviations

The following abbreviations are used in the list of configurations:

- **velocity→roughness 0.02→61,66, 0.20→121** indicates that, in the roughness table, C-factor assignments of 61 and 66 were made to some pipe types when their flows were more than 0.02 metres per second and assignments of 121 were made to some pipe types when their flows were more than 0.20 metres per second.

**EA**= Evolution analysis

**Vel**= Velocity influenced roughness

**MI**= average sum of minor losses applied to all pipes

**Fn**= flow node pressure in psi

#### List of Configurations

##### **VicCalib, VicCalib1**

- no velocity influence, no evolution analysis
- same CI roughness values used up to VicCalib6a

##### **VicCalib2 to VicCalib6**

- EA 1885-2004 5 year increment, 55 flow tests
- conversion from meter unit in CivilSystems = 23.000

##### **VicCalib2**

- velocity→roughness 0.10-0.21→variable C for variable sizes and ages

##### **VicCalib3**

- velocity→roughness 0.15→101, 0.20→121 for all sizes and ages

##### **VicCalib4**

- velocity→roughness 0.01→41-66 variable for size, 0.10→121 all

##### **VicCalib5**

- velocity→roughness 0.02→41-66 variable for size, 0.15→121 all

##### **VicCalib6**

- velocity→roughness 0.02→61,66, 0.20→121

##### **VicCalib6a to VicCal34 and beyond**

- 23.214 meter unit conversion fixed (was 23.000)
- new .WAT file from City

##### **VicCalib6a (9 configurations tried)**

- velocity→roughness 0.02→61,66, 0.20→121
- MI=0.8,1.0,1.5,2.0, Fn=0.0, Fn=4.0, Fn=5.0 psi

#### **VicCalib7**

- VicCalib6 with all CI and steel pipe C's reduced by 10 with no effect on static pressures throughout
- MI=1.0, Fn=5.0 psi
- velocity→roughness 0.02→61,66, 0.20→121

#### **VicCalib8 to VicCal34 and beyond**

- EA mod for 1965/CI replacements disabled
- MI=1.0, Fn=5.0 psi unless otherwise noted

#### **VicCalib8**

- VicCalib6 with all CI and steel pipe C's reduced by 5 with no effect on static pressures throughout
- velocity→roughness 0.02→61,66, 0.20→121

#### **VicCal9 to VicCal 14**

- velocity→roughness 0.01→61,66, 0.10→121 **VicCal9**
- velocity→roughness 0.01→61,66, 0.15→121 **VicCal10**
- velocity→roughness 0.01→61,66, 0.20→121 **VicCal11**
- velocity→roughness 0.01→61,66, 0.25→121 **VicCal12**
- velocity→roughness 0.01→61,66, 0.30→121 **VicCal13**
- velocity→roughness 0.01→61,66, 0.35→121 **VicCal14**

#### **VicCal15 to VicCal 20**

- velocity→roughness 0.02→61,66, 0.10→121 **VicCal15**
- velocity→roughness 0.02→61,66, 0.15→121 **VicCal16**
- velocity→roughness 0.02→61,66, 0.20→121 **VicCal17**
- velocity→roughness 0.02→61,66, 0.25→121 **VicCal18**
- velocity→roughness 0.02→61,66, 0.30→121 **VicCal19**
- velocity→roughness 0.02→61,66, 0.35→121 **VicCal20**

#### **VicCal21 to VicCal26**

- velocity→roughness 0.03→61,66, 0.10→121 **VicCal21**
- velocity→roughness 0.03→61,66, 0.15→121 **VicCal22**
- velocity→roughness 0.03→61,66, 0.20→121 **VicCal23**
- velocity→roughness 0.03→61,66, 0.25→121 **VicCal24**
- velocity→roughness 0.03→61,66, 0.30→121 **VicCal25**
- velocity→roughness 0.03→61,66, 0.35→121 **VicCal26**

#### **VicCaHp2**

- same as VicCal17

#### **VicCal27**

- same as VicCal17
- larger (>300) steel pipes changed to 140

#### **VicCal28**

- same as VicCal17
- all DI pipes set to 140

#### **VicCal29**

- velocity→roughness 0.02→61,66, 0.20→131

#### **VicCal30**

- velocity→roughness 0.02→71-76, 0.20→121

#### **VicCal31**

- velocity→roughness 0.02→71-76-81, 0.20→121

#### **VicCal32**

- velocity→roughness 0.02→61, 0.20→121

#### **VicCal33**

- velocity→roughness 0.02→61,66, 0.20→121 **VicCal17**
- Divide diameters by 25 then multiply by 25.4, MI= 1.0, Fn=5.0

**VicCal34**

- velocity→roughness 0.01→61,66, 0.25→121 **VicCal12**
- Divide diameters by 25 then multiply by 25.4, MI= 1.0, Fn-5.0

**VicCal35**

- velocity→roughness 0.02→61,66, 0.20→121 **VicCal17**
- velocity→roughness 0.02→61,66, 0.15→121 **Steel**
- Divide diameters by 25 then multiply by 25.4, MI= 1.0, Fn-5.0

**VicCal36**

- VicCal33 revised 83 leakage, CRD mains 0 leakage

**VicCal1a**

- VicCal36 with no EA, no abating velocities

**VicCal1b**

- VicCal1a. No EA, no abating velocities
- Diameters 1"= 25mm, MI= 1.0, Fn-0.0

**VicCal1c**

- VicCal1a. No EA, no abating velocities
- Diameters 1"= 25mm, MI= 0.0, Fn-5.0

**VicCal1d**

- VicCal1a. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0

**VicCal1e**

- VicCal1a. No EA, no abating velocities
- Diameters 1"= 25mm, MI= 0.0, Fn-0.0

**VicCal1f**

- VicCal1d. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153 to bring CI Cs back to older values

**VicCal1g**

- VicCal1a. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 1.0, Fn-0.0

**VicCal1h**

- VicCal1f. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153, 0-153 CI dia Cs increased by 5

**VicCal1i**

- VicCal1f. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153, 0-149 CI dia Cs increased by 5
- mid-range 200 Cs, made 153-204 and increased by 5

**VicCal1j**

- VicCal1f. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153, all CI dia Cs increased by 5

**VicCal1k**

- VicCal1f. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153, 0-149 CI dia Cs increased by 5
- mid-range 200 Cs, made 153-204 and increased by 5
- upp-range 200 Cs, made 204- and increased by 5

**VicCal1L**

- VicCal1f. No EA, no abating velocities
- Divide diameters by 25 then multiply by 25.4, MI= 0.0, Fn-0.0
- mid-range 150 Cs, made 150-153, 0-149 CI dia Cs increased by 5

- mid-range 200 Cs, made 153-204 and increased by 10
- upp-range 200 Cs, made 204- and increased by 10

#### **VicCal38**

- VicCal1j with abating velocities
- Divide diameters by 25 then multiply by 25.4, M1= 0.0, Fn-5.0

#### **VicCal39**

- VicCal1j with abating velocities
- Divide diameters by 25 then multiply by 25.4, M1= 1.0, Fn-5.0

## **Scoring Sheet Definitions**

A page was produced for each configuration to compare the model's calculated pressures to the field-recorded pressures. The numbers on each line represent the calculated pressure in PSI minus the field-tested pressure: the left-most number (second left column) is the PSI difference at the flowed hydrant/node, the next three are at the other hydrants/nodes. The right-most column is the node number associated with the flow hydrant.

On the very left of the sheet is a set of three to four scoring codes representing the PSI pressure differences calculated:

**0** calculated to within  $\pm 5$  psi

**+**  $> 5$  psi and  $\leq 7$  psi

**-**  $< -5$  psi and  $\geq -7$  psi

**A**  $> 7$  psi

**V**  $< -7$  psi

A summary of totals counted for each of the above codes is shown at the bottom of each scoring sheet and in some of the comparison matrices which follow.

The complete set of scoring sheets is stored in the file VicCalib.DOC. The most significant ones are recorded in this report on the pages which follow.

# VicCal 1a Scoring Sheet

VV-V	-9	-7	-6	-7	16
VV--	-9	-9	-5	-5	117
V000	-8	1	-0	-3	140
0000	-2	-1	-1	0	29
000	-4	2	-0		59
V0V0	-14	-0	-9	-2	74
V0-0	-8	-1	-5	-2	346
0000	-3	-2	2	-0	105
V000	-32	-3	0	-3	147
0000	-5	0	3	1	113
-000	-5	2	3	-0	726
0000	-2	2	-0	2	240
-000	-6	3	3	-1	268
0000	-2	5	4	3	287
V00	-11	2	-3		668
0000	-2	1	4	3	926
V000	-7	-1	0	3	698
0000	-2	3	-1	-0	687
0000	0	0	4	4	635
VV00	-9	-7	-4	-2	1020
VV00	-9	-10	-7	-1	1015
-0-0	-6	-3	-6	0	1435
V-V-	-13	-6	-8	-6	1454
VV0-	-10	-8	-3	-6	1319
V0--	-23	-3	-6	-6	1097
-00V	-7	-4	-4	-8	1323
--00	-6	-6	-3	-1	1405
V000	-27	-3	1	-2	1473
-000	-7	-0	1	-4	976
VV00	-25	-8	-7	1	1415
00-0	-4	-3	-5	-3	963
0000	-2	1	2	0	952
000V	-2	-3	-5	-8	1399
0000	1	-4	-1	-2	1372
V-00	-8	-6	-2	-4	1363
V000	-10	-2	-4	-1	1368
VV00	-11	-8	-3	-5	1073
0000	-2	-1	-1	-3	1172
-000	-5	-2	1	1	361
0000	-3	1	-1	4	1298
-0-0	-7	-4	-5	2	1331
-000	-6	-3	-0	2	1323
00-	-2	-1	-5		1300
0000	-2	1	-2	5	651
0000	-4	1	0	4	723
0000	-2	2	3	4	680
0+00	-0	5	1	1	590
0000	-3	1	3	4	707
V00	-8	2	-5		1267
V000	-19	1	0	-3	1255
0000	-5	-4	-1	0	1240
0000	-4	0	-2	-0	1232
V000	-7	1	-3	0	1092
V000	-12	0	-2	-0	1472
-A00	-6	7	-2	5	563

## VicCal 1a Totals

Flow Node:

0 23

+ 0

- 10

A 0

V 22

Other Nodes:

0 130

+ 1

- 15

A 1

V 14

- No abating velocities, no evolution analysis
- VicCal36 with no evolution analysis:
- 23.214 meter unit conversion
- Divide diameters by 25 then multiply by 25.4
- MI= 1.0, Fn-5.0
- revised 83 leakage, CRD mains 0 leakage

<u>Within Range</u>	<u>Flow Node</u>	<u>Other Nodes</u>
± 10 psi	82%	100%
± 7 psi	78%	91%
± 5 psi	42%	81%

## VicCal 1j Scoring Sheet

0000	-2	-5	-3	-5	16
0-00	-1	-6	-3	-3	117
0000	-2	2	0	-2	140
0000	4	-0	-0	0	29
000	3	3	1		59
-0V0	-6	0	-7	-1	74
0000	-2	-0	-5	-2	346
0000	3	-1	2	1	105
V000	-26	-2	0	-2	147
0000	1	1	3	2	113
0000	0	3	3	0	726
0000	4	2	-0	3	240
0000	-0	4	4	-0	268
0000	3	5	4	4	287
-00	-5	3	-2		668
0000	3	2	4	3	926
0000	-1	-1	0	3	698
0000	4	4	-0	0	687
+000	6	1	4	4	635
0-00	-2	-5	-2	-0	1020
0V00	-1	-8	-5	1	1015
0000	1	-1	-4	2	1435
00-0	-4	-4	-5	-4	1454
0-00	-3	-6	-1	-4	1319
V000	-15	-1	-5	-5	1097
000-	-0	-2	-3	-7	1323
0000	2	-5	-1	0	1405
V000	-21	-1	2	-1	1473
0000	-1	1	2	-3	976
V--0	-19	-7	-6	2	1415
0000	3	-2	-4	-2	963
0000	4	2	3	1	952
000-	4	-2	-3	-7	1399
A000	8	-3	1	-1	1372
0000	-1	-4	-1	-2	1363
0000	-4	-0	-3	0	1368
0-00	-4	-6	-1	-3	1073
0000	4	1	0	-2	1172
0000	1	-1	1	2	361
0000	3	2	0	5	1298
0000	0	-2	-3	4	1331
0000	0	-2	1	3	1323
000	5	1	-4		1300
000+	4	2	-1	5	651
0000	2	2	1	4	723
0000	4	3	4	4	680
++00	6	6	2	1	590
0000	3	2	4	5	707
000	-1	4	-3		1267
V000	-12	3	2	-1	1255
0000	2	-3	0	2	1240
0000	2	2	-0	1	1232
0000	-1	3	-2	2	1092
-000	-5	1	-1	1	1472
0A0+	0	8	-2	5	563

### VicCal 1j Totals

Flow Node:

0 44

+ 2

- 3

A 1

V 5

Other Nodes:

0 146

+ 3

- 9

A 1

V 2

- No abating velocities, no evolution analysis
- VicCal36 with no evolution analysis:
- 23.214 meter unit conversion
- Divide diameters by 25 then multiply by 25.4
- Ml= 0.0, Fn-0.0
- revised 83 leakage, CRD mains 0 leakage
- mid-range 150 CI Cs made 150-153 mm dia
- all CI Cs increased by 5

Within Range	Flow Node	Other Nodes
± 10 psi	91%	100%
± 7 psi	89%	98%
± 5 psi	80%	91%

# VicCal 36 Scoring Sheet

0000	-4	-2	-1	-2	16
0000	-3	-3	0	0	117
-000	-6	3	1	-1	140
0000	-1	0	1	1	29
000	-2	3	2		59
V000	-8	1	-5	-2	74
0000	-0	0	-2	2	346
0000	-1	-1	3	1	105
V000	-31	-2	1	-1	147
0000	-1	2	5	4	113
0000	-4	4	4	1	726
0000	3	2	-0	2	240
-000	-6	4	4	-0	268
00++	0	3	6	6	287
V00	-7	4	2		668
00++	-0	3	6	5	926
0000	-3	3	1	4	698
0+00	0	5	1	2	687
00++	2	2	6	6	635
000+	-1	1	4	6	1020
000+	-1	-3	1	7	1015
000+	0	3	0	7	1435
0000	-4	2	0	-1	1454
0000	-2	-0	4	1	1319
V000	-9	3	-1	1	1097
+000	6	2	2	-1	1323
A000	15	-0	3	5	1405
V0+0	-9	3	7	2	1473
0000	0	2	4	1	976
000+	3	-1	-1	7	1415
0000	0	1	-1	1	963
0000	1	4	4	3	952
0000	4	3	2	-2	1399
+0+0	7	2	5	3	1372
0000	-1	0	4	3	1363
000+	-3	5	2	5	1368
0++0	2	5	5	1	1073
+++0	5	6	6	4	1172
0000	-4	-0	2	3	361
0+0A	2	6	3	8	1298
000A	2	2	2	9	1331
+0+A	5	4	5	7	1323
0+0	5	6	1		1300
000A	1	3	2	7	651
000+	-2	3	3	5	723
000+	1	3	5	6	680
0+00	2	7	4	2	590
00++	-1	3	5	7	707
0A0	-1	9	2		1267
VA+0	-12	8	7	5	1255
000+	1	1	5	7	1240
0+0+	2	6	4	6	1232
0+0+	-1	7	2	6	1092
A000	10	4	1	4	1472
0A0A	0	9	1	7	563

## VicCal 36 Totals

Flow Node:

0 41  
+ 4  
- 2  
A 2  
V 6

Other Nodes:

0 121  
+ 32  
- 0  
A 8  
V 0

- Abating velocities, evolution analysis
- velocity→roughness 0.02→61,66, 0.20→121
- 23.214 meter unit conversion
- Divide diameters by 25 then multiply by 25.4
- MI= 1.0, Fn-5.0
- revised 83 leakage, CRD mains 0 leakage

<u>Within Range</u>	<u>Flow Node</u>	<u>Other Nodes</u>
± 10 psi	95%	100%
± 7 psi	85%	95%
± 5 psi	75%	75%

## Scoring Matrix VicCalib1 to VicCalib6a

VicCalib1  
no-EA no-Vel  
 Flow Node:  
 0 35  
 + 2  
 - 4  
 A 0  
 V 14  
 Other Nodes:  
 0 123  
 + 2  
 - 15  
 A 0  
 V 21

VicCalib2  
 EA, Vel  
 Flow Node:  
 0 30  
 + 10  
 - 3  
 A 5  
 V 7  
 Other Nodes:  
 0 124  
 + 23  
 - 6  
 A 6  
 V 2

VicCalib3  
 EA, Vel  
 Flow Node:  
 0 31  
 + 9  
 - 2  
 A 6  
 V 7  
 Other Nodes:  
 0 120  
 + 28  
 - 4  
 A 7  
 V 2

VicCalib4  
 EA, Vel  
 Flow Node:  
 0 19  
 + 15  
 - 1  
 A 16  
 V 4  
 Other Nodes:  
 0 111  
 + 33  
 - 0  
 A 16  
 V 1

VicCalib5  
 EA, Vel  
 Flow Node:  
 0 26  
 + 12  
 - 1  
 A 12  
 V 4  
 Other Nodes:  
 0 119  
 + 29  
 - 0  
 A 12  
 V 1

VicCalib6a EA  
 1885-2004 noCir  
 Flow Node:  
 0 25  
 + 14  
 - 4  
 A 10  
 V 2  
 Other Nodes:  
 0 120  
 + 32  
 - 1  
 A 8  
 V 0

VicCalib6a EA  
 1885-2004 CIREPL  
 Flow Node:  
 0 25  
 + 14  
 - 4  
 A 10  
 V 2  
 Other Nodes:  
 0 120  
 + 32  
 - 1  
 A 8  
 V 0

VicCalib6a no-EA  
 1900-2004  
 104 yrInc  
 Flow Node:  
 0 25  
 + 15  
 - 2  
 A 11  
 V 2  
 Other Nodes:  
 0 118  
 + 33  
 - 1  
 A 9  
 V 0

## Scoring Matrix VicCalib6a - Minor Losses & Hydrant Losses

VicCalib6a EA  
1885-2004 CIREpl  
Flow Node:  
0 25  
+ 14  
- 4  
A 10  
V 2  
Other Nodes:  
0 120  
+ 32  
- 1  
A 8  
V 0

VicCalib6a EA  
=+ Ml=0.8  
Flow Node:  
0 30  
+ 10  
- 3  
A 9  
V 3  
Other Nodes:  
0 125  
+ 28  
- 1  
A 7  
V 0

VicCalib6a EA  
=+ Ml=1.0  
Flow Node:  
0 30  
+ 10  
- 3  
A 9  
V 3  
Other Nodes:  
0 126  
+ 27  
- 1  
A 7  
V 0

VicCalib6a EA  
=+ Ml=1.5  
Flow Node:  
0 32  
+ 9  
- 2  
A 9  
V 3  
Other Nodes:  
0 127  
+ 24  
- 3  
A 7  
V 0

VicCalib6a EA  
=+ Ml=2.0  
Flow Node:  
0 35  
+ 6  
- 0  
A 9  
V 5  
Other Nodes:  
0 130  
+ 22  
- 2  
A 6  
V 1

VicCalib6a EA  
=+ Ml=0.0 Fn-5  
Flow Node:  
0 39  
+ 3  
- 4  
A 3  
V 6  
Other Nodes:  
0 120  
+ 32  
- 1  
A 8  
V 0

VicCalib6a EA  
=+ Ml=0.8 Fn-5  
Flow Node:  
0 39  
+ 3  
- 4  
A 2  
V 7  
Other Nodes:  
0 125  
+ 28  
- 1  
A 7  
V 0

VicCalib6a EA  
=+ Ml=1.0 Fn-5  
Flow Node:  
0 40  
+ 2  
- 4  
A 2  
V 7  
Other Nodes:  
0 126  
+ 27  
- 1  
A 7  
V 0

VicCalib6a EA  
=+ Ml=1.5 Fn-5  
Flow Node:  
0 39  
+ 2  
- 4  
A 2  
V 8  
Other Nodes:  
0 127  
+ 24  
- 3  
A 7  
V 0

VicCalib6a EA  
=+ Ml=1.0 Fn-4  
Flow Node:  
0 38  
+ 4  
- 4  
A 3  
V 6  
Other Nodes:  
0 126  
+ 25  
- 3  
A 7  
V 0

## Scoring Matrix VicCal9 to VicCal26 - Upper and Lower Abating Velocities

	0.10 mps	0.15	0.20	0.25	0.30	0.35
mps	VicCal9	VicCal10	VicCal11	VicCal12	VicCal13	VicCal14
	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:
0.01	0 39	0 37	0 39	0 39	0 40	0 39
	+ 3	+ 5	+ 2	+ 2	+ 1	+ 1
	- 2	- 3	- 5	- 5	- 4	- 5
	A 7	A 5	A 3	A 3	A 3	A 3
	V 4	V 5	V 6	V 6	V 7	V 7
	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:
	0 115	0 121	0 126	0 128	0 134	0 140
	+ 31	+ 30	+ 26	+ 25	+ 20	+ 15
	- 0	- 0	- 0	- 2	- 1	- 1
	A 14	A 9	A 8	A 6	A 5	A 4
0.02	V 1	V 1	V 1	V 0	V 1	V 1
	VicCal15	VicCal16	VicCal17	VicCal18	VicCal19	VicCal20
	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:
	0 39	0 38	0 40	0 39	0 40	0 39
	+ 3	+ 4	+ 2	+ 2	+ 1	+ 1
	- 3	- 4	- 4	- 4	- 4	- 4
	A 6	A 4	A 2	A 2	A 2	A 2
	V 4	V 5	V 7	V 8	V 8	V 9
	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:
	0 116	0 124	0 126	0 127	0 134	0 141
0.03	+ 31	+ 29	+ 27	+ 24	+ 18	+ 12
	- 1	- 1	- 1	- 3	- 3	- 3
	A 13	A 7	A 7	A 6	A 5	A 4
	V 0	V 0	V 0	V 1	V 1	V 1
	VicCal21	VicCal22	VicCal23	VicCal24	VicCal25	VicCal26
	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:	Flow Node:
	0 37	0 36	0 38	0 38	0 39	0 38
	+ 3	+ 4	+ 2	+ 1	+ 1	+ 1
	- 4	- 5	- 5	- 6	- 4	- 5
	A 6	A 4	A 2	A 2	A 2	A 2
	V 5	V 6	V 8	V 8	V 9	V 9
	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:	Other Nodes:
	0 118	0 123	0 127	0 129	0 137	0 142
	+ 29	+ 30	+ 25	+ 22	+ 15	+ 12
	- 1	- 1	- 2	- 2	- 3	- 3
	A 13	A 7	A 7	A 6	A 5	A 3
	V 0	V 0	V 0	V 2	V 1	V 1

## Scoring Totals VicCal7 to VicCal8 and VicCal27 to VicCal39

VicCalib7  
Flow Node:  
0 38  
+ 3  
- 2  
A 2  
V 10  
Other Nodes:  
0 121  
+ 28  
- 2  
A 8  
V 2

VicCal29  
Flow Node:  
0 39  
+ 3  
- 4  
A 2  
V 7  
Other Nodes:  
0 124  
+ 29  
- 1  
A 7  
V 0

VicCal33  
Flow Node:  
0 41  
+ 4  
- 2  
A 2  
V 6  
Other Nodes:  
0 122  
+ 31  
- 0  
A 8  
V 0

VicCal37  
Flow Node:  
0 26  
+ 11  
- 1  
A 16  
V 1  
Other Nodes:  
0 117  
+ 30  
- 0  
A 14  
V 0

VicCalib8  
Flow Node:  
0 39  
+ 2  
- 3  
A 2  
V 9  
Other Nodes:  
0 121  
+ 28  
- 5  
A 7  
V 0

VicCal30  
Flow Node:  
0 41  
+ 3  
- 4  
A 4  
V 3  
Other Nodes:  
0 121  
+ 30  
- 0  
A 10  
V 0

VicCal34  
Flow Node:  
0 40  
+ 4  
- 3  
A 3  
V 5  
Other Nodes:  
0 124  
+ 28  
- 1  
A 8  
V 0

VicCal38  
Flow Node:  
0 41  
+ 3  
- 4  
A 3  
V 4  
Other Nodes:  
0 120  
+ 28  
- 0  
A 13  
V 0

VicCal27  
Flow Node:  
0 38  
+ 3  
- 5  
A 2  
V 7  
Other Nodes:  
0 124  
+ 28  
- 2  
A 7  
V 0

VicCal31  
Flow Node:  
0 40  
+ 4  
- 4  
A 4  
V 3  
Other Nodes:  
0 118  
+ 32  
- 0  
A 11  
V 0

VicCal35  
Flow Node:  
0 41  
+ 3  
- 2  
A 3  
V 6  
Other Nodes:  
0 121  
+ 32  
- 0  
A 8  
V 0

VicCal39  
Flow Node:  
0 41  
+ 4  
- 2  
A 2  
V 6  
Other Nodes:  
0 123  
+ 31  
- 0  
A 7  
V 0

VicCal28  
Flow Node:  
0 41  
+ 2  
- 3  
A 2  
V 7  
Other Nodes:  
0 124  
+ 29  
- 1  
A 7  
V 0

VicCal32  
Flow Node:  
0 39  
+ 2  
- 5  
A 2  
V 7  
Other Nodes:  
0 125  
+ 26  
- 3  
A 7  
V 0

VicCal36  
Flow Node:  
0 41  
+ 4  
- 2  
A 2  
V 6  
Other Nodes:  
0 121  
+ 32  
- 0  
A 8  
V 0

## Scoring Totals VicCal 1A to VicCal 1L

VicCal1a  
Flow Node:  
0 23  
+ 0  
- 10  
A 0  
V 22  
Other Nodes:  
0 130  
+ 1  
- 15  
A 1  
V 14

VicCal1e  
Flow Node:  
0 40  
+ 2  
- 3  
A 0  
V 10  
Other Nodes:  
0 126  
+ 1  
- 18  
A 1  
V 15

VicCal1i  
Flow Node:  
0 42  
+ 3  
- 5  
A 0  
V 5  
Other Nodes:  
0 136  
+ 1  
- 16  
A 1  
V 7

VicCal1b  
Flow Node:  
0 39  
+ 1  
- 4  
A 0  
V 11  
Other Nodes:  
0 123  
+ 1  
- 19  
A 1  
V 17

VicCal1f  
Flow Node:  
0 38  
+ 3  
- 4  
A 0  
V 10  
Other Nodes:  
0 132  
+ 1  
- 15  
A 1  
V 12

VicCal1j  
Flow Node:  
**0 44**  
**+ 2**  
**- 3**  
**A 1**  
**V 5**  
Other Nodes:  
**0 146**  
**+ 3**  
**- 9**  
**A 1**  
**V 2**

VicCal1c  
Flow Node:  
0 21  
+ 0  
- 7  
A 0  
V 27  
Other Nodes:  
0 126  
+ 1  
- 18  
A 1  
V 15

VicCal1g  
Flow Node:  
0 42  
+ 2  
- 4  
A 0  
V 7  
Other Nodes:  
0 130  
+ 1  
- 15  
A 1  
V 14

VicCal1k  
Flow Node:  
0 43  
+ 2  
- 4  
A 1  
V 5  
Other Nodes:  
0 143  
+ 3  
- 12  
A 1  
V 2

VicCal1d  
Flow Node:  
0 42  
+ 3  
- 3  
A 0  
V 7  
Other Nodes:  
0 135  
+ 1  
- 15  
A 1  
V 9

VicCal1h  
Flow Node:  
0 42  
+ 3  
- 5  
A 0  
V 5  
Other Nodes:  
0 136  
+ 1  
- 16  
A 1  
V 7

VicCal1L  
Flow Node:  
0 41  
+ 5  
- 3  
A 1  
V 5  
Other Nodes:  
0 146  
+ 5  
- 7  
A 1  
V 2