BOWEN ISLAND MUNICIPALITY

COVE BAY WATER SYSTEM LONG RANGE PLAN UPDATE

NOVEMBER 2009

Dayton & Knight Ltd.
CONSULTING ENGINEERS

360.18

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Bowen Island Municipality

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1.0 INTRODUCTION

1.1 Objectives

The Cove Bay Water System (CBWS) provides water to over 630 service connections principally in the Snug Cove, Millers Landing, Cates Hill and Queen Charlotte Heights areas of Bowen Island. The source of water is Grafton Lake. The water treatment is chlorination with contact time in the supply main.

The CBWS current long range plan was developed in 1998. The CBWS service area population and associated demands as well as issues of supply, treatment and distribution have all grown significantly since this plan was developed.

This report updates the long range plan for improvement and expansion to the existing CBWS.

1.2 Scope of Work

In order to meet the study objectives, the following work plan was adopted for the update to the Long Range Plan for the CBWS:

1. Existing System Review: Review existing system characteristics as well as a summary of previous relevant reports.

2. Population and Water Demand Review: Review 2006 census data and water consumption statistics to update Cove Bay Water System water models to 2009 conditions. Study Bowen Island Official Community Plan (OCP) to project population growth and future water demands in Bowen Island.

3. Drought Management: Summarize Grafton Lake watershed characteristics, drought management and an estimate of the watershed yield under various drought conditions.

4. Reporting: Prepare two memoranda addressing population and development growth and meet with the Municipality to discuss study findings. Update the Long Range Plan, incorporating the memoranda and the feedback from the Municipal staff. Submit the Long Range Plan update to the Municipality.

Relevant studies, completed previously on Bowen Island's waterworks, are listed as follows:

- "Cove Bay Water System Long Range Plan (1997)", Dayton & Knight Ltd., 1998.
- "Cove Bay Water System Drought Management Plan", Dayton & Knight Ltd., 1998.
- "Cove Bay Water System Drinking Water Quality – Annual Report 2004", Bowen Island Municipality, June 2008.
- "Cove Bay Water System Drinking Water Quality – Annual Report 2006", Bowen Island Municipality, June 2008.
- "Cove Bay Water System Drinking Water Quality – Annual Report 2007", Bowen Island Municipality, June 2008.

This study incorporates the latest developments in Bowen Island and proposes a practical plan to upgrade Bowen Island's water supply in order to meet the continuing growth of the Municipality.

The following information provided by the Municipality has been reviewed in this memo:

- Cove Bay Water System Yearly Flow Records (1993 to 1996)
- Cove Bay Water System Yearly Flow Records (2000 to 2008)
- Grafton Lake - Lake Level Records (2004 to 2008)
- Snug Cove Sewer District – Metering Data (2003 to 2008)

We have been informed by the Municipality that the flow records for the Cove Bay Chlorination (i.e. 'CoveChlor') station are available on the KWL Emerald system. Online data from the 'CoveChlor' station reveal the Cove Bay Water System flows but only since November 2007.

1.3 Previous Reports

Dayton & Knight Ltd., along with A.J. Whitehead and Associates, completed a comprehensive water study for the Greater Vancouver Regional District in March 1998, which resulted in the Cove Bay Water System Long Range Plan (1997). The report proposed design criteria, reviewed the existing supply and distribution system, established water supply requirements based on projected population growth, and provided recommendations to improve water quality and water use efficiency in the distribution system. It reviewed Grafton Lake's hydrology, ecology and storage requirements. It was estimated that the full 320,000 m^3 (70 Mgals) of storage on Grafton Lake would be needed to supply water to an estimated 780 service connection equivalents in a 1 in 10 year drought (not taking into account effects of water conservation programs). A recommendation to raise the spillway to accommodate an increase in storage was never implemented.

1.4 Conduct of Study

The Cove Bay Water System Local Management Committee (CBWSLMC) authorized Dayton & Knight Ltd. (D&K) on February 9th, 2009 to update the Cove Bay Water System Long Range Plan. The work was to be carried out in accordance with D&K's proposal dated December 5th, 2008.

The study was conducted by Mr. Seamus Frain, P.Eng. and Clive Leung, E.I.T., of Dayton & Knight Ltd.

Mr. Wil Hilsen, Acting Public Works Manager – Engineering and Mr. Bob Robinson, Public Works Coordinator (Utilities)/Acting Manger Operations, provided the historic data on water demands and population while Environment Canada's online data archives were accessed for historic precipitation and temperature records.

Draft memoranda entitled "Population and Demand Projection" (Memorandum #1) and "Grafton Lake Hydrology Update and 10 Year Return Drought Capacity" (Memorandum #2) were submitted to the municipality. The Draft 1 for both memoranda were sent on May 15, 2009, while Draft 2 for the first memorandum was submitted on June 10, 2009, and the second memorandum on June 12, 2009.

1.5 Acknowledgements

Dayton & Knight Ltd. wishes to thank the Municipality staff for their help and cooperation, in particular, Mr. Wil Hilsen and Mr. Bob Robinson of the Bowen Island Public Works Department, and Mr. Bill Hamilton and Mr. David McEachern of the Cove Bay Water System Local Management Committee for their input during the meetings.

2.0 EXISTING WATER SYSTEM

A section provides a brief overview of the existing water system and its service population. For taxation purposes the service area is divided into three Local Service Areas (LSA) including the original Cove Bay LSA, the Cates Hill/Valhalla LSA, and the Queen Charlotte Heights LSA.

2.1 System Features

2.1.1 Grafton Lake

Bowen Island supplies its own water. The sole supply of water to the CBWS is from Grafton Lake. The Ministry of Environment completed a detailed physical survey of the lake in 1983. Grafton Lake, with a surface area of 19.1 ha, is about 14.3 m deep at the deepest point. The watershed is about 710 ha in area.

The watershed has a rugged topography, characterized by shallow soils and frequent bedrock outcrops. Because of the steep topography of Bowen Island, wells were originally constructed in the 1920s and 1930s, but most have been replaced due to observed arsenic levels. However, some properties still operate on well systems and Bowen Island does not treat the supply.

The highest point on the island is Mount Gardner, 754 m above sea level, northwest of Grafton Lake. Due to the impermeable nature of the soils and underlying bedrock, groundwater infiltration and interflow is not generally a significant factor in the water supply.

The CBWS intake, located in about 10 m of water about 178 m from shore at the north end of Grafton Lake, consists of 10.8 m of 300 mm screens attached to a 350 mm diameter pipe. The screen provides coarse filtering of the water as it enters the pipeline. The screen is manually cleaned once a year.

The Grafton Lake earthen dam is about 35 m in length, about 4 m wide and about 2 m high with a top elevation of 106.81 m. It has a concrete control spillway with a top elevation of 106.01 m and wooden walkway. The dam includes a manually operated 600 mm diameter pipe and control gate that allows for release of water to Terminal Creek. The bottom of the release pipe is at elevation 104.56 m. A figure highlighting the dam elevation is presented in Figure 2-1. The dam seismic stability is unknown.

2.1.2 Supply Main

The supply main between the lake and the Snug Cove area is about 2450 m in length of mainly 250 mm, 300 mm and 350 mm diameter pipe located principally on private property within right-of-ways. There is also a length of 200 mm diameter asbestos cement pipe installed in the mid 1960's.

2.1.3 Water Treatment

The present CBWS water treatment is by disinfection by chlorination with the minimum contact time of 20 minutes in the supply main. The wood frame facility is located about 550 m from the intake and includes chlorination with sodium hypochlorite and flow measuring equipment. Disinfection is accomplished by injection of 12% sodium hypochlorite solution under controlled conditions into the supply main. The rate of pumping of the solution is adjusted with rate of flow in the supply main to maintain a constant chlorine dosage.

A re-chlorination station was installed in the Queen Charlotte Heights area in late 2004 to address consistently failing chlorine residuals in part of the CBWS.

2.1.4 Distribution System

The Cove Bay Water System is the largest of seven water systems wholly owned and operated by the Bowen Island Municipality (BIM). The CBWS currently provides water to around 630 residential and commercial connections principally in the Snug Cove, Millers Landing, Cates Hill, Queen Charlotte Heights and Scarborough areas of Bowen Island.

The Cove Bay Water System service area extends from Crown lands to the north, Apodaca Park to the south, Metro Vancouver Parks Crippen Regional Park and the ecological reserve to the west, and Queen Charlotte Channel to the east.

The Cove Bay Water System is divided into eleven pressure zones as shown in Table 2-1.

TABLE 2-1
COVE BAY WATER SYSTEM
DISTRIBUTION NETWORK AND PRESSURE ZONES

Cove Bay Water Pressure Zones	Method of Supply
Lake – Government / Miller	Gravity
Pump Station – Cates Hill Reservoir	Pumped / Gravity
Cates Hill	PRV
Valhalla Pump Station – Valhalla Reservoir	Pumped / Gravity
Valhalla PRV Queen Charlotte	PRV
Cliff Road PRV	PRV
Queen Charlotte – Taylor Rd.	PRV
Taylor Road PRV – Hummingbird Rd.	PRV
Miller Road PRV – Cove Snug Point	PRV
Deep Bay	PRV
High Zone pump station - Reservoir	Pumped / Gravity

Statistics for the Cove Bay Water distribution system are as follows:

- Service population: 1890 (est.)
- Domestic service connections: 630
- Commercial service connections: 43 (recounted in 2004)
- Reservoirs: 1 (Grafton Lake)
- Storage Tanks: 4
- Pressure Zones: 11
- Pressure-reducing stations 9
- Booster pumping stations 3

- Watermains:
  - Supply mains (200mm to 350mm) ~ 2,540 metres
  - Distribution mains (50mm to 200mm) ~ 13,050 metres
  - Watermain materials: PVC, CI, DI, AC
  - Watermain installation dates: 1950s to present

2.2 Ministry of Environment Water Licences

There are seven water licences served by Grafton Lake.

TABLE 2-2
GRAFTON LAKE WATER LICENCES

Licence	Licencee	Purpose	Maximum Licenced Withdrawal/Storage				Date Issued
			Annual	Unit	Daily	Unit	
C119741	Bowen Island Municipality	Waterworks	73,000,000	ig	200,000	ig	07/20/2004
C119753	Bowen Island Municipality	Waterworks	65,700,000	ig	300,000	ig	07/20/2004
C119745	Bowen Island Municipality	Storage	12	ac·ft	-	-	07/20/2004
C119749	Bowen Island Municipality	Storage	6	ac·ft	-	-	07/20/2004
C119750	Bowen Island Municipality	Storage	250	ac·ft	-	-	07/20/2004
C119940	Gary Davies	Storage	0.6	ac·ft	-	-	10/05/2004
C119944	Island Garden Estates	Domestic	-	-	500	ig	09/23/2004

Total Maximum Annual Licenced Storage:	268.6 ac-ft
Total Maximum Annual Licenced Withdrawal:	138,700,000 ig
Total Maximum Daily Licenced Withdrawal:	500,500 ig

Along with the storage requirements, the water licences also come with an additional requirement to provide a minimum released flow of 0.3 ft^3/s (8.5 L/s) from the dam to Terminal Creek at all times in order to satisfy the requirements of downstream licensees and the fisheries resource.

2.3 Existing Area Population

Based on updated data in 2009 (from BIM), there are an estimated 630 service connections and, assuming 3 persons per service connection, a service area population of 1,890.

2.4 Water Use Efficiency Measures

In 1996, the CBWS started to meter the water demand to all commercial and institutional service connections and all new residential service connections. A water metering program was implemented beginning in 2005 to meter the remaining residential service connections in the service area. There have been 240 meters installed, and approximately 107 residents (as of November 2007) that need to apply for a meter. The metering program is expected to be completed in 2009.

The revised B.C. Water Conservation (Plumbing) Regulation, which took effect September 30th, 2005, requires that all new toilets installed on Bowen Island must be six-litre, low-consumption models.

3.0 WATER SUPPLY REQUIREMENTS

This section reviews the Bowen Island Municipality's (BIM) historical population and per capita demand rates within the Cove Bay Water System. Based on a thorough review of the Municipality's flow records, demands are projected based on BIM's current zoning, OCP, and potential demands from bulk water customers.

3.1 Population

3.1.1 Historical Population

Table 3-1 illustrates the historical populations of the Municipality from 1996 to 2006. The Municipality of Bowen Island population figures were referenced from BC Stats online data.

TABLE 3-1
BOWEN ISLAND MUNICIPALITY
HISTORICAL POPULATION (1996 to 2006)

Year	Municipality of Bowen Island		
	Census Population	% Growth	% Yearly Growth
1996	2,738	-	-
2001	2,957	8.0	1.55
2006	3,362	13.6	2.60

Table 3-2 illustrates the historical populations of the Cove Bay Water System from 1992 to 2008. The Cove Bay Water System population figures were approximated from data provided from the Municipality. Population figures were estimated based on an assumption of 3 persons per service connection.

TABLE 3-2
COVE BAY WATER SYSTEM
HISTORICAL POPULATION (1992 to 2008)

Year	Cove Bay Water System			
	# of Service Connections	Estimated Population*	% Growth	% Yearly Growth
1992	342	1,026	-	-
1998	475	1,425	38.9	5.63
2008	630	1,890	32.6	2.86

* based on 3 persons per service connection

3.1.2 Population Projection

An annual growth rate of 2.60% has been assumed for future projection of service population. This growth rate is based on averaging the historical population and has been compared to the Municipality's Official Community Plan (OCP) from 1995. The Municipality is currently updating its OCP so new population growth figures are not available for this report.

Based on BC Stats data as shown in Table 3-1, the Municipality experienced an increase in population from 2001 to 2006. The growth rate from 2001 to 2006 is estimated at 2.60%, which is much lower than the Municipality's OCP growth rate of approximately 5.0% p.a. from 1991 to 1994.

Table 3-3 illustrates the population projections for the period from 2010 to 2030. A growth rate of 2.60% p.a. is used for both the Municipality of Bowen Island and the Cove Bay Water System.

TABLE 3-3
SERVICE POPULATION PROJECTION TO 2030

Year	Municipality of Bowen Island	Cove Bay Water System
2010	3,726	1,990
2015	4,236	2,262
2020	4,816	2,572
2025	5,476	2,924
2030	6,226	3,324

The projected population in the Cove Bay Water System in 2030 of 3,324 people is equivalent to 1,108 service connections based on an assumption of 3 persons per service connection.

3.2 Water Demand

3.2.1 Historical Consumption and Per Capita Demands

The historical demands of the Cove Bay Water System (CBWS) from 1993 to 1996 and 2000 to 2008 provided by the Municipality were reviewed. Table 3-4 summarizes the total demands of the CBWS, and the average day, peak day and peak hour demands.

The average day demands (ADD) were estimated by dividing the total annual demands by the number of days in a year. The peak day demands (PDD) were estimated using the maximum daily demands from the daily flow records provided by the Municipality. The peak hour demands (PHD) were estimated using flow data recorded at the chlorination station. Data has not been provided for the years between 1997 and 1999.

Online data has been available at the chlorination facility for Cove Bay Water System flows since November 2007. Flow data recorded at a five minute intervals are available and provide sufficient data to measure the peak hour demands in the system. The peaking factor is approximately 4.3 for average day demand to peak hour demand in the CBWS.

TABLE 3-4
HISTORICAL DEMANDS (1993 to 2008)

Year	Total Demand (ML)	Average Day Demand (L/s)	Peak Day Demand (L/s)	Peak Hour Demand (L/s) (1)
1993	191 (2)	6.1	13.2	26.1
1994	156 (2)	5.0	11.7	21.3
1995	189 (2)	6.0	13.1	25.8
1996	196 (2)	6.2	16.7	26.8
2000	308 (2)	9.7	28.3	41.9
2001	261 (2)	8.3	21.1	35.6
2002	284 (2)	9.0	21.0	38.7
2003	273 (2)	8.6	19.2	37.2
2004	295	9.4	27.0	40.2
2005	254	8.0	17.4	34.6
2006	269	8.5	25.4	36.7
2007	291	9.2	20.6	39.6
2008	283	9.0	18.9	38.6

(1) Peaking Factor of 4.3 used
(2) Calculated from Average Day Demand

Based on the historical population in Table 3-4, the per capita rates for average day demand, peak day demand and peak hour demand are summarized in Table 3-5. These per capita demands are also illustrated in Figure 3-1.

TABLE 3-5
PER CAPITA DEMANDS (1993 to 2008)

Year	Per Capita Demands (L/c/d)		
	Average Day	Peak Day	Peak Hour
1993	483	1,054	2,077
1994	374	882	1,610
1995	429	937	1,844
1996	421	1,127	1,810
2000	558	1,619	2,401
2001	462	1,175	1,985
2002	488	1,135	2,097
2003	455	1,010	1,958
2004	479	1,380	2,059
2005	400	864	1,720
2006	413	1,227	1,774
2007	434	968	1,864
2008	410	865	1,763
AVERAGE	**447**	**1,096**	**1,920**
AVERAGE (05-08)	414	981	1,780

Figure 3-1 Historical Per Capita Demands

As illustrated in Figure 3-1, the per capita demands are generally higher from 1993 to 1996, with the per capita ADD at 427 L/c/d. The per capita demands then peak in 2000 with an ADD of 558 L/c/d, and then decrease from 2000 onwards, with the per capita ADD reaching 410 L/c/d in 2008.

Water conservation alerts were announced in the summers of 2004, 2006, and 2008, along with lawn sprinkling restrictions in August and September 2006. However, it can be seen in Figure 3-1 that these alerts had no discernible effect on reducing water usage in the CBWS.

Per capita demand for the CBWS in 2004 was at 479 L/c/d. This is lower than the provincial average of 649 L/c/d and the national rate of 609 L/c/d. However, due to its island municipality nature, low irrigation demand, and low industrial demand, per capita demands are not directly comparable to other municipalities in the province.

The universal metering program that the municipality may initiate after metering all properties could lower the expected CBWS water demand. Evidence of this is shown in a recent universal metering program carried out by the District of West Vancouver, where water usage reduced from a high of 758 L/c/d to 592 L/c/d (22% decrease). However, since the per capita demand of the residents is already low compared to the provincial and national rates of water storage, it is difficult to predict how much lower the water demand will become if water conservation strategies were put into place.

3.2.2 Institutional, Commercial and Industrial (ICI) Demands

The per capita demands estimated in Section 3.2.1 are a summation of ICI demands and residential per capita demands. ICI users typically demand a significant amount of water, occasionally up to 50% of a municipality's water supply.

Information was not available on demand assignment for each of the ICI customers in the municipality. Metering data for all ICI consumers in the municipality will provide data to separate the commercial and residential demands of the Municipality.

The Municipality should meter ICI data on a more frequent basis (weekly snapshot) to monitor peak periods as well. However, in the absence of frequent measurements, based on our experience, we believe that a typical peaking factor is approximately 1.2 to 2 for average day to maximum day demand and approximately 1.8 to 3 for average day demand to peak hour demand in commercial areas.

We recommend metering and reporting ICI demands for the Municipality's future demand projections.

3.2.3 Residential Per Capita Demands

The Municipality's residential per capita demands can be estimated by subtracting the reported ICI demands from the total historical demands, and then divided by the population to estimate the residential per capita demands.

The Municipality is currently implementing a consumer metering program for all residential properties in the Cove Bay Water System. Metering and reporting of residential meters will also provide residential per capita demands for the Municipality.

We recommend the calculation of residential per capita demands for the Municipality's future demand projections.

In the absence of ICI and residential per capita demands, future demand projection in this update will be estimated based on per capita water usage as analyzed in Section 3.2.1, and on service population projection as discussed in Section 3.1.2.

3.2.4 Future Demand Projection

Projection for future water demands can be more accurately measured upon review of existing information such as the metering data for the ICI demands, the residential demands, as well as gathering information on possible future developments in the Cove Bay Water System area.

Since this data is not available, future demands were predicted solely based on existing per capita demands and future population projections. Per capita demands are taken from Table 3-5.

TABLE 3-6
PROJECTED DEMANDS TO 2030

Per Capita Demand (L/c/d)		414	981	1,780
Year	Population	ADD (L/s)	PDD (L/s)	PHD (L/s)
2010	1,997	9.6	22.7	41.1
2015	2,270	10.9	25.8	46.8
2020	2,581	12.4	29.3	53.2
2025	2,935	14.1	33.3	60.5
2030	3,337	16.0	37.9	68.7

3.3 Design Criteria

The design criteria used for this report included a review of minimum service pressures and available fire flows as described under this section

3.3.1 Service Pressures

Service pressures are shown in Table 3-7.

TABLE 3-7
COVE BAY WATER SYSTEM
MINIMUM SERVICE PRESSURES

Peak Hour	275 kPa (40 psi)	
Maximum Day	Hydrant Pressure	150 kPa (20 psi)
Plus Fire Flow	System Pressure	150 kPa (20 psi)

3.3.2 Fire Protection and Storage

Water distribution systems must be able to deliver large volumes of water for fire protection in addition to normal water demands. Fire protection considerations are:

1. Only one fire will be fought at any one time.

2. To ensure pumpers of the fire department obtain adequate water supplies from hydrants, a minimum residual pressure of 150 kPa (20 psi) on the street main is required during fires.
3. Fire flow is coincident with peak day demand.

Fire flow criteria are based on the Fire Underwriters Survey Publication "Water Supply for Public Fire Protection" (1999).

TABLE 3-8
COVE BAY WATER SYSTEM
FIRE FLOW CRITERIA

Zone	Required Minimum Fire Flow		Required Duration of Fire Flow
	(L/s)	(USgpm)	(Hours)
Single Family Residential	60	1,000	1.5
Institutional/Commercial/Recreational (up to 1,600 m^2)	100	1,600	2.0
Institutional/Commercial/Recreational (up to 3,000 m^2)	170	2,650	2.0

3.4 Summary and Recommendations

We reviewed the historical population and flow data provided by the Municipality. Based on a thorough review of this information, we developed a per capita flow rate based on municipal water usage per person. However, the ICI users for the entire Municipality have not been provided and thus the overall residential per capita rates and ICI rates could not be developed.

Based on known residential per capita and ICI demands, along with a projection of the increase in population and ICI users, an accurate projection of future demand can be made. In the absence of this information, the water demands for the Municipality have been projected based solely on the per capita demands and projected population only. Table 3-6 summarizes the five demand scenarios at 2010, 2015, 2020, 2025 and 2030.

We understand the Municipality records the ICI uses currently. We recommend the Municipality to meter on a more frequent basis (weekly snapshot) to monitor peak periods. We also note that BIM is currently near completion of the implementation of a residential metering program. Data from these residential meters, as well as ICI meters should be collected to produce the residential per capita and ICI demands to give a more accurate projection of future demand in the Municipality.

4.0 GRAFTON LAKE HYDROLOGY AND STORAGE REQUIREMENTS

This section reviews the hydrology of Bowen Island Municipality's (BIM) Grafton Lake watershed and determines the one in ten (1 in 10) year return drought capacity of Grafton Lake. Storage capacity is projected based on rainfall records, estimates of water losses due to evapotranspiration and lake evaporation losses, system demands and minimum downstream releases, followed by a frequency analysis to determine the 1 in 10 year low summer flow scenario. Available storage capacity is then presented in terms of an additional number of equivalent residential units (ERUs) available to the Cove Bay Water System (CBWS). The water demands are derived from historical usage data provided from the Municipality. All daily precipitation and monthly temperature data has been obtained from Environment Canada.

4.1 Historical Lake Levels

The Grafton Lake earthen dam is about 35 m in length, about 4 m wide and about 2 m high with a top elevation of 106.81 m. It has a concrete control spillway with a top elevation of 106.01 m and wooden walkway. The dam includes a manually operated 600 mm diameter pipe and control gate that allows for release of water to Terminal Creek. The bottom of the release pipe is at elevation 104.56 m.

A figure highlighting the dam elevation was presented in Figure 2-1.

The water level in Grafton Lake is typically at or above the elevation of the spillway at the control structure from the middle of November until May of each year. The water level varies from May until the middle of November depending on a number of factors including precipitation, inflow from tributary streams, evapotranspiration, evaporation, release rate and CBWS demand. The release gate on the control structure is typically closed and the water level in the lake is at or above the elevation of the spillway until the beginning of May each year.

The lake level profile for the periods 2000 to 2009 are illustrated on Figure 4-1.

It can be seen in Figure 4-1 that lake levels in 2002, 2004 and 2006 had dropped the most. The lake level in 2002 was at the same elevation as the spillway until mid-May, but decreased by 1.0 m by the end of October. This year was noted by the Municipality as one of the driest years on record. Data for 2003 was not available but has been noted as a dry year as well. Meanwhile, lake levels for the years 2000, 2005, 2008 and 2009 did not show large decreases in elevation and are assumed adequate for supply. In 2001 and 2007, the CBWS experienced wet seasons and lake levels did not fluctuate greatly with the top of the spillway.

4.2 Grafton Lake Watershed Yields

Precipitation in any watershed is either transported to underground systems through infiltration through soils, or is captured by tributaries which collect rainwater to a central storage location, usually a lake. In the Grafton Lake watershed, the predominant soils are a thin gravel mantle over bedrock. Therefore, little or no groundwater losses are anticipated in a weekly time period. In addition to precipitation, consideration will also be given to evapotranspiration, the other major parameter affecting watershed yield.

4.2.1 Precipitation

There are seven sites on Bowen Island where precipitation and temperature data are collected by Environment Canada. The station with the longest history of records is the Arbutus Bay rainfall station, which extends back to 1961.

The Josephine Ridge rainfall station, located inside the Grafton Lake watershed, is most representative of the precipitation patterns falling on the watershed. However, only four complete years of data have been recorded at this station. A regression analysis with the monthly precipitation measured at Sunset Park, Arbutus Bay, Bowen Bay, Cates Hill, Millers Landing, and Killarney rainfall stations was done to estimate the rainfall from 1961 to present at Josephine Ridge. For most months, monthly values from Bowen Bay extend the period of estimation from 1966 to 1976, and from 1996 to 2008. For the most part the Millers Landing rainfall station was used to extend the period of estimation from 1978 to 1991. A regression with the Arbutus station completes the regression analysis from 1961 to 1965. Table 4-1 presents a summary of climatic normals for the Josephine Ridge rainfall station since 1961.

TABLE 4-1
JOSEPHINE RIDGE PRECIPITATION NORMALS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Precipitation	224.6	155.9	154.5	109.2	102.9	67.8	48.7	65.4	82.1	190.6	247.7	236.5
Maximum Precipitation	424.4	367.5	362.1	242.6	191.7	160.4	198.3	373.5	292.6	527.2	434.6	449.8
Minimum Precipitation	27.5	7.6	37.5	30.2	32.1	14.2	3.8	0.6	2.9	24.0	79.4	90.7

The regression tables for each separate month can be found in Appendix A.

The mean monthly precipitation for the Josephine Ridge rainfall station was then used to calculate the Grafton Lake inflows. All the rain that fell in the watershed was assumed to reach the lake, except for the evapotranspiration losses from the forest vegetation.

4.2.2 Potential Evapotranspiration

Since groundwater infiltration is assumed to be negligible on Bowen Island, the precipitation that falls over the watershed area either enters the lake, or evapotranspirates. A monthly loss was calculated using the Thornewaite equation:

$Loss = 16\,(10\,T_a/I)^a$,

Loss	=	monthly potential evapotranspiration in mm
T_a	=	mean monthly air temperature in °C
a	=	$.675\,(10^{-6})\,I^3 - 0.0771\,(10^{-3})\,I^2 + 0.01792\,I + 0.49$
I	=	$\Sigma(T_a/5)^{1.514}$

Losses due to evapotranspiration are calculated to determine inflows to the lake before evaporation losses from the lake, downstream releases and water demand releases occur.

4.2.3 Watershed Yield

The estimated monthly inflows into Grafton Lake equals the difference between monthly precipitation and evapotranspiration in mm, distributed over the 709.2 ha surface of the watershed. The calculation is based on the assumptions of one hundred percent runoff, one hundred percent potential evapotranspiration and one hundred percent drainage (i.e. no depressional storage losses). The following section discusses the sensitivity of the analyses to these assumptions.

4.2.4 Improvements to Watershed Yield Calculations

It should be noted that the watershed yield calculations are theoretical estimates based on the assumptions mentioned, and further supporting information should ultimately be established to confirm/adjust the data.

A watershed characterization program is an option to better understand and assess the reliability and availability of the watershed yield approximates. A streamflow measurement program, which consists of a weir installation program at all streams entering Grafton Lake, will give an accurate estimate of watershed yield. This is similar in nature to the Voluntary streamflow measurement program currently in place and measured by A.J. Whitehead Associates from 2003 to 2008. However, it is required that measurements will have to be continuously measured through summer months to accurately measure runoff into Grafton Lake.

4.3 Grafton Lake Watershed Losses

Water is lost from Grafton Lake by evaporation, controlled releases to Terminal Creek and withdrawal for CBWS consumption through the supply main.

4.3.1 Evaporation Losses

Evaporation losses from Grafton Lake were calculated from the product of the surface area of Grafton Lake and the average monthly pan evaporation. The evaporation data used was from previously obtained information from the University of British Columbia weather station, which was also used in the 1997 Cove Bay Water System analysis. A constant average reservoir surface area of 19.1 ha was used to evaluate the lake evaporation of each month. The maximum evaporation was 23,302 m^3 in July while the minimum was 2,330 m^3 in December.

4.3.2 Minimum Release Rate

The Ministry of Environment water license requires the CBWS to maintain a minimum flow of 8.5 L/s (0.3 ft^3/s) downstream of the Grafton Lake Dam. This is assumed to be from storage.

4.3.3 CBWS Demand

The CBWS historical water demand was collected for the years 2000 to 2008 from the Municipality. The daily and weekly variation in the summer water demand varies from year to year. For purposes of this analysis, a modified summer 2008 CBWS demand profile, as illustrated in Figure 4-2, was used in the analysis of the Grafton Lake storage impacts.

The year 2008 was chosen to accurately represent the current demands in the CBWS. The summer demand from May to October totaled 157,927 m^3, which corresponds to a daily flow of 858,299 L/d, and a per connection demand of 1,362 L/conn/day at 630 connections.

4.3.4 Watershed Losses

The estimated monthly losses from Grafton Lake equal the sum of the evaporation losses, the minimum release to Terminal Creek, and the CBWS demand. Calculations are based on the assumptions of one hundred percent evaporation, and a constant rate of flow of 8.5 L/s to Terminal Creek. CBWS demands are based on total municipality water usage flows obtained from the Cove Bay Chlorination Facility.

4.3.5 Improvements to Watershed Loss Calculations

It is important to note that during the peak month of evaporation (i.e. the month of July), water evaporates at a rate of 23,302 m^3/month (8.7 L/s). At the same time, the minimum release to Terminal Creek is at 8.5 L/s, and the CBWS demand is at an average of 13.5 L/s. While the flows to the CBWS are measured at the chlorination facility and assumed to be accurate, the assumptions of one hundred percent evaporation and a constant release of 8.5 L/s to Terminal Creek should be reviewed at the discretion of the Municipality to confirm/adjust the approximates.

4.4 Grafton Lake Storage Capacity

The volume of water is stored in Grafton Lake is a function of its bathometry. Table 4-2 tabulates the stage – storage curve that describes the amount of storage volumes and surface area that is available for a range of lake depths. These relationships are from the Ministry of Environment bathometric survey undertaken in 1983.

Grafton Lake presently has a live storage capacity of 222,000 m^3 tributary to Terminal Creek, although the MOE license is for 320,000 m^3. Live storage refers to the lake depth behind the control dam which can be released to Terminal Creek by gravity flow. Raising the control dam about 0.5 m (2.0 ft) would provide the additional storage allowed under the MOE license.

TABLE 4-2
GRAFTON LAKE STORAGE CAPACITY

Contour Elevation	Storage Capacity				Remarks
	Depth of Storage (m)	Area (ha)	Storage (dm^3)		
			Net	Gross	
103.00		11.80	52.0		Dead Storage
	-1.50	11.90	7.1	190	
	-1.00	12.40	61.0	130	
	-0.80	12.60	25.0	105	
	-0.60	12.80	25.0	79	
		12.80	5.1		
	-0.40	13.10	21.0	53	
	-0.20	13.40	26.0	27	
	0.00	13.70	27.0	0	Invert
	0.20	14.00	28.0	28	Live Storage
	0.40	14.30	28.0	56	
		14.40	5.7		
	0.60	15.20	24.0	85	
	0.80	16.10	31.0	117	
	1.00	17.00	33.0	150	
	1.20	18.00	35.0	185	
	1.40	18.90	37.0	222	
106.01	1.45	19.20	1.9	231	Potential Storage
	1.60	20.20	30.0	261	
	1.80	21.60	42.0	302	
106.56	2.00	23.00	45.0	347	

4.5 Grafton Lake Storage Capacity Analysis

It is common engineering practice to design water supply reservoirs for the one in ten year drought. A one in ten year low summer inflow volume will be analyzed as part of the storage capacity calculations of Grafton Lake. Results of the storage analysis will be represented as a percentage of 2008 flows, which will be converted to additional flow capacity, and finally into potential additional equivalent residential units. The equivalent residential unit calculation is a tool that the municipality can use to better understand the extent of the future capacity of Grafton Lake.

4.5.1 Monthly Frequency Analysis

The monthly net inflows into Grafton Lake as estimated from the regression analysis of monthly rainfall for the 41 year period of extended record, 1961, 1963, 1965 – 1978, 1984 – 2008, were analyzed to determine the frequency of inflows. Figure 4-3 presents a comparison of the monthly inflows with a 90% probability of exceedance in any one year (i.e. the 1:10 monthly drought flows). Appendix B has the frequency curves for each month.

4.5.2 Summer Inflow Frequency Analysis

The reservoir is full at the beginning of May and is typically replenished by rainfall in early November. Summer inflows are low to negative. While the estimated monthly inflows with a 90% probability of exceedance are shown in Figure 4-7, the likelihood of the combination of these monthly volumes occurring in the same year is less frequent. The entire summer season for each year, May to mid-September inclusive, was analyzed to obtain the 1:10 low summer inflow into Grafton Lake. The monthly lake evaporation and required downstream water releases are assumed constant throughout the period of analysis and therefore only the rainfall minus the potential evapotranspiration losses were included in the summer period frequency analysis.

From the frequency curve developed for the 41 year period of extended record, the 1:10 May to mid-September summer inflow total estimated volume is 190,000 m^3 and the 1:2 summer inflow total estimated volume is 550,000 m^3. The 1:15 summer inflow total estimated volume is 130,000 m^3, and the 1:20 summer inflow total estimated volume is 68,000 m^3. The frequency curve for the summer total can also be found in Appendix B.

Four years in the period of extended record are below the 1:10 year low flow estimate:

- 2003 with 0 m^3
- 1963 with 66,000 m^3
- 1965 with 166,000 m^3
- 1967 with 184,000 m^3

Not only is the overall summer volume crucial to the supply of water but so also is the pattern of rainfall. In 2003, rainfall equalled potential evapotranspiration losses from May to mid-September. No net inflows are estimated to enter the lake until October. In 1963, slight inflows are estimated to have occurred in May, with no positive inflows estimated to have occurred in the rest of the summer period.

4.5.3 Grafton Storage Analysis

The analysis of the storage requirements and service potential of the present facilities at Grafton Lake was based on recorded daily rainfall at the Josephine Ridge station and the idealized weekly demand curve, developed from 2008 recorded demands. The results are presented as a percentage of 2008 demand, which are then converted into additional supply capacity in L/d, and finally converted into equivalent residential units (ERUs), described below, which will give the Municipality a better understanding of the potential development in the CBWS.

4.5.3.1 Equivalent Residential Units

Measurements of the additional service capacity of Grafton Lake will be presented in Equivalent Residential Units (ERUs). An ERU is generally defined as the total single-family residential demand divided by the number of single-family residential connections. Other demand classifications are then defined in ERUs by dividing the total demand for that classification by the calculated ERU value.

Data has been provided by the Municipality on 79 metered connections in the Snug Cove Sewer District. Sewer costs are based on water usage, while water usage is in turn charged based on a water tariff system for these connections, and will provide information on expected usage for metered connections in the CBWS for the following classifications:

- Single-Family Residential
- Multi-Unit Residential
- Commercial
- Civic

The calculated per classification average demand based on the metering records and subsequent ERUs are presented in Table 4-3.

TABLE 4-3
AVERAGE DEMAND AND EQUIVALENT RESIDENTIAL UNITS FOR METERED CONNECTIONS IN SNUG COVE SEWER DISTRICT

Classification	L/conn/day	ERU
Single-Family Residential	589	1.0
Multi-Unit Residential	265	0.45
Commercial	2,065	3.51
Civic	2,419	4.11
Average Metered Connection	1,255	-

It is noted that the average metered connection demand is 1,255 L/conn/day, which is 8% less than the current per connection CBWS demand of 1,362 L/conn/day as calculated in Section 4.3.3. This evidence supports a decreased demand in water usage upon metering of the properties on Bowen Island. Water usage has been charged on metering in the Snug Cove Sewer District since the start of metering in 2003, so the 8% reduction in demand is a useful number in determining total water reduction due to metering.

However, it is also noted that the demand of 1,255 L/conn/day is representative based on a distributed property classification as seen in the Snug Cove Sewer District (i.e. 79 connections to 63 Single-Family, 44 Multi-Family, 19 Commercial, and 2 Civic users). As the density of commercial and civic addresses are higher in the Snug Cove Sewer District compared to the CBWS, the demand of 1,255 L/conn/day is a high estimate for potential metered connections. Therefore, there is possibility for water use efficiency savings for the CBWS.

4.5.3.2 Storage Analysis Results

As the rainfall volume and intensity are both crucial to the storage analysis, a range of years were analyzed to determine the worst case scenario for the purposes of this report. Drought years of 2002, 2004, 2006 and 2008 were analyzed. This study recommends the 1:10 year drought volume with the 2002 rainfall distribution pattern to estimate the maximum potential number of additional ERUs that could be accommodated under the present MOE storage license.

The 2002 daily rainfall minus the estimated monthly potential evaporation, prorated to occur with the rainfall, over the watershed area was adjusted to have the same volume as the 1:10 year drought. During weeks when there was no rainfall, evapotranspiration was assumed not to occur. The total evapotranspiration loss for the month, however, equaled the monthly potential estimate. The potential evapotranspiration was prorated to occur with the rainfall by multiplying the daily rainfall by the ratio of the monthly potential evapotranspiration to the monthly total precipitation. Thus evapotranspiration losses occurred in the same week as the rainfall.

The estimated constant daily losses due to lake evaporation and required downstream releases to Terminal Creek were deducted from the estimated inflows to Grafton Lake. The sum for the week was compared to the water demand. Excess inflow increased the lake live storage volume to its present capacity of 222,000 m3 in one scenario, and to the limit of its MOE license, 320,000 m3in the second. Weekly water demands greater than the estimated inflow decreased the lake live storage.

Figure 4-4 illustrates the calculated lake volume changes over the period May to November for the current lake capacity. Table 4-4 lists the potential maximum number of ERUs.

Note that the Grafton Lake storage analysis may be overestimating the amount of evapotranspiration and evaporation losses.

In a similar fashion, the 2007 daily rainfall pattern minus the prorated monthly potential evapotranspiration over the watershed area was adjusted to have the same total summer volume as the estimated 1:2 year inflows. Losses were deducted and the resultant inflows compared to releases. Figure 4-5 illustrates the lake volume changes over the summer while Table 4-4 lists the results of the analysis.

TABLE 4-4
SUMMARY OF GRAFTON LAKE STORAGE ANALYSIS

	Lake Capacity of 222,000 m^3			Lake Capacity of 320,000 m^3		
	% of 2008 CBWS Demand Serviced	Additional Capacity		% of 2008 CBWS Demand Serviced	Additional Capacity	
		L/d	ERU		L/d	ERU
2002 actual summer volume	175	643,724	1,093	236	1,167,287	1,982
2002 adjusted to 1:10 summer volume	66	-	-	127	232,490	395
2004 adjusted to 1:10 summer volume	109	77,247	131	211	952,712	1,618
2007 actual summer volume	167	575,060	976	305	1,759,513	2,987
2007 adjusted to 1:2 summer volume	143	369,069	627	212	961,295	1,632

The volume of inflow has less effect than the rainfall distribution pattern. While the 2002 summer inflow volume is 153 percent of the expected 1:10 low inflow volume, the percentage of potential demand serviced increases by 265 percent (from 66% to 175%). The same amount of summer inflow volume, but distributed according to a different rainfall pattern (e.g. 2004 rainfall), increases the potential demand serviced. As Figure 4-4 shows, very dry Junes, Julys, Augusts and Septembers are a usual drought pattern. Therefore, it is reasonable to limit the number of service connections based on the 2002 pattern of rainfall distribution adjusted to the 1:10 year summer volume.

4.6 Sensitivity Analysis

The water balance conducted for this study has been limited by four years of recorded data for the daily rainfall, the use of average monthly pan evaporation from a weather station which is no longer in service, and no actual consistent flow measurements into the lake. Assumptions were made regarding the groundwater losses, potential evapotranspiration, lake evaporation losses, the water demand and the actual boundary of the watershed. The following sub-sections discuss the sensitivity on the water balance analysis of Grafton Lake storage capacity to these assumptions.

4.6.1 Water Demand

Past water conservation measures taken by BIM include public education programs, and the posting of water conservation alerts and sprinkling restrictions in the community newsletter and on Bowen Island's website. However, as concluded after reviewing historical consumption numbers, these alerts had no discernable effect on water consumption in the CBWS.

Universal metering of all properties could lower the expected CBWS water demand. However, this is hard to quantify as the CBWS is already very water conscious and has taken steps to monitor its flow. Conversely, in the absence of water use efficiency measures, the water demand in the future could increase. Table 4-5 presents the range of the number of service connections which can be accommodated with a variation in the assumed per unit water demand.

TABLE 4-5
SENSITIVITY OF ESTIMATE TO WATER DEMAND

Percentage of 2008 Demand	Lake Capacity of 222,000 m^3			Lake Capacity of 320,000 m^3		
	% of 2008 CBWS Demand Serviced	Additional Capacity		% of 2008 CBWS Demand Serviced	Additional Capacity	
		L/d	ERU		L/d	ERU
80	83	-	-	159	404,150	686
85	78	-	-	150	361,235	613
90	73	-	-	141	318,320	540
95	70	-	-	134	275,405	467
100	66	-	-	127	232,490	395
105	63	-	-	121	189,575	322
110	60	-	-	116	146,660	249
115	57	-	-	111	103,745	176
120	55	-	-	106	60,830	103

The variation is a strict percentage of the idealized water demand curve, with no adjustments to the demand pattern. The table is based on the design 1:10 year inflow. As seen from the table, when the unit demand lowers to 80% of the present unit idealized demand, the number of additional ERUs increases by 74 percent. If the unit demand increases to 120% of the present unit idealized demand, the maximum number of additional ERUs that could be accommodated decreases by 74 percent. There is no reason to expect the latter to occur.

4.6.2 Drainage Area

Any errors in the estimation of the drainage area, the losses to groundwater, evaporation, evapotranspiration or depressional storage will alter the frequency analysis. Table 4-6 lists the range of the maximum number of service connections possible if the estimate of the 1:10 summer inflow differs because of under estimation of the groundwater and depressional storage losses (assumed equal to zero in this study), the evaporation losses or inaccurate drainage boundaries. The table is based on the 2008 idealized demand curve and current and potential lake capacities.

TABLE 4-6
SENSITIVITY OF ESTIMATE TO DRAINAGE AREA

Variance (Percent)	1:10 Estimate (m^3)	Drainage Area [(1)] (ha)	Lake Capacity of 222,000 m3			Lake Capacity of 320,000 m3		
			% of Demand Serviced	Additional Capacity		% of Demand Serviced	Additional Capacity	
				L/d	ERU		L/d	ERU
-20	152,000	567	51	-	-	112	106,733	181
-15	161,500	603	55	-	-	116	138,172	235
-10	171,000	638	59	-	-	120	167,612	285
-5	180,500	674	62	-	-	123	201,051	341
0	190,000	709	66	-	-	127	232,490	395
5	199,500	745	70	-	-	131	263,929	448
10	209,000	780	73	-	-	134	295,368	501
15	218,500	816	77	-	-	138	326,807	555
20	228,000	851	81	-	-	142	358,247	608

(1) If the error in the 1:10 estimate is due solely to the measurement of the drainage area

4.7 Summary and Recommendations

4.7.1 Summary

The present Grafton Lake storage capacity of 222,000 m^3 is capable of supplying about 66% of the current CBWS demand based on the CBWS's present rate and pattern of water demand under a 1:10 estimated summer inflow volume. However, this percentage is theoretical and based on assumptions mentioned in this report. Watershed yield and watershed loss calculations can be refined to give a better estimate of storage capacity.

Raising the control dam 0.50 m (20 inches) would increase live storage to the limit of the MOE license (320,000 m^3) and permit about 127% of the current CBWS demand to be serviced. This results in a surplus capacity of 232,490 L/d which will allow up to 395 ERUs to be constructed. A reduction of 10% in the water demand would service 141% of the CBWS demand and allow up to 540 ERUs to be allocated.

4.7.2 Recommendations

It is recommended that the Municipality:

1. Continue monitoring the lake levels on a weekly basis during May to October of each year.
2. Increase the available storage in Grafton Lake to match the storage allowed in the water licenses by raising the spillway by 0.5 m (20 in.).
3. Set the maximum number of additional residential equivalent service connections allowed on the CBWS at 395, assuming the lake is raised by 0.5 m, and that it be reviewed in ten years as historical watershed data is obtained.

5.0 WATER QUALITY

5.1 British Columbia Safe Drinking Water Regulation

The British Columbia Drinking Water Protection Regulation was instituted on May 16, 2003. The regulation provides a framework for the construction and operation of a domestic water system to ensure that potable water system is supplied to all users of a waterworks system. The regulation specifically identifies the microbiological standards to be met (Table 5-1). Failure to meet the B.C. standards can result in a fine of not more than $200,000 or imprisonment for not more than 12 months or both.

TABLE 5-1
B.C. DRINKING WATER PROTECTION REGULATION
MICROBIOLOGICAL STANDARD

For a waterworks system to meet the standard, sample tests must meet the following criteria:		
Fecal coliform bacteria		0 fecal coliform/100 mL
Escherichia coli		0 total escherichia coli/100 mL
Total coliform bacteria		
i.	One sample in a 30-day period.	0 total coliform/100 mL
ii.	More than one sample in a consecutive 30-day period.	90% or more of the samples must have 0 total coliform/100 mL and no sample must have more than 10 total coliform/100 mL.

In addition, while general in definition in the British Columbia Drinking Water Protection Act (April 2001), potable water must "meet the standards prescribed by the regulation" and be "safe to drink and fit for domestic purposes without further treatment". The criteria adopted by Health Canada are the "Guidelines for Canadian Drinking Water Quality".

In these guidelines, Maximum Acceptable Concentrations (MAC) have been established for certain substances that are known or suspected to cause adverse effects on health. They have been derived to safeguard health on the basis of lifelong consumption. To the extent possible, the use of drinking water for all usual domestic purposes, including personal hygiene, has been considered in the derivation of the Guidelines. However, water of higher quality may be required for some special purposes, including renal dialysis.

The guidelines are the result of a cooperative Federal/Provincial process and are used as targets for drinking water quality.

Health Canada provides the leadership in determining what guidelines need review. The present 2008 edition of the Guidelines contain guidelines on biological water quality, aesthetic water quality, chemical and physical characteristics and radiological characteristics. At the present time, there are 68 MAC for chemicals, 25 aesthetic objectives, and 1 operational guidance value. About 30 parameters have no guidelines as there is either no data indicating a health risk, or may be harmful but not registered for use in Canada or not likely to occur in drinking water.

The need to review or develop a new guideline is determined on a priority basis by Health Canada. The initial of a review could be triggered for a number of reasons, but is usually the result of a review of recent scientific information. The provinces and territories all have appointed representatives to the Federal/Provincial Subcommittee on Drinking

Water. It is this group which is responsible to provide a technical review of the proposed changes and establish a provincial or territorial position.

5.2 Long Term 2 Enhanced Surface Water Treatment Rule

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) mandates filtration and disinfection for all water utilities in the U.S. using surface water as a source unless the raw water is of high enough quality that disinfection alone is suitable. The United States Environmental Protection Agency (USEPA) has assumed that all surface water supplies are at risk of contamination from Cryptosporidium parvum, Giardia lamblia and other protozoa, viruses and pathogenic bacteria. All public water systems are required to disinfect and, unless certain water quality source requirements are met, filtration is mandated. Treatment (disinfection with or without filtration) must achieve at least 99.9 percent (referred to as 3 log) removal or inactivation of Giardia lamblia cysts, 99.99 percent (referred to as 4 log) removal or inactivation of viruses and provide at least 99 or 99.9 percent (2 or 3-log) inactivation of Cryptosporidium parvum oocysts, depending on the results of their monitoring.

5.2.1 Filtration

Operating criteria are established for systems that must install filtration. At no time must the filtered water turbidity exceed 1 nephelometric turbidity unit (NTU) and 95% of the measurements taken at each plant must be less than or equal to 0.3 NTUs.

The residual disinfectant in treated water entering the distribution system must not be less than 0.2 mg/L and must be detectable anywhere in the distribution system.

5.2.2 Filtration Variance

Filtration of a surface water source or a groundwater source under the direct influence of surface water may not be necessary if *all* of the following conditions are met:

1. Overall inactivation is met using a minimum of two disinfectants:

   - ultraviolet irradiation or ozone to inactivate cysts/oocysts;
   - chlorine (free chlorine) to inactivate viruses; and
   - chlorine or chloramines to maintain a residual in the distribution system.

   Disinfection should reliably achieve at least a 99% (2-log) reduction of *Cryptosporidium* oocysts,* a 99.9% (3-log) reduction of *Giardia lamblia* cysts and a 99.99% (4-log) reduction of viruses. If mean source water cyst/oocyst levels are greater than 10/1000 L, more than 99% (2-log) reduction of *Cryptosporidium* oocysts and 99.9% (3-log) reduction of *Giardia lamblia* cysts should be achieved. Background levels for *Giardia lamblia* cysts and *Cryptosporidium* oocysts in the source water should be established by monitoring as described in the most recent "Protozoa" guideline document, or more frequently during periods of expected highest levels (e.g., during spring runoff or after heavy rainfall).

2. Prior to the point where the disinfectant is applied, the number of *Escherichia coli* bacteria in the source water does not exceed 20/100 mL (or, if *E. coli* data are not available, the number of total coliform bacteria does not exceed 100/100 mL) in at least 90% of the weekly samples from the previous 6 months.

3. Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are around 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period. Source water turbidity also does not show evidence of protecting microbiological contaminants.

4. A watershed control program (e.g., protected watershed, controlled discharges, etc.) is maintained that minimizes the potential for fecal contamination in the source water.

5.3 Grafton Lake Water Quality and Issues

While the Ministry of Health analyses water quality every week for bacteriological quality, the CBWS has limited historical Grafton Lake water quality data to identify the issues. Water quality data is available for the following dates:

TABLE 5-2
GRAFTON LAKE WATER QUALITY REPORTS

Date	Comment
June 28, 2004	Enhanced Water Potability
December, 2004	Enhanced Water Potability
March 21, 2006	Enhanced Water Potability
December 12, 2006	Enhanced Water Potability
December 18, 2006	THM and HAA Analysis
May 15, 2007	Enhanced Water Potability
December 6, 2007	Enhanced Water Potability
December 9, 2007	THM and HAA Analysis
June 18, 2008	Enhanced Water Potability
December 28, 2008	THM and HAA Analysis
December 29, 2008	Enhanced Water Potability

The reports for the above sample dates are provided in Appendix C.

In the absence of water quality data, however, the following potential issues are noted in a comparison with the B.C. Drinking Water Protection Regulations and the Guidelines for Canadian Drinking Water Quality.

a) **Microbiological**

i) Giardiasis: *Giardia lamblia* (Protozoa) is an intestinal parasite which is transmitted by most warmblooded animals and can affect humans. There is renewed concern about Giardia since a beaver population became established in Grafton Lake.

The CBWS has not yet received a positive test for Giardia, however, it has received previous notification from North Shore Health in a letter dated May 27, 1997 indicating concern about the presence of beavers in Grafton Lake and the potential health risks associated.

ii) Cryptosporidium: Cryptosporidium and the threat of cryptosporidiosis have emerged since 1976 when it was learned that this organism could cause disease in humans. Cryptosporidium is a protozoan parasite that can live in the intestines of humans and animals. Several species of Cryptosporidium exist, but only one, Cryptosporidium parvum, is know to be infective by an outer shell called an oocysts. Once ingested, the organism emerges from the shell and infects the lining of the intestine. Cryptosporidium is prevalent in surface water (lakes, river, and streams). Cryptosporidium can be found in animal droppings and human sewage.

The CBWS has not yet received a positive test for Cryptosporidium in its source waters.

iii) Total and Fecal Coliforms: A number of organisms have been considered as indicators of health risk for consumption of drinking water. These include the fecal coliforms which have been used for a number of years as the legal water quality indicator. Coliform bacteria occur naturally in the soil and on vegetation, whereas fecal coliforms are restricted to the gastro-intestinal tract of warm-blooded animals such as birds and mammals, including humans. Because the number of pathogenic organisms present in water are few and difficult to isolate, the coliform organisms which is more numerous (each person discharges 100 to 400 billion coliform organisms per day) and more easily tested for, is used as an indicator organism. The presence of coliform organisms is taken as an indication that pathogenic organisms may also be present and the absence of coliform organisms is taken as an indication that the water is free from disease producing organisms. According to Health Canada guidelines, the maximum acceptable concentration for total coliforms in public drinking water systems, in water leaving a treatment plant is no organisms detectable per 100 mL. However, in practice, this level is not always attainable.

In a distribution system, no consecutive samples from the same site or not more than 10% of samples in a given sampling period, based on a minimum of 10 samples, should show the presence of total coliform bacteria. In distribution systems where fewer than 10 samples are collected, no sample should contain total coliform bacteria. If the above conditions are exceeded, the system owner should notify all responsible authorities and immediately re-analyse the coliform-positive sample(s) and resample and test the positive site(s) to confirm the presence or absence of both *E. coli* and total coliforms.

Total and fecal coliform counts have been detected in the raw water. Steps have been taken by the CBWSLAC to prevent the main source of waste accumulation, which is swimming in Grafton Lake.

The present disinfection system effectively eliminates coliforms from the CBWS. The use of sodium hypochlorite in addition to a re-chlorination station maintains a disinfectant residual throughout the system at all times.

b) **Turbidity:** Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines through a liquid sample. Turbidity in water is caused by any suspended matter which interferes with the clarity of the water. This may include clay or silt, algae, and other organic or inorganic compounds.

Typical sources of turbidity in drinking water include runoff from disturbed or eroding watersheds, algae or aquatic weeds and products of their breakdown in water reservoirs, rivers or lakes and humic acids and other organic compounds resulting from decay of plants and leaves in water sources.

Excessive turbidity in drinking water is not only unsightly, but also may be a health concern, since the turbidity-causing particles can interfere with the disinfection process. In effect, the particles of turbidity provide "shelter" for microbes by reducing their exposure to the action of the disinfectant. Turbidity also reacts with disinfectants directly, causing quick depletion of disinfecting power, possibly allowing disease causing pathogens to survive and be passed into the distribution system. Turbidity causing particles can provide food for microbes, promoting their regrowth in the distribution system.

Filtration of a surface water source may not be necessary if *all* of the following conditions are met:

i. Overall inactivation is met using a minimum of two disinfectants:
   - Ultraviolet irradiation or ozone to inactivate cysts/oocysts;
   - Chlorine (free chlorine) to inactivate viruses; and
   - Chlorine or chloramines to maintain a residual in the distribution system.

ii. Prior to the point where the disinfectant is applied, the number of *Escherichia coli* bacteria in the source water does not exceed 20 / 100 ml (or, if E. coli data are not available, the number of total coliform bacteria does not exceed 100 / 100 ml) in at least 90% of the weekly samples from the previous 6 months.

iii. Average daily source water turbidity levels measured at equal intervals (at least every 4 hours), immediately prior to where the disinfectant is applied, are annual 1.0 NTU but do not exceed 5.0 NTU for more than 2 days in a 12-month period.

iv. A watershed control program (e.g., protected watershed, controlled discharges, etc.) is maintained that minimizes the potential for faecal contamination

The CBWS currently treats its water supply with chlorine to inactivate viruses, and with further chlorine in its system to maintain a residual in the distribution system. While total coliforms and NTU measurements from the CBWS meet the guidelines above, measurements are not as frequent as recommended by Health Canada, and therefore the reliability of the cleanliness of the source waters cannot be commented on with confidence.

The CBWS should seek to install a filtration system to secure a cleaner and more reliable supply for its residents.

c) **pH:** The pH value is a measure of the hydrogen iron concentration in the water and it indicates the balance between acids and bases. The Guidelines for Canadian Drinking Water Quality recommend a pH for drinking water between 6.5 to 8.5. A pH greater than 8.5 increases the frequency of incrustation and scaling while a pH less than 6.5 indicates a corrosive water. The Grafton Lake pH varied between 6.1 and 7.5, which indicates that the water is approximately neutral, but slightly corrosive at times during the year.

d) **Alkalinity/Hardness:** Alkalinity is a measure of the water's capacity to neutralize an acid while hardness is a measure of the divalent cations, especially magnesium and calcium. Alkalinity standards have been set as a guide to chemical balance with water for treatment processes involving chemical addition, to control corrosion within a distribution system, provide conditions that do not favour the leaching of lead, and to minimize gastro-intestinal problems. Hardness can have a positive effect on human health but may have a detrimental effect on piping due to scaling. According to Health Canada guidelines, the acceptable alkalinity range is 25 to 75 mg/L as CaCO3 while the hardness should be between 80 to 100 mg/L as CaCO3.

The Grafton Lake hardness was about 16 to 30 mg/L as CaCO3. Numbers on alkalinity were not reviewed in the enhanced potability tests. The water would be classified by Health Canada as very soft. Soft water can lead to corrosion of pipes, and consequently, certain heavy metals such as copper, zinc, lead and cadmium may be present in the distributed water. The degree to which this occurs is also a function of pH, alkalinity and dissolved oxygen concentration. In some communities, corrosion is so severe that the water must be treated.

e) **Corrosion:** The CBWS has very soft water because it is derived from rain water and snowmelt, and its short contact time with the soil significantly reduces the opportunity to acquire buffering minerals before being withdrawn at the intake.

The initiation and optimization of a comprehensive corrosion control program are based on the levels of specific contaminants at the consumer's tap. Although corrosion will affect the leaching of several contaminants, lead will be examined since it is the contaminant whose presence is most likely to result in adverse health effects.

The technical guideline from Health Canada to monitor corrosion in distribution systems through sampling at consumer's cold drinking water taps is currently being updated and has not been summarized in this report.

f) **Colour:** The Health Canada recommended maximum objective level is less than 15 True Colour Units (TCU). While the standard is set for aesthetic considerations, the presence of colour is viewed as an indicator of levels of complex natural organic matter (humic substance) resistant to microbial degradation. Organic content is a problem for a number of reasons:

1. Certain organics contribute to taste and odour problems.
2. The presence of organic matter may lead to problems with biological quality changes in the distribution system.
3. The presence of organic matter may aggravate corrosion problems.
4. Organic compounds have been shown to interfere with oxidation and removal of iron and manganese.
5. Haloforms and other halogenated organic compounds can be formed on addition of chlorine.
6. Certain organic compounds are harmful.
7. Organic matter can shield waterborne pathogens from disinfection treatment and can lead to water quality problems in the distribution system.
8. May adversely affect some industrial processes.

Colour could also be a result of natural mineral components such as iron and manganese.

The CBWS raw water colour was less than the Health Canada objective of 15 TCUs for all water quality tests. In general, colour has not been a problem based on available historical data.

g) **Total Organic Carbon:** The Total Organic Carbon (TOC) is a direct expression of the total organic carbon in the water such as humic substances, which have the potential to create Disinfection By-Products (DBP's). The TOC measures the amount of carbon associated with organic compounds in a sample. The lower the TOC the lower the organic compounds present and the lower the DBP in reaction with disinfectants such as chlorine.

There are no standards for the TOC levels in B.C. Drinking Water Protection Regulation or the Guidelines from Health Canada. According to the Water Quality Guidelines from the Environmental Protection Division of the Ministry of Environment, a maximum recommended level of 4 mg/L is acceptable in source waters where chlorination is the treatment method.

The TOC at the intake was not measured, but tests suggest this number may be exceeded, with evidence of fecal and total coliforms in enhanced water potability tests in 2004, 2006, and 2007.

h) **Disinfection By-Products:** Disinfection by-products form a by-product when a disinfectant is added to water. The resulting reaction of the disinfectant with organics in the water forms disinfection by-products. These by-products are a concern because some are suspected carcinogens. As a result of this concern, trihalomethanes (THMs), a disinfection by-product, is presently regulated by Health Canada at an average annual limit of 0.100 mg/L (100 μg/L) based on a locational running annual average of a minimum of quarterly samples. Haloacetic Acids (HAA), another disinfection by-product, is also regulated by Health Canada with a maximum acceptable concentration of 0.08 mg/L (80 μg/L) based on at least four water samples.

From three tests done in December 2006, 2007 and 2008, it was found the average Trihalomethane count in the Cove Bay Water System was at 0.094 mg/L

(94 μg/L). However, it should be noted that at least four samples are required by Health Canada to identify the average annual reading of trihalomethanes in the supply. It should also be noted that the THM measurement taken in 2008 was 150 μg/L, which is high compared to the recommended limit.

i) **Temperature:** A water temperature of less than 15°C is considered acceptable for domestic consumption according to the Health Canada Guidelines. Water temperature also affects the efficiency of some water treatment processes, influences the biological growth in distribution lines and may impact on taste and odour characteristics. There is no historical Grafton Lake raw water temperature.

j) **Bacterial Regrowth:** Bacterial regrowth occurs on the walls of the distribution system and in the distribution system water either as cells associated with suspended solids or as free living cells. Bacterial regrowth within the distribution system is a complex phenomenon influenced by the impact of disinfection, water temperature, available nutrients, residence time in the distribution system, total organic carbon and chlorine residual. Other factors include pipe material, water pH, and shear forces between the moving water and the stationary pipe walls.

The CBWS and the Ministry of Health take routine water samples from selected locations within the CBWS's water distribution system. However, information was not available for review in this report.

5.4 Summary and Recommendations

5.4.1 Summary

Identified issues with Grafton Lake water quality include turbidity levels that exceed Health Canada guidelines. The hardness and colour values also do not reach minimum limits in the guidelines. It was found in the 2008 THM Analysis that disinfection by-products may possibly exceed values in Health Canada guidelines. However, more tests are needed to accurately determine its levels according to the guidelines.

There are a number of activities that may impact the Grafton Lake water quality and a program is not in place to identify the possible water quality issues. Potential concerns include runoff from the roads and animal rearing pens, and from human activity resulting from commercial and industrial businesses. For example, indications of an impact of wood preservatives include the presence of arsenic, chromium, ammonium, copper and/or pentachlorophenol.

5.4.2 Recommendations

It is recommended that the CBWS should seek to install a filtration system to better treat and secure its water supply. It is recommended that disinfection by-products be monitored more frequently to a minimum of four times per year as recommended by the Health Canada guidelines. It is also recommended that further tests for Giardia/Cryptosporidium be carried out for the system and a parameter to measure TOC levels and alkalinity at the CBWS intake be included in future potability tests.

6.0 SUMMARY AND RECOMMENDATIONS

This section summarizes the key elements in the recommended long range plan.

6.1 Water Supply Requirements

6.1.1 Summary

A global per capita flow rate was developed through the historical population and flow rates provided by the Municipality. However, the ICI uses in the Municipality have not been provided and residential per capita rates and ICI rates could not be developed. In absence of this information, the water demands for the Municipality have been projected based solely on the global per capita demands and projected population only.

Per Capita Demand (L/c/d)		414	981	1,780
Year	Population	ADD (L/s)	PDD (L/s)	PHD (L/s)
2010	1,997	9.6	22.7	41.1
2015	2,270	10.9	25.8	46.8
2020	2,581	12.4	29.3	53.2
2025	2,935	14.1	33.3	60.5
2030	3,337	16.0	37.9	68.7

6.1.2 Recommendations

It is recommended that the Municipality:

1. Continue recording the ICI flow meters bi-annually, increasing its monitoring frequency (e.g. weekly) during the summer months to determine peak periods.
2. Record data from newly installed residential meters, including if water costs are charged based on metering records.
3. Update projected population and demand growth in the future by calculating ICI usage rates and residential usage rates from metering records.

6.2 Grafton Lake Hydrology and Storage Requirements

6.2.1 Summary

The present Grafton Lake storage capacity of 222,000 m^3 is capable of supplying about 66% of the current CBWS demand based on the CBWS's present rate and pattern of water demand under a 1:10 estimated summer inflow volume. However, this percentage is theoretical and based on assumptions mentioned in this report. Watershed yield and watershed loss calculations can be refined to give a better estimate of storage capacity.

Raising the control dam 0.50 m (20 inches) would increase live storage to the limit of the MOE license (320,000 m^3) and permit about 127% of the current CBWS demand to be serviced. This results in a surplus capacity of 232,490 L/d which will allow up to 395 additional ERUs to be constructed. A reduction of 10% in the water demand would service 141% of the CBWS demand and allow up to 540 ERUs to be allocated. A reduction in the water demand of 20% would service 159% of the CBWS demand and allow up to 686 ERUs.

Water use efficiency should be able to reduce water demand by 10% to 20%.

6.2.2 Recommendations

It is recommended that the Municipality:

1. Continue monitoring lake levels on a weekly basis during May to October each year.
2. Review watershed loss values in this report, and improve estimates on watershed loss by evaporation (e.g. by obtaining current pan evaporation data) and by release to Terminal Creek (e.g. by monitoring flows released to Terminal Creek)
3. Increase the available storage in Grafton Lake to match the storage allowed in the water licenses by raising the spillway by 0.5 m (20 in.).
4. Set the maximum number of additional equivalent residential units allowed on the CBWS at 395 (over 2009 figures), assuming the lake is raised by 0.5 m, and that it be reviewed in ten years as historical watershed data is obtained.

6.3 Water Quality

6.3.1 Summary

Identified issues with Grafton Lake water quality include turbidity levels that exceed Health Canada guidelines. The hardness and colour values also do not reach minimum limits in the guidelines. Further, it was found the possibility that disinfection by-products may exceed values in Health Canada guidelines. However, more tests are needed to determine if the guidelines have been exceeded.

There are a number of activities that may impact the Grafton Lake water quality and a program is not in place to identify the possible water quality issues. Potential concerns include runoff from the roads and animal rearing pens, and from human activity resulting from commercial and industrial businesses.

6.3.2 Recommendations

It is recommended that the Municipality:

1. Determine its feasibility to install a filtration system in the CBWS to better secure and treat its supply.
2. Include parameters to measure alkalinity and TOC levels at the CBWS intake in future potability tests.
3. Increase the frequency for monitoring disinfection by-products to four times per year as indicated through Health Canada guidelines.
4. Continue to carry out annual tests for Giardia/Cryptosporidium, as well as maintain the current bi-annual schedule for potability tests.

BOWEN ISLAND MUNICIPALITY

COVE BAY WATER SYSTEM
LONG RANGE PLAN UPDATE

APPENDIX A

PRECIPITATION REGRESSION ANALYSIS RESULTS

January Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	320.4	229			320.9			5.0
1963	27.4	19.6			27.5			0.6
1965	219.4	156.8			219.7			2.6
1966	284.0	203			284.4			3.5
1967	423.1	258.3	349.2		423.7			4.6
1968	423.8	284.4	349.8		424.4			3.7
1969	200.0	158.7	165.1		200.3			2.3
1970	152.4	126.3	125.8		152.6			3.6
1971	301.8	256.9	249.1		302.2			2.5
1972	113.3	95.3	93.5		113.4			0.9
1973	317.7	196.2	262.2		318.1			2.8
1974	271.0	238.2	223.7		271.4			2.8
1975	185.7	185.8	153.3		186.0			2.8
1976	242.1	192.6	199.8		242.4			4.5
1977	113.2	101	93.4		113.3			2.7
1978	170.6		140.8		170.8			3.9
1984	246.5				246.8	275.2		4.9
1985	30.3				30.3	33.8		2.7
1986	221.6				221.9	247.4		6.7
1987	177.5				177.8	198.2		4.6
1988	111.1			101.1	111.2	124		4.0
1989	155.7			207.3	155.9	173.8		3.7
1990	281.9			306.4	282.4	314.8		4.6
1991	204.7			238.1	205.0	228.6		2.2
1992	373.6			469.1	374.1	417.1		6.3
1993	162.8		158.2	182.6	173.2		185.4	
1994	176.1		138.6	224.7	182.2	207.4	227	
1995	251.8		190	246.1	235.9	256.7	301	
1996	241.6		171.1	258	246.1	277	274.2	
1997	254.9	251.1	221.0	298.0	268.1	291.5		3.6
1998	228.8	204.1	235.6	246.2	285.9	264.8		3.8
1999			285.9	363.8	346.9	347.6		4.5
2000	168.0		195.1	179.8	236.7	109.1		2.7
2001	162.0		155.8		189.0	85.8		4.6
2002	162.4		144.0		174.7			
2003	182.6		78.2		94.9			
2004	215.2		190.4		231.0			5.5
2005			159.0		192.9			2.9
2006	393.0		368.6		447.2			
2007	251.2		271.9		329.9			
2008			191.3		232.1			

Josephine = m*Bowen
m = 1.2133129
Josephine = p*Millers
p= 0.8969765
Josephine = r*Arbutus
r= 1.401213
Sunset = n*Josephine
s= 0.998499
Josephine = q*Sunset
q= 1.0015035
Josephine = k * Cates
k= 1.157756

Febuary Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	362.0	305.9			367.5			5.9
1963	194.6	164.4			197.5			7.5
1965	225.5	190.5			228.9			4.3
1966	98.7	83.4			100.2			4.8
1967	179.2		147		181.9			5.2
1968	156.8	112	128.6		159.2			6.4
1969	134.2	71	110.1		136.3			3.5
1970	86.7	63	71.1		88.0			6.2
1971	225.9	135.6	185.3		229.4			4.5
1972	204.7	128.4	167.9		207.8			4.2
1973	135.5	95	111.1		137.5			5.3
1974	270.2	150.1	221.6		274.3			4.5
1975	166.9	154.3	136.9		169.4			2.4
1976	249.0	127.7	204.2		252.7			4.1
1977	146.2	83	119.9		148.4			7.2
1978	174.8		143.4		177.5			5.8
1984	220.5				223.8	263.9		6.2
1985	89.2				90.6	106.8		3.7
1986	152.3				154.6	182.3		4.3
1987	75.0				76.2	89.8		6.8
1988	101.6			122.2	103.2	156.5		5.7
1989	70.0				71.1	83.8		1.1
1990	183.7			220.8	186.4			3.2
1991	169.3			203.6	171.9	212.3		7.4
1992	115.7			139.1	117.5	121.8		7.2
1993	7.6	4.9	6	9.3	7.6		9.2	
1994	198.9	149	176.7	259	218.7		285	
1995	202.4	155.7	149.9		178.9		227.6	
1996	152.8	126.3	123.8	168.8	161.8		188.8	
1997	142.7	127.6	148.4	123.6	183.7	126.2		5.2
1998	164.7	142.6	180.8	208.2	223.8	208.4		7.0
1999	309.8		253.2	344.3	313.4	321.2		4.8
2000	91.8		88.5	94.5	109.5			
2001	28.4		26.8		33.2	29.2		4.7
2002	172.6		156.3		193.5			
2003	39.9		33.5		41.5			
2004	128.6		115.7		143.2			7.5
2005	65.0		66.1		81.8			6.1
2006	64.0		64.3		79.6			
2007	198.4		190.6		235.9			
2008			108.7		134.5			

Joesphine = m*Bowen
m = 1.2377322
Josephine = p*Millers
p= 0.848039
Josephine = r*Arbutus
r= 1.201419
Sunset = n*Josephine
s= 0.985080
Josephine = q*Sunset
q= 1.005362
Josephine = p*Cates
p= 0.844372

March Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	179.5	133.3			176.8			7.0
1962	114.4	84.9			112.6			4.8
1963	100.2	74.4			98.7			6.2
1964	150.9	112			148.6			5.7
1965	84.9	63			83.6			5.1
1966	113.3	84.1			111.6			6.3
1967	179.2	119.3	150.6		176.4			5.2
1968	255.5	164.1	214.8		251.7			7.4
1969	154.2	109.6	129.6		151.8			6.3
1970	105.5	54.8	88.7		103.9			6.4
1971	258.3	194.4	217.1		254.4			4.2
1972	257.7	223.3	216.6		253.8			6.9
1973	123.8	80.6	104.1		122.0			6.2
1974	367.7	247.1	309.1		362.1			6.0
1975	180.7	127.2	151.9		178.0			4.9
1976	232.1	142.8	195.1		228.6			4.2
1977	139.7	64.4	117.4		137.5			5.6
1978	119.6	88.8			117.8			7.3
1979	106.9	79.4			105.3			7.5
1984	186.4				183.6	179.7		7.9
1985	112.1				110.4	108.1		5.5
1986	205.7				202.6	198.3		8.2
1987	207.3				204.2	199.9		8.1
1988	176.9			145.9	174.2	170.3		6.9
1989	214.9			177.3	211.7	178.7		3.6
1990	155.2			128	152.8	126.1		7
1991	137.3			113.3	135.3	120.3		5.6
1992	54.4			44.9	53.6	41.8		9.1
1993	174.2	130.5	143	199.2	177.1	199	213.8	
1994	133.3	115.3	106.1	147.6	134.1	129.5	161.2	
1995	153.8	135	136.2	196.5	141.9	170.9	195.4	
1996	113.3		123.8	106.4	115.0411	127.8	126	
1997	295.8	308.4	253.3	309.2	296.8	284.4		5.6
1998	99.0		91.9	127.6	107.7	109.2		5.3
1999	148.8		157.6	186.5	184.6	171.2		6.2
2000	176.6		177.2	197.4	207.6	178.2		6.6
2001	155.4		126.4		148.1	146.2		7.2
2002	89.2		97.1		113.8			
2003	180.6		161.3		189.0			8.2
2004	155.8		137.2		160.7			9.1
2005	167.4		164.2		192.4			9.8
2006	162.8		194.0		227.3			
2007			191.9		224.8			
2008			118.7		139.1			

Josephine = m*Bowen
m = 1.171588
Josephine = p*Millers
p= 1.02148
Josephine = r*Arbutus
r= 1.328521
Sunset = n*Josephine
s= 1.015367
Josephine = k * Cates
k= 1.193690
Josephine = q*Sunset
q= 1.015367

April Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	77.0	63.5			75.0			8.4
1962	119.3	98.4			116.2			9.3
1963	80.5	66.4			78.4			8.8
1964	59.3	48.9			57.7			7.9
1965	58.8	48.5			57.3			8.8
1966	31.0	26.8	24.7		30.2			8.5
1967	92.9	41.9	73.9		90.5			7.1
1968	71.9	35.9	57.2		70.0			8.1
1969	201.3		160.2		196.1			7.9
1970	155.8	87.4	124		151.8			8
1971	85.3	50.4	67.9		83.1			8.4
1972	139.4	113.2	110.9		135.7			6.8
1973	31.3	20.2	24.9		30.5			8.7
1974	190.6	133.3	151.7		185.7			8.7
1975	86.8	59.4	69.1		84.6			7
1976	125.4	80.2	99.8		122.2			8.5
1977	107.7	66.8	85.7		104.9			9.6
1978	105.7	87.2			103.0			8.8
1983	89.3				87.0	97.2		9
1984	161.7				157.5	176		8.7
1985	94.6				92.2	103		8.5
1986	120.6				117.5	131.3		8.2
1987	102.7			116.4	100.1	111.8		10.4
1988	111.6			101.1	108.7	121.5		9.5
1989	61.4			74	59.8	66.8		10.6
1990	91.2			84.6	88.8	99.2		10.6
1991	142.1			156.4	138.4	154.6		8.9
1992	159.9			187.4	155.7	174.0		10.4
1993	236.8	204.4	189.0	244.4	227.9	273	304.8	
1994	133.3	118.7	101.7	118.8	136.1	117	124.8	
1995	79.8	59.9	67.7	80.6	75.0	71	91.2	
1996	249.2	206.5	196.3	280.8	242.6	273.8	291.6	
1997	156.2	139.8	119.0	166.4	145.7	151.1		8.9
1998	57.4	38.0	50.4	63.2	61.7	50.8		16.3
1999	88.2		59.8	91.8	73.2	79.0		9.5
2000	60.8		55.9	72.6	68.4	67.6		10.1
2001	106.6		83.9		102.7	0.0		6.7
2002	122.0		100.6		123.1			
2003	198.2		208.0		254.6			10.0
2004	44.0		35.2		43.1			12.8
2005	118.1		122.7		150.2			11.4
2006	93.0		88.4		108.2			
2007			118.8		145.4			
2008			66.7		81.6			

Joesphine = m*Bowen
m = 1.2239965
Josephine = p*Millers
p= 0.894985
Josephine = r*Arbutus
r= 1.180913
Sunset = n*Josephine
s= 1.026700
Josephine = q*Sunset
q= 0.9736032
Josephine = p*Cates
p= 0.8690988

May Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	153.2	96.8			167.4			12.2
1962	56.3	35.6			61.6			10.7
1963	65.5	41.4			71.6			13.0
1964	74.9	47.3			81.8			10.8
1965	58.2	36.8			63.6			10.3
1966	71.8	59.2	60.7		78.5			11.3
1967	46.0	33.1	38.9		50.3			11.9
1968	68.8	52.9	58.1		75.1			12.3
1969	42.6	37.1	36.0		46.6			13.1
1970	29.3	27.5	24.8		32.1			11.5
1971	73.3	35.2	61.9		80.0			11.7
1972	35.0	30.6	29.6		38.3	41.2		12.9
1973	90.3	61.5	76.3		98.7			12.3
1974	170.9		144.4		186.7			10.2
1975	52.0	37.6	43.9		56.8			11.3
1976	118.6	96.4	100.2		129.6			11.0
1977	91.9	70.2	77.7		100.5			11.0
1978	160.3	101.3			175.2			11.4
1983	96.9				105.9	97.2		13.5
1984	175.4				191.7	176		10.8
1985	102.6				112.2	103		12.3
1986	130.9				143.0	131.3		12.0
1987	111.4			109.9	121.8	111.8		12.7
1988	121.1			147.9	132.3	121.5		12.1
1989	66.6			131.6	72.7	66.8		12.6
1990	98.9			75.4	108.0	99.2		12.6
1991	154.1			98.9	168.4	154.6		12.0
1992	173.4			30.8	189.5	174.0		13.6
1993	129.8	79.3	112.1	157.4	146.3	137.2	155.3	
1994	53.4	36.1	48.5	42.6	50.9	46.9	61.0	
1995	49.5	37.6	34.4	55.0	56.8	42.8	55.7	
1996	120.2	79.5	99.0	101.8	128.0		108.8	
1997	122.0	114.8	98.8	65.8	127.8	163.6		14.7
1998	122.4	117.4	107.5	110.7	139.0	107.6		14.1
1999	94.2		69.7	85.7	90.1	99.6		11.6
2000	127.6		100.1	127.8	129.4			
2001	78.7		66.9		86.5	88.2		12.9
2002	90.0		7.8		10.1			
2003	51.2		46.7		60.4			
2004	76.0		65.4		84.6			15.3
2005	99.0		87.0		112.5			15.4
2006			50.8		65.7			
2007			93.9		121.4			
2008			47.3		61.2			

Josephine = m*Bowen
m = 1.2931794
Josephine = p*Millers
p= 1.0890525
Josephine = r*Arbutus
r= 1.729480
Sunset = n*Josephine
s= 0.915088

June Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	26.8	25.2			28.7			16.4
1962	20.6	19.4			22.1			14.5
1963	39.3	37			42.1			14.9
1964	72.3	68			77.4			14.1
1965	19.2	18.1			20.6			14.4
1966	49.5	58.3	48.2		52.9			13.8
1967	13.2	11.7	12.9		14.2			16.5
1968	63.6	68.8	62		68.1			14.4
1969	49.8	92.6	48.5		53.2			16.9
1970	17.3	11.6	16.9		18.6			16.2
1971	81.5	70.4	79.4		87.2			13.0
1972	64.4	59	62.8		68.9	63.5		14.0
1973	92.2	69.8	89.9		98.7			13.7
1974	30.8	27.7	30		32.9			14.2
1975	30.6	29.8	29.8		32.7			13.5
1976	64.3	84.8	62.7		68.8			13.0
1977	22.8	21.4			24.3			14.9
1978	23.0	21.6			24.6			16.1
1983	98.0				104.9	94.2		14.7
1984	94.3				100.9	90.6		14.2
1985	44.4				47.6	42.7		14.9
1986	58.0				62.6	55.7		15.4
1987	28.1			53.8	30.1	27		15.3
1988	79.0			49.1	84.5	75.9		14.8
1989	89.5			100.6	95.8	86		15.9
1990	108.3			98.9	115.9	104.1		15.1
1991	98.1			102.2	105.0	94.3		14.1
1992	89.3			85.9	107.8		79.2	16.5
1993	64.5	79.3	61.9	88	71.3	70	85.8	
1994	148.7	134.1	150	151.8	160.4	140.8	169.4	
1995	52	42.3	44.7	62	58.8	53.6	66.6	
1996	45.2	31.2	26.6	22.8	29.2		24.2	
1997	106.4	94.9	77.0		84.5	112.9		15.7
1998	45.8	30.0	34.2		37.5	31.6		17.1
1999	94.0		76.9	92.4	84.4	80.4		14.6
2000	98.8		84.5		92.8	95.4		16.6
2001	79.2		63.7		69.9	91.8		14.9
2002	57.6		40.6		44.6			
2003	33.2		24.2		26.6			17.9
2004	36.8		28.3		31.1			18.5
2005	86.2		75.2		82.6			15.0
2006	84.0		73.7		80.9			
2007			69.6		76.4			
2008			64.9		71.3			

Josephine = m*Bowen
m = 1.097852
Josephine = p*Millers
p= 1.113394
Josephine = r*Arbutus
r= 1.137770
Sunset = n*Josephine
s= 0.934679

July Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	52.9	43.1			43.7			18.2
1962	21.0	17.1			17.3			16.5
1963	89.7	73.1			74.1			16.0
1964	113.5	92.5			93.8			16.0
1965	5.6	4.6			4.7			17.4
1966	89.3	56	50.5		73.9			15.7
1967	40.9	22.6	23.1		33.8			17.3
1968	93.0	38.2	52.6		76.9			17.6
1969	48.8	33.3	27.6		40.4			16.5
1970	77.8	34.5	44		64.4			16.5
1971	32.4	14.7	18.3		26.8			17.3
1972	136.3	105.1	99.3		112.7	121.1		17.0
1973	54.0	26.8	30.5		44.6			16.1
1974	239.9	125.7	135.6		198.3			15.5
1975	18.6	13.7	10.5		15.4			17.5
1976	61.2	43.7	34.6		50.6			16.0
1977	64.7		36.6		53.5			15.9
1983	135.9				112.4	120.7		16.0
1984	5.2				4.3	4.6		17.0
1985	6.5				5.4	5.8		19.3
1986	54.4				45.0	48.3		15.5
1987	114.5			71.6	94.7	101.7		17.1
1988	32.5			34.4	26.9	28.9		17.1
1989	45.5			52.8	37.6	40.4		16.8
1990	28.3			28.3	23.4			
1991	57.9			56.6	47.8	51.4		17.6
1992	39.8			50.4	42.2		51.4	17.9
1993	77.6	45.8	35.1	65.4	53.0	57.8	78.8	
1994	12.9	14.3	12.6	13.2	13.8	9.6	10.4	
1995	62.4	53.9	52.3	71.2	60.3	64.8	69.8	
1996	32.2	35.5	35.7	52.8	27.4			
1997	67.6	69.7	49.4		72.3	82.4		18.2
1998	56.2	45.7	42.6	64.4	62.3	58.4		19.6
1999	25.6		29.9	38.1	43.7	38.4		17.4
2000	87.2		70.8		103.6	88.4		18.0
2001	46.0		40.0		58.5	27.6		17.9
2002	26.0		20.7		30.3			
2003	34.8		30.0		43.9			
2004	18.4		14.4		21.1			20.6
2005	59.0		49.0		71.7			19.0
2006	28.6		24.4		35.7			
2007			78.7		115.1			
2008			26.5		38.8			

Joesphine = m*Bowen
m = 1.4626286
Josephine = p*Millers
p= 0.930929
Josephine = r*Arbutus
r= 1.014297
Sunset = n*Josephine
s= 1.209402
Josephine = q*Sunset
q= 0.768170
Josephine = p*Cates
p= 0.826030

August Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	110.8	72.9			110.2			18.8
1962	163.3	107.4			162.4			16.1
1963	15.8	10.4			15.7			17.7
1964	42.6	28			42.3			15.8
1965	90.9	59.8			90.4			16.8
1966	55.2	36.3	37.7		54.9			16.8
1967	5.8	3.8	2.8		5.7			19.3
1968	138.2	90.9	91.2		137.4			16.1
1969	82.2	54.1	55.7		81.8			15.3
1970	24.0	15.8	19.3		23.9			16.4
1971	33.6	22.1	24.4		33.4			17.8
1972	43.3	28.5	25.2		43.1	31		17.5
1973	60.2	39.6	32.4		59.9			15.3
1974	8.1	5.3	5.3		8.0			16.9
1975	168.1	110.6	119.1		167.2			15.2
1976	145.3	95.6	106.6		144.5			15.4
1977	78.1		55		77.6			18.3
1983	41.4				41.1	32.5		17.3
1984	27.5				27.3	21.6		17.3
1985	37.7				37.5	29.6		17.1
1986	0.6				0.6	0.5		18.5
1987	12.2			9.1	12.2	9.6		17.2
1988	35.1			35	34.9	27.6		17.2
1989	147.3			97.2	146.5	115.7		16.7
1990	57.3			49	57.0	45.0		
1991	375.5			316.4	373.5	295.0		17.6
1992	28.8			34.8	33.5		30.6	17.6
1993	26.6	19.8	21.1	27	27.6	24.8	31.6	
1994	33.6	30.3			33.6	34.8	32.4	
1995	128.6	80.1	126.6		126.3	96	114.4	
1996	18.4	14.0	19	3.6	21.2			
1997	45.8	42.6	40.7	53.4	57.4	45.2		19.9
1998	8.2	7.8	6.5	8.6	9.2	7.0		19.8
1999	46.8		35.9	54.2	50.7	52.2		18.6
2000	12.0		10.4		14.7	7.2		17.8
2001	165.6		134.4		189.7	167.7		17.9
2002	19.8		16.2		22.9			
2003	11.4		9.2		13.0			
2004	95.4		74.1		104.6			20.0
2005	29.0		25.0		35.3			19.9
2006	10.6		7.8		11.0			
2007			15.5		21.9			
2008			83.3		117.6			

Josephine = m*Bowen
m = 1.411472
Josephine = p*Millers
p= 1.265935
Josephine = r*Arbutus
r= 1.511905
Sunset = n*Josephine
s= 1.005560

September Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josesphine	Millers	Killarny	Mean Temp.
1961	46.5	52.2			54.53191			13.4
1962	66.7	74.9			78.24598			14.6
1963	27.4	30.7			32.07146			16.8
1964	115.2	129.3			135.0762			12.9
1965	16.4	18.4			19.22198			13.1
1966	82.9	70.8	68.1		97.2			15.0
1967	109.9	78.7	90.3		128.8			15.8
1968	130.9	96.3	107.6		153.5			14.1
1969	249.6	180.6	205.1		292.6			14.1
1970	115.4	94.5	94.8		135.2			13.0
1971	126.9		104.3		148.8			13.1
1972	90.1	86.2	89.4		105.7	109.6		12.6
1973	52.1	39.4	42.8		61.1			14.8
1974	39.9	29.5	32.8		46.8			16.3
1975	2.4	1.5	2		2.9			14.7
1976	47.0	52.4	38.6		55.1			14.9
1977	123.5		101.5		144.8			12.9
1978	104.9	117.7			122.958			13.8
1983	97.9				114.7	119		13.5
1984	48.0				56.3	58.4		13.9
1985	59.5				69.7	72.3		13.3
1986	84.0				98.4	102.1		14.4
1987	24.5			29.3	28.7	29.8		15.6
1988	80.8			103.6	94.7	98.2		14.6
1989	18.6			19	21.8	22.6		15.4
1990	28.9			23.8	33.9	35.2		16.2
1991	5.8				6.7	7.0		15.2
1992	73.3			88.8	85.2		90.2	13.7
1993	2.4	5.1	3.9	7	3	10	4.6	
1994	56.8	68.7	49.9	54.2	66.2	67.4	75.6	
1995	32.8	19.5	18.8	44.8	40.6	42.5	44.7	
1996	120.2	92.5	83.7	73.4	140.9			
1997	169.1	173.5	159.9	209.4	228.1	208.6		16.4
1998	10.6	8.5	7.3	10.0	10.4	8.4		16.9
1999	23.8		19.8	25.9	28.2	23.4		15.8
2000	80.2		61.5		87.7	87.4		14.8
2001	71.2		67.6		96.4	66.4		15.3
2002	50.1		39.7		56.6			
2003	55.0		44.0		62.8			
2004	128.6		130.2		185.8			14.2
2005	73.6		66.2		94.4			
2006	65.4		47.3		67.5			
2007			16.8		24.0			
2008			26.6		37.9			

Josephine = m*Bowen
m = 1.4266684
Josephine = p*Millers
p= 0.9840828
Josephine = r*Arbutus
r= 1.044673
Sunset = n*Josephine
s= 0.853022
Josephine = q*Sunset
q= 1.171833

October Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	229.5	191.5			233.4			9.3
1962	137.7	114.9			140.0			11.3
1963	255.2	212.9			259.5			11.8
1964	83.2	69.4			84.6			10.4
1965	241.1	201.2			246.2			11.7
1966	242.7	135.5	169.9		246.8			9.6
1967	513.3		359.4		522.0			10.8
1968	346.2	232.7	242.4		352.1			10
1969	173.5	110.6	121.5		176.5			10.1
1970	137.7	81.1	96.4		140.0			9.5
1971	282.2	207.5	197.6		287.0			9.3
1972	77.4	57.1	54.2		78.7	63.9		8.7
1973	218.3		152.8		221.9			9.8
1974	64.3	45.7	45		65.4			10.8
1975	531.8	321.7	372.3		540.8			9.6
1976	156.3	58.7	109.4		158.9			9.9
1977	202.3		141.6		205.7			9.8
1978	67.1	56.0			68.2			10.9
1983	127.2				129.4	131.9		10.1
1984	249.3				253.5	258.4		9.1
1985	446.0				453.6	462.4		9.9
1986	66.4				67.5	68.8		11.4
1987	15.8			18.6	16.1	40.3		11.7
1988	108.8			128.0	110.7	123.6		11.4
1989	183.2				186.3	189.9		10.8
1990	152.2			179.0	154.8	166.0		9.9
1991	25.5			30.0	25.9	25.0		9.8
1992	198.2				209.5		243.7	11.4
1993	77.8	247.8	55.2	95	82.1	83.6	105.4	
1994	125.0	104.6		128	118.4	120.8	142.8	
1995	217.2	173.4	161.7	255.2	216.8		277	
1996	256.0	246.8	170	268	264.1			
1997	236.9	206.9	221.2	272.0	321.3	277.2		9.8
1998	181.9		166.2	227.0	241.4	217.0		11.2
1999	162.1		158.6	193.7	230.4	60.8		11.0
2000	191.0		167.6		243.4	206.0		10.8
2001	212.2		170.8		248.1	196.2		9.7
2002	29.6		27.3		39.7			
2003	325.2		283.7		412.1			
2004	180.8		158.4		230.1			11.6
2005	173.4		212.0		307.9			
2006			76.3		110.8			
2007			132.6		192.6			
2008			135.1		196.2			

Joesphine = m*Bowen
m = 1.4524893
Josephine = p*Millers
p= 0.980936
Josephine = r*Arbutus
r= 1.218711
Sunset = n*Josephine
s= 0.983376
Josephine = q*Sunset
q= 0.9854798
Josephine = p*Cates
p= 0.8646995

November Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1961	216.2	186.2			225.0			7.4
1963	208.9	179.9			217.4			5.3
1964	177.3	152.7			184.6			7.5
1965	264.2		229.6		275.0			6.7
1966	222.5	191.6	229.6		231.6			6.8
1967	135.3	116.5	156.3		140.8			7.1
1968	162.9	140.3	192		169.6			7.2
1969	105.0	90.4	113.8		109.3			6.1
1970	182.8	157.4	193.5		190.2			6.5
1971	239.5	206.3	231		249.3			6.8
1972	147.0	126.6	173.9		153.0	240.6		4.4
1973	255.9	220.4	339.1		266.4			6.6
1974	248.9	214.4	234		259.1			5.5
1975	324.3	279.3	276.9		337.6			6.6
1976	76.3	65.7	66.3		79.4			5.1
1977	251.1		218.2		261.4			4.3
1978	145.1	125			151.1			5.8
1983	417.5				434.6	475.2		6.1
1984	360.2				375.0	410.0		0.5
1985	94.9				98.8	108.0		6.4
1986	170.7				177.7	194.3		8.4
1987	206.5			196.4	214.9	235.0		7.1
1988	256.5			268.2	267.0	292.0		7.3
1989	260.7			287.6	271.4	296.8		6.8
1990	384.7			448.8	400.5	437.9		7.5
1991	324.6				337.9	369.5		6.7
1992	241.5			282.5	232.6		241.5	
1993	122.1	99.2	89.8	163	124.6	143.2	163.8	
1994	257.3	212.2	258.3	251.1	282.1	237.6	284.1	
1995	358.7	317.7	289.1	477.8	365.4	435.9	479.3	
1996	225.4	178.9	210.8	220.8	231.2			
1997	196.2	176.2	163.7	261.5	196.1	242.1		8.4
1998	353.8		337.1	464.0	403.8	250.4		7.0
1999	290.8		275.1	357.8	329.5	162.2		7.0
2000	122.2		115.2		138.0	128.0		5.8
2001	231.0		203.5		243.8	259.4		7.7
2002	250.8		216.4		259.2			
2003	185.2		210.1		251.7			
2004	250.8		241.8		289.6			7.4
2005	144.8		135.0		161.7			
2006	410.4		334.8		401.0			
2007			133.9		160.4			
2008			185.4		222.1			

Josephine = m*Bowen
m = 1.1978439
Josephine = p*Millers
p= 0.9145171
Josephine = r*Arbutus
r= 1.208640
Sunset = n*Josephine
s= 0.960633
Josephine = q*Sunset
q= 1.025887

December Rainfalls

Year	Sunset	Arbutus	Bowen	Cates	Josephine	Millers	Killarny	Mean Temp.
1962	308.6	263.4			301.1			5.3
1963	255.5	218.1			249.3			5.0
1964	192.5	164.3			187.8			1.3
1965	266.5	227.5			260.0			3.8
1966	405.0	268.3	331.3		395.1			5.8
1967	261.0	138	213.5		254.6			3.8
1968	305.6	260.9	250.0		298.1			1.5
1969	265.0	163.2	216.8		258.6			5.6
1970	330.8	175.9	270.6		322.7			3.3
1971	297.5	246.3	243.4		290.3			1.2
1972	461.1	351.6	377.2		449.8	469.8		2.1
1973	339.6	206.2	277.8		331.3			5.4
1974	338.4		276.8		330.1			5.5
1975	283.8	231.9	232.2		276.9			3.8
1976	165.9	143.2	135.7		161.8			5.6
1977	162.2		132.7		158.3			3.4
1978	142.7	121.8			139.2			2
1983	93.0				90.7	100.5		1.3
1984	224.8				219.3	243		1.2
1985	111.4				108.7	120.4		2.3
1986	309.7				302.1	334.8		5.2
1987	144.8			150.3	141.2	156.5		3.7
1988	237.6			278	231.8	256.9		5.2
1989	136.3			157.3	133.0	147.4		5.4
1990	263.3			329.7	256.9	284.7		0.8
1991	204.2			235.9	199.3	220.8		6.1
1992	142.3		132.8	142	158.4		144.8	2.2
1993	268.7	247.8	243.6	299.6	261.2	283.2	298.3	
1994	299.8	239.4	239.7	350.8	284.1	318.7	384.4	
1995	300.2	253.7	242.1	338.4	301.6	335.8	389.2	
1996	258.5	253.7	191.9	162.4	252.0			
1997	169.0	171.9	187.6	227.0	223.7	216.4		5.4
1998	299.9		285.8	347.0	340.8	321.4		3.3
1999	266.6		278.1	302.0	331.7	299.4		4.2
2000	137.2		137.6		164.1			
2001	261.0		274.3		327.1	265.0		4.0
2002	186.4		184.1		219.6			
2003	169.0		202.5		241.5			5.6
2004	250.4		241.0		287.4			6.0
2005	182.6		163.1		194.5			
2006	201.0		183.0		218.2			
2007			269.3		321.2			
2008			143.5		171.1			

Josephine = m*Bowen
m = 1.1925978
Josephine = p*Millers
p= 0.9024159
Josephine = r*Arbutus
r= 1.142968
Sunset = n*Josephine
s= 1.024998
Josephine = q*Sunset
q= 0.975013

BOWEN ISLAND MUNICIPALITY

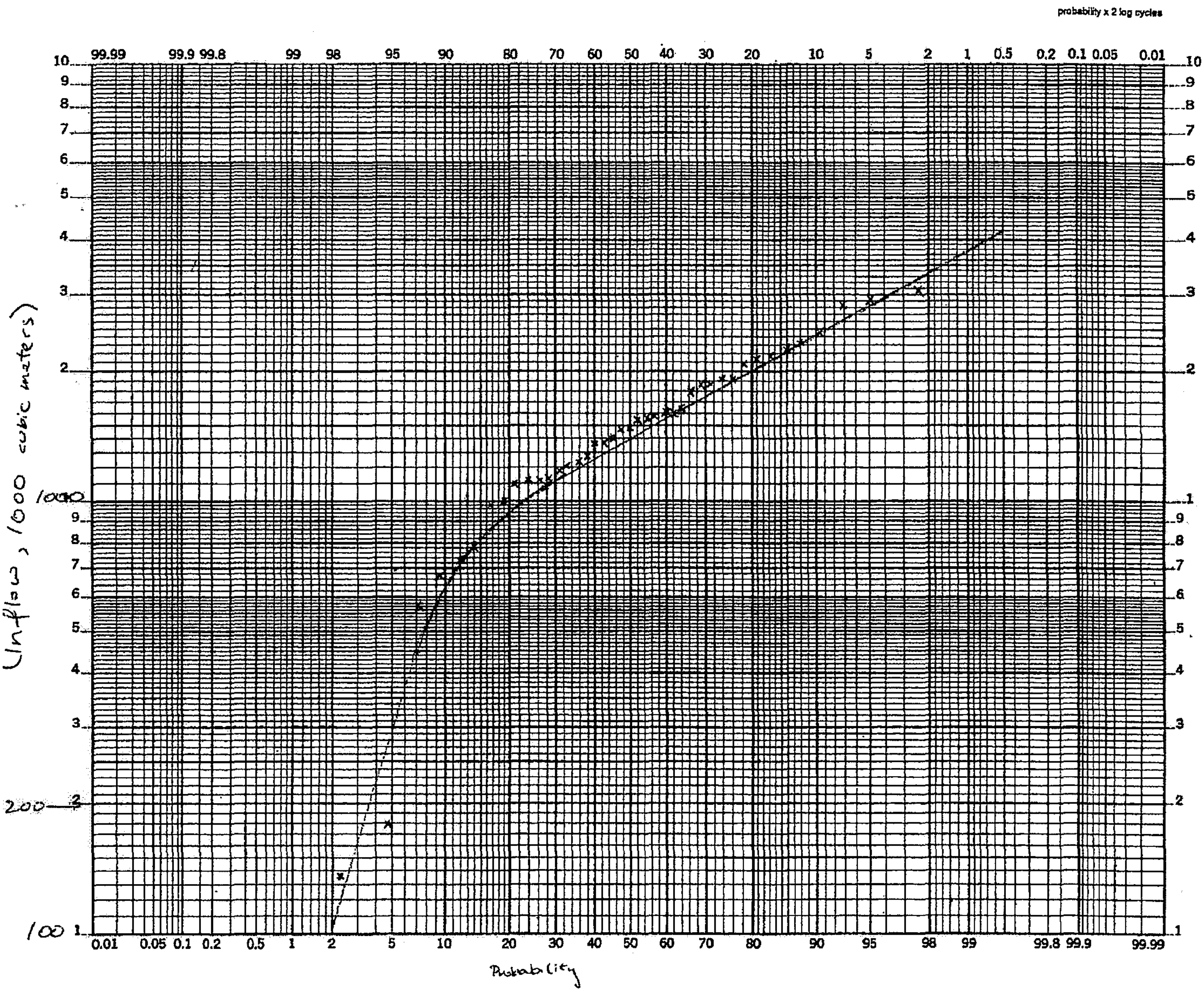
COVE BAY WATER SYSTEM
LONG RANGE PLAN UPDATE

APPENDIX B

MONTHLY AND SUMMER FREQUENCY CURVES

Grafton Lake Monthly and Summer Inflows, in 1000 m3, ranked for frequency plotting

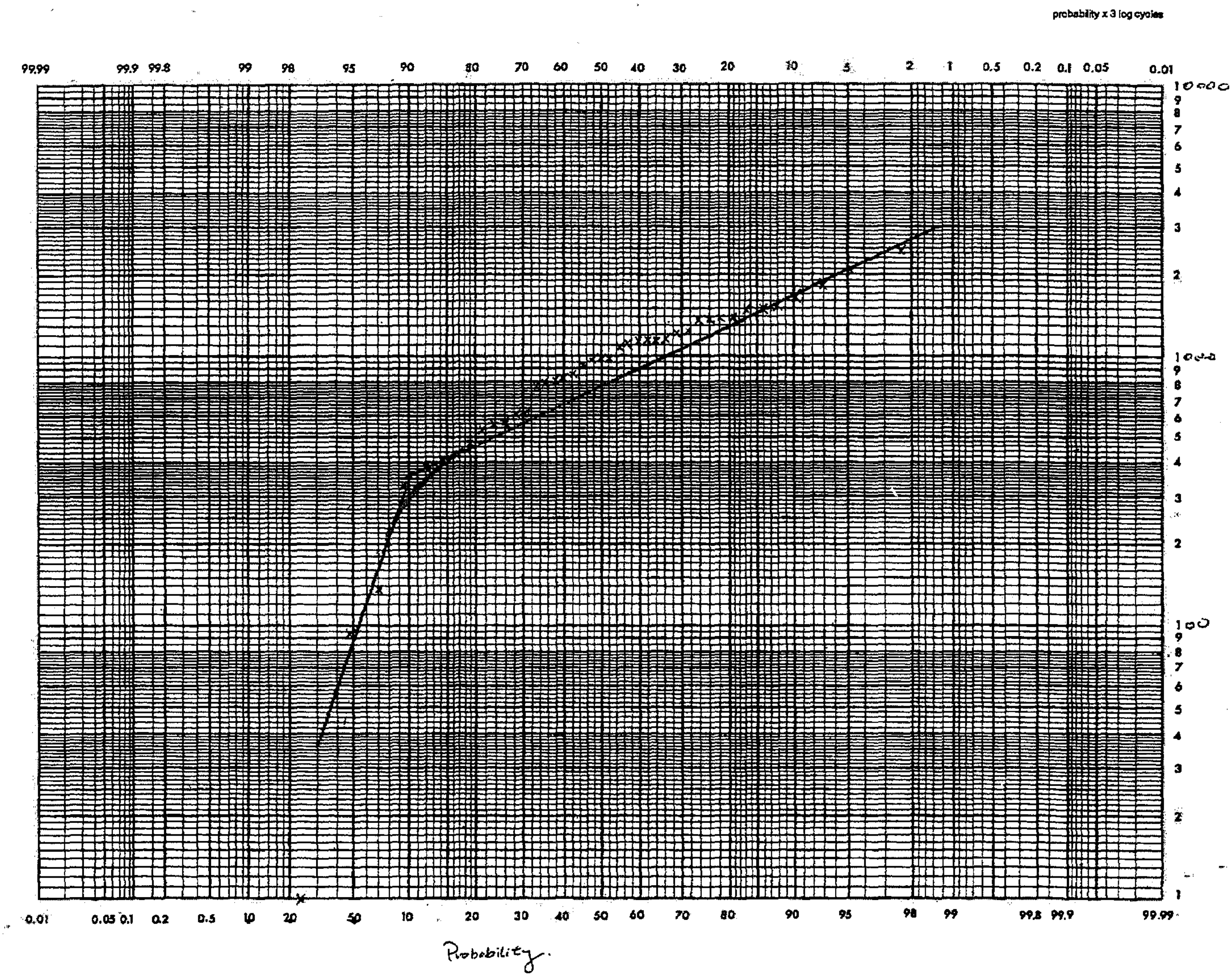
Weibail Position		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Summer
1	0.02381	136	-4	79	-13	-11	-21	-23	-20	-12	-6	406	705	0
2	0.047619	178	90	431	-13	-11	-21	-23	-20	-12	-6	499	777	66
3	0.071429	566	132	501	-13	-11	-21	-23	-20	-12	-6	584	892	166
4	0.095238	669	324	531	-13	-11	-21	-23	-20	-12	97	679	952	184
5	0.119048	725	388	589	64	-11	-21	-23	-20	-12	103	773	1048	211
6	0.142857	780	403	595	111	-11	-21	-23	-20	-12	120	798	1051	255
7	0.166667	976	429	597	143	-11	-21	-23	-20	-12	237	891	1061	259
8	0.190476	996	472	598	199	8	-21	-23	-20	-12	274	933	1066	264
9	0.214286	1095	530	607	222	14	-21	-23	-20	-12	403	943	1101	291
10	0.238095	1121	554	608	226	19	-21	-23	-20	-12	441	952	1223	303
11	0.261905	1122	563	666	251	46	-21	-23	-20	-12	494	974	1267	361
12	0.285714	1132	603	742	261	62	-21	-23	-20	-12	680	990	1421	400
13	0.309524	1186	616	777	270	68	-21	-23	-20	-12	771	1070	1435	467
14	0.333333	1201	776	781	270	85	-21	-23	-20	-12	800	1120	1444	479
15	0.357143	1238	793	797	308	104	-21	-23	-20	-12	918	1145	1485	510
16	0.380952	1284	811	797	357	113	-21	-23	-20	-12	962	1300	1523	516
17	0.404762	1355	823	817	368	170	-21	-23	-20	-12	1021	1361	1540	591
18	0.428571	1363	861	840	369	171	-21	-23	-20	-12	1047	1371	1665	625
19	0.452381	1392	927	857	406	173	-21	-23	-20	-12	1105	1428	1675	636
20	0.47619	1469	965	875	420	245	-21	-23	-20	-12	1136	1436	1733	638
21	0.5	1484	983	1013	435	263	-21	-23	-20	-12	1193	1446	1737	641
22	0.52381	1540	987	1028	451	280	-21	-23	-20	-12	1244	1483	1740	655
23	0.547619	1567	1078	1039	458	335	-21	-23	-20	36	1251	1554	1765	678
24	0.571429	1584	1108	1044	507	340	-21	-23	-20	108	1268	1581	1792	679
25	0.595238	1601	1130	1047	560	376	-4	-23	-20	131	1339	1635	1802	686
26	0.619048	1602	1132	1072	564	397	4	-23	-20	151	1347	1663	1853	688
27	0.642857	1639	1142	1087	582	429	32	-23	-20	163	1350	1668	1903	706
28	0.666667	1796	1161	1108	656	442	36	-23	-20	165	1368	1682	1943	711
29	0.690476	1845	1211	1111	677	488	43	-23	-20	168	1435	1711	1973	795
30	0.714286	1864	1227	1169	683	498	55	-23	22	199	1440	1724	1984	838
31	0.738095	1915	1347	1184	722	500	67	-23	39	317	1445	1797	2000	849
32	0.761905	1915	1365	1260	735	526	76	-23	44	362	1500	1820	2027	868
33	0.785714	2073	1391	1386	738	547	83	-23	108	396	1529	2117	2166	870
34	0.809524	2124	1393	1390	753	606	115	-23	210	493	1731	2187	2181	898
35	0.833333	2176	1490	1403	810	618	162	-23	272	513	1840	2188	2202	1091
36	0.857143	2234	1493	1490	826	772	178	59	404	584	1956	2389	2227	1141
37	0.880952	2325	1513	1545	1026	786	215	88	446	601	2168	2603	2229	1171
38	0.904762	2458	1669	1578	1128	856	218	191	481	605	2579	2642	2258	1227
39	0.928571	2867	1809	1673	1308	877	248	197	650	827	2892	2644	2322	1303
40	0.952381	2902	2076	1928	1413	982	288	227	707	1045	3346	2647	2691	1857
41	0.97619	3067	2423	2378	1469	995	600	856	2023	1589	3522	2894	3026	3086



JAN GRAFTON LAKE

Est. 630,000 m^3
as 1:10 Jan inflow

1961 - 2008
41 years

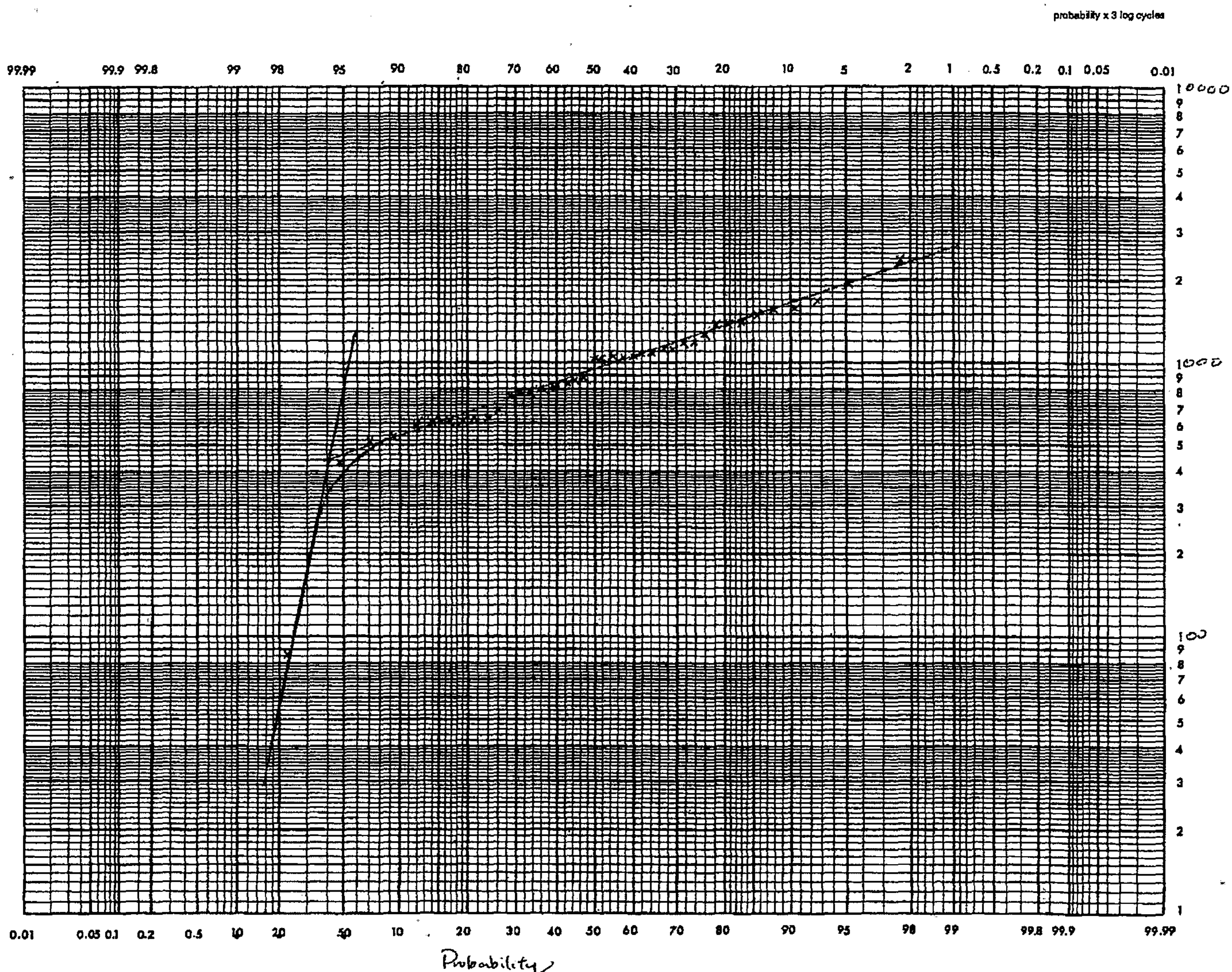


FEB GRAFTON LAKE

Est. 310,000 m^3
as 1:10 Feb inflow

1961 - 2008

41 years

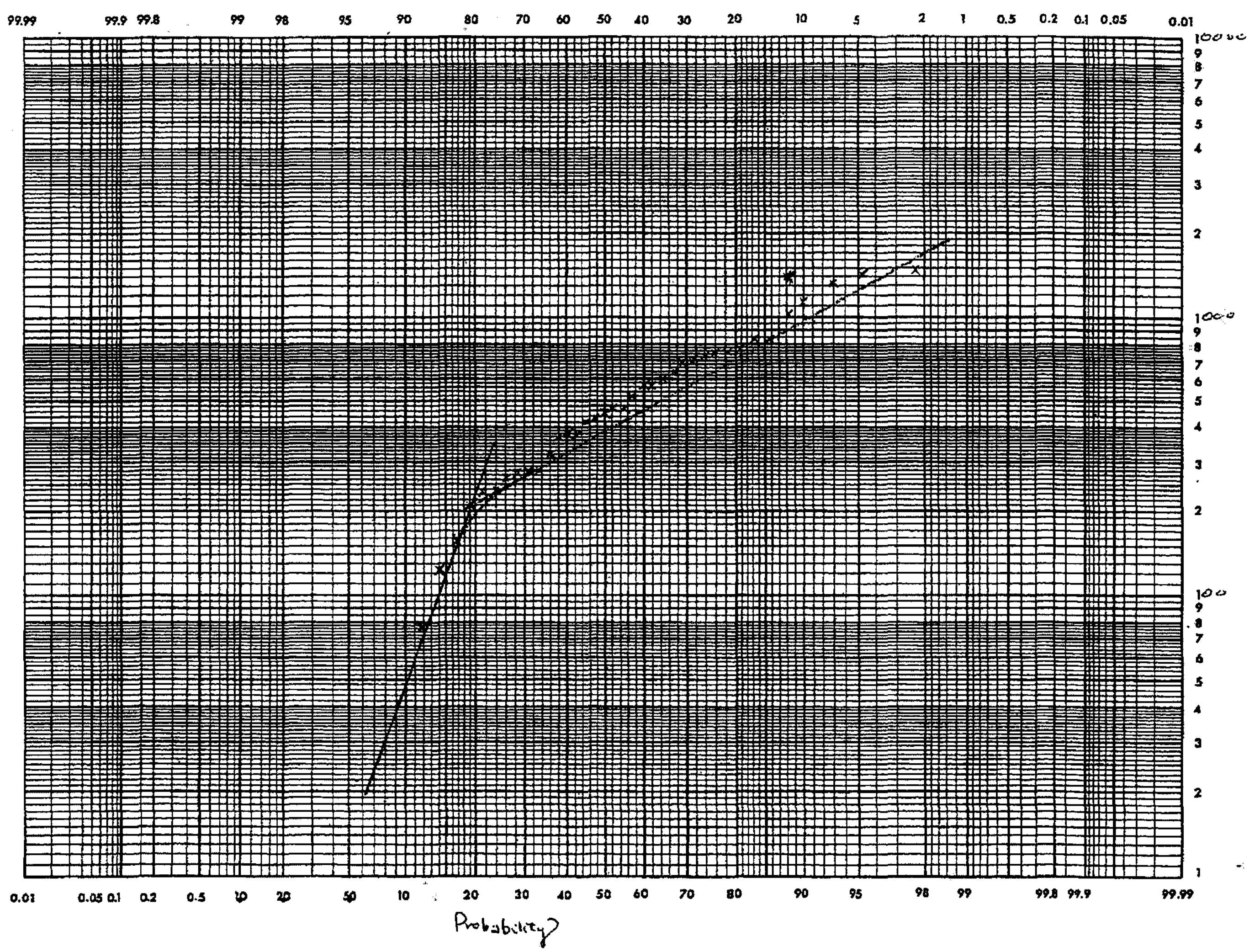


MAR GRAFTON LAKE

1961 - 2008

41 years

Est. 540,000 m³
as 1:10 Mar inflow

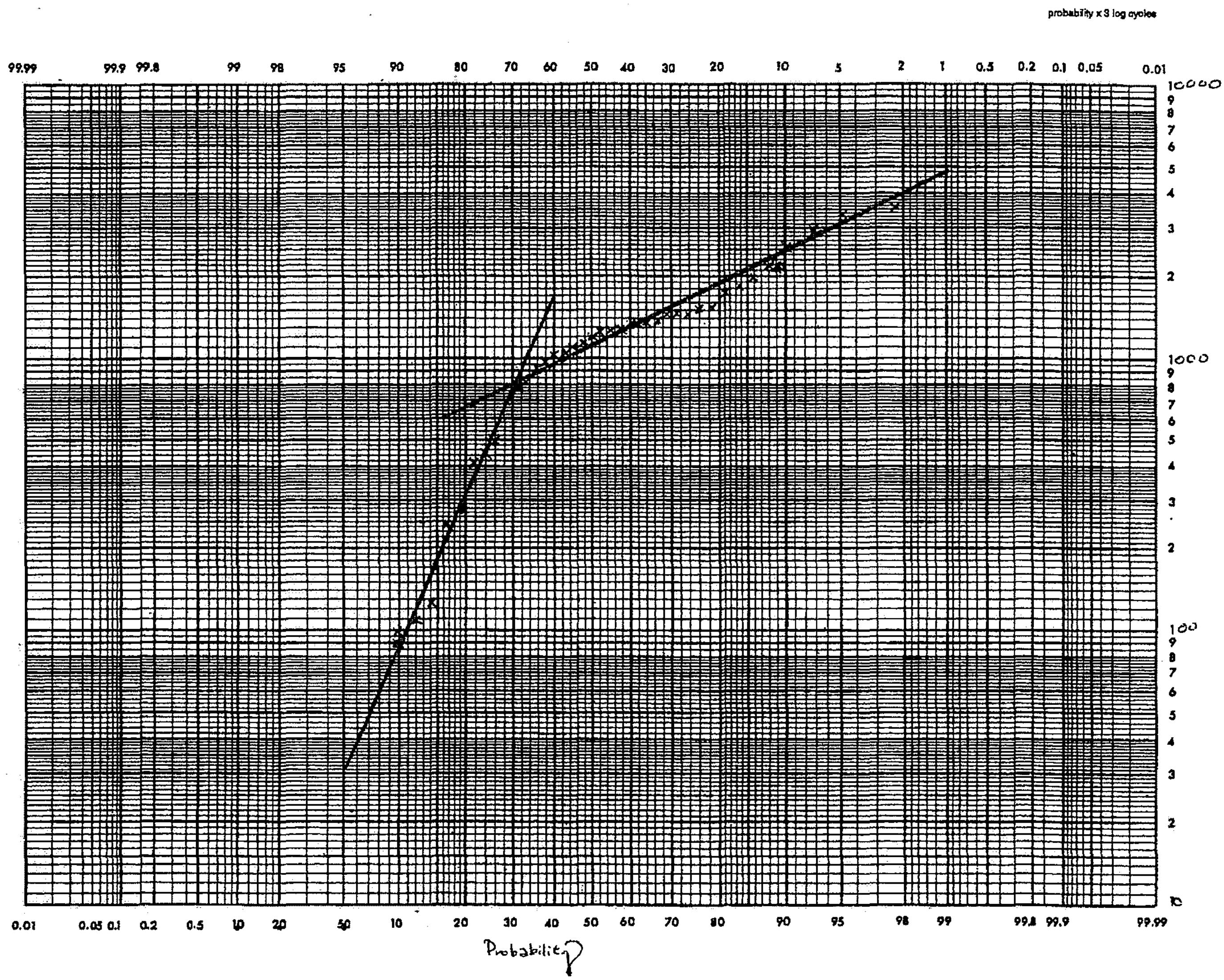


APRIL GRAFTON LAKE

1961 - 2008

41 years

Est. 48,000 m^3
as 1:10 Apr inflow

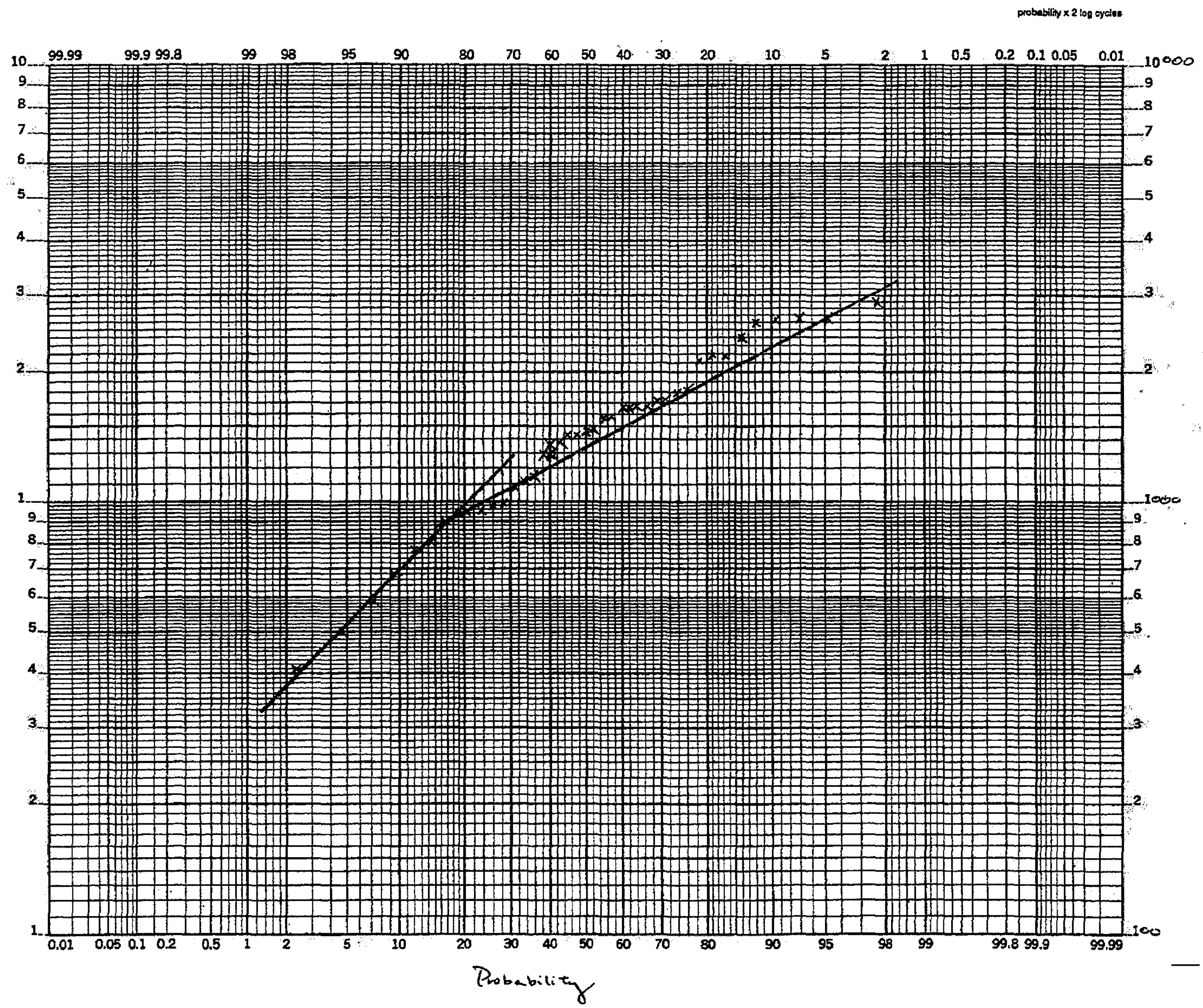


OCT GRAFTON LAKE

1961 - 2008

41 years

Est. 95,000 m^3
as 1:10 Oct Inflow

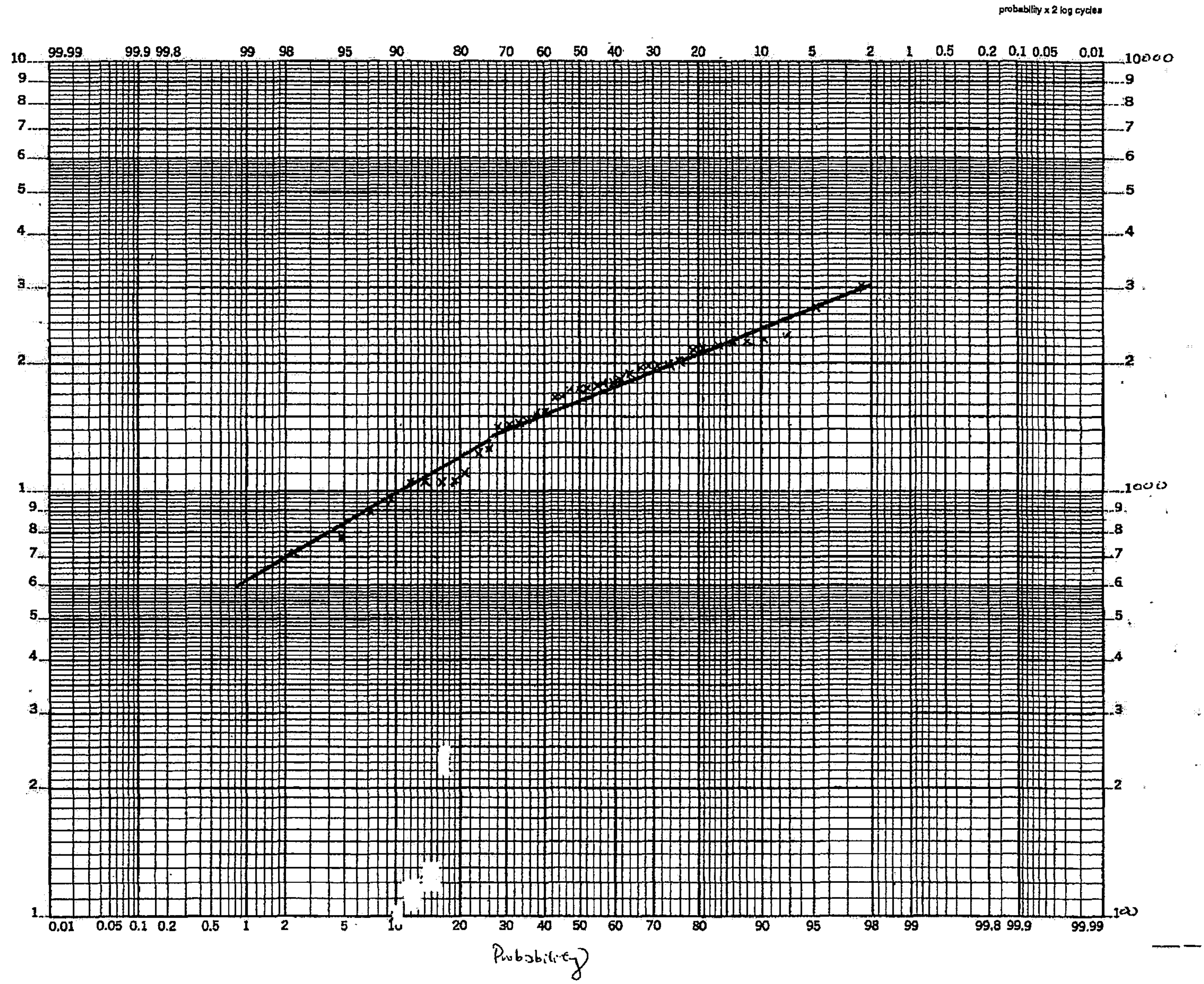


NOV GRAFTON LAKE

1961 - 2008

41 years

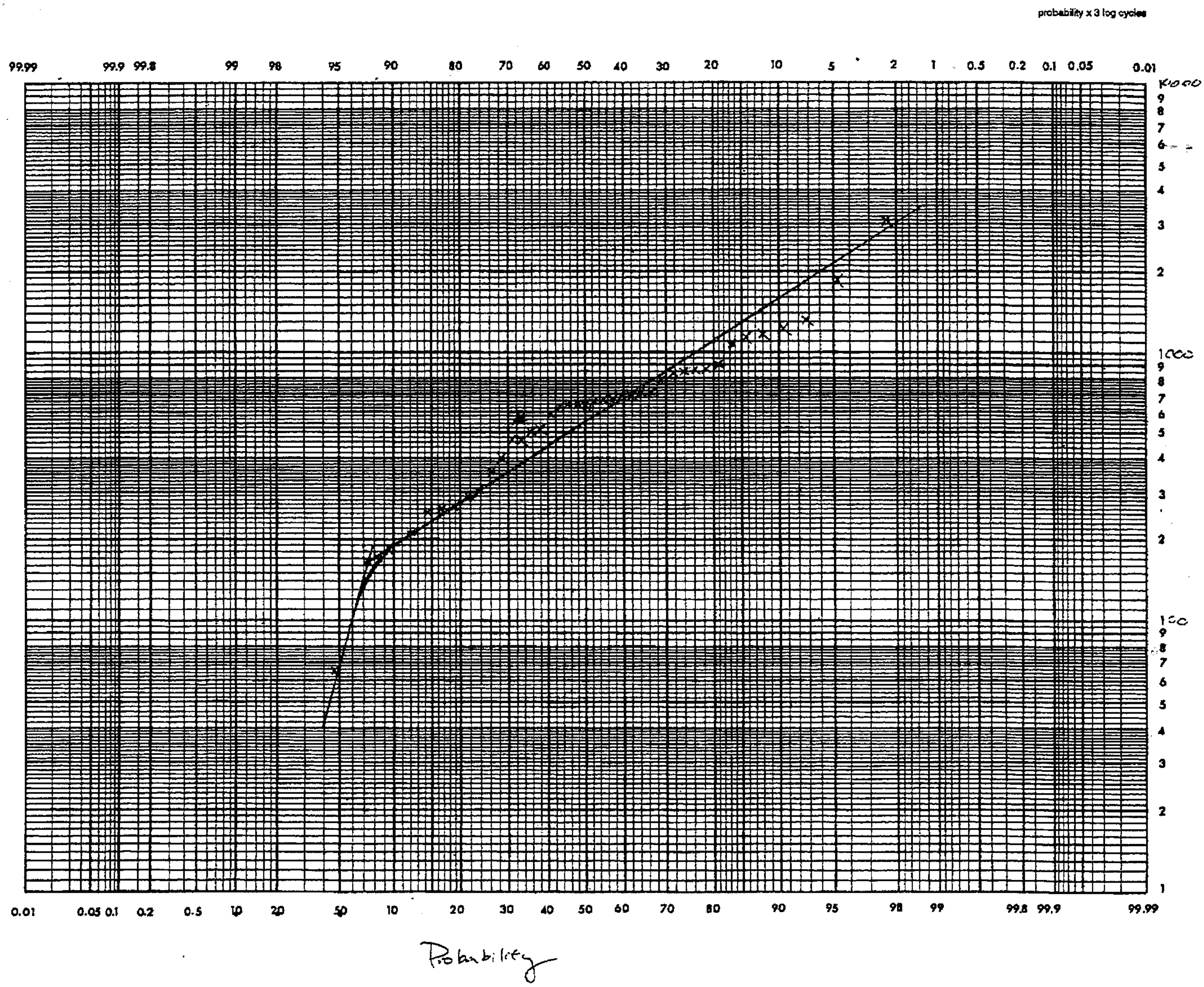
Est. 690,000 m^3
as 1:10 Nov inflow.



DEC GRAFTON LAKE

Est. 990,000m³
as 1:10 Dec inflow

1961 - 2008
41 years



Est. 190,000 m^3
as 1:10 summer inflow

SUMMER GRAFTON LAKE
1961 - 2008
41 years

1:2 => 550,000 m^3
1:5 => 275,000 m^3
1:10 => 190,000 m^3
1:15 => 130,000 m^3
1:20 => 68,000 m^3

BOWEN ISLAND MUNICIPALITY

COVE BAY WATER SYSTEM
LONG RANGE PLAN UPDATE

APPENDIX C

GRAFTON LAKE WATER QUALITY REPORTS

Typical Raw Water Sample Test Results Appendix D

BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0406S184

For: *Bowen Island Municipality* HOX
P.O. Box 179, Bowen Island
BC, V0N 1G5
Attn: *Bob Robinson*
Fax: *604-947-0193*

ENHANCED WATER POTABILITY ANALYSIS

Project: Raw Water Sampling
Sample Name: Cove Bay Water
Sampling Time: June 28, 2004

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L		25		
Barium (Ba)	8.0	ug/L		1000.0		
Boron (B)	<0.02	mg/L		5.0		
Chromium (Cr) *	<1	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	0.90	mg/L		10.0		
Nitrite (NO2)	<0.05	mg/L		1.0		
Fecal Coliform	0	Cfu/100ml		0		
Total Coliform	0	Cfu/100ml		0		
Copper (Cu)	9	ug/L			1000.0	
Iron (Fe)	0.10	mg/L			0.3	
Manganese (Mn)	0.02	mg/L			50	
Zinc (Zn)	<0.005	mg/L			5.0	
Total Hardness	24	mg/L CaCO3			200	
pH	6.3	SU	UL		6.5 to 8.5	
Total Dissolved Solids	48	mg/L			500	
Turbidity	<1	NTU			5	
Cadmimum	<0.1	ug/L		5		
Selenium	0.1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	5.8	mg/L			200	
Chloride	7	mg/L			250	
Magnesium	1.2	mg/L				150
Conductivity	98.0	uS/cm				700
True Color	<1	color unit				15

N/A = Not Applicable NL = No Limit OL = Over Limit

COMMENTS:

Sample is within Drinking Water limits for health parameters.
Sample satisfies Drinking Water requirements for aesthetic parameters except pH.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: [signature] Date: *7-Jul-04*

A0406S184(HOX)

128A-3989 Henning Drive, Burnaby, BC V5C 6N5 Canada • Tel: 604-320-1588 • Fax: 604-434-9577

Typical Raw Water Sample Test Results Appendix D

BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0412S228-3
For: Bowen Island Municipality HOX
P.O. Box 179, Bowen Island
BC, V0N 1G5
Attn: Bob Robinson
Fax: 604-947-0193

ENHANCED WATER POTABILITY ANALYSIS

Project: Raw Water Sampling
Sample Name: Cove Bay Water
Sampling Time: De

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	c 6, 2004		25		
Barium (Ba)	8.0	ug/L		1000.0		
Boron (B)	<0.02	mg/L		5.0		
Chromium (Cr)	<1	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	3.6	ug/L		10		
Nitrate (NO3)	0.28	mg/L		10.0		
Nitrite (NO2)	<0.08	mg/L		1.0		
Fecal Coliform	43	Cfu/100ml	OL	0		
Total Coliform	9	Cfu/100ml	OL	0		
Copper (Cu)	8	ug/L			1000.0	
Iron (Fe)	0.15	mg/L			0.3	
Manganese (Mn)	5.90	mg/L			.05 50	
Zinc (Zn)	1.80	mg/L			5.0	
Total Hardness	30	mg/L CaCO3			200	
pH	6.1	SU	UL		6.5 to 8.5	
Total Dissolved Solids	36	mg/L			500	
Turbidity	<1	NTU			5	
Cadmium	0.11	ug/L		5		
Selenium	<1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	5.9	mg/L			200	
Chloride	8	mg/L			250	
Magnesium	5.3	mg/L				150
Conductivity	30.0	uS/cm				700
True Color	<1	color unit				15

N/A = Not Applicable NL = No Limit OL = Over Limit

COMMENTS:

Sample is within Drinking Water limits for health parameters except Total and Fecal Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters except pH.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: [signature] Date: 2004/12/22

A0412S228-3(HOX)

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BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0603S369
For: *Bowen Island Municipality* HOX
P.O. Box 179, Bowen Island
BC, V0N 1G5
Attn: *Bob Robinson*
Fax: *604-947-0193*

ENHANCED WATER POTABILITY ANALYSIS

Project: Enhanced Potability
Sample Name: Cove Bay
Sampling Time: march 21, 2006 (20:06)

Parameter	Results	Units	HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L	25		
Barium (Ba)	6.7	ug/L	1000.0		
Boron (B)	<0.1	mg/L	5.0		
Chromium (Cr)	9.0	ug/L	50.0		
Fluoride (F), Dissolved	<0.05	mg/L	1.50		
Lead (Pb)	<1	ug/L	10		
Nitrate (NO3)	0.20	mg/L	10.0		
Nitrite (NO2)	<0.05	mg/L	1.0		
Fecal Coliform	<1	Cfu/100ml	0		
Total Coliform	<1	Cfu/100ml	0		
Copper (Cu)	1	ug/L		1000.0	
Iron (Fe)	33.00	ug/L		300	
Manganese (Mn)	3.40	ug/L		50	
Zinc (Zn)	<0.01	mg/L		5.0	
Total Hardness	22	mg/L CaCO3		200	
pH	7.1	SU		6.5 to 8.5	
Total Dissolved Solids	159	mg/L		500	
Turbidity	0.28	NTU		5	
Cadmimum	<0.05	ug/L	5		
Selenium	<0.1	ug/L	10.0		
Mercury	<1	ug/L	1.0		
Uranium	<0.001	mg/L	0.10		
Sodium (Na)	4.4	mg/L		200	
Chloride	4	mg/L		250	
Magnesium	1.4	mg/L			150
Conductivity	316.0	uS/cm			700
True Color	6.0	color unit			15

N/A = Not Applicable NL = No Limit OL = Over Limit

COMMENTS:

Sample is within Drinking Water limits for health parameters.
Sample satisfies Drinking Water requirements for aesthetic parameters.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: [signature] Date: *2006/4/18*

A0603S369(HOX).xls

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BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0812S423
For: *Bowen Island Municipality* **HOX**
P.O. Box 179, Bowen Island
BC, V0N 1G5
Attn: *Bob Robinson*
Fax: *604-947-0193*

ENHANCED WATER POTABILITY ANALYSIS

Project: **Enhanced Potability**
Sample Name: **Cove Bay**
Sampling Time: **Dec 12, 2006**

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L		25		
Barium (Ba)	7.8	ug/L		1000.0		
Boron (B)	<0.1	mg/L		5.0		
Chromium (Cr)	1.0	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	0.40	mg/L		10.0		
Nitrite (NO2)	<0.05	mg/L		1.0		
Fecal Coliform	1	Cfu/100ml	OL	0		
Total Coliform	5	Cfu/100ml	OL	0		
Copper (Cu)	13	ug/L			1000.0	
Iron (Fe)	45.00	ug/L			300	
Manganese (Mn)	1.47	ug/L			50	
Zinc (Zn)	2.10	mg/L			5.0	
Total Hardness	22	mg/L CaCO3			200	
pH	6.9	SU			6.5 to 8.5	
Total Dissolved Solids	36	mg/L			500	
Turbidity	0.80	NTU			5	
Cadmimum	<0.05	ug/L		5		
Selenium	<0.1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	5.2	mg/L			200	
Chloride	6	mg/L			250	
Magnesium	1.3	mg/L				150
Conductivity	73.0	uS/cm				700
True Color	8.0	color unit				15

N/A = Not Applicable **NL = No Limit** **OL = Over Limit**

COMMENTS:

Sample is within Drinking Water limits for health parameters except Total and Fecal Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: **Date:** ***1/5/2007***

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A0812S423(HOX)

BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0705S461C
For: Bowen Island Municipality HOX
P.O. Box 179, Bowen Island
BC, V0N 1G6
Attn: Bob Robinson
Fax: 604-947-0193

ENHANCED WATER POTABILITY ANALYSIS

Project: Enhanced Potability
Sample Name: Cove Bay
Sampling Time: May 15, 2007 (06:30 am)

Parameter	Results	Units		Health Limit	Aesthetic Limit	IMAC Limit
Arsenic (As)	<1	ug/L		25		
Barium (Ba)	6.5	ug/L		1000.0		
Boron (B)	<0.1	mg/L		5.0		
Chromium (Cr)	9.0	ug/L		50.0		
Fluoride (F). Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	0.10	mg/L		10.0		
Nitrite (NO2)	<0.05	mg/L		1.0		
Fecal Coliform	1	Cfu/100ml	OL	0		
Total Coliform	7	Cfu/100ml	OL	0		
Copper (Cu)	1	ug/L			1000.00	
Iron (Fe)	24.00	ug/L			300	
Manganese (Mn)	2.10	ug/L			50	
Zinc (Zn)	<0.01	mg/L			5.0	
Total Hardness	16	mg/L CaCO3			200	
pH	6.2	SU	UL		6.5 to 8.5	
Total Dissolved Solids	30	mg/L			500	
Turbidity	0.28	NTU			5	
Cadmium	<0.05	ug/L		5		
Selenium	<0.1	ug/L		10		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	4.1	mg/L			200	
Chloride	2	mg/L			250	
Magnesium	0.8	mg/L				150
Conductivity	59.0	uS/cm				700
True Color	3.0	Color unit				15

NA = Not Applicable NL = No Limit OL = Over Limit

Comments:

Sample is within Drinking Water limits for health parameters except Total and Fecal Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters except pH.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by "Dr. Parker Shieh" Director, Environmental Services

FROM :BCAT FAX NO. :6044349577 Jan. 17 2008 09:30AM P2

BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0712S528A
For: Bowen Island Municipality HOX
P.O. Box 179, Bowen Island
BC, V0N 1G5
Attn: Bob Robinson
Fax: 604-947-0193

ENHANCED WATER POTABILITY ANALYSIS

Project: Enhanced Potability Fall 2007
Sample Name: Cove Bay
Sampling Time: December 6, 2007

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L		25		
Barium (Ba)	4.3	ug/L		1000.0		
Boron (B)	<0.1	mg/L		5.0		
Chromium (Cr)	8.2	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	0.42	mg/L		10.0		
Nitrite (NO2)	<0.05	mg/L		1.0		
Fecal Coliform	6	Cfu/100ml	OL	0		
Total Coliform	34	Cfu/100ml	OL	0		
Copper (Cu)	1	ug/L			1000.0	
Iron (Fe)	19.00	ug/L			300	
Manganese (Mn)	1.20	ug/L			50	
Zinc (Zn)	<0.01	mg/L			5.0	
Total Hardness	10	mg/L CaCO3			200	
pH	7.6	SU			6.5 to 8.5	
Total Dissolved Solids	58	mg/L			500	
Turbidity	0.47	NTU			5	
Cadmimum	<0.05	ug/L		5		
Selenium	<0.1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	7.1	mg/L			200	
Chloride	6	mg/L			250	
Magnesium	0.8	mg/L				150
Conductivity	118.0	uS/cm				700
True Color	13.0	color unit				15

N/A = Not Applicable NL = No Limit OL = Over Limit

COMMENTS:

Sample is within Drinking Water limits for health parameters except Total and Fecal Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: [signature] Date: 12/31/2007

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BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0806S661A

For: *Bowen Island Municipality* *HOX*

P.O. Box 179, Bowen Island

BC, V0N 1G5

Attn: *Bob Robinson*

Fax: *604-947-0193*

ENHANCED WATER POTABILITY ANALYSIS

Project: Enhanced Potability Summer 2008

Sample Name: Cove Bay

Sampling Time: June 18, 2008

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L		25		
Barium (Ba)	8.4	ug/L		1000.0		
Boron (B)	<0.1	mg/L		5.0		
Chromium (Cr)	3.1	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	0.42	mg/L		10.0		
Nitrite (NO2)	<0.05	mg/L		1.0		
Fecal Coliform	<1	Cfu/100ml		0		
Total Coliform	1	Cfu/100ml	OL	0		
Copper (Cu)	2	ug/L			1000.0	
Iron (Fe)	15.00	ug/L			300	
Manganese (Mn)	0.60	ug/L			50	
Zinc (Zn)	<0.01	mg/L			5.0	
Total Hardness	24	mg/L CaCO3			200	
pH	7.0	SU			6.5 to 8.5	
Total Dissolved Solids	67	mg/L			500	
Turbidity	0.47	NTU			5	
Cadmimum	<0.05	ug/L		5		
Selenium	<0.1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	18.5	mg/L			200	
Chloride	6	mg/L			250	
Magnesium	1.2	mg/L				150
Conductivity	137.0	uS/cm				700
True Color	13.0	color unit				15

N/A = Not Applicable **NL = No Limit** **OL = Over Limit**

COMMENTS:

Sample is within Drinking Water limits for health parameters except Total Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: [signature] **Date:** *7/10/2008*

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BCAT British Columbia Analytical Technologies Ltd.

CERTIFICATE OF ANALYSIS

No: A0812S600-4

For: *Bowen Island Municipality* — *HOX*

981 Artisan Lane

BC, V0N 1G0

Attn: *Bob Robinson*

Fax: *604-947-0193*

ENHANCED WATER POTABILITY ANALYSIS

Project: Enhanced Potability Winter 2008

Sample Name: Cover Bay

Sampling Time: December 29, 2008

Parameter	Results	Units		HEALTH LIMIT *	AESTHETIC LIMIT **	IMAC LIMIT***
Arsenic (As)	<1	ug/L		10		
Barium (Ba)	8.0	ug/L		1000.0		
Boron (B)	<0.1	mg/L		5.0		
Chromium (Cr)	<10	ug/L		50.0		
Fluoride (F), Dissolved	<0.05	mg/L		1.50		
Lead (Pb)	<1	ug/L		10		
Nitrate (NO3)	1.80	mg/L		10.0		
Nitrite (NO2)	0.07	mg/L		1.0		
Fecal Coliform	1	Cfu/100ml	OL	0		
Total Coliform	17	Cfu/100ml	OL	0		
Copper (Cu)	<10	ug/L			1000.0	
Iron (Fe)	80.0	ug/L			300	
Manganese (Mn)	17.0	ug/L			50	
Zinc (Zn)	<0.01	mg/L			5.0	
Total Hardness	20	mg/L CaCO3			200	
PH	6.8	SU			6.5 to 8.5	
Total Dissolved Solids	41	mg/L			500	
Turbidity	0.31	NTU			5	
Cadmimum	<0.05	ug/L		5		
Selenium	<0.1	ug/L		10.0		
Mercury	<1	ug/L		1.0		
Uranium	<0.001	mg/L		0.10		
Sodium (Na)	4.7	mg/L			200	
Chloride	4	mg/L			250	
Magnesium	1.13	mg/L				150
Conductivity	84	uS/cm				700
True Color	8.0	color unit				15

N/A = Not Applicable **NL = No Limit** **OL = Over Limit**

COMMENTS:

Sample is within Drinking Water limits for health parameters except Total and Fecal Coliform.
Sample satisfies Drinking Water requirements for aesthetic parameters.
Sample satisfies Drinking Water requirements for max tolerable parameters.

Certified by: **Date:** *2009/1/14*

Analytical Results: (ug/L)

Parameter	Cove Bay Winter 2008	Eagle Cliff Winter 2008	Hood Point Winter 2008	Detection Limit
Sampling Date	Dec 28, 2008 18:00	Dec 28, 2008 17:00	Dec 28, 2008 16:45	-
Monochloroacetic Acid	< 5	< 5	< 5	5
Monobromoacetic Acid	< 5	< 5	< 5	5
Dichloroacetic Acid	23.5	< 5	26.3	5
Trichloroacetic Acid	32.5	< 5	28.5	5
Bromochloroacetic Acid	8.1	< 5	< 5	5
Dibromoacetic Acid	10.5	< 5	11.6	5
2,4-Dichlorophenol	< 5	< 5	< 5	5
2,4,6-Trichlorophenol	< 5	< 5	< 5	5

* Unit: ug/L (microgram per Litre, equivalent to parts per billion, ppb)
* <= Less than detection limit

Quality Control: Surrogate Recovery (%)

Parameter	Cove Bay Winter 2008	Eagle Cliff Winter 2008	Hood Point Winter 2008	-
3,5-Dichlorobenzoic Acid	73	71	69	-

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Analytical Results: (ug/L)

Parameter	Cove Bay Winter 2008	Eagle Cliff Winter 2008	Hood Point Winter 2008	Detection Limit
Sampling Date	Dec 28, 2008 18:00	Dec 28, 2008 17:00	Dec 28, 2008 16:45	
Bromodichloromethane	8.8	0.9	3.3	0.1
Bromoform	<0.2	<0.2	<0.2	0.2
Chlrorform	140	8.1	87	0.3
Dibromochloromethane	0.2	<0.1	<0.1	0.1
Total Trihalomethanes	**150**	**9.0**	**90**	**0.1**

* Unit: ug/L (microgram per Litre, equivalent to parts per billion, ppb)

* < = Less than detection limit

Quality Control: Surrogate Recovery (%)

Parameter	Cove Bay Winter 2008	Eagle Cliff Winter 2008	Hood Point Winter 2008	-
1,2-Dichloroethane-d4	111	104	99	-
Toluene-d8	98	102	97	-
Bromoflorobenzene	99	98	95	-

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