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February 10, 1995
File: M9412-15

Town of Ladysmith
P.O. Box 220
Ladysmith, B.C. V0R 2E0

Attention: **Mr. Bob Marchand**
Superintendent of Public Works

Dear Sirs:

Re: Ladysmith Water Study

We are pleased to submit our report on the Ladysmith Water Study, which details the recommended staged implementation for improvements to the water system. Twelve copies of the report are presented.

This report includes appropriate comments and information added since our presentations of the draft report to Town staff, the Mayor, and some members of Council.

We look forward to discussing this final report with you further, at your convenience. We also look forward to assisting the Town during detailed design and implementation of the proposed works.

Thank you for retaining us to work on this interesting project.

Yours truly,

KOERS & ASSOCIATES ENGINEERING LTD.

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — D. SHILLABEER

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — N. E. WINTON

D. Shillabeer, P.Eng.
Project Manager

Norman E. Winton, P.Eng.
Project Engineer

EXECUTIVE SUMMARY

The Town of Ladysmith draws water from two sources, Stocking Lake and Holland Creek, and delivers it to consumers in Lladysmith and into a reservoir which serves the Diamond Improvement District. Stocking Lake is also the source for Saltair, through a system operated by the Cowichan Valley Regional District. The water quality from both sources is generally good, but high turbidity and colour tends to occur in Holland Creek after heavy rainfall. See Section 5.0.

The average residential water demand is 566 litres per capita per day (lpcd). When the industrial, institutional, and commercial demands are added in the total becomes 790 lpcd. Appendix A provides more information on the water demands. Most houses, and some commercial premises are not metered. The introduction of meters and other water conservation measures could reduce the water demands by approximately 20%.

With respect to the water sources, two issues are to be addressed, water quantity and water quality.

Assuming a 20% reduction in per capita demands, the water supply system is capable of serving 9,000 people in a year of low flow in the creeks. Improved efficiency of operation will allow a greater number to be served. The first step in improving the efficiency will be to install a remotely controlled valve and water meter at the Holland Lake outlet.

Additional water can be obtained from Holland Lake by increasing the embankment height. Up to 18,000 people could be served if the embankment is raised by 1.0 m. Appendix E contains the geotechnical report by EBA Engineering Ltd on the preliminary investigation at Holland Lake. As an alternative to the work at Holland Lake, wells could be drilled in the Cassidy aquifer to develop a groundwater source for the Town. It may be possible that wells could be drilled closer to town to reduce the cost of a connecting pipeline. Appendix F contains a report on the groundwater potential from Pacific Hydrology Consultants Ltd.

If Holland Lake is to upgraded and remain the main source of water, then the occasional high turbidity events must be addressed. One possible method of dealing with the problem would be to install a pipeline from Holland Lake to Chicken Ladder. However, water quality samples from the lake in winter show that this water does not always meet the Canadian Drinking Water Guidelines. It is concluded that the pipeline would be an expensive, ineffective solution.

This report recommends that the pipeline should not be installed. The preferred solution is the construction of a water filtration plant, downstream from the Chicken Ladder intake.

If wells are developed they would have sufficient capacity to meet the winter demands, without the need to draw water from Holland Creek. The groundwater is unlikely to require treatment, and, therefore, the water quality to consumers during the winter high turbidity events would not be affected. High turbidity can still occur during heavy summer storms, and to ensure that the water quality is satisfactory, a filtration plant can be installed to treat only that portion of the water that comes from the creek.

The existing Arbutus reservoir is unlined and open to the atmosphere. It is not suitable for the storage of drinking water and should be replaced with a concrete or steel enclosed reservoir. The new reservoir should be at a higher elevation than at present so that pressures in the higher parts of town can be increased to acceptable levels. To deliver water into the new reservoir, a new pipeline will be required from Chicken Ladder to Arbutus. The diameter of the pipe will depend on whether a groundwater source is being developed, or all the water is supplied from Holland Creek.

The other supply mains carrying water from the sources to town are adequately sized to serve a population of 18,000.

With the new, higher reservoir in service, the system pressures will be increased. Existing pressures at the lower elevations are already excessively high, so a rearrangement of the pressure zones is recommended. Figures No. 2 and 4 show the existing and proposed pressure zones. New pressure reducing stations and some new watermains are required to allow the adjustment of the pressure zone boundaries.

Section 10.0 summarizes the proposed water supply improvements, and provides cost estimates. Section 11.0 contains the conclusions and recommendations.

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1.0 INTRODUCTION

1.1 GENERAL

The Town of Ladysmith draws water from the Holland Creek watershed and the Stocking Creek watershed, and delivers it to residential, commercial, institutional, and industrial users in town, as well as into a reservoir operated by the Diamond Improvement District. The current Town population is approximately 6,000. Because of rapid population growth, the Town wished to review the system capacity and to identify improvements which are required. In April 1994 the Town authorized Koers & Associates Engineering Ltd. to undertake a study of the water supply system.

The terms of reference require Koers and Associates to evaluate the demands, sources, treatment, distribution, and system operation, and to present recommendations and cost estimates. This Report sets out the findings of the Study.

1.2 RELEVANT DOCUMENTS

During this study, reference was made to the following documents:

Correspondence concerning water supply, to the Town of Ladysmith from Willis, Cunliffe Tait, 1976 through 1980.

Town of Ladysmith - Analysis of Water Supply System, by Chatwin Engineering Ltd., December 1986.

Holland Creek/Stocking Lake Hydrology, Data Summary and Analysis,by A.R.Chapman and D.E.Reksten, Water Management Division, April 1993.

Holland Creek and Stocking Lake, Interim Water Quality Assessment and Objectives, L.Pommen, Water Management Division, July 1993.

Town of Ladysmith, Development Cost Charge Evaluation, by UMA Engineering Ltd., July 1993.

Town of Ladysmith Official Community Plan, August 1994.

Various Water Licences issued to the Town of Ladysmith and the Cowichan Valley Regional District by the Province of British Columbia.

Draft Objectives for the Holland Creek/Stocking Lake Integrated Watershed Management Plan, July, 1994.

Where project subconsultants referred to additional documents, these are identified in the Appendices to this report.

1.3 STUDY TEAM

Two subconsultants were retained for separate aspects of this study. EBA Engineering Ltd. carried out the geotechnical work, which included an inspection of the Holland Lake embankments, evaluation of their ability to be heightened, and the review of alternative dam sites in the Holland Lake watershed. Pacific Hydrology Consultants Ltd. investigated potential groundwater sources in the vicinity of Ladysmith. Koers & Associates Engineering Ltd. provided all the other engineering services required for this study.

1.4 ACKNOWLEDGEMENTS

Koers & Associates Engineering Ltd. wish to thank the Town of Ladysmith Public Works staff for their valuable assistance and advice during this study. In particular, Bob Marchand and Charles Cale who made themselves available for meetings and site visits, and, with help from Darcy Kohuch, assembled material which assisted the study. Gord Horth, Aministrator, Ed Gilman, Clerk, and Ruth Malli, Treasurer, provided information on the Development Cost Charges.

We also wish to thank Bob Cook and Al Boom of the Water Management Division of BC Environment, and Dave Woodgate, chairperson of the Holland Creek/Stocking Lake Integrated Watershed Management Plan Technical Committee for their assistance. Staff of the Cowichan Valley Regional District kindly supplied information on population and water demand growth in the Saltair area.

2.0 EXISTING SYSTEM

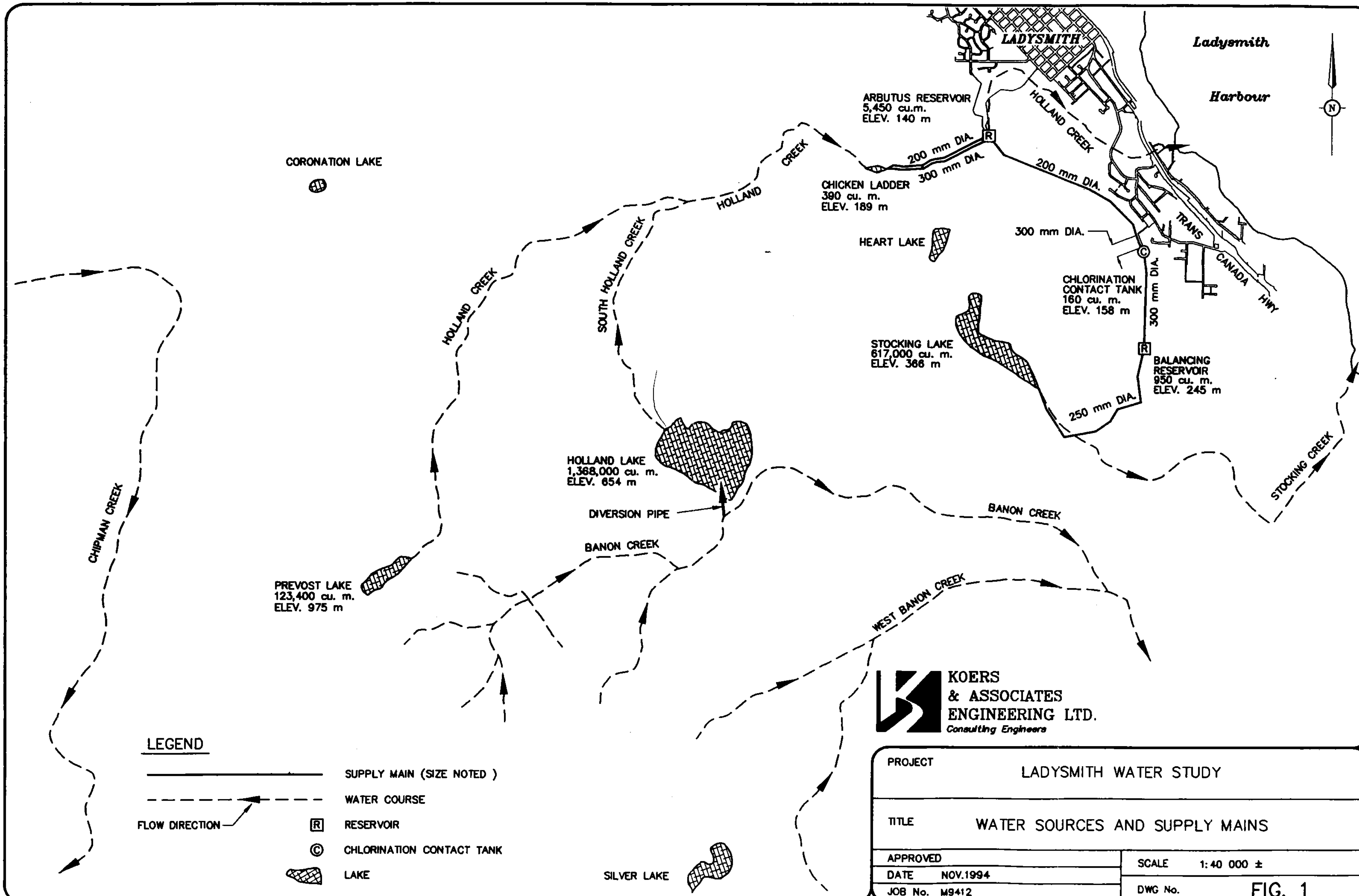
2.1 SUPPLY SYSTEM

Figure No. 1 shows an outline of the Ladysmith water supply system.

The Town draws water from the Stocking Lake and Holland Creek watersheds. Stocking Lake is also the source for the Saltair water system, operated by the Cowichan Valley Regional District. Section 4.2 of this report gives details of the water licences held by the Town of Ladysmith and the Cowichan Valley Regional District.

Water drawn from Stocking Lake for Ladysmith is carried through a 250 mm pipe into a balancing reservoir. From this balancing reservoir water is carried through a 300 mm pipe to a chlorination facility above Thetis Drive, and can then be fed into the South Ladysmith water distribution system through a 200 mm pipe. South Ladysmith, as far as water supply is concerned, is roughly the area south of Holland Creek and west of the Trans-Canada Highway. The chlorination facility incorporates a contact tank with a top water level of 158 m. From just upstream of the chlorination facility, unchlorinated water can be fed into the Arbutus Reservoir through a pipe which is partly 300 mm and partly 200 mm diameter.

The Holland Creek watershed has three impoundment reservoirs in it, Holland Lake, Prevost Lake, and Chicken Ladder dam. During the winter months water is diverted from the Banon Creek watershed into Holland Lake. Water is released from Holland Lake and Prevost Lake into Holland Creek, then water is extracted from Chicken Ladder dam which is on the creek, further down the valley. From Chicken Ladder water is carried through two parallel pipes, one 300 mm and one 200 mm, to Arbutus Reservoir. Arbutus Reservoir serves all of Ladysmith, except South Ladysmith, through 350 mm and 300 mm pipes.



PROJECT	LADYSMITH WATER STUDY		
TITLE	WATER SOURCES AND SUPPLY MAINS		
APPROVED		SCALE	1: 40 000 ±
DATE	NOV.1994		
JOB No.	M9412	DWG No.	FIG. 1

2.2 WATERSTORAGE

Table No. 1 gives information on the water storage in the Ladysmith system. The contact tank has a roof, the others are open to the atmosphere.

TABLE NO. 1 - WATER STORAGE

Reservoir	Capacity (m3)	Top Water Level (m)
Holland Lake	1,368,000	654
Prevost Lake	123,400	975
Chicken Ladder	390	189
Arbutus Reservoir	5,450	140
Stocking Lake	617,000	366
Balancing Reservoir	950	245
Contact Tank	160	158

2.3 TREATMENT

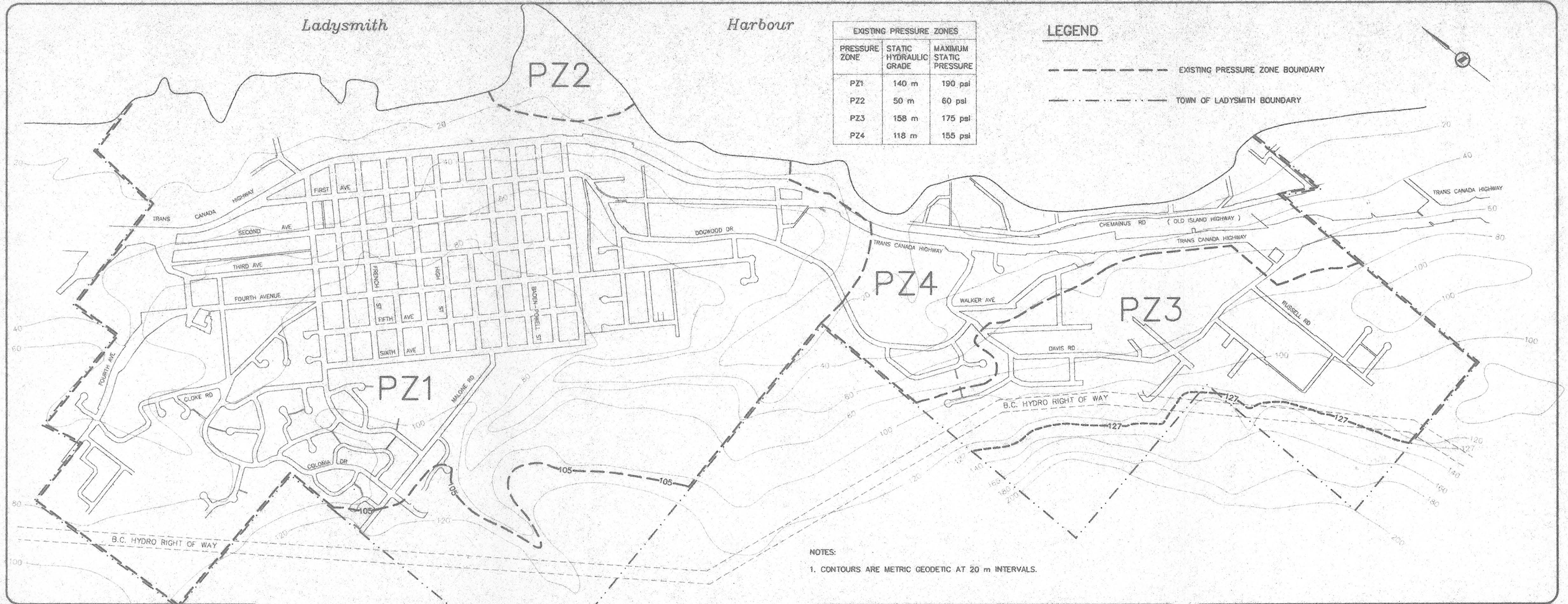
Water drawn from Stocking Creek for South Ladysmith is strained and chlorinated at the facility above Thetis Drive. Water drawn from Holland Creek for North Ladysmith is screened and chlorinated on the downstream side of Arbutus Reservoir. The water is not subject to any other treatment.

Section 5.0 of this report discusses the water quality and the chlorination.

2.4 DISTRIBUTION

The Town is built on a hillside, with service connections at elevations ranging from 5 m to 110 m. To control the pressures in the system, pressure reducing valves are installed to divide the area into separate pressure zones. Figure No. 2 shows the extent of the distribution system, together with the static hydraulic grade level and maximum static pressure in each zone.

The Town supplies bulk water to the Diamond Improvement District through a metered connection at Strathcona Road and Fourth Avenue. There is a control valve on the inlet to the Diamond District reservoir, activated by the pressure in the distribution system near Walkem Road. When the pressure at this location falls below 620 kPa the valve closes and water flow into the reservoir stops.



EXISTING PRESSURE ZONES		
PRESSURE ZONE	STATIC HYDRAULIC GRADE	MAXIMUM STATIC PRESSURE
PZ1	140 m	190 psi
PZ2	50 m	60 psi
PZ3	158 m	175 psi
PZ4	118 m	155 psi

LEGEND

EXISTING PRESSURE ZONE BOUNDARY

TOWN OF LADYSMITH BOUNDARY

NOTES:

1. CONTOURS ARE METRIC GEODETIC AT 20 m INTERVALS.

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers

CLIENT: TOWN OF LADYSMITH

PROJECT: WATER STUDY

TITLE: EXISTING PRESSURE ZONES

APPROVED		SCALE	1:10 000
DATE	NOV. 1994		
JOB No.	M9412	DWG No.	FIG. 2

3.0 WATER DEMANDS

3.1 GENERAL

In evaluating the capacity of a water supply system, three levels of water demand are normally considered. These are:

> Average day demand, which is the total annual water consumption divided by 365.
>
> Maximum day demand, which is the total water used during the day of highest demand in the year.
>
> Peak hour demand, which is the highest flow rate, maintained for an hour or more, on the maximum day of the year.

The system must also be capable of providing the water required for fire fighting. The fire flow required depends on the type of buildings to be protected, their materials of construction, their proximity to other buildings, and other factors.

3.2 METERING

There are three master water meters on the Ladysmith system. There is a 300 mm meter on the main from the balancing reservoir to the contact tank, a 200 mm meter measuring flow into South Ladysmith, and a 300 mm meter on the outlet from Arbutus Reservoir into North Ladysmith. These meters are read daily. Each meter also has a flow recorder which produces charts showing the variation of flow over a 24 hour period.

From the meter readings the annual water usage, and hence the average day demands, as well as the maximum day demands can be established. From the flow recorder charts the peak hour demands can be established.

There are 2,410 residential services in Ladysmith. There are water meters on some residential services in South Ladysmith, but they are not being read at present. In newer subdivisions allowance has been made for the future installation of residential water meters.

There are 44 meters currently being read monthly and billed on industrial, commercial, and institutional premises. There are also three meters on Town of Ladysmith premises which are not billed. There are a further 75 commercial services and six halls and churches which are not metered but are billed at a flat rate.

There is a meter on the connection from Ladysmith to the Diamond Improvement District. This meter is read semi-annually.

3.3 EXISTING WATER DEMANDS

Appendix A to this report contains background calculations on the water demands in the Ladysmith system.

From an analysis of the various meter readings and flow charts, the water consumption information shown in Table 2 was derived. The total water usage at the metered connections is divided by the population to give the per capita water demands at industrial and commercial premises. The units are litres per capita per day (lpcd) and litres per second (lps).

TABLE No. 2 - EXISTING WATER DEMANDS

Average day demand	residential services	566 lpcd
	non-residential services	224 lpcd
	Diamond I.D.	2.47 l/s
Maximum day demand	residential services	1313 lpcd
	non-residential services	392 lpcd
	Diamond I.D.	5.68 l/s
Peak hour demand	residential services	2429 lpcd
	non-residential services	725 lpcd
	Diamond I.D.	5.68
Max day/ave day ratio	residential services	2.3
	non-residential services	1.75
	Diamond I.D.	2.3
Peak hour/max day ratio	residential services	1.87
	non-residential services	1.87
	Diamond I.D.	1.00

The following information is provided for comparison purposes. The average day residential demands in adjacent communities are:

Ladysmith	566 lpcd
Nanaimo	530 lpcd
Parksville	480 lpcd
Qualicum Beach	590 lpcd
Lantzville I.D.	370 lpcd
North Cedar I.D.	280 lpcd
B.C. average (1983-91)	420 lpcd

3.4 FIRE FLOWS

The distribution system must be able to deliver water for fire fighting. It is common practice to ensure that the system can deliver the required fire flow simultaneously with the maximum day demand. The required fire flows are dependent on the facilities which are being protected. The Chatwin Report states that the minimum fire flow at the Ludlow Mill is 106 lps, and at the Coronation Square shopping centre is 110 lps. These flows are reasonable.

In the computer analysis, flows of 150 lps were allowed for the proposed Waterfront development, and at the Secondary School on Sixth Avenue. Fire flows of 60 lps were allowed for in the residential subdivisions.

If land is rezoned to a use which may require higher fire flows, say from single family to commercial, or if a high density development is proposed, the computer model should be re-run to confirm that the system can deliver the higher flows. If the system cannot meet the demand, the developer may wish to amend the building materials used or revise the building spacing to limit the fire flow demand.

3.5 WATER DEMAND PROJECTIONS

Ladysmith is experiencing rapid residential growth, but it is assumed that the growth of industrial and commercial water use, and growth in Diamond, will be at lower rates. For the purposes of this report it is assumed that water use at metered connections will increase at an average annual rate equal to two-thirds of the residential growth rate. The quantity of water delivered to users outside the town boundary, such as Diamond, will depend on the policy adopted by the Town. In this report it is assumed that the supply of water to Diamond will increase at a rate equal to two-thirds the rate of the residential growth in Ladysmith. If the supply to Diamond is curtailed, then the population which can be served in Ladysmith will be increased accordingly.

It is expected that the installation of residential water meters in Ladysmith would lead to a reduction in per capita water usage. Experience has shown that reductions in the order of 15% to 20% can be expected if meters are installed. Additional water conservation methods, such as reduced flow plumbing fixtures and leak detection, and adjustment of the rates charged for water can further reduce per capita consumption.

Residential water meters were recently installed in the Black Creek/Oyster Bay area north of Courtenay. The first year following the meter installation showed an average water consumption decrease of over 30%. The reduction which can be expected, however, is dependent to a great extent on the water rates charged to the consumer.

For the purposes of this Study it is assumed that universal metering will be implemented and that per capita consumption will fall by 20% within 2 or 3 years following the completion of meter installation.

If the Town does not install meters then the improvements recommended in this report should be implemented at population levels that are 20% less than those indicated in the report.

The water demand projections for the Town, up to a total population of 18,000 people are shown in Tables No. 3A and 3B. The future population levels are not related to specific years since the annual population growth rate will vary with time. Table 3A shows projections with universal metering and Table 3B shows projections without metering. As can be seen from the tables, an annual supply of 4,200,000 m^3 can supply a 15,000 population without meters or an 18,000 population with meters.

From a review of the current zoning and the development densities in the Official Community Plan, the maximum population which can be accommodated in the present Town boundaries is approximately 15,000. Over a period of time, rezoning may occur which will allow higher densities in some parts of the Town, and it would then become possible that up to 18,000 people could be accommodated within the existing boundaries.

The projected Ladysmith population for 1995 is 6,533. An average annual growth rate of 4% would give a population of 14,315 in the year 2015, and a rate of 5% would give a population of 17,335 in 2015.

TABLE NO. 3A – SUMMARY OF WATER DEMAND PROJECTIONS
WITH ALL SERVICES METERED

POPULATION	6000	9000	12000	15000	18000
ANNUAL DEMAND (m3)					
Ladysmith residential	1,239,540	1,488,105	1,984,140	2,480,175	2,976,210
Ladysmith non–residential	480,942	641,095	801,249	961,883	1,122,037
Diamond District	77,420	103,201	128,982	154,840	180,621
Total	1,797,902	2,232,401	2,914,370	3,596,898	4,278,867
MAXIMUM DAY (l/s)					
Ladysmith residential	91.2	109.4	145.8	182.3	218.8
Ladysmith non–residential	27.2	35.6	44.5	53.4	62.3
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	124.1	152.5	199.7	247.0	294.2
PEAK HOUR (l/s)					
Ladysmith residential	168.7	202.3	269.8	337.2	404.7
Ladysmith non–residential	50.4	65.8	82.3	98.7	115.2
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	224.7	275.7	361.4	447.3	533.1

TABLE NO. 3B – SUMMARY OF WATER DEMAND PROJECTIONS WITHOUT WATER METERS

POPULATION	6000	9000	12000	15000	18000
ANNUAL DEMAND (m3)					
Ladysmith residential	1,239,540	1,859,310	2,479,080	3,098,850	3,718,620
Ladysmith non–residential	480,942	641,095	801,249	961,883	1,122,037
Diamond District	77,420	103,201	128,982	154,840	180,621
Total	1,797,902	2,603,606	3,409,310	4,215,573	5,021,277
MAXIMUM DAY (l/s)					
Ladysmith residential	91.2	136.8	182.4	228.0	273.5
Ladysmith non–residential	27.2	35.6	44.5	53.4	62.3
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	124.1	179.9	236.2	292.6	349.0
PEAK HOUR (l/s)					
Ladysmith residential	168.7	253.0	337.4	421.7	506.1
Ladysmith non–residential	50.4	65.8	82.3	98.7	115.2
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	224.7	326.3	429.0	531.8	634.4

4.0 WATERSHEDS

4.1 GENERAL

The Town of Ladysmith obtains its water from three watersheds, Stocking Creek, Holland Creek, and Banon Creek. The Cowichan Valley Regional District also draws water from Stocking Lake for delivery to Saltair, and the District of North Cowichan draws water from Banon Creek for delivery to Chemainus. A report on the watersheds has been prepared by the Hydrology Branch, Water Management Division, Ministry of Environment, Lands, and Parks, as an appendix to the Holland Creek/Stocking Lake Integrated Watershed Management Plan. The report is titled Holland Creek/Stocking Lake Hydrology - Data Summary and Analysis by A.R. Chapman and D.E. Reksten, and is included in Appendix B.

4.2 LICENCES

The Town of Ladysmith holds five conditional licences in the watersheds, as follows:

CL 005333	500,000 gal/day (2273 m^3/day) from Stocking Lake/Creek
CL 017746	600,000 gal/day (2727 m^3/day) from Holland Creek
CL 021164	200 ac-ft (247,000 m^3) storage at Holland Lake
CL 029821	100 ac-ft (123,000 m^3) storage at Holland Creek/Provost Lake
CL 067480	During the period November 1 through May 31 a maximum of 1,475 ac-ft (1,819,000 m^3) may be diverted from Banon Creek. Of this amount a maximum 625 ac-ft (771,000 m^3), at a rate not exceeding 800,000 gal/day (3,640 m^3/day) may be diverted through Holland Lake and rediverted to Holland Creek during the same period. The remainder of the water may be stored in Holland Lake and during the period June 1 through October 31 each year may be released to Holland Creek and rediverted from Holland Creek.

replaced by CL 112812 in 2000 (1,048,000 m³)
replaced by CL 112813

The Cowichan Valley Regional District (CVRD) holds four conditional licences in the Stocking Creek watershed, as follows:

CL 067481	98,500,000 gal/year (448,000 m^3/year) from Stocking Creek
CL 067482	105,000,000 gal/year (477,000 m^3/year) from Stocking Creek
CL 067483	100 ac-ft (123,000 m^3) storage in Stocking Lake
CL 067484	650 ac-ft (802,000 m^3) storage in Stocking Lake

The two licences which permit the diversion of water by the CVRD allow a maximum annual usage of:

CL 067481	448,000 m^3
CL 067482	477,000 m^3
TOTAL	925,000 m^3

4.3 OPERATION OF SOURCES

In assessing the ability of a surface water source to support a public water supply system, consideration should be given to:

(a) the low flows which occur during a dry year,
(b) the residual flow which should be maintained in the creek downstream of the intake,
(c) the water licences which permit the storage and diversion of water,
(d) the ability of impoundment dams to store water during the winter for release during the summer, and
(e) the quality of the water.

The water quality in Stocking Lake is good. The quality in Holland Creek is generally good, but during and immediately after heavy rainfall the turbidity increases to unacceptable levels. Section 5 of this Report provides more information on the water quality. To avoid drawing high turbidity water from Holland Creek, Ladysmith staff closes the intake on Holland Creek in the late fall and draws only from Stocking Lake for a period of four to five months during the low demand period. The average daily water demand in Ladysmith during the past several winters exceeded the 2273 m^3/day permitted by CL 005333 on Stocking Lake. For example, the average day demand in 1994 was 3,835 m^3/day.

The upper pressure zone of South Ladysmith, shown as Pressure Zone 3 on Figure No. 2, is supplied from Stocking Lake all year round, because this part of South Ladysmith is at too high an elevation to be fed by gravity from the Arbutus Reservoir. In addition, a small amount of water is allowed to flow through the 200 mm pipe to Arbutus reservoir to prevent stagnation of water in the pipe.

The water quality from Prevost Lake is poorer than from the other sources. The area behind Prevost dam was not cleared of trees and vegetation before the lake was formed, so the water carries organic colour, and probably associated odour and taste. The Public Works staff leave the outlet from the lake open so that water impounded in the winter is released in the spring and early summer. The capacity of Prevost Lake is approximately 10% of the capacity of Holland Lake.

4.4 STOCKING CREEK WATERSHED

The total diversion permitted annually by the licences held on the Stocking Creek watershed is:

Ladysmith	830,000 m^3
CVRD	925,000 m^3
Total	1,755,000 m^3

The Chapman/Reksten report estimates that, during a 10-year return period low flow, the discharge in Stocking Creek is 1,340,000 m^3, which is less than the licensed amount. The Water Management Division, therefore, is unlikely to issue additional licences on Stocking Creek for either diversion or storage.

The existing capacity of Stocking Lake is 1,073,000 m^3, and the CVRD is licensed to store 925,000 m^3. Ladysmith does not hold a licence to store water in this watershed.

With adequate storage and efficient operation, the licensed amount of 925,000 m^3 would be sufficient to serve approximately 5,600 people in Saltair. The current population of Saltair is 2,300, and the population projected for the year 2015 is 3,635. The annual Saltair water demand in the year 2015 is projected to be 597,000 m^3.

As previously stated, the whole of Ladysmith is supplied with water from Stocking Lake during months in which high turbidity is expected in Holland Creek. The quantity drawn under these conditions exceeds the daily amount allowed in the Town's licence CL 005333. The Town, therefore, should revise its operational procedures to reduce the amount of water drawn from the Stocking Creek watershed. However, any new procedures should allow the Town to continue to draw water from Stocking Lake for supply to Pressure Zone 3 in South Ladysmith.

The licence CL 005333 allows Ladysmith to extract up to 2,273 m^3 from the Stocking Creek watershed per day. On the maximum day in South Ladysmith the per capita residential demand will be 1,050 litres, assuming that a 20% reduction in consumption is achieved through conservation and metering. The population which can be served from Stocking Creek is therefore 2,165. At 2.6 persons per unit, 832 residential units can be served. Over a 12-month period, 2,165 people will use 358,000 m^3 of water. In 20 years time the total annual water usage from Stocking Lake by both Saltair and Ladysmith will be 960,000 m^3, which is less than the total licensed amount, and less than the 10 year return period low flow.

It is concluded that the Stocking Creek watershed has sufficient good quality water to meet the needs of Saltair and Pressure Zone 3 in South Ladysmith for at least the next 20 years, provided that the population of Pressure Zone 3 is limited to 2,165 and water conservation measures are introduced.

A suitable boundary for Pressure Zone No. 3 can be formed by the closing of gate valves. This is discussed in Section 6.5, and shown on Figure No. 4. With the present zoning approximately 2,200 people can be accommodated in the area south of Davis Road and the Highway, including Thetis Drive, Craig Road, Hillview Avenue, and Russell Road. The boundary can be adjusted from time to time so that the population served does not exceed 2165. The remainder of the population in South Ladysmith will be served from the Holland Lake system.

If the Water Management Division would agree to amend licence CL 005333 so that the permitted amount of water can be drawn on an annual basis instead of a daily basis, the Town would have more flexibility in using the source. The daily limit is 2,273 m^3 at present. An annual amount would be 2273 x 365 = 830,000 m^3. This would allow the Town to use more than 2,273 m^3 on a day of high demand, provided that the annual allowance was not exceeded.

4.5 HOLLAND CREEK WATERSHED

The total diversion permitted annually by the licences held in the Holland Lake watershed is:

CL 017746	995,000 m^3
CL 067480	1,819,000 m^3
Total	2,814,000 m^3

The Chapman/Reksten report estimates that the annual discharge in the watershed, including the diversion from Banon Creek, is 33,900,000 m^3 for a 10 year return period low flow, and 24,700,000 m^3 for a 25 year return period low flow. This shows that, with adequate storage, the watershed is capable of providing more water than is currently licensed.

The maximum population which can be served under the Holland/Banon licences is 11,600. With the 2,165 being served from Stocking, the total Ladysmith population which can be served is 13,765. If the Town continues to use surface water only, an additional licence will be needed when the population reaches that level.

One important aspect of the operation of the Holland Lake watershed is the ability of Holland Lake to store and release water as required.

Two of the criteria which should be used in assessing the ability of Holland Creek to meet the projected demands are (a) the regulated discharge at Chicken Ladder should be sufficient to maintain the required flow into Arbutus reservoir, and (b) the residual discharge below Chicken Ladder should meet the environmental requirements such as fisheries needs.

The flow required to meet Criterion (a) depends on the method of operation for filling Arbutus reservoir. At present the Public Works staff try to keep Arbutus reservoir full to ensure that sufficient water is available for fire-fighting, and to maintain pressure on the highest service connections. This means that the flow into the reservoir during summer should be equal to the peak hour demand. If a larger and higher reservoir is constructed, peaking flows can be met from the reservoir and the flow into the reservoir can be reduced to the maximum day demand.

It is not practical for the Public Works staff to release from Holland Lake the exact amount of water needed at Chicken Ladder. There is approximately 7.0 km of creek between the two, and water is lost through evaporation and leakage into the ground under the creek bed and into the creek banks. Water is also gained from side streams and springs. The amount of water gained and lost will vary depending on the time of year and the weather. There is also a lag between the time water is released from Holland Lake and the time it reaches Chicken Ladder. The time taken probably varies from 6 hours in the winter to 18 hours in the summer.

The poor condition of the road, owned and maintained by TimberWest Forest Ltd., up to Holland Lake, also makes it more difficult for Public Works staff to control the discharge from Holland Lake on a day-to-day basis.

Given that water gains and losses can occur, and that Arbutus reservoir should be kept as full as possible for fire-fighting and to maintain pressures at the highest services, the quantity of water released from Holland Lake should be approximately 200% of the quantity to be delivered to Arbutus reservoir.

The water licences do not establish a required residual flow below Chicken Ladder dam. It is therefore assumed that the residual flow should not be less than the minimum flow which occurs during the average year. In the Chapman/Reksten report, the minimum natural flow below Chicken Ladder during the mean year is estimated to be 165,000 m^3 per month.

In their report, Chapman and Reksten present a series of tables showing the Holland Creek runoff, diversion, and withdrawal under circumstances of low runoff with various return periods. Tables 4 and 5 are adaptations of the Chapman/Reksten tables. In Tables 4 and 5 it is assumed that all of Ladysmith, except for Pressure Zone 3 in South Ladysmith, is served year round from Holland Creek. It is also assumed that the regulated flow in Holland Creek must be at least 200% of the required flow into Arbutus reservoir. In both tables the natural discharge shown is for the 10 year return period low flow. Table 4 represents conditions when the total population of Ladysmith is 9,000, and Table 5 represents conditions when the total population is 12,000.

Table 4 shows that when the population is 9,000 the regulated discharge in Holland Creek is greater than 200% of the required discharge into Arbutus reservoir, and that the residual flow downstream of Chicken Ladder dam is greater than 165,000 m^3 during the month of lowest flow. Table 4 indicates that the existing method of operation would be satisfactory until the population reaches 9,000, provided that an extremely dry year (greater than a 10 year return period) does not occur and that Public Works staff are very efficient in their operation of the source.

Table 5 shows that the conditions when the population is 12,000 are marginally acceptable. Given the difficulties in operating the system efficiently and the lack of firm data on rainfall and streamflows, it would be preferable to make improvements to the water sources by the time the population reaches 9,000.

As a first stage to ensure efficient operation, automatically or remotely controlled valves will be required to allow Public Works staff to control the water usage with the minimum of wastage. These requirements are discussed in Section 6.4 of this report.

TABLE NO.4 HOLLAND CREEK RUNOFF, DIVERSION, AND WITHDRAWAL SUMMARY
10 YEAR RETURN PERIOD LOW RUNOFF 9,000 POPULATION

	Natural Discharge	Water from Banon			Water from Holland		Regulated Discharge	Ladysmith Consumption	200% of Consumption	Discharge Balance
		To Storage	To Creek	From Storage	To Storage	From Storage				
Jan	5,860	153	113		54		5,919	141		5,778
Feb	5,160	140	102		49		5,213	118		5,095
March	4,530	153	113		54		4,589	137		4,452
April	2,630	149	109		52		2,687	116		2,571
May	1,320	153	113		54		1,379	152		1,227
June	465			20		0	485	156	311	329
July	168			265		100	533	199	397	334
Aug	93			420		130	643	244	487	399
Sept	101			325		139	565	210	420	355
Oct	899			20		0	919	150	300	769
Nov	3,890	149	109		54		3,945	126		3,819
Dec	6,950	153	113		52		7,011	129		6,882
Annual	32,066	1050	772	1050	369	369	33,888	1874		32,012

Notes: Units are dam3 (thousands of cubic metres)

TABLE NO.5 HOLLAND CREEK RUNOFF, DIVERSION, AND WITHDRAWAL SUMMARY
10 YEAR RETURN PERIOD LOW RUNOFF 12,000 POPULATION

	Natural Discharge	Water from Banon			Water from Holland		Regulated Discharge	Ladysmith Consumption	200% of Consumption	Discharge Balance
		To Storage	To Creek	From Storage	To Storage	From Storage				
Jan	5,860	153	113		54		5,919	192		5,727
Feb	5,160	140	102		49		5,213	161		5,052
March	4,530	153	113		54		4,589	187		4,402
April	2,630	149	109		52		2,687	158		2,529
May	1,320	153	113		54		1,379	207		1,172
June	465			20		0	485	212	424	273
July	168			265		100	533	271	542	262
Aug	93			420		130	643	332	665	311
Sept	101			325		139	565	286	573	279
Oct	899			20		0	919	204	409	715
Nov	3,890	149	109		54		3,945	171		3,774
Dec	6,950	153	113		52		7,011	176		6,835
Annual	32,066	1050	772	1050	369	369	33,888	2556		31,329

Notes: Units are dam3 (thousands of cubic metres)

5.0 WATER QUALITY

5.1 GENERAL

The water quality in the Holland Creek and Stocking Creek watersheds has been monitored for several years, and intermittent records are available from 1977 to 1994.

For the Integrated Watershed Management Plan, the Ministry of Environment, Lands and Parks has produced a draft report on the water quality. This draft is titled Holland Creek and Stocking Lake Interim Water Quality Assessment and Objectives, prepared by L.W. Pommen of the Water Quality Branch of the Water Management Division of the Ministry. The report summarizes the findings of an assessment of historical water quality data, and the results of a 1992/93 monitoring programme. Mr. Pommen will be finalizing his report in 1995, and will incorporate any further data which is available at that time. Appendix C contains the results of water analyses during the 1992/93 programme.

5.2 PARAMETERS

The water from the two watersheds is generally good and meets most of the guidelines established in the Canadian Drinking Water Standards. The parameters which occasionally exceed the guidelines are turbidity, colour, pH, and fecal coliform. These parameters are discussed below.

Turbidity, or cloudiness in the water caused by suspended particles, is important not only for aesthetics but also because it can interfere with the chlorination process. The drinking water guidelines specify a limit of 1.0 Nephelometric Turbidity Units (NTU) in water entering a distribution system, but permit up to 5 NTU if it can be shown that disinfection is not compromised.

Colour in water is not in itself a health hazard, but it generally indicates the presence of dissolved organic material. The organic material can sometimes lead to the formation of trihalomethanes (THM) and odours when chlorine is added to the water. The aesthetic objective for colour is 15 True Colour Units (TCU). The maximum acceptable concentration for THM is currently 0.35 mg/l, but is under review and may be reduced to 0.1 mg/l.

pH is a measure of the acidity of the water. The drinking water standards allow a range of 6.5 to 8.5, with the lower number indicating a more acidic water.

Fecal coliform indicate contamination of the water by animal or human waste. The Ministry of Health Guidelines for Raw Water Supplies state that drinking water which receives only chlorination should have a 30-day, 90th percentile of less than 10/100ml. Coliform is removed by chlorination, provided high turbidity does not interfere with the process.

5.3 STOCKING CREEK WATERSHED

The report by Pommen lists the pertinent water quality data gathered from 1984 to March 1993. Turbidity, coliform, THM, and colour concentrations were satisfactory in the relatively few samples which had been analyzed for these parameters. On three sampling dates out of 90, the pH readings were lower than the recommended values. Pommen concluded that these occurrences probably resulted from heavy rains in the 1 to 2 weeks prior to the sampling.

On December 15, 1989, algae were taken from the Stocking Lake screens for analysis. It was found that the species present were predominantly green algae. The laboratory suggested that these algae would break up easily and chlorination dosage may have to be increased to disinfect the water. There are no reports that this is a frequent problem.

Overall the water quality in Stocking Lake is satisfactory as a raw water, for disinfection and distribution to the public.

5.4 HOLLAND CREEK WATERSHED

The Holland Creek watershed has been sampled more frequently than the Stocking Creek watershed. This is probably because the water quality in Holland Creek has proven to be more variable than that in Stocking Creek. Samples have been taken at Banon Creek, Holland Lake, the north fork of Holland Creek (indicative of quality from Prevost Lake), and Chicken Ladder dam.

Water turbidity is generally satisfactory, but can increase greatly after heavy rainfall in the watershed. It is believed that high turbidity is caused by erosion at old logging roads and drainage ditches which were not constructed to current standards. These high turbidity events seem to be relatively short-lived, but there are not always daily readings available to confirm this assumption. Because of these events, Ladysmith stops drawing water from Holland Creek in the late fall and starts feeding the whole town from Stocking Lake for a period of four to five months. High turbidity does occur occasionally in the summer months as well, after a heavy rainfall.

During the period 1979 to 1983 the Town undertook a water quality monitoring program, with the assistance of Willis Cunliff Tait & Company Ltd. At Chicken Ladder dam on 246 sampling dates, it was found that the turbidity exceeded 5.0 NTU on 8 occasions, and 1.0 NTU on 61 occasions. When the concentrations exceeded 5.0 NTU, they rose up to 86 during the winter and 33 during the summer. The following sequences of readings taken during 1980 indicate that the turbidity can rise and fall within a few days:

Feb 4	2.2 NTU
Feb 18	29 NTU
Feb 20	3.5 NTU
Feb 22	1.0 NTU
Feb 25	2.1 NTU
Feb 26	86 NTU
Feb 27	28 NTU
March 10	1.15 NTU

Aug 5	0.8 NTU
Aug 6	1.53 NTU
Aug 8	17 NTU
Aug 9	33 NTU
Aug 11	1.42 NTU

During 1980 through 1982 the Town took samples at Holland Lake on 22 dates, and on these dates the maximum turbidity was 3.6 NTU. The Water Management Division monitoring programme during 1992/93 tested for turbidity on 39 dates between May 4, 1992 and November 1, 1993. On two dates at Holland Lake and two dates at the Holland Creek North Fork the turbidity rose above 1.0 NTU. At Chicken Ladder, on the 23 dates when turbidity was tested, the value never exceeded 1.0 NTU. In his report Pommen states that high turbidity events could have been missed because of the infrequent sampling.

As noted previously in this report, Public Works staff open the connection from Banon Creek at the beginning of November each year and leave it open until the following May. The flow from Banon Creek will refill Holland Lake within four weeks and for the remainder of the winter overflows from the lake into Holland Creek, increasing the peak flows in the creek by up to 20%. If the Banon Creek connection is closed when the lake is full, the peak flows for the remainder of the winter will be lower than at present and the turbidity after heavy rains may be reduced.

Of the more than 250 sampling dates during 1979-1982, the acceptable colour value of 15 TCU was exceeded only four times. The highest value was 25 TCU on August 29, 1994, which coincided with a high turbidity reading of 33 NTU. The 1993/94 programme produced two readings over 15 TCU at Chicken Ladder in 37 sampling dates.

On three occasions in 1992, tests were carried out for THM on the chlorinated water from Holland Lake by the Ministry of Health. The results ranged from 0.014 to 0.017 mg/l, well below the current minimum of 0.35 mg/l and the proposed minimum of 0.1 mg/l.

During 1978/79 the Town tested the pH of water from Chicken Ladder on five occasions. On four of these occasions the pH was in the range of 5.76 to 6.48 which is less than the acceptable level of 6.5. A sample taken by the Town in March, 1994, gave a pH of 5.9, but the Water Management Division 1992/93 program gave all 23 pH readings at Chicken Ladder within the acceptable range. A low pH value can indicate that a water is corrosive, however corrosivity is a complex matter and depends on several other parameters as well. Water corrosivity is discussed in Section 5.4 below.

The fecal coliform analysis in the 1992/93 programme gave three samples where the value exceeded 200/100 ml of which one was 1400/ 100 ml. In his report Pommen surmises that animal, and possibly human, fecal matter was washed into the stream during heavy rainfall events. He also points out that the Ladysmith chlorination system successfully disinfected the water and no fecal coliform were detected in the distribution system.

In summary, the water quality in Holland Creek is acceptable for drinking water use, provided it is adequately chlorinated, except on those relatively few occasions when heavy rainfall causes the turbidity and colour to increase to unacceptable levels.

5.5 WATER CORROSIVITY

Corrosive water can attack metal fittings in the distribution system and in household plumbing. It can also attack the internal surface of asbestos cement pipe, allowing asbestos fibres to be released into the water. An indication of the water corrosivity can be obtained using a formula based on pH, hardness, and alkalinity. From analyses of water from Holland Creek and from Stocking Creek it is concluded that these waters can be highly aggressive to asbestos cement pipes.

If asbestos cement (AC) pipes are being attacked, the internal surface will be softened as material is released from it. However, Public Works staff report that there is no indication of surface softening in the pipe when pieces of AC pipe are cut for repairs to the system, neither is there any sign of attack to metallic system components such as brass curb stops.

It will be recommended in this report that the Public Works staff check for any evidence of corrosion when they excavate watermains for repairs or other reasons. Any future water treatment facility should include a process for reducing the corrosivity of the water.

5.6 CHLORINE CONTACT TIME

The Ladysmith water supply is disinfected by the injection of chlorine. The chlorine takes time to react in the water, to ensure the effectiveness of the disinfection process. The time required depends on several factors including pH, temperature, and turbidity. Generally contact times of 20 to 30 minutes are adequate.

At present, there are two locations at which chlorine is injected into the water. One is downstream of Arbutus reservoir and the other is on the pipe from Stocking Lake to South Ladysmith. After chlorine injection on the Stocking Lake line, water passes through a contact tank with capacity of 160 m^3. This reservoir will provide adequate contact time for water supply to South Ladysmith. After injection of chlorine at Arbutus reservoir, contact occurs in the pipeline between the reservoir and the first consumer. For 1995 peak hour flows the contact time will be a minimum of 16 minutes. As demands increase, the contact time will be reduced. This is not satisfactory.

A reservoir or contact tank is required downstream of the chlorination point at Arbutus. Later in this report it is recommended that a new reservoir should be constructed at Arbutus. At that time a new chlorination facility should be installed on the upstream side of the reservoir, so that the required contact time is provided in the reservoir.

5.7 WATERSHED PROTECTION

The Town is represented on the Technical Planning Committee for the Holland Creek/Stocking Lake Integrated Watershed Management Plan. The committee faces the problems of reaching a compromise for management of the watershed among the groups and individuals with competing interests in the watersheds. However, from a public health standpoint, the Town's best interests would be served if public access to the watershed is minimized.

In the opinion of Koers & Associates Engineering Ltd. there should be no increased access to the Holland Creek watershed, indeed the access should be further controlled by the installation of gates at a suitable distance from Holland Lake to provide the required security, similar to that achieved on Stocking Lake. The Town is responsible for providing a safe supply of potable water to its residents, and this should take precedence over recreational uses.

It is good engineering practice to restrict access to watersheds, where the water is not filtered before being delivered to the consumer. The Greater Vancouver Regional District has strict controls, and the Greater Nanaimo Water District is implementing recommendations contained in a recent report for the introduction of more stringent measures to control watershed access. In the opinion of Koers & Associates Engineering Ltd., Ladysmith should be following this trend. This policy could be reviewed once the filtration plant is installed.

6.0 SYSTEM EVALUATION

6.1 DISTRIBUTION RESERVOIRS

In the Ladysmith water supply system, there are different types of reservoirs. Holland Lake, Stocking Lake and Prevost Lake are storage reservoirs which store water from periods of high flow for use during periods of low flow, whereas Arbutus reservoir and the contact tank are distribution reservoirs which store water to meet the daily variation of demands in the distribution system. This section deals with the two distribution reservoirs.

Distribution reservoirs perform three functions; they provide storage for fire fighting, storage for emergencies such as a break in a supply main, and storage for meeting the daily peaks in demand. A generally accepted formula for establishing the required capacity of a storage reservoir is:

fire storage	fire flow x duration of fire
emergency storage	15% of average day demand
peaking storage	25% of maximum day demand

Based on this formula the minimum storage required for Pressure Zone 3, and for the remainder of Ladysmith is shown in Table No. 6. The storage for Pressure Zone 3 is at the Stocking Lake system contact tank and the storage for the remainder of Ladysmith is at Arbutus. It is assumed that the required fire flows are 115 lps in Pressure Zone 3, and 150 lps in the remainder of Ladysmith. The storage for Pressure Zone No. 3 remains constant after the population reaches 9,000 because the pressure zone population remains constant at 2,165.

TABLE NO. 6 – REQUIRED WATER STORAGE CAPACITIES (m3)

Total Population	6,000	9,000	12,000	15,000	18,000
PRESSURE ZONE 3					
fire storage	828	828	828	828	828
15% of average day	58	149	149	149	149
25% of maximum day	221	570	570	570	570
total	1106	1546	1546	1546	1546
REMAINDER OF LADYSMITH					
fire storage	1080	1080	1080	1080	1080
15% of average day	684	843	1058	1308	1547
25% of maximum day demand	2460	3005	3778	4703	5597
total	4223	4928	5916	7091	8224

The contact tank has a capacity of 160 m^3, which is in itself inadequate for fire fighting. Under present conditions, however, water for fire fighting can be supplemented by a flow from the balancing reservoir into the contact tank, and from Stocking Lake into the balancing reservoir. The rate at which the contact tank can be replenished is limited only by the capacity of the chlorination equipment. The contact tank contains less than four hours supply at the average day demand for the 2,165 population in Pressure Zone 3, but this is considered adequate for emergency purposes.

As is shown later in this report, after improvements are made to the system, water can be delivered from Arbutus reservoir to Pressure Zone 3 in an emergency. For this reason a new storage reservoir at the contact tank is not required.

Table 6 shows that the required storage for the remainder of Ladysmith, at Arbutus, is 8,224 m^3 when the population reaches 18,000. The capacity of Arbutus reservoir is 5,450 m^3 which is sufficient until the population reaches 10,500, after which additional storage will be required.

Although Arbutus reservoir has adequate capacity for the near future, its condition is poor and not up to accepted health standards for public water supply. Basically the reservoir is a hole excavated in the ground, with no roof or other protection from pollution. What is needed is a roofed concrete or steel reservoir. As part of its capital spending program the Town should allow for the construction of an enclosed reservoir with a minimum capacity of 8,250 m^3.

As shown in Section 6.4, the distribution system pressures are inadequate in the area of Mackie Road and upper Malone Road. For this reason, the location for a new Arbutus reservoir should be selected at a higher elevation than at present. The reservoir will be filled by gravity from Chicken Ladder which has a water level of 189 m. The top water level of the new reservoir should, therefore, not exceed 180 m. This will increase the static pressure in the distribution system by 390 kPa (55 psi). A new, larger pipe will be needed to deliver the water from Chicken Ladder to the new reservoir. The new reservoir site should have space to accommodate a chlorination facility and a treatment plant on its upstream side.

6.2 DISTRIBUTION SYSTEM EVALUATION CRITERIA

In assessing the performance of the distribution system, the pressure at the service connections is an important criterion. For satisfactory operation of a plumbing system the pressure should be at least 280 kPa (40 psi), and perhaps more if fire sprinklers are installed in the building. If there is a hydrant in use for fire fighting, the pressure in the immediate area can be permitted to drop to 140 kPa (20 psi). It is preferable if the maximum pressure in the system does not exceed

700 kPa (100 psi), however some parts of the Ladysmith water system have pressures which are much higher than this.

Fire flows of 60 lps were adopted for the residential areas, and 150 lps for the larger commercial, industrial, and institutional premises. For system analyses, fire flows are taken to occur simultaneously with the maximum day demand.

The distribution system is analyzed to establish whether it can deliver the peak hour demand to all consumers at pressures not less than 280 kPa, and whether it can deliver fire flows, simultaneously with maximum day demands, at pressures not less than 140 kPa.

6.3 COMPUTER MODEL

A computer model of the water distribution system was used to evaluate the system performance under various demand conditions. The computer model was based on the model currently used by the Public Works Department, updated to include the most recent subdivisions. Figure No. 3 shows the pipes and nodes which make up the computer model. The WATERWORKS for EXCEL, Version 1.2, computer program, together with the latest WATER program from Municipal Hydraulics Ltd., was used in the system analyses. Where analyses show that there are improvements needed under existing or future demands, the model was modified and the analysis rerun to establish the diameter of the new pipe required. The model was run for peak hour demand conditions and for conditions with a fireflow coincident with a maximum day demand. These runs were made for demands projected for population levels at 6,000, 12,000, and 18,000.

Copies of selected computer printouts are contained in Appendix D.

6.4 CONDITIONS AT 6,000 POPULATION

The current population of Ladysmith is approximately 6,000. Computer runs for 6,000 population and the existing distribution system show that:

- under peak hour demands pressures of less than 280 kPa occur on Nash Place, Mackie Road, and the west end of Malone Road.
- under maximum day demand conditions with simultaneous fire flows, pressures of less than 140 kPa occur in the area south of Davis Road, east of Thetis Drive.
- under low flow conditions, excessively high pressures occur on the Esplanade and on the waterfront.

Any improvements recommended to rectify these problems should be consistent with improvements which are required at later stages of Ladysmith's development. Therefore consideration should now be given to the long term improvements.

6.5 SYSTEM FOR 18,000 POPULATION

In making the computer runs for 18,000 population, it was assumed that the new Arbutus reservoir has a top water level of 180 m, and Pressure Zone 3 is separated from the rest of Ladysmith by pressure reducing valves and closed valves. The boundary of Pressure Zone No. 3 can be adjusted from time to time to ensure that the population inside the boundary does not exceed 2,165. A computer run was made with the existing distribution system for peak hour conditions with a population of 18,000. The results showed:

- excessively high pressures in the lower elevations in Pressure Zone No. 1

- insufficient pressure in the upper area of Pressure Zone 4

Runs were then made with fire flow demands at selected critical locations in the system, simultaneously with a maximum day demand. The results showed that adequate fire flows cannot be provided at the upper elevations of Pressure Zone No. 3. For example, only 20 lps at a pressure of 140 kPa, is available at the west end of Thetis Drive, instead of the required flow of 60 lps at 140 kPa.

Various improvements were evaluated, to determine the most effective way to provide adequate service to all consumers. It was found that the installation of a new connection from the contact tank to Russell Road in Pressure Zone 3, together with a branch to Craig Road, would allow adequate fire flows and pressures throughout this zone up to an elevation of 127 m. A possible route for this main is shown on Figure No. 3, but this route could be varied to suit future subdivisions in this area. The contour plans show that the 127 m contour is close to the Hydro right-of-way, which is the upper limit for land zoned for suburban residential development.

With the new Arbutus reservoir at an elevation of 180 m, water can flow from Arbutus to the east end of Pressure Zone 4 through the existing 200 mm diameter main. Figure No. 3 shows a proposed 200 mm connection from the existing pipe, through a park, into Ryan Place. This connection will allow the boundary of Pressure Zone 3 to be adjusted so that the number of residents being served from Stocking Lake is limited to 2,165.

To prevent excessively high pressures in the distribution system, the existing pressure zone arrangement should be modified. Figure No. 4 shows a satisfactory arrangement, with the boundaries of the zones formed with pressure reducing valves or closed valves. Pressure Zone 3 will continue to be served from the contact tank, but the boundary will be adjusted so that there are no more than 2,165 residents in it.

A new pipe is required between Wallace Place and Nash Place, so that services at the south end of Nash Place receive adequate pressure, once the pressure zone boundary is established. There is a lane between these roads in which the 200 mm pipe can be installed.

The closing of valves in the system creates dead-end pipes, where water can stagnate. In some cases there are hydrants at the dead ends where water can be flushed. In the other cases flushouts can be installed.

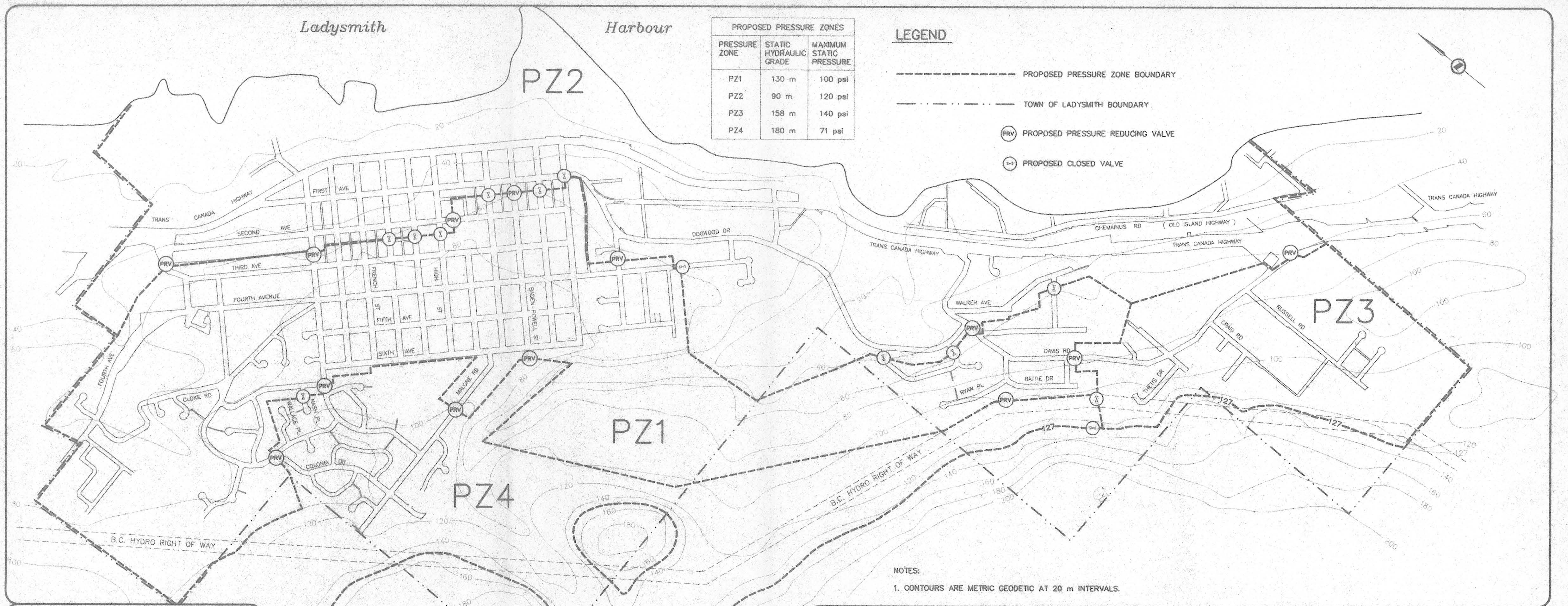
The pressure reducing valve locations and settings are given in Table No. 7.

TABLE NO. 7 - PRESSURE REDUCING VALVES

Location	Pipe No.	Pipe Dia. mm	Valve Dia. mm	HGL (m)
Strathcona	211	100	100	90
Symonds, below Third	216	150	150	90
Second, near High	45	200	150	90
Baden-Powell, above First	39	200	150	90
Belair, below Fourth	28	150	150	90
Colonia, below Delcourt	146	250	200	130
Dunsmuir, above Sixth	153	200	150	130
Malone, below Mackie	163	150	150	130
Public Works Yard	5	200	150	130
Davis, above Walker	509	200	150	90
Davis, above Highway	848	200	200	84
Davis, near Battie	617	200	150	120
Ryan and Battie	900	200	150	130

There are existing pressure reducing valves in pipes 509 and 848 which will remain in service. There is also an existing 200 mm valve outside the sewage treatment plant which can be moved to a new location. The remaining valves will be new.

The computer model was adjusted to incorporate these changes, and then run for peak hour conditions, and for maximum day conditions with fire flows at selected locations. It was found that this model provided satisfactory flows and pressures with a population of 18.000.



PROPOSED PRESSURE ZONES		
PRESSURE ZONE	STATIC HYDRAULIC GRADE	MAXIMUM STATIC PRESSURE
PZ1	130 m	100 psi
PZ2	90 m	120 psi
PZ3	158 m	140 psi
PZ4	180 m	71 psi

LEGEND

- PROPOSED PRESSURE ZONE BOUNDARY
- TOWN OF LADYSMITH BOUNDARY
- PRV PROPOSED PRESSURE REDUCING VALVE
- PROPOSED CLOSED VALVE

NOTES:

1. CONTOURS ARE METRIC GEODETIC AT 20 m INTERVALS.

KOERS & ASSOCIATES ENGINEERING LTD.
Consulting Engineers

CLIENT	TOWN OF LADYSMITH
PROJECT	WATER STUDY
TITLE	PROPOSED PRESSURE ZONES
APPROVED	
DATE	NOV. 1994
JOB No.	M9412
SCALE	1:10 000
DWG No.	FIG. 4

The new model was also run with average day demands and with the supply from the contact tank out of service. It was found that Arbutus reservoir could supply water to Pressure Zone 3, through the 200 mm pipe for a population of 18,000.

It is concluded that the distribution system, modified to include the pressure reducing valves and the closed valves shown on Figure No. 4, and the additional pipes shown on Figure No. 3, will satisfactorily meet the demands of a population of 18,000.

6.6 TIMING OF DISTRIBUTION SYSTEM IMPROVEMENTS

It has been shown that improvements to the distribution system are required before the population reaches 18,000. It is now necessary to determine the sequence and timing of these improvements.

Section 6.1 of this report stated that a new reservoir is required at Arbutus, and that the top water level of this reservoir should be 180 m. As soon as the reservoir is constructed, the pressures at the lower elevations will increase to unacceptable levels. This means that before the new reservoir is put into service, either the pressure reducing valves (PRV's) must be installed and the necessary valves closed, or a single PRV must be installed at the outlet from the new reservoir. The pipe connecting Wallace and Nash Places must also be installed, when the PRV is installed on Dunsmuir.

The existing Pressure Zone 3 has approximately 600 residents. The existing distribution system can meet their peak hour demands, but cannot provide the required fire flows. The proposed pipe from the contact tank to Russell Road and Craig Road should, therefore, be installed in the near future. The route of this pipe will depend on the layout of the subdivisions in this area.

The installation of the new pressure reducing valve on Davis Road, near Battie Drive, should be made before the population inside the present Pressure Zone 3 reaches 2,165. At that time the pipe from the existing 200 mm pipe to Ryan Place should also be installed. Since there is considerable pressure for development in Pressure Zone 3, it is likely that these improvements will be required within the next few years.

6.7 PIPE RENEWAL PROGRAMME

The distribution system consists of watermains which have been installed over a long period of time. There is a mixture of pipe materials; newer areas have mostly PVC, whereas the older established areas have asbestos cement (AC) and cast iron. There are also ductile iron, steel and copper pipes in the system. Many of these pipes are reaching the end of their useful life and a programme should be established for their eventual replacement.

There are over 60 km of watermains in the Ladysmith supply and distribution pipes of which 45 km are made of asbestos cement (AC). AC pipe is an acceptable pipe material, but in recent years it has been superseded by PVC which is more robust and easier to install. Most new pipes being installed in the Ladysmith distribution system are PVC. AC pipes deteriorate with time, especially if the water is corrosive, as can be the case in Ladysmith. It will be a recommendation of this report that the Town should budget $100,000 per year for the replacement of deteriorating watermain, as the need or opportunity arises.

6.8 SUPPLY MAINS

The mains which deliver water into the distribution reservoirs must be suitably sized to carry the projected flows. These flows will depend on which sources are in use under any particular circumstances. In Sections 7.0 and 8.0 consideration is given to the sources and their operation. The sizing of the supply mains are then addressed in Section 9.0.

7.0 WATER SOURCE IMPROVEMENTS

7.1 GENERAL

Alternative improvements which could be made to the water sources are:

- additional water storage and licence in the Holland Creek watershed
- surface water from an adjacent watershed
- groundwater

7.2 HOLLAND LAKE IMPROVEMENTS

The mean annual runoff in Holland Creek, including the permitted diversion from Banon Creek, is 50,400,000 m^3. The projected annual water demand in Ladysmith for a population of 18,000 is 4,125,240 m^3. It therefore follows that, if adequate storage is provided, additional water could be drawn from Holland Creek. The storage could be obtained by increasing the height of the Holland Lake embankments, or by constructing a new impoundment dam elsewhere on the creek.

EBA Engineering Ltd inspected the embankments at Holland Lake to assess whether it would be possible to raise the height of these embankments. Their conclusions are contained in a letter-report titled "Ladysmith Water Resource Study - Water Retention Structures", a copy of which is included as Appendix C to this report. EBA conclude that the embankments can be safely increased in height by at least 1.0 m. More investigation would be required to establish whether the embankments can be increased by a height of more than 1.0 m. Increasing the height by 1.0 m would increase the usable capacity of Holland Lake from 1,368,000 m^3 to approximately 1,820,000 m^3. The maximum amount of water which can be diverted into Holland Lake from Banon Creek under the existing licence is 1,820,000 m^3, so an additional storage licence is not required.

Table No. 8 is a spreadsheet showing how water could be stored and released if the lake capacity is increased to 1,820,000 m^3. In the table it is assumed that Pressure Zone 3 is served from Stocking Creek and the remainder of the town is served from Holland Creek, and that a 10 year return period low flow is occurring. The table indicates that under improved operating procedures Holland Creek can meet the demands when the population is 18,000. It is estimated that this arrangement could possibly meet demands up to a population of over 20,000. It should be noted, however, that the total water demand exceeds the licensed amount and an additional water diversion licence will be required, by the time the total population reaches 13,740.

EBA Engineering Ltd estimates that the raising of the dam by 1.0 m will cost approximately $2,300,000, including contingencies and engineering.

TABLE NO.8: HOLLAND CREEK RUNOFF, DIVERSION, AND WITHDRAWAL SUMMARY
10 YEAR RETURN PERIOD LOW RUNOFF 18,000 POPULATION

	Natural Discharge	Water from Banon			Water from Holland		Regulated Discharge	Ladysmith Consumption	Balance
		To Storage	To Creek	From Storage	To Storage	From Storage			
Jan	5,860	266			0		5,860	294	5,566
Feb	5,160	242			0		5,160	247	4,913
March	4,530	266			0		4,530	286	4,244
April	2,630	258			0		2,630	243	2,387
May	1,320	266			0		1,320	318	1,002
June	465			100		0	565	325	240
July	168			490		0	658	416	242
Aug	93			652		0	745	510	235
Sept	101			580		0	681	439	242
Oct	899			0		0	899	314	585
Nov	3,890	258			0		3,890	263	3,627
Dec	6,950	266			0		6,950	271	6,679
Annual	32,066	1822	0	1822	0	0	33,888	3921	29,963

Notes: Units are dam3 (thousands of cubic metres)
Storage is increased at Holland Lake to hold all Banon Creek diversion

If this alternative is to be pursued, several further investigations will be required. A predesign geotechnical investigation will be required to confirm assumptions made about the dam conditions, to excavate test pits on and near the dam, and to identify sources of suitable material for embankment raising. The approximate cost of the geotechnical investigations would be $10,000. Once preliminary details of the work are established, discussions would be required with the Fish and Wildlife Branch of BC Environment to identify any special precautions required to protect fish stocks.

7.3 ALTERNATIVE SITES ON HOLLAND CREEK

Topographic maps were reviewed to identify any other potential dam sites within the Holland Creek watershed. In the opinion of EBA Engineering Ltd, there is not another site on Holland Creek, downstream of the lake, which can be economically developed to form an impoundment reservoir.

Prevost Lake lies within the Holland Creek watershed. If Prevost Lake is to function properly as an impoundment dam, several improvements are required. The area behind the dam needs to be cleared of organic material, repairs are required to the dam spillway, and the access road would require considerable upgrading. The volume of water stored in Prevost Lake is approximately 10 % of the present Holland Lake, and would be approximately 7% of an expanded Holland Lake. If Ladysmith continues to grow at current rates, upgrading of Prevost Lake may only meet one or two year's population increase. For this reason the cost of the remedial work at Prevost Lake is not considered to be justified.

7.4 GROUNDWATER

An investigation into the groundwater potential of the area around Ladysmith was undertaken by Pacific Hydrology Consultants Ltd. A copy of their report is attached as Appendix F.

Pacific Hydrology identified three areas in which adequate quantities of ground water might be found. These areas are the Cassidy Aquifer, Davis Lagoon, and Rocky Creek. The Cassidy Aquifer has abundant water but it is farthest from the Town boundary, a distance of approximately 6 km. Davis Lagoon would be a higher risk in exploring for water, and the residential development might make it difficult to find a suitable site for a well field. There are no existing wells in the Rocky Creek area so this must also be considered as a high risk exploration area.

If groundwater wells could be developed at reasonable cost, they would meet some of the Town's water requirements. Since Holland Creek has high turbidity concentrations in the winter, groundwater could be used to meet winter demands and to supplement the summer demands.

Pacific Hydrology states that either a 400 mm well or a series of three 200 mm wells could deliver 88 lps. These wells, used in conjunction with the existing Holland Creek system, would be capable of meeting the summer demand for a population of 15,000. These wells would be capable of meeting winter demands of a population of 11,000, not including Pressure Zone 3, with the Holland Creek source closed off, after which an additional well could be installed.

A pipeline would be required from the wells to the Ladysmith distribution system. A potential pipeline route from Cassidy to Arbutus reservoir would be alongside the B.C. Hydro right of way. A 300 mm pipe would be sufficiently large to carry the flow, but a detailed comparison of capital cost versus operating cost would be required to confirm whether this is the most economical diameter. For estimating purposes it should be assumed that the pipe would be a maximum of 350 mm diameter and a maximum of 8 km long.

If wells are developed in the Davis Lagoon or Rocky Creek area, the shorter pipelines would mean that the total cost of implementing a groundwater supply would be less than developing at Cassidy, but the chances of finding a good water source are less. For estimating purposes, therefore, it will be assumed that the wells are developed at Cassidy.

7.5 ADDITIONAL WATERSHED

Only one adjacent watershed appears suitable as an additional source of water for Ladysmith. The Chipman Creek watershed lies west of the Holland Creek watershed, as shown on Figure No. 1. The watershed rises to the 1,200 m elevation and has a catchment area of approximately 7.0 km^2 above the 600 m contour. The 10 year return period low flow from this catchment area is estimated to be approximately 10,000,000 m^3 per year. This compares to 51,000,000 m^3 per year in the Holland Creek watershed, including the Banon Creek diversion, and 1,000,000 m^3 per year in the Prevost Lake watershed during the 10 year return period low flow.

An intake installed in Chipman Creek near the 590 m contour would be approximately 2 km from the Holland Creek watershed boundary. A channel 3 km long would be required to deliver water from Chipman Creek into North Holland Creek.

The Water Management Branch is unlikely to permit water diversion from Chipman Creek during the summer. A storage reservoir would therefore be required to receive water in the winter then release it during the summer. It is possible that a dam could be constructed at Coronation Lake to form such a storage reservoir.

No site inspection has been made of Chipman Creek and Coronation Lake to assess their potential for development as a water source for Ladysmith. However, it is estimated that the cost of the development would be much more than for the raising of the Holland Lake embankments or the development of a groundwater source.

The development of a Chipman Creek water source could be considered for Ladysmith at some time beyond the span of this study, say when the population reaches 18,000.

8.0 SYSTEM OPERATION DURING HIGH TURBIDITY

8.1 HOLLAND LAKE SOURCE

8.1.1 General

In future, the methods adopted for dealing with the occasional deterioration of the Holland Creek water quality will depend on whether Holland Lake is upgraded, or a groundwater source is developed. If Holland Lake is upgraded, there are three possible methods of dealing with the problem:

- install a pipeline from Holland Lake to Chicken Ladder,
- use Stocking Lake as a water source when the Holland Creek turbidity is high,
- install water treatment facilities.

If a groundwater source is developed, then water quality deterioration in Holland Creek during the winter will not be a problem, because all the demand will be met from groundwater. During the summer, demands can be met from groundwater and Stocking Lake on those few occasions when there is a summer high turbidity event in Holland Creek.

8.1.2 Holland Lake Pipeline

In their 1986 report Chatwin Engineering Ltd said that consideration should be given to installing a pipeline from Holland Lake to the Arbutus reservoir. The objective was to be able to draw better quality water directly from Holland Lake during periods when high turbidity was occurring in the creek. Chatwin suggested that a water quality monitoring programme should be established at Holland Lake during the fall and winter to confirm that water of acceptable quality is available.

During the 1992-93 water quality monitoring programme only seven water samples from the lake were analyzed, during the period November through May. One reason for so few samples being taken is that the road to Holland Lake becomes impassable after heavy rains. As shown in Table No. 9, the analyses indicate that turbidity concentrations at the lake outlet are less than the permissible value of 5.0 NTU. Unfortunately none of the readings was taken when there was high turbidity in the creek. On six of these seven occasions samples were also taken at Chicken Ladder, in each case the turbidity at Chicken Ladder was less than or equal to that measured at the lake. On three occasions in December 1992 the colour readings exceeded the aesthetic objective of 15 TCU, and on all of these occasions the colour at Chicken Ladder was less than at the lake.

TABLE NO. 9 – HOLLAND CREEK WATER QUALITY				
Station	Holland Lake		Chicken Ladder	
	Colour TCU	Turbidity NTU	Colour TCU	Turbidity NTU
Date				
4-Nov-92	15	1.4	–	–
23-Nov-92	10	0.8	15	0.6
9-Dec-92	30	1.6	20	0.6
14-Dec-92	40	0.8	30	0.3
16-Dec-92	30	0.8	10	0.2
5-April-93	10	0.5	10	0.2
20-April-93	10	0.4	<5	0.2
Notes:	Data is taken from Appendix C to this report			

A pipeline to carry water from Holland Lake to Arbutus reservoir would be 300 mm minimum diameter, and would be approximately 6,500 m long. A potential route is southwest along a logging road from Chicken Ladder dam to Camp Six, then south to the west end of Holland Lake. Because of the high pressures which would occur in this pipeline, ductile iron is the preferred material of construction. A minimum of three pressure reducing valves will be required in the pipeline to protect the pipe from excessively high pressures. A preliminary cost estimate for the pipeline installation is $2,200,000, including contingencies and engineering.

The basic idea of drawing water from the lake through a pipeline when turbidity in the creek is high is probably valid. However, sufficient water quality monitoring during the period January through March, to confirm this assumption, has not yet been undertaken.

8.1.3 Stocking Lake Source

With Arbutus reservoir at its present location, and a population of 12,000, the existing pipe from the contact tank to Arbutus has sufficient capacity to supply Stocking Lake water to the whole Town during the winter. If the new Arbutus reservoir is constructed and development occurs at higher elevations, the pipeline delivering Stocking Lake water must be upgraded.

Discussions would be necessary with the Water Management Division to confirm that this method of operation is acceptable to them, since the amount of water drawn on days of high turbidity would exceed the licensed daily limit. It will be a recommendation of this report that the Town applies to the Water Management Division for an amendment to the licence CL 005333. The amendment would allow the town to divert 830,000 m^3 per year from Stocking Lake, instead of the current 2,273 m^3 per day (2273 x 365 = 830,000). If the application is successful, then the pipeline upgrading from above Battie Drive to Arbutus reservoir should be undertaken. The annual amount is sufficient to supply Pressure Zone 3 all year and the whole Town for 35 days, when the population is 18,000.

8.1.4 Water Treatment Facilities

It would very expensive to construct water treatment facilities on the Holland Lake system for use during the few days when turbidity and/or colour exceed the desirable limits. However, regulatory authorities in North America are moving towards making the filtration of surface water mandatory before the water is delivered to the consumer. In the United States, the Environmental Protection Agency permits very few authorities to distribute unfiltered water from a surface source. The Canadian Federal Government now requires filtration of all new surface water sources on land under their jurisdiction, for example Indian Reserves. It appears likely that Provincial Governments will ultimately follow this trend. The Town of Ladysmith should be aware that the B.C. Government may legislate within the next ten to twenty years that a filtration plant will be required on the Holland Lake and Stocking Lake sources. If the Town is unfortunate enough to have an outbreak of "Beaver Fever" from Giardia in the area served by the water supply system, installation of a filtration plant may become necessary earlier.

If it becomes necessary to treat the water from Holland Creek, an investigation will be required to determine the most efficient treatment process. It is likely that a treatment plant would include filtration, pH correction, and chlorination. The treatment plant should be located at an elevation which allows the distribution system to be served by gravity, say 180 m. The treatment facilities would be located between Chicken Ladder dam and the Arbutus reservoir.

A preliminary estimate of the capital cost of a treatment plant to serve 18,000 population is in the order of $ 1,000,000.

8.1.5 Comparison of Turbidity Control Measures

The estimated capital costs, including contingencies and engineering, for the three alternatives are:

Pipeline from Holland to Chicken Ladder	$2,200,000
Pipeline from Battie Drive to Arbutus	$1,176,000
Treatment plant	$1,000,000

Sufficient water samples have not yet been taken to confirm that the pipeline from Holland Lake to Chicken Ladder would be effective in eliminating the water quality problems. The installation of a water treatment plant would involve high annual costs for operation, maintenance, power, and chemicals.

The capital cost of the pipeline from Holland Lake to Chicken Ladder is considerably more expensive than the construction of a treatment plant, and is not likely to continuously deliver water which meets the drinking water standards. It will, therefore, be a recommendation of this report that the pipeline should not be built.

8.2 GROUNDWATER SOURCE

If a groundwater source is developed and Holland Lake is not upgraded, then the system operation during periods of high turbidity in Holland Creek will be simplified. During the winter the supply from Holland Creek would be turned off and the groundwater source would meet the demands of the Town, except for Pressure Zone 3 which will be served from Stocking Lake. It is possible that high turbidity events can occur during the summer. If so, the Holland Creek supply would be closed and it may be possible to supply the Town by groundwater and from a temporarily increased flow from Stocking Lake. Alternatively, a treatment plant could be used to treat the water being drawn from Holland Creek.

9.0 SUPPLY MAINS AND CONTROLS

9.1 SUPPLY MAINS

Supply mains are those pipelines which deliver water from the intakes to the distribution reservoirs on the town boundaries. In this section the maximum capacity of each supply main is established and then that capacity is compared to the future projected flows.

The future projected flows depend on whether the Town develops a groundwater source or, alternatively, upgrades Holland Lake and continues to depend on Holland Creek as its major source. Three alternative arrangements are considered below.

Alternative 1 has Holland Creek as the main source, with a treatment plant to be used when there is poor water quality in the creek. Pressure Zone 3 would be served from Stocking Lake, but the system will have the capacity to supply the whole town from Holland Creek if that becomes necessary.

Alternative 2 also has Holland Creek as the main source, but with no treatment plant. Under this system water would be supplied from Stocking Lake when there is poor water quality in Holland Creek. It would be necessary to upgrade the supply mains from Stocking Lake to Arbutus, and to obtain an amended licence on Stocking Lake.

Alternative 3 assumes the development of a groundwater source. Then during the winter Holland Creek will be taken out of service and groundwater will meet the demands of the whole of Ladysmith except for Pressure Zone 3. In summer the demands will be met by water from Holland Creek and groundwater, and Pressure Zone 3 will be fed from Stocking Lake.

The projected water usage from the various sources for a population of 18,000 are shown in Table No. 10. In mainly residential areas, winter flows are usually less than the annual average flows. In the case of Ladysmith, however, the records show that the winter flow can be as high as 110% of the average, probably because of the water demands at the mills. The winter flows are taken as 110% of the average day flow, and the summer flow is taken as the maximum day demand.

The supply mains must be capable of carrying the appropriate flows. Table 11 summarizes the capacities and required pipe sizes. The existing supply mains are asbestos cement, so when upgrading is required it is assumed that a new pipe will be installed to carry the whole of the flow and the existing pipe will be taken out of service.

TABLE 10 – PROJECTED WATER USAGE FROM SOURCES (lps) FOR 18,000 POPULATION

	Source	Normal Conditions		Poor Water Quality in Holland Creek		Poor Water Quality in Stocking Lake	
		Winter	Summer	Winter	Summer	Winter	Summer
<u>Alternative No. 1</u> Holland Lake upgraded and treatment plant installed	Holland Creek Stocking Lake	131 13	256 29	131 13	256 29	144 –	285 –
<u>Alternative No. 2</u> Holland Lake upgraded and mains from Stocking Lake upgraded	Holland Creek Stocking Lake	131 13	256 29	– 144	– 285	144 –	285 –
<u>Alternative No. 3</u> Groundwater source developed and treatment plant installed	Holland Creek Stocking Lake Groundwater	– 13 131	125 29 131	– 13 131	125 29 131	13 – 131	154 – 131
	Total Usage	144	285	144	285	144	285

TABLE 11 – SUPPLY MAIN IMPROVEMENTS

Water Sources	Pipe	Existing Diameter (mm)	Existing Capacity (lps)	Maximum Projected Flow (lps)	Proposed Diameter (mm)	Installation Cost	Timing
ALTERNATIVE 1 Holland Creek with treatment plant	A1	200+300	265	285	–		
	A2	200+300	117	285	500	$795,000	1
	B	250	166	29	–		
	C	300	340	29	–		
	D	300	223	–	–		
	E	200	179	–	–		
					Total	$795,000	
ALTERNATIVE 2 Holland Creek +Stocking Lake (no treatment)	A1	200 + 300	265	285	–		
	A2	200 + 300	117	285	500	$795,000	1
	B	250	166	285	300	$404,500	2
	C	300	340	285	–		
	D	300	223	256	450	$246,500	3
	E	200	179	235	450	$525,000	4
					Total	$1,971,000	
ALTERNATIVE 3 Holland Creek +Stocking Lake +groundwater	A1	200 + 300	265	125	–		
	A2	200 + 300	117	125	350	$387,000	1
	B	250	166	154	–		
	C	300	340	154	–		
	D	300	223	125	–		
	E	200	179	101			
					Total	$387,000	

Notes:

Pipes
- A1 Chicken Ladder to Arbutus (top water level 140 m)
- A2 Chicken Ladder to Arbutus (top water level 180 m)
- B Stocking Lake to Balancing reservoir
- C Balancing reservoir to contact tank
- D Contact tank to above Battie Drive
- E Above Battie Drive to Arbutus

Maximum projected flows are for 18,000 population
Estimated costs include contingencies and engineering

Timing
1. When Arbutus reservoir is built
2. When population reaches 9,000
3. When population reaches 14,000
4. When population reaches 7,000

There are two parallel pipes between Chicken Ladder and Arbutus reservoir, one 300 mm and the other 200 mm diameter. The total capacity of these two pipes is 265 lps. This is sufficient to meet the maximum day demand in Ladysmith up to a population of 18,000. The pipe capacity is dependent on the difference of the water elevations at the two ends, Chicken Ladder and Arbutus. If a new reservoir is built with a top water level of 180 m, as discussed in Section 6.1, the existing pipes are no longer adequate.

The pipe from Stocking Lake to the balancing reservoir is 250 mm diameter and has a capacity of 166 lps. The capacity of this pipe is much greater than the amount of water which can be drawn from Stocking Lake under the Town's water licence, and can meet the peak hour demands of Pressure Zone 3. The capacity is also sufficient to meet the demands of 18,000 population during high turbidity in Holland Creek, under Alternative 3. Under Alternative 2 the pipe from Stocking Lake to the balancing reservoir will not have sufficient capacity once the population exceeds 9,000, and must be upgraded to 300 mm diameter.

The pipe from the balancing reservoir to the chlorination contact tank is 300 mm diameter and has a capacity of 340 lps. This is sufficient to meet any demands which will be placed upon it when the population reaches 18,000.

There is a pipeline from a point upstream of the contact tank to Arbutus reservoir. The pipeline is 300 mm for part of its length and 200 mm diameter for the remainder. The capacity of this pipeline is 75 lps. This pipe needs to be upgraded under Alternative 2, but not under the other two alternatives. It can deliver sufficient water from Stocking Lake to Arbutus reservoir during a winter high turbidity event in Holland Creek until the population reaches 12,000. This pipeline is no longer able to meet Ladysmith demands during a summer high turbidity event in Holland Creek.

If the 200 mm section of the pipe from the contact tank to Arbutus is replaced by a 300 mm pipe, this new pipe could deliver water from Arbutus to Pressure Zone 3, if required. For example, if filtration of surface water becomes mandatory, the Town would construct one treatment plant at Chicken Ladder to supply the whole Town, and close off the supply from Stocking Lake.

9.2 SYSTEM CONTROL

The present system of operation uses the Stocking Creek watershed as a source for the whole of Ladysmith during the winter. Since the daily water demand in winter exceeds the limits of the licence to draw water from Stocking Creek, the Town should modify its method of operation.

The system operation procedures which are to be established should make efficient use of the sources. For the near future, say until the treatment plant is constructed, this would entail using Stocking Creek as a source for the whole town only when the turbidity exceeds 5.0 NTU, or some other preset value. At other times the higher elevation area of South Ladysmith would be served from Stocking Creek and the remainder of the town would be served from Holland Creek. The development of a Supervisory Control and Data Acquisition (SCADA) system would assist in allowing automatic switching from one source to another as the turbidity changes. The SCADA system would also allow Public Works staff to monitor conditions in the system and, to a limited extent, operate valves from a central location.

Once a treatment plant is installed or other improvements are made, switching between sources will become infrequent and automatic switchover is unlikely to be necessary.

The SCADA system would consist of instruments and control valves at remote locations, linked through a communication system with a central control point, possibly in the Public Works yard. Such SCADA systems are common in smaller communities in Central Vancouver Island, and are used in Qualicum, Parksville, Lantzville, and Port Alberni. In most cases the communications system consists of dedicated telephone lines, and power is available for the operation of the valves. The remoteness of Holland Lake, Prevost Lake, and Chicken Ladder, means that radio may be used for communication and solar generators for instrument power supply. If power is required at these remote sites for valve operation, either a generator should be installed or power should be brought into the site.

A possible layout for the SCADA system is shown on Figure No. 5. There would be a Master Terminal Unit (MTU), a desk-top computer, and a printer in the Public Works yard control centre. Each remote station would have a Remote Terminal Unit (RTU) to accept data from the instruments at that location and to transmit that information to the MTU. The data gathered at the MTU would be displayed on the computer screen and stored in the memory. Selected information would be printed out for hard copy storage as required. The computer program would automatically open and close valves in the system to suit current conditions. Public Works staff would also be able to initiate the opening and closing of selected valves.

The outline of the SCADA system operation is given below.

When the turbidity in Holland Creek exceeds a preset value, valve V1 would close automatically. The valve would automatically reopen when the turbidity decreases to an acceptable value. When valve V1 closes valve V5 would automatically open, and would close again when V1 reopened. This procedure allows the automatic switching from one source to the other as turbidity in Holland Creek varies. Valves V1 and V2 would act as altitude valves when in operation, opening and closing as required by the water levels in Arbutus Reservoir.

A turbidimeter T1 would be required to detect changes in turbidity, and it would preferably be located at Chicken Ladder dam so that the valve could be closed before the turbid water enters the pipelines to Arbutus. However, communication would be simplified if the turbidimeter is installed at the inlet to Arbutus Reservoir. The quantity of turbid water stored in the pipelines between Chicken Ladder and Arbutus would be approximately 155 m^3, which is 2.8% of the volume of Arbutus Reservoir. Therefore there would only be a minor effect on the water quality in Arbutus Reservoir when V1 reopened.

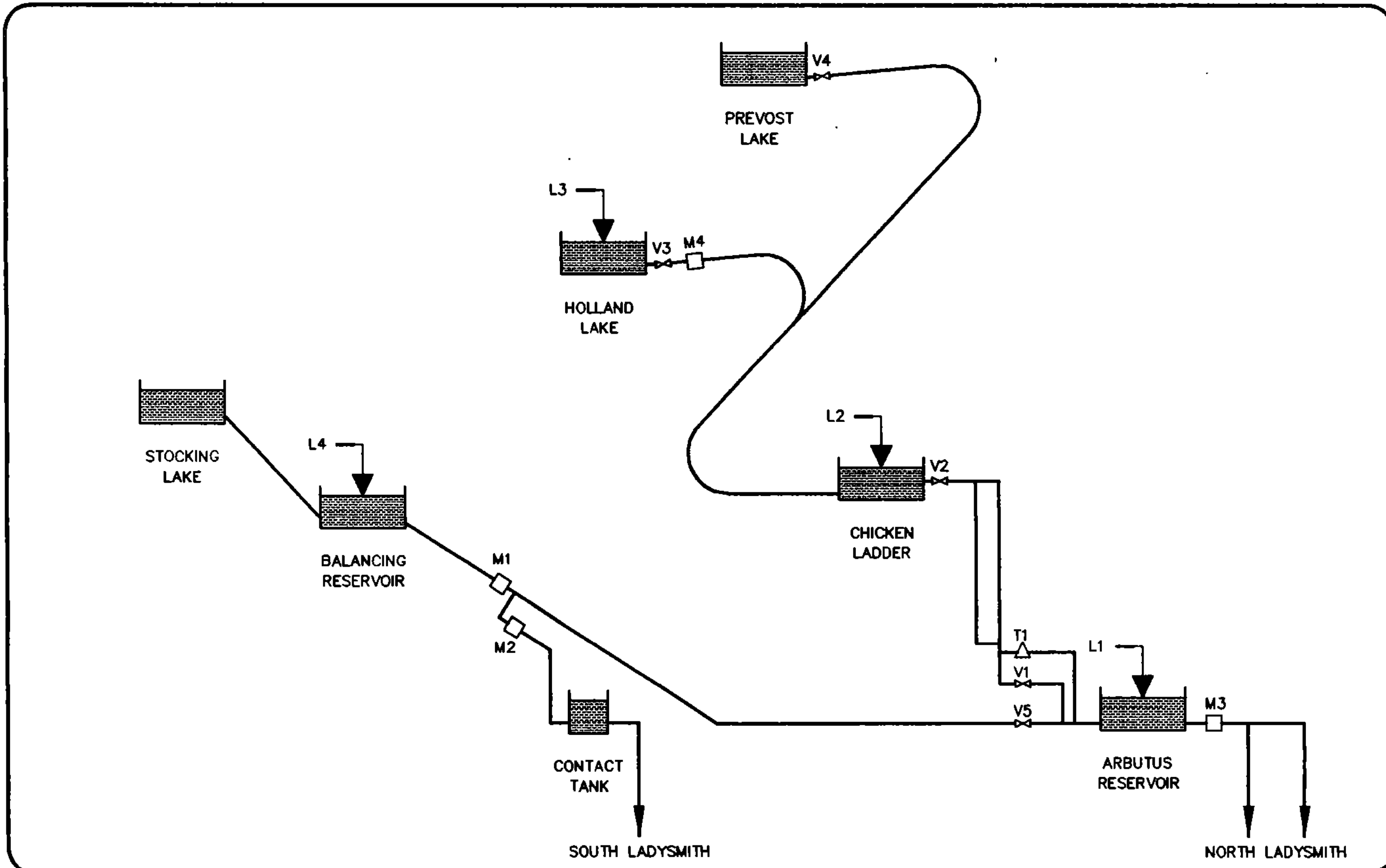
To detect when the turbidity in Holland Creek has decreased to an acceptable value, a constant flow through the turbidimeter is required. This flow could be into Arbutus reservoir or to waste. Once the turbidity at Chicken Ladder is back to normal, it would take approximately 12 hours for a complete change of water in the pipeline. The reading at the turbidimeter would lag by about 12 hours the quality improvement at Chicken Ladder.

Valve V3 would be a flow control valve. The SCADA system would incorporate a generator or other power source at Holland Lake and adjust the valve position by radio communication. An orifice plate or other flow measuring device would allow flow data to be sent back to the Public Works yard.

Prevost Lake is considerably smaller than Holland Lake and there seems little advantage in installing power and communications to automatically operate valve V4. It is likely that in the foreseeable future, the valve at the outlet from Prevost Lake should continue to be operated manually.

The information brought to the central control would include the following:

> levels in each reservoir as measured by devices L1, L2, L3, and L4 would be indicated and recorded,
>
> flow measured by meters M1, M2, M3 and M4 would be indicated, totalized, and recorded, and
>
> the position of each valve, whether closed or the percentage open, would be indicated and recorded.



KOERS & ASSOCIATES ENGINEERING LTD. *Consulting Engineers*	CLIENT: TOWN OF LADYSMITH	SUBJECT: CONTROL SYSTEM DIAGRAM
	PROJECT: WATER STUDY	APPROVED
		DATE: NOV. 1994
		JOB No.: M9412
		SCALE: N.T.S.
		DWG No.: FIG. 5

10.0 SYSTEM UPGRADING

10.1 GENERAL

The water system upgrading is addressed in separate components:

- feasibility investigations
- sources
- supply mains and storage
- distribution
- control system

10.2 FEASIBILITY INVESTIGATIONS

Before making a decision on which of the available alternatives are to be adopted, the Town requires further information on the feasibility of the works. Site investigations should be carried out on the proposal to raise the embankments at Holland Lake, and a geotechnical report, with updated cost estimates, should be produced. A drilling programme and hydrogeological investigation should be carried out into the proposed groundwater source. A feasibility report which summarizes the findings of these two investigations, complete with updated cost estimates, should then be prepared and submitted to the Town.

The estimated cost of this work is:

Geotechnical report on Holland Lake	$10,000
Well exploration and hydrogeological report	55,500
Feasibility report on source upgrading	10,000
Total	$75,500

10.3 SOURCES

The main decision on water sources to be made by the Town is whether to develop a groundwater source, or to raise the embankments of Holland Lake. Either of these alternatives would allow the system to meet the demands of a population of up to 18,000. No upgrading is required on the Stocking Lake system.

Alternative 1 - Groundwater source

Three potential groundwater sources have been identified in the Ladysmith area, the Cassidy Aquifer, Davis Lagoon, and Rocky Creek, as described in Appendix F. The use of groundwater in winter would allow the disconnection of the Holland Creek source at times when the water quality is poor. During the summer the groundwater would supplement the supply from Holland Creek so that peak hour demands can be met. In case a water quality problem occurred in Holland Creek during the summer, a water treatment plant should be constructed. The plant should be capable of treating 125 lps when the population is 18,000.

The preliminary capital cost estimate for developing an 88 l/s well at the Cassidy Aquifer and connecting it to the Town distribution system is given below. When taken in conjunction with the existing Holland Creek supply system, the 88 l/s well would be sufficient to meet the demands of a population of 11,000. To meet the demands of 18,000 people, an additional well would be installed at a Present Value of $ 50,000, assuming a 10 year delay and a discount rate of 6%.

Initial well	$60,000
Subsequent well	50,000
Pumphouse etc	70,000
Control system	30,000
Pipeline	1,760,000
Treatment plant	500,000
Land acquisition	50,000
Subtotal	$2,520,000
Engineering & Contingencies	630,000
Total	$3,150,000

If wells could be developed in the Davis Lagoon or Rocky Creek area, the shorter pipelines would mean that the total cost of implementing a groundwater supply would be less than the estimate shown above.

Alternative 2 - Raising the Holland Lake embankments

The raising of the Holland Lake embankments would increase the available supply of water, but the quality of the water during the winter will still be poor at times. A treatment plant should be installed, with a capability of treating 285 l/s when the population is 18,000.

The preliminary capital cost estimates for the raising of the Holland Lake embankments and the associated works are shown below. It is assumed that a water treatment plant will be installed.

Raise embankments	$1,750,000
Treatment plant	1,000,000
Upgrade access road	100,000
Subtotal	$2,850,000
Engineering & contingencies	712,000
Total capital cost	$3,562,000

10.4 STORAGE

No upgrading is required on the storage for the water from the Stocking Creek watershed.

A new reservoir is required at Arbutus, and a site which will give a maximum top water level of 180 m is recommended. The reservoir should have a minimum capacity of 8,250 m^3. The water should be chlorinated before it enters the new reservoir, so that contact time is given in the reservoir. This means that a new chlorination facility should be constructed adjacent to the reservoir.

The preliminary capital cost estimate for the upgrading of the storage is:

8,000 m^3 Reservoir	$1,400,000
Chlorination facility	100,000
Civil works and land	100,000
Subtotal	$1,600,000
Engineering & contingencies	400,000
Total capital cost	$2,000,000

10.5 SUPPLY MAINS

As shown in Table 11, the estimated capital cost of the supply main upgrading would be $387,000 if groundwater is developed, and $795,000 if Holland Lake is upgraded and a treatment plant installed. If Holland Lake is upgraded and no treatment plant is built, the supply mains from Stocking to Arbutus would have to be upgraded at an estimated cost of $1,971,000.

10.6 DISTRIBUTION SYSTEM

The upgrading of the distribution system consists of the installation of additional watermains and the establishment of a new pressure zone system. The new pressure zones will be established by installing pressure reducing valves and the closing of selected gate valves. Figures No. 5 and 6 show the extent of these works.

The preliminary estimate for the capital cost of these works is:

New watermains	$197,400
Pressure reducing stations	335,000
Subtotal	$532,400
Engineering & contingencies	133,100
Total capital cost	$665,500

The installation of meters on all unmetered services is estimated to cost $1,000,000 including contingencies and engineering.

The replacement of deteriorating watermains, will be spread over a number of years. A programme to replace these pipes would require an annual expenditure of $100,000, in 1995 dollars. Most of the existing supply mains from the sources to town are asbestos cement. Damage to these mains due to an earthquake or other emergency, would jeopardize the water supply to Ladysmith. These mains should therefore have a high priority in the schedule for replacement.

10.7 CONTROL SYSTEM

The implementation of a control system, as described in Section 9.2, would allow more efficient use of the water which is available to the Town. The first stage of the system would be the installation of a remotely controlled valve on the outlet from Holland Lake at an estimated cost of $70,000. The remaining works would cost an additional $80,000 for a total of $150,000 including engineering and contingencies.

10.8 COST ESTIMATES

The Town needs to decide which options for water system improvements are to be adopted. The cost estimates for two alternatives are presented for consideration in Table No. 12. Alternative 1 is based on the upgrading of Holland Lake and the construction of a water treatment plant. Alternative 2 is based on the development of a groundwater source.

The cost estimates include allowances for engineering, and contingencies. GST has not been included.

10.9 DEVELOPMENT COST CHARGES

The Town has a Development Cost Charges (DCC) Bylaw in place. The bylaw authorizes the collection of DCC's for the construction of the pipeline from Holland Lake to Chicken Ladder, and some funds are being held for this project. DCC's are also being collected for South Davis Road watermain upgrading, Chemainus Road-E&N crossing watermain upgrading, and the Waterfront watermain. It is a recommendation of this report that the pipeline from Holland Lake should not be constructed. In a telephone conversation, an official with the Ministry of Municipal Affairs stated that the revision of the bylaw and the transfer of the funds currently held to a similar project would probably be acceptable to the Ministry.

After Council has decided which water supply projects are to be constructed, a new or amended bylaw should be prepared.

The establishment of DCC's for water system upgrading have been the subject of separate discussions with Town staff.

10.10 WATER RATES

The water rates which are charged to consumers can be used to encourage conservation, while providing funds for the operation and maintenance of the water supply system. An increasing block rate structure, based on actual water used as metered, is an effective method of billing. This establishes rates which charge more per unit of water when water use is in excess of a reasonable base amount. The operation and maintenace of the system should be funded by the user rates, while the capital costs are funded from a parcel tax. The Town should investigate such a structure when water is to be charged according to metered use.

TABLE NO. 12 – COST ESTIMATES

	Component	Alternative 1 Upgrade Holland Lake	Alternative 2 Develop Groundwater
1	Geotechnical investigation into upgrading Holland Lake	$10,000	$10,000
2	Hydrogeological investigation into groundwater sources	55,000	55,000
3	Review alternatives for source augmentation	10,000	10,000
4	Design and install wells, pumps, and pipeline to Town	–	2,525,000
5	Heighten embankments at Holland Lake	2,310,000	–
6	Design and construct new Arbutus reservoir	2,000,000	2,000,000
7	Upgrade supply mains	522,000	387,000
8	Treatment Plant	1,000,000	1,000,000
9	Establish new pressure zone system	665,000	665,000
10	Install meters on all services	1,000,000	1,000,000
11	Control system	150,000	150,000
	Total	$7,722,000	$7,802,000

11.0 CONCLUSIONS AND RECOMMENDATIONS

11.1 CONCLUSIONS

1. The licence held by the Town on the Stocking Creek watershed is sufficient to meet the maximum day water demands of a population of 2,165. However, it is not sufficient to meet the winter demands of the whole town.

2. The licences held by the Town on the Holland Creek watershed are sufficient to meet the water demands of a population of 11,600.

3. The existing licences in the two watersheds can meet the demands of a total population of 13,750.

4. The projected 1995 population of Ladysmith is 6,533. The population which can be accommodated in the Town, within the present boundaries and with the current zoning, is approximately 15,000.

5. It is unlikely that an additional licence will be granted on the Stocking Creek watershed, but the Water Management Branch may be willing to amend the existing licence from a daily basis to an annual basis. This would allow a greater number of people to be served from this source.

6. It is possible that an additional water licence could be granted in the Holland Creek watershed. Discussions with the Water Management Branch will be required to confirm this.

7. Under the existing method of operation the Holland Lake and Chicken Ladder system could serve a population of 6,900, with the 10 year low flow return period in the creek. Together with the 2,100 being served from Stocking Lake, the total maximum population served would be 9,000.

8. The installation of a remotely controlled valve on the Holland Lake outlet will allow more efficient use of the water in the Lake.

9. Raising the height of the embankments at Holland Lake by 1.0 m, together with more efficient use of the resource, will allow a total population of 18,000 to be served.

10. No suitable site for another impoundment dam was identified in the Holland Creek watershed, below Holland Lake.

11. Three areas were identified as being potential groundwater sources. The

water quality from these groundwater sources is expected to be good.

12. The upper Chipman Creek watershed has the potential to be an additional source of water for the Town.

13. The quality of water from Stocking Lake is good.

14. The quality of water in Holland Creek is generally good, but turbidity and colour occasionally exceed drinking water standards, particularly during the winter.

15. If Holland Lake is to be used as a year-round water source, the quality can be improved by either installing a water treatment plant, or installing a pipeline from Holland Lake to Chicken Ladder.

16. While a pipeline from Holland Lake to Chicken Ladder would improve the water quality during periods of high turbidity, it is unlikely that the water would always meet the required Drinking Water Standards.

17. A water treatment plant has a lower capital cost than a pipeline, and would ensure that the water quality is always to the acceptable standards.

18. The pipelines from Stocking Lake have sufficient capacity to carry the licensed amount of water to South Ladysmith.

19. The pipeline from the Stocking Lake system to Arbutus has sufficient capacity to serve a total population of 12,000 in winter. However, this amount exceeds the Town's licence for Stocking Lake.

20. Arbutus reservoir has sufficient capacity to serve a population of 12,000.

21. Arbutus reservoir is open to the atmosphere and is not secure. The reservoir presents a public health risk and should be replaced by a closed reservoir.

22. There is insufficient chlorine contact time to disinfect effectively the water from Arbutus reservoir.

23. The chlorine contact tank on the Stocking Lake system has sufficient capacity and is of suitable construction to serve the 2,165 people who will be supplied from it.

24. Excessively high pressures occur in the distribution system at lower elevations.

25. Under peak flow conditions, the pressures at Nash Place, Mackie Road, and Malone Road can be below the desirable standards.

26. At present the Town does not have a policy on the quantity of water delivered to other communities. The sizing of system components depends to some extent on the quantities of water to be supplied to consumers, such as those in the Diamond Improvement District, outside the Town boundary.

27. Adequate fire protection cannot, at present, be provided in the area south of Davis Road and east of Thetis Drive. The installation of a 200 mm diameter watermain from the contact tank to Russell Road and Craig Road will provide adequate fire flows to these areas.

28. A new Arbutus reservoir with a top water level of 180 m and a capacity of 8,000 m^3 would provide adequate pressure at the higher elevations, and would have sufficient capacity to serve a total population of 18,000.

29. A new pipeline would be required to deliver water from Chicken Ladder to the new, higher Arbutus reservoir. If a groundwater source is developed, the pipeline diameter should be 350 mm. If a groundwater source is not developed, the pipeline diameter should be 500 mm.

30. If a chlorination facility is installed ahead of the new Arbutus reservoir, sufficient contact time will be provided in the reservoir to disinfect the water.

31. The installation of 11 new pressure reducing stations, and the closure of some existing gate valves, would create a suitable pressure zone system in the Town, consisting of four separate zones.

32. With a new pressure zone system, additional watermains with a total length of 1500 m, as shown on Figure No. 3, are required.

11.2 RECOMMENDATIONS

It is recommended that the Town of Ladysmith:

1. Requests that the Integrated Watershed Management Plan restricts public access to the Holland Creek watershed.

2. Applies to the Water Management Branch for an amendment to licence CL005333, to change the Stocking Lake supply from a daily limit to an annual limit.

3. Establishes a policy on the supply of water to users outside the Town boundary.

4. Establishes that a pipeline from Holland Lake to Chicken Ladder is not an effective or economic solution to the water quality problems in Holland Creek.

5. Discusses with the Ministry of Municipal Affairs the transfer of funds already collected under the DCC bylaw, to the proposed works so that investigations into the source works can start immediately.

6. Prepares a full review of the DCC bylaw, setting out the long term plans for water system improvements.

7. Designs and installs the flow control valve and flowmeter at the Holland Lake outlet, together with the radio controlled RTU's and solar/battery power system. Funds are allocated in the 1995-96 Public Works budget for this work.

8. Authorizes the design and construction of the recommended works, including the following:

    - water treatment plant.

    - new pipeline from Chicken Ladder to the new Arbutus reservoir.

    - new Arbutus reservoir, complete with a chlorination facility.

- modifications to the pressure zoning system by:

  - installing new pressure reducing stations
  - adjusting the settings on the existing pressure reducing stations
  - closing the required gate valves in the distribution system
  - installing the watermains shown on Figure No. 3

- SCADA system on the supply and storage systems, so that valves can be actuated automatically and/or remotely, and instruments can be remotely monitored and recorded.

Initiates a programme to install meters on all unmetered water services within a period of five years.

Initiates an annual programme for the replacement of deteriorating watermains, on a priority basis.

9. Authorizes the investigation by a consulting engineer into the potential water source improvements, by:

    Initiating a detailed geotechnical investigation into raising embankments at Holland Lake.

    Initiating a groundwater investigation programme.

    Reviewing the results of the groundwater and geotechnical programmes.

    Preparing cost estimates for alternative improvements to the water sources.

    Discussing the findings with the appropriate government authorities, particularly the Water Management Division.

    Presenting a report to Council on the findings of the investigation.

    Subject to the approval of the Ministry of Municipal Affairs, funds from the existing DCC accounts are available for this work.

10. Decides whether a groundwater supply is to be developed to supplement the existing sources, or the embankments at Holland Lake are to be upgraded.

11. Authorizes the investigation by a consulting engineer into the potential water source improvements, by:

- new water source works, by <u>either:</u>

  wells, pumps, wellhead equipment, and pipeline from the wells to the Town.

<u>or:</u>

  improvements to Holland Lake, including raising the embankments, and making the necessary applications to the Water Management Division.

APPENDIX A

WATER DEMANDS

APPENDIX A

WATER DEMANDS

The following table is based on the recorded water consumption during the period 1988 through 1992.

WATER CONSUMPTION (in m3)

Year	Population	Average day (excl. Diamond) m3	Average day per capita m3/cd	Maximum day (incl. Diamond) m3	Maximum day per capita m3/cd
1988	4585	3450	0.752	8401	1.832
1989	4681	3670	0.784	9086	1.941
1990	4777	3803	0.796	8243	1.726
1991	4875	3851	0.790	8345	1.712
1992	5073	4025	0.793	8635	1.702
Average			0.783		1.783

It should be noted that the populations shown above are estimates only, apart from 1991 which was a census year.

From the above it is assumed that the average day demand is 790 l/cd not including the water delivered to the Diamond Improvement District, and that the maximum day demand is 1785 l/cd including the water delivered to Diamond.

From the meter readings at the connection to the Diamond District, it is found that the total annual water consumption by Diamond is approximately 4.5% of the Ladysmith consumption. Assuming this is also true for the maximum day, this means that on the maximum day the water consumed in Ladysmith, not including Diamond, was 95.5% of 1785 l/cd which is 1705 l/cd.

The ratio of maximum day demand to average day demand is 1705/790 = 2.16.

The premises of the major water users are metered. These users include industrial, commercial, and institutional facilities. There are other commercial premises which are not metered and are assumed to have water consumption similar to a suburban residence. Over the period 1988 through 1992, the metered services in Ladysmith accounted for approximately 25% of the total water used in town. Of the non-metered connections, 96% are residential and the remaining 4% are commercial or institutional. On the average day, therefore, the water consumption was:

non-metered, residential	566 l/cd
non-metered, other	24 l/cd
metered	200 l/cd
total	790 l/cd

Since the meters are read monthly, and not daily, there is no record of the maximum day demands at metered premises. The ratio of maximum day demand to average day demand at the metered connections will be less than at residential connections, since the residential connections are more likely to require lawn-watering which is the main cause of water use variation. For the purposes of this study, it is assumed that the ratio of maximum day to average day demand for the non-residential services is 1.75, which gives a maximum day demand of 224 x 1.75 = 392 l/cd. The maximum day demand for residential services is 1705-392 =1313 l/cd and the ratio for non-metered services then becomes 1313/566 = 2.3. This ratio is consistent with those of similar communities on the east coast of Vancouver Island.

The day of highest demand in 1993 was August 5. The Arbutus flow recorder chart for this day shows that the demand over 24 hours was 8699 m^3 which gives a maximum day demand of 100 l/s. The highest demand over a 60 minute period on this day was 185 l/s. The ratio of peak hour demand to maximum day demand on this occasion was 185/100 = 1.85.

Over a five year period the quantity of water delivered to the Diamond Improvement District averaged 4.5% of the total water drawn by Ladysmith. It is assumed that the ratio of maximum day to average day in Diamond is the same as in Ladysmith. Since Diamond has a storage reservoir from which peaks in demand can be drawn, it is assumed that during the hour of peak demand the rate of flow into the Diamond reservoir is equal to their maximum day demand.

When the population of Ladysmith was 6000, the average day demand in Diamond would be 0.045 x 6000 x 790 = 213,300 litres per day or 2.47 l/s. The maximum day demand would be 2.47 x 2.3 = 5.68 l/s.

To summarize, the current water demands in litres per capita per day are taken as:

residential average day	566 l/cd
residential maximum day	1313 l/cd
ratio maximum/average	2.3
non-residential average day	224 l/cd
non-residential maximum day	392 l/cd
ratio maximum/average	1.75
ratio peak hour/maximum	1.85
Diamond average day (1995)	2.47 l/s
Diamond maximum day	5.68 l/s
Diamond peak hour	5.68 l/s

It is anticipated that the installation of water meters and the implimentation of water conservation measures will reduce per capita water demands. For the purposes of this study it is assumed that per capita water demands at services which are not metered at present, will decrease by 20% by the time the meter installation is completed, which is assumed to occur by the time the population reaches 9,000. It is also assumed that there will be no decrease in the per capita demand for metered services in Ladysmith or in Diamond which is fully metered.

Of the metered demands, the highest consumption is by the two mills on the waterfront. These mills consume 55% of the annual metered water usage in Ladysmith. Although the Official Community Plan states that industrial development should be encouraged, it is unlikely that new industries will use as large amounts of water as the mills. In estimating the future water demands, therefore, it is assumed that metered water demands will grow at two-thirds of the rate of residential demands. The population of Diamond Improvement District will continue to grow. At this stage, however, it is not known whether the quantity of water delivered by Ladysmith to Diamond will be increeased to meet the increased demands in Diamond. For the purposes of this report, it is assumed that growth in quantity of water supplied to the Diamond district will be at two-thirds of the Ladysmith residential rate.

Table A1 shows the water demand projections for population levels of 6,000, 9,000, 12,000, 15,000, and 18,000.

TABLE NO. A1 – SUMMARY OF WATER DEMAND PROJECTIONS WITH ALL SERVICES METERED

POPULATION	6000	9000	12000	15000	18000
ANNUAL DEMAND (m3)					
Ladysmith residential	1,239,540	1,488,105	1,984,140	2,480,175	2,976,210
Ladysmith non–residential	480,942	641,095	801,249	961,883	1,122,037
Diamond District	77,420	103,201	128,982	154,840	180,621
Total	1,797,902	2,232,401	2,914,370	3,596,898	4,278,867
MAXIMUM DAY (l/s)					
Ladysmith residential	91.2	109.4	145.8	182.3	218.8
Ladysmith non–residential	27.2	35.6	44.5	53.4	62.3
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	124.1	152.5	199.7	247.0	294.2
PEAK HOUR (l/s)					
Ladysmith residential	168.7	202.3	269.8	337.2	404.7
Ladysmith non–residential	50.4	65.8	82.3	98.7	115.2
Diamond District	5.7	7.5	9.4	11.3	13.2
Total	224.7	275.7	361.4	447.3	533.1

APPENDIX B

HOLLAND CREEK / STOCKING LAKE HYDROLOGY

Ministry of Environment, Lands and Parks
Water Management Division
Hydrology Branch

Holland Creek/Stocking Lake Hydrology
Data Summary and Analysis

A. R. Chapman
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Victoria, British Columbia
April 1993

Holland Creek/Stocking Lake Hydrology
Data Summary and Analysis

A. R. Chapman and D. E. Reksten

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1. INTRODUCTION

This report, which is an appendix to the Holland Creek/Stocking Lake Integrated Watershed Management Plan, provides a summary and analysis of streamflow and precipitation data for the Holland Creek and Stocking Lake watersheds. In addition, the storage, release and utilization of water from Holland Creek is summarized. This information is used to estimate hydrologic characteristics of the two watersheds, and can be used as input to water supply assessment, resource use impact assessment, and for the development of guidelines and prescriptions for various resource use proposals for the watersheds.

The watersheds are located along the east side of Vancouver Island, near the town of Ladysmith (Figure 1). The Holland Creek watershed has an area of 28.0 km^2 and varies in elevation from sea level to 1,300 m, with a median elevation of approximately 570 m. The Stocking Lake watershed is very small, comprising an area of only 1.65 km^2, and varies in elevation from 360 to 600 m, with a median elevation of 380 m. Holland Creek and Stocking Lake both serve as the water supply for Ladysmith and the Saltair area (Cowichan Valley Regional District).

2. PRECIPITATION

This section describes the pattern of annual and seasonal precipitation for the Holland Creek and Stocking Lake watersheds. The Atmospheric Environment Service (AES) stations located in the vicinity of the watersheds include Ladysmith (1913-1923), Chemainus (1919-1979), Nanaimo Airport (1947-1990), and Cowichan Lake Forestry (1950-1990). The Ladysmith, Chemainus and Nanaimo Airport stations are all located near sea level, while Cowichan Lake Forestry is located at an

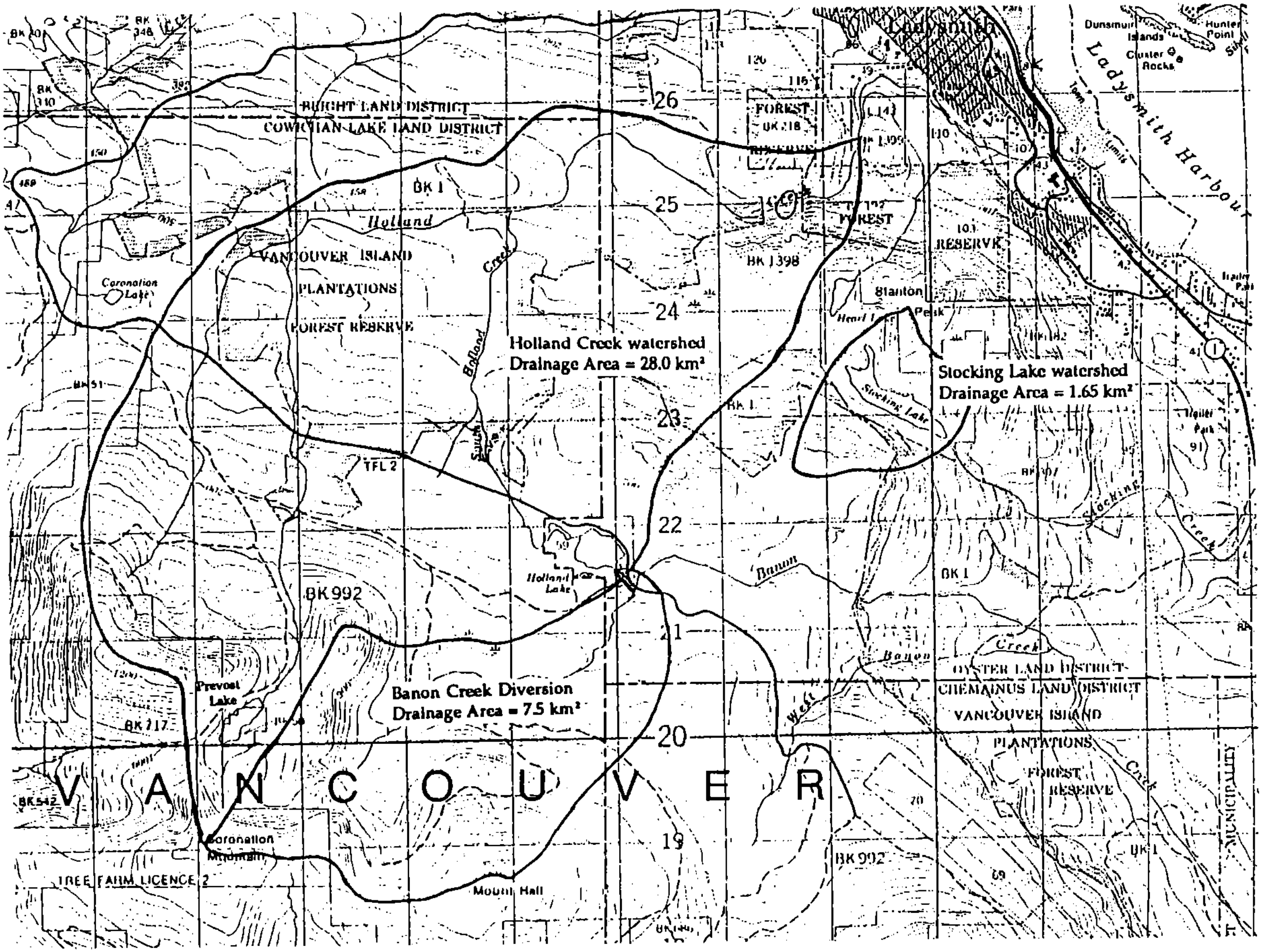


Figure 1. Study Area

elevation of 177 m. In addition, precipitation data collected by the town of Ladysmith at Stocking Lake (elevation 360 m), and snow water equivalent data from snow course 3B16, Sno-Bird Lake (elevation 1,400 m), operated by BC Environment's Water Management Division, are also examined.

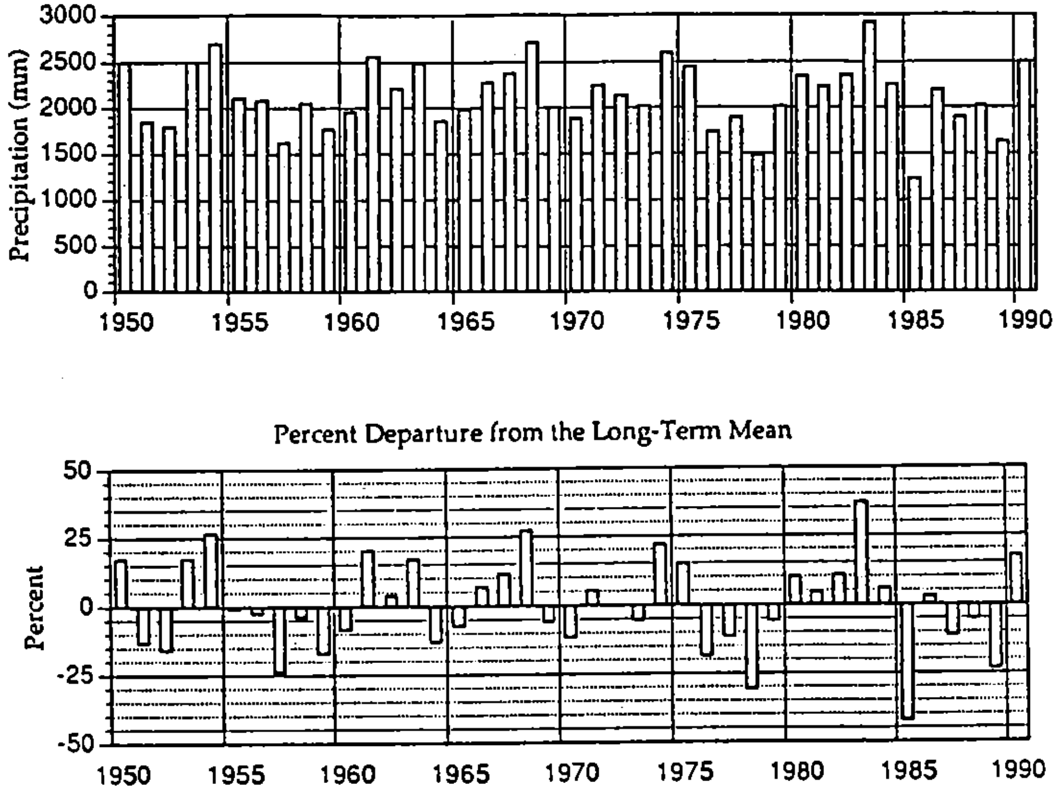
2.1 Annual Precipitation

Annual precipitation along the east side of Vancouver Island near Ladysmith varies with elevation, as a result of the orographic effect of the mountains. Mean annual precipitation measured near sea level at Chemainus and Nanaimo Airport is approximately 1,125 mm. Mean annual precipitation measured at Ladysmith (adjusted to account for the short period of record) is approximately 1,200 mm. With elevation, however, precipitation increases. The 20 year mean annual precipitation measured at Stocking Lake is 1,575 mm, and the mean annual precipitation measured at Cowichan Lake Forestry is 2,130 mm. As another indicator of the increased precipitation with elevation, mean May 1 snow water equivalent at the Sno-Bird Lake snow course is 1,480 mm (1966-1985). This corresponds to a mean annual precipitation of more than 2,300 mm.

Mean annual precipitation on the Holland Creek watershed varies from about 1,200 mm near sea level to as much as 2,500 mm at upper elevations. Basin average precipitation is estimated to be approximately 2,200 mm. The Stocking Lake watershed is estimated to receive about 1,700 mm of precipitation annually.

Precipitation can vary considerably from year to year. Figure 2 shows graphically the annual precipitation measured at Cowichan Lake Forestry, and the percent deviation each year's precipitation is from the long-term mean. As examples, precipitation during the 1976-79 and 1985-89 periods were generally lower than average, with the 1985 annual precipitation being 42 percent less than the long-

Figure 2
Cowichan Lake Forestry
Annual Precipitation, 1950-1990



term mean. On the other hand, the 1980-1984 period had greater than usual precipitation, with 1983 receiving 37 percent greater precipitation than the long-term mean.

2.2 Monthly Precipitation

The Holland Creek and Stocking Lake watersheds receive the majority of their precipitation during the winter. Estimated mean monthly precipitation for the Holland Creek watershed is shown in Figure 3. The six month period of October to March receives, on average, greater than 80 percent of the annual precipitation. December and January are the months of highest precipitation, while July and

August are the months of lowest precipitation. Monthly precipitation can also vary greatly from year to year. This is indicated in Figure 4, showing the mean, maximum and minimum monthly precipitation at Cowichan Lake Forestry during 40 years of record.

Figure 3
Holland Creek Watershed Estimated Mean Monthly Precipitation

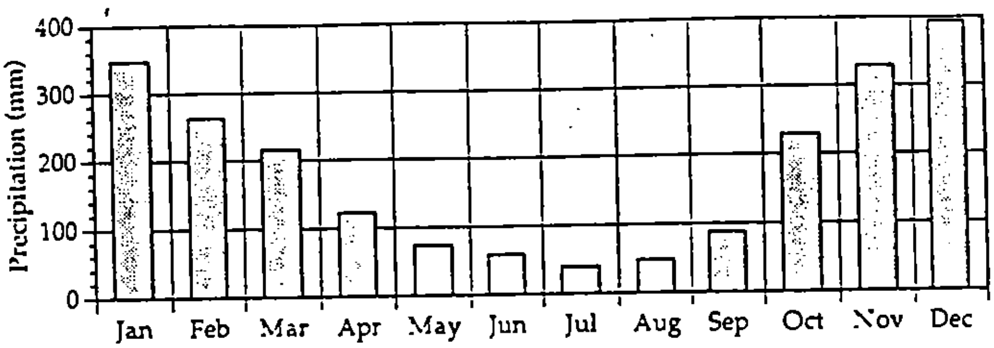
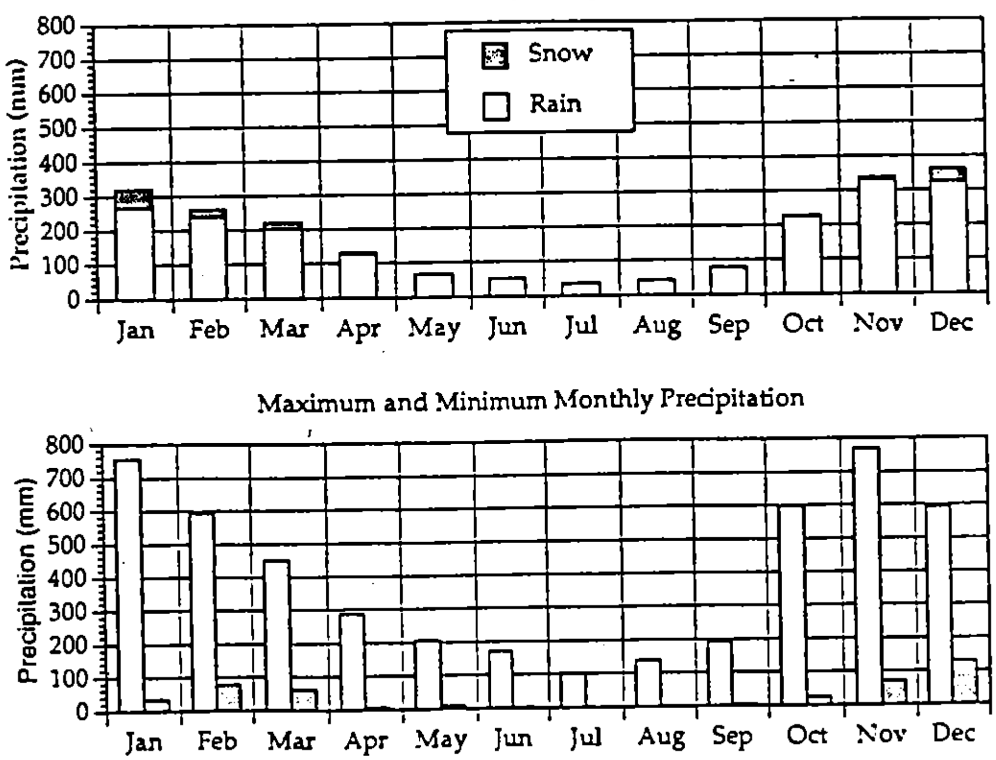


Figure 4
Cowichan Lake Forestry Station, 1950-1990
Mean Monthly Precipitation



2.3 Snow Accumulation

The portion of monthly and annual precipitation occurring as snow varies greatly between low elevation and high elevation locations in the watersheds. Near sea level, about 5 percent of the annual precipitation occurs as snow, mostly in December and January, with small amounts occasionally in other winter months. High elevation snow precipitation is more difficult to estimate because of the paucity of data. However, 20 years' data from the Sno-Bird Lake snow course (elevation 1,400 m) indicates that as much as 60 percent of annual precipitation can occur as snow at high elevation locations. The Holland Creek watershed, with a median elevation of 650 m, will possibly receive as much as 15-20 percent of its mean annual precipitation as snow.

2.4 Short Duration Rainfall

Short duration, high intensity rainfall can produce large amounts of runoff. The recording rain gauges at Nanaimo Airport and Nanaimo City Yard provide the only intensity-duration-frequency estimates available for the Holland Creek area. The Nanaimo City Yard values, shown in Tables 1a and 1b, correspond best to the Stocking Lake watershed and low- to mid-elevation areas of the Holland Creek watershed. For high elevation areas in the Holland Creek watershed; the precipitation intensity and magnitude values for events of 12 hour and 24 hour duration should be augmented by a factor of 1.5[1]

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1 Rainfall Frequency Atlas for Canada, by. W. D. Hogg and D. A. Carr. 1985. Canadian Climate Centre, Atmospheric Environment Service, Downsview, Ontario.

Table 1a. Nanaimo City Yard, 1980 - 1990
Precipitation magnitude (mm)-duration-frequency

Duration	Return Period (Years)				
	2	5	10	25	50
5 Min	3.1	4.4	5.3	6.4	7.2
10 Min	4.7	6.8	8.2	9.9	11.2
15 Min	5.6	8.1	9.7	11.7	13.3
30 Min	7.7	10.7	12.7	15.2	17.1
1 Hr	10.3	13.4	15.4	18.0	19.9
2 Hr	15.0	17.9	19.9	22.4	24.2
6 Hr	29.9	36.1	40.2	45.4	49.2
12 Hr	44.7	55.5	62.6	71.7	78.4
24 Hr	57.3	74.5	85.9	100.3	110.9

Table 1b. Nanaimo City Yard, 1980 - 1990
Precipitation intensity (mm/hr)-duration-frequency

Duration	Return Period (Years)				
	2	5	10	25	50
5 Min	37.2	52.9	63.3	76.4	86.1
10 Min	28.2	40.6	48.9	59.4	67.1
15 Min	22.5	32.3	38.8	47.0	53.0
30 Min	15.3	21.4	25.4	30.4	34.2
1 Hr	10.3	13.4	15.4	18.0	19.9
2 Hr	7.5	9.0	9.9	11.2	12.1
6 Hr	5.0	6.0	6.7	7.6	8.2
12 Hr	3.7	4.6	5.2	6.0	6.5
24 Hr	2.4	3.1	3.6	4.2	4.6

3. STREAMFLOW

This section describes some hydrologic characteristics of the Holland Creek and Stocking Lake watersheds. Because there is no stream discharge information available, the hydrologic characteristics of the watershed must be inferred from other regional Water Survey of Canada stations. The stations used in this analysis are listed in Table 2.

Table 2. Regional Water Survey of Canada Stations

Water Survey of Canada Station Number	Name	Drainage Area km^2	Years of Record	Mean Annual Runoff (mm)	Median Elev (m)
08HA003	Koksilah River at Cowichan Station	209	1915,16,60-90	1,490	508
08HA016	Bings Creek near the mouth	15.5	1962-65,68-82,85-90	975	170
08HB027	Millstone Creek near Wellington	46.1	1962,63,69-74	1,080	340
08HB032	Millstone Creek at Nanaimo	86.2	1962-64,87-90	850	260
08HB041	Jump Creek at the mouth	62.2	1970-90	2,430	705

As shown in Figure 5, mean annual runoff varies substantially with basin elevation, as a result of the orographic effect of the Vancouver Island mountains. Based on this median elevation - mean annual discharge relationship, mean annual runoff for the Holland Creek watershed is estimated to be approximately 1,800 mm (1.60 m^3/s; 50,400 dam^3), and mean annual runoff for the Stocking Lake watershed is estimated to be 1,300 mm (0.068 m^3/s; 2,150 dam^3). Annual runoff can be quite variable, as indicated in Figure 6, showing the 1960-1990 runoff values for the Koksilah River and the percent deviation of annual runoff from the long-term mean. The 1976-1979 and 1985-1989 periods experienced lower runoff than average, with the 1978 and 1985 being only about 50 percent of the long-term mean.

Figure 5
Elevation-Runoff Relationship for Regional Water Survey of Canada Stations

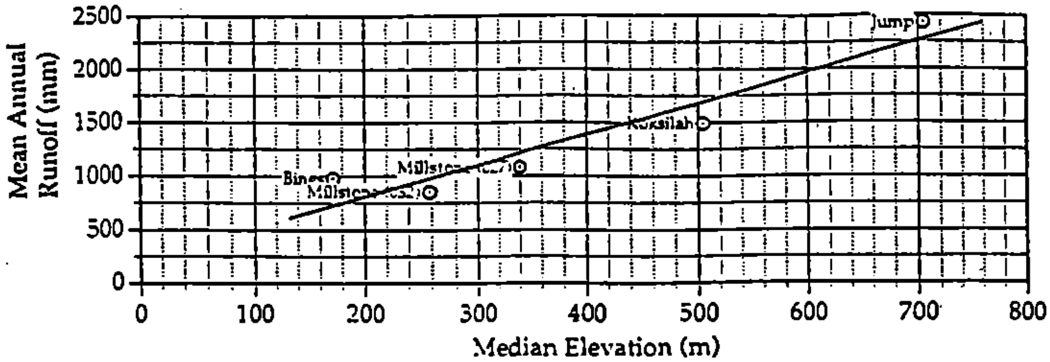
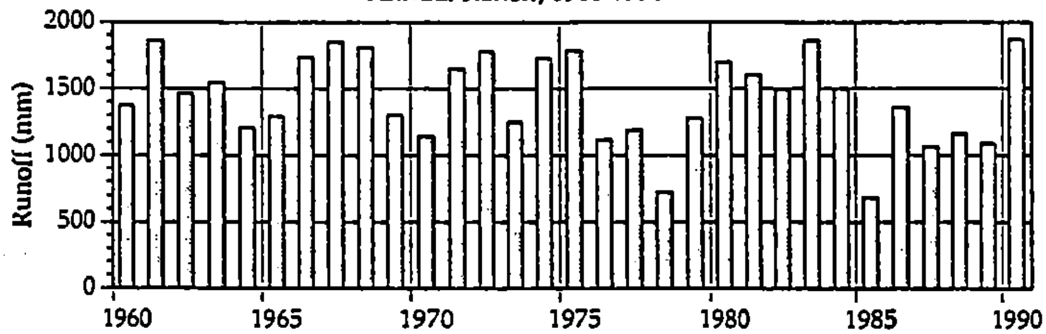
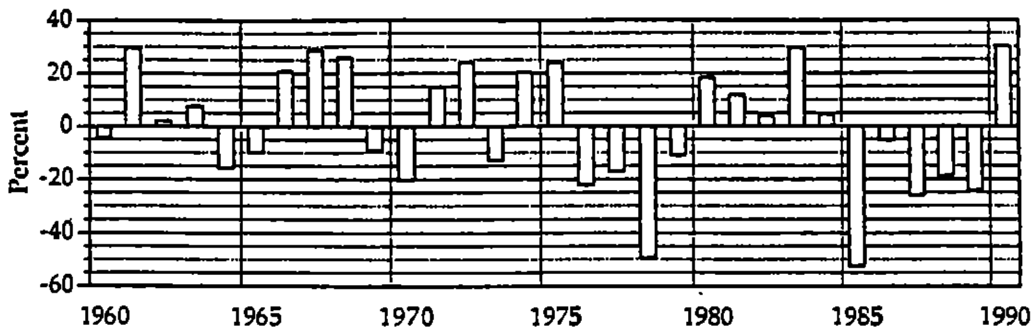


Figure 6
Koksilah River at Cowichan Station
Annual Runoff, 1960-1990



Percent Departure from the Long-Term Mean



3.1 Holland Creek Flow Regulation, Diversion and Consumption

The natural runoff in the Holland Creek watershed has been altered considerably by the diversion of water from the neighbouring Banon Creek watershed, by the storage and regulation of discharge from Holland Lake and Prevost Lake in the Holland Creek watershed, and by the withdrawal of water from Holland Creek by the town of Ladysmith. Holland Lake has a storage of 1,370 dam^3, while the much smaller Prevost Lake has a storage capacity of 124 dam^3.

The town of Ladysmith has a water license to divert up to 1,475 acre-feet (1,820 dam^3) of water from Banon Creek to Holland Lake during the November 1 to April 30 period. Of this water, 625 acre-feet (770 dam^3) can be diverted through Holland Lake for immediate use during the winter and the remaining 850 acre-feet (1,050 dam^3) are stored in Holland lake and released to augment discharge during the summer. In addition, there are 300 acre-feet (370 dam^3) of storage of Holland Creek water in Holland Lake and Prevost Lake. This water is stored during the winter and released during the summer.

In addition to diverting and storing water in the upper portion of the Holland Creek watershed, the town of Ladysmith impacts stream discharge by withdrawing and consuming water from Holland Creek and Stocking Lake. In general, Stocking Lake serves as the water supply during the winter months when Holland Creek experiences high turbidity, and Holland Creek serves as the water supply during the summer (a 1990 reconnaissance survey of the Holland Creek watershed determined that much of the turbidity results from historic logging and road building practices[2]). During 1990 Ladysmith consumed about 1,450 dam^3 of water from Stocking Lake and Holland Creek, of which about 966 dam^3 (0.052 m^3/s; 582,000 gal/day) came from Holland Creek during the approximately seven month period of withdrawal.

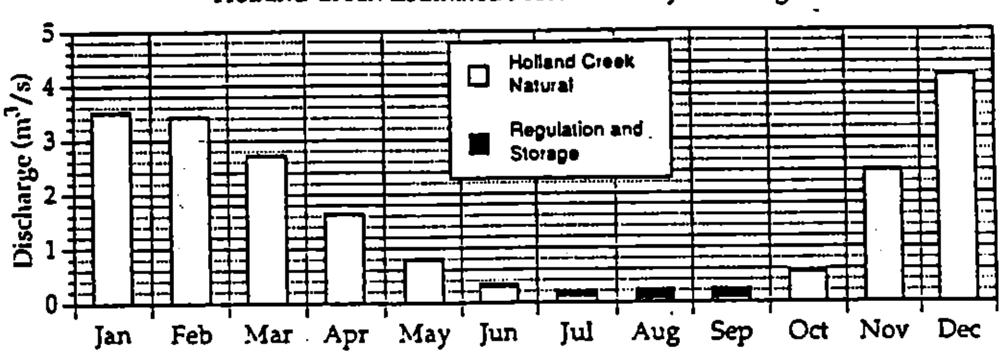
2 A Watershed Assessment of Stocking Lake - Holland Creek Watersheds: Water Supply for the Town of Ladysmith, March 26, 1990, Ministry of Forests Memorandum from S. Chatwin, Manager, Fish/Forestry Watershed Assessment, to Tom Walker, District Manager, Duncan Forest District

The effect of the Banon Creek diversion, Holland Lake and Prevost Lake storage, and Ladysmith withdrawal on the estimated monthly and annual Holland Creek discharge is summarized in Table 3.

3.2 Holland Creek Monthly Discharge

Monthly discharge from Holland Creek varies considerably during the year, as indicated in Table 3 and Figure 7, corresponding to the seasonal pattern of annual precipitation. Eighty-five percent of the "natural" unregulated runoff occurs during the six month period of October to March, while only 1.25 percent occurs during the July to September period. The diversion of water from Banon Creek and storage in Holland Lake, along with the storage of Holland Creek water in Holland Lake and Prevost Lake, increase considerably Holland Creek discharge during the July to September period. The augmented flows in August and September are approximately 350 percent greater than what they would be during mean year runoff conditions.

Figure 7
Holland Creek Estimated Mean Monthly Discharge



Although Ladysmith withdraws less than two percent of the mean annual discharge from Holland Creek, the withdrawals can be a large portion of the available water during the summer months. As indicated in Table 3, about 25-30 percent of the summer period discharge can be withdrawn by Ladysmith during an "average" flow year.

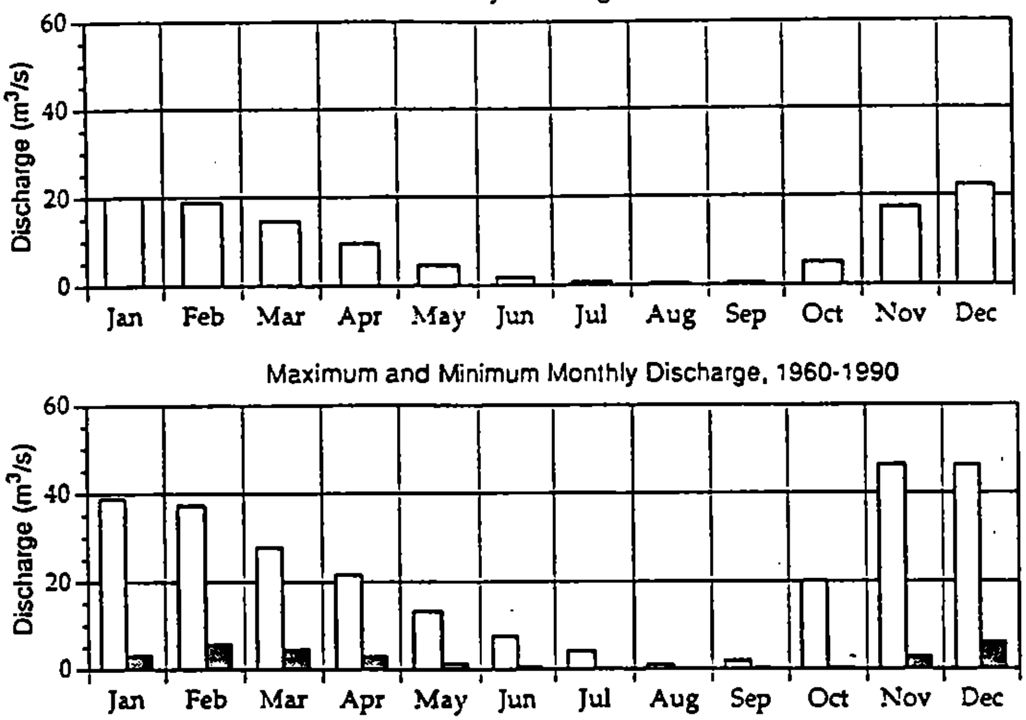
Table 3. Holland Creek runoff, diversion and withdrawal summary, mean year runoff.

	Holland Creek "Natural" Discharge			Diversion and Storage			Holland Creek Regulated Discharge		Ladysmith Consumption from Holland Creek		Discharge Balance	
	mm	dam³	m³/s	Banon	Holland	Total	dam³	m³/s	dam³	Percent	dam³	m³/s
				dam³	dam³	dam³						
Jan	328.	9,390	3.50	113	-54	59	9,450	3.53	0	0.0	9,450	3.53
Feb	292.	8,270	3.42	102	-49	53	8,320	3.44	0	0.0	8,320	3.44
Mar	254.	7,260	2.71	113	-54	59	7,320	2.73	0	0.0	7,320	2.73
Apr	148	4,220	1.63	109	-52	57	4,280	1.65	115	2.7	4,170	1.61
May	73.8	2,110	0.788	113	-54	59	2,170	0.810	131	6.0	2,040	0.761
Jun	25.7	736	0.284	105	37	142	878	0.339	149	17.0	729	0.281
Jul	10.4	299	0.111	210	74	284	582	0.217	167	28.6	416	0.155
Aug	5.8	165	0.062	336	118	454	619	0.231	167	27.0	452	0.169
Sep	6.3	180	0.070	336	118	454	634	0.245	132	20.8	502	0.194
Oct	49.5	1,420	0.529	63	22	85	1,510	0.560	106	7.1	1,410	0.521
Nov	218.	6,230	2.40	109	-54	55	6,290	2.42	0	0.0	6,290	2.42
Dec	390.	11,100	4.16	113	-52	60	11,200	4.18	0	0.0	11,200	4.18
Annual	1,800	51,400	1.63	1,820	0	1,820	53,200	1.69	966	1.8	52,200	1.66

Notes:
1. Banon Creek diversion and storage in Holland Lake is 1,475 acre-feet (1,820 dam³). 625 acre-feet (770 dam³) may be diverted through Holland Lake for immediate use during the November to May period, while 850 acre-feet (1,050 dam³) are stored in Holland lake during November to May for use during the summer.
2. There are 300 acre-feet (370 dam³) of storage of Holland Creek water in Holland Lake and Prevost Lake. The water is stored during the winter and released during the summer.
3. Ladysmith consumed 1,450 dam³ of water from Holland Creek and Stocking lake during 1990, of which about 966 dam³ are estimated to have come from Holland Creek during the April to October period. The monthly distribution of annual consumption is estimated to be approximately: April - 7.9%, May - 9.0%, June - 10.3%, July - 11.5%, August - 11.5%, September - 9.1%, and October - 7.3%.
4. The discharge balance is the estimated discharge to the Strait of Georgia.

Monthly runoff can vary considerably from year to year, as indicated in Figure 8 showing the mean, maximum and minimum monthly discharge for the Koksilah River at Cowichan Bay during the 1960 to 1990 period.

Figure 8
Koksilah River at Cowichan Station
Mean Monthly Discharge, 1960-1990



3.3 Holland Creek Low Flows

As discussed above, the lowest flows on Holland Creek occur generally during the months of July, August and September. However, these "natural" low flows are augmented to a large degree by the release of stored water from Holland Lake and Prevost Lake.

Annual low flows of various return periods were estimated from a regional frequency analysis of annual flows. The 10-year, 25-year and 50-year return period annual low flow estimates, distributed on a monthly basis, are presented in Tables 4, 5 and 6, respectively.

3.4 Stocking Lake Discharge

Stocking Lake is estimated to have a mean annual inflow of 1,300 mm (0.068 m^3/s, 2,140 dam^3), as shown in Table 7, and has a storage capacity of 1070 dam^3. The town of Ladysmith is estimated to withdraw approximately 484 dam^3 of water from Stocking Lake during the November to March period. This withdrawal is met by natural inflows which are high during this season.

The Cowichan Valley Regional District (CVRD) has licenses to store 925 dam^3 and withdraw 769 dam^3 annually to supply the Saltair area. The monthly distribution of this use (Table 7 to 10) is based on data in a November 1984 Engineer's Report.

During a mean runoff year, Ladysmith and Saltair consume in total almost 60 percent of the annual inflow to Stocking Lake. During June - September demand well exceeds inflow but storage is sufficient to cover the difference. However, during low runoff years, consumption can be a much greater percentage of natural inflow (Tables 8-10). During a 25 year return period low runoff year (Table 9) demand exceeds supply by about 30%. If no stored water was in place on October 1 there could be significant deficiencies from June to November. (A water supply study would have to be done to assess this in detail.)

3.5 Peak Flows

The annual peak flows in the Holland Creek and Stocking Lake watersheds occur during the winter months, as a result of rain or rain-on-snow precipitation.

Table 4. Holland Creek runoff, diversion and withdrawal summary, 10 year return period low runoff.

	Holland Creek "Natural" Discharge			Diversion and Storage			Holland Creek Regulated Discharge		Ladysmith Consumption from Holland Creek		Discharge Balance	
	mm	dam^3	m^3/s	Banon	Holland	Total	dam^3	m^3/s	dam^3	Percent	dam^3	m^3/s
				----------	dam^3	----------						
Jan	205.	5,860	2.19	113	-54	59	5,920	2.21	0	0.0	5,920	2.21
Feb	182.	5,160	2.13	102	-49	53	5,210	2.15	0	0.0	5,210	2.15
Mar	158.	4,530	1.69	113	-54	59	4,590	1.71	0	0.0	4,590	1.71
Apr	92.1	2,630	1.02	109	-52	57	2,690	1.04	115	4.3	2,580	0.994
May	46.1	1,320	0.492	113	-54	59	1,380	0.514	131	9.5	1,250	0.465
Jun	16.3	465	0.180	105	37	142	607	0.234	149	24.6	458	0.177
Jul	5.9	168	0.063	210	74	284	451	0.169	167	36.9	285	0.106
Aug	3.2	93	0.035	336	118	454	546	0.204	167	30.5	380	0.142
Sep	3.5	101	0.039	336	118	454	555	0.214	132	23.8	423	0.163
Oct	31.4	899	0.336	63	22	85	985	0.368	106	10.8	879	0.328
Nov	136.	3,890	1.50	109	-54	55	3,950	1.52	0	0.0	3,950	1.52
Dec	243.	6,950	2.60	113	-52	60	7,010	2.62	0	0.0	7,010	2.62
Annual	1,120	32,100	1.02	1,820	0	1,820	33,900	1.08	966	2.9	32,900	1.04

Notes:
1. Banon Creek diversion and storage in Holland Lake is 1,475 acre-feet (1,820 dam^3). 625 acre-feet (770 dam^3) may be diverted through Holland Lake for immediate use during the November to May period, while 850 acre-feet (1,050 dam^3) are stored in Holland lake during November to May for use during the summer.
2. There are 300 acre-feet (370 dam^3) of storage of Holland Creek water in Holland Lake and Prevost Lake. The water is stored during the winter and released during the summer.
3. Ladysmith consumed 1,450 dam^3 of water from Holland Creek and Stocking lake during 1990, of which about 966 dam^3 are estimated to have come from Holland Creek during the April to October period. The monthly distribution of annual consumption is estimated to be approximately: April - 7.9%, May - 9.0%, June - 10.3%, July - 11.5%, August - 11.5%, September - 9.1%, and October - 7.3%.
4. The discharge balance is the estimated discharge to the Strait of Georgia.

Table 5. Holland Creek runoff, diversion and withdrawal summary, 25 year return period low runoff.

	Holland Creek "Natural" Discharge			Diversion and Storage			Holland Creek Regulated Discharge		Ladysmith Consumption from Holland Creek		Discharge Balance	
	mm	dam^3	m^3/s	Banon	Holland	Total	dam^3	m^3/s	dam^3	Percent	dam^3	m^3/s
					dam^3							
Jan	146.	4,190	1.56	113	-54	59	4,250	1.58	0	0.0	4,250	1.58
Feb	130.	3,690	1.52	102	-49	53	3,740	1.55	0	0.0	3,740	1.55
Mar	113.	3,240	1.21	113	-54	59	3,300	1.23	0	0.0	3,300	1.23
Apr	65.8	1,880	0.726	109	-52	57	1,940	0.748	115	5.9	1,830	0.704
May	32.9	941	0.351	113	-54	59	1,000	0.373	131	13.1	869	0.325
Jun	11.5	328	0.127	105	37	142	470	0.181	149	31.8	321	0.124
Jul	3.8	109	0.041	210	74	284	393	0.147	167	42.4	226	0.084
Aug	2.1	60	0.022	336	118	454	514	0.192	167	32.4	347	0.130
Sep	2.3	66	0.025	336	118	454	520	0.201	132	25.4	388	0.150
Oct	22.9	654	0.244	63	22	85	739	0.276	106	14.3	633	0.236
Nov	97.1	2,780	1.07	109	-54	55	2,840	1.09	0	0.0	2,840	1.09
Dec	174.	4,970	1.86	113	-52	60	5,030	1.88	0	0.0	5,030	1.88
Annual	803	22,900	0.728	1,820	0	1,820	24,700	0.785	966	3.9	23,700	0.753

Notes:
1. Banon Creek diversion and storage in Holland Lake is 1,475 acre-feet (1,820 dam^3). 625 acre-feet (770 dam^3) may be diverted through Holland Lake for immediate use during the November to May period, while 850 acre-feet (1,050 dam^3) are stored in Holland lake during November to May for use during the summer.
2. There are 300 acre-feet (370 dam^3) of storage of Holland Creek water in Holland Lake and Prevost Lake. The water is stored during the winter and released during the summer.
3. Ladysmith consumed 1,450 dam^3 of water from Holland Creek and Stocking lake during 1990, of which about 966 dam^3 are estimated to have come from Holland Creek during the April to October period. The monthly distribution of annual consumption is estimated to be approximately: April - 7.9%, May - 9.0%, June - 10.3%, July - 11.5%, August - 11.5%, September - 9.1%, and October - 7.3%.
4. The discharge balance is the estimated discharge to the Strait of Georgia.

Table 6. Holland Creek runoff, diversion and withdrawal summary, 50 year return period low runoff.

	Holland Creek "Natural" Discharge			Diversion and Storage			Holland Creek Regulated Discharge		Ladysmith Consumption from Holland Creek		Discharge Balance	
	mm	dam³	m³/s	Banon	Holland	Total	dam³	m³/s	dam³	Percent	dam³	m³/s
				---- dam³ ----								
Jan	102.	2,920	1.09	113	-54	59	2,980	1.11	0	0.0	2,980	1.11
Feb	90.7	2,570	1.06	102	-49	53	2,620	1.09	0	0.0	2,620	1.09
Mar	78.9	2,260	0.843	113	-54	59	2,320	0.865	0	0.0	2,320	0.865
Apr	45.9	1,310	0.506	109	-52	57	1,370	0.528	115	8.4	1,260	0.484
May	23.0	656	0.245	113	-54	59	715	0.267	131	18.3	585	0.218
Jun	8.0	230	0.089	105	37	142	371	0.143	149	40.2	222	0.086
Jul	2.4	68	0.025	210	74	284	351	0.131	167	47.4	185	0.069
Aug	1.3	37	0.014	336	118	454	491	0.183	167	33.9	325	0.121
Sep	1.4	41	0.016	336	118	454	495	0.191	132	26.7	363	0.140
Oct	15.9	456	0.170	63	22	85	541	0.202	106	19.6	435	0.163
Nov	67.7	1,940	0.747	109	-54	55	2,000	0.769	0	0.0	2,000	0.769
Dec	121.	3,470	1.29	113	-52	60	3,530	1.32	0	0.0	3,530	1.32
Annual	560	16,000	0.507	1,820	0	1,820	17,800	0.565	966	5.4	16,800	0.533

Notes:
1. Banon Creek diversion and storage in Holland Lake is 1,475 acre-feet (1,820 dam³). 625 acre-feet (770 dam³) may be diverted through Holland Lake for immediate use during the November to May period, while 850 acre-feet (1,050 dam³) are stored in Holland lake during November to May for use during the summer.
2. There are 300 acre-feet (370 dam³) of storage of Holland Creek water in Holland Lake and Prevost Lake. The water is stored during the winter and released during the summer.
3. Ladysmith consumed 1,450 dam³ of water from Holland Creek and Stocking lake during 1990, of which about 966 dam³ are estimated to have come from Holland Creek during the April to October period. The monthly distribution of annual consumption is estimated to be approximately: April - 7.9%, May - 9.0%, June - 10.3%, July - 11.5%, August - 11.5%, September - 9.1%, and October - 7.3%.
4. The discharge balance is the estimated discharge to the Strait of Georgia.

Table 7. Stocking Lake runoff and withdrawal summary, mean year runoff.

	Stocking Lake "Natural" Discharge			Consumption from Stocking Lake		
				Ladysmith	Saltair	Total
	mm	dam³	m³/s	dam³	dam³	dam³
Jan	237	391	0.146	100	41	141
Feb	211	344	0.142	90	48	138
Mar	183	302	0.113	103	52	155
Apr	107	176	0.068	0	52	52
May	53.3	88	0.033	0	89	89
Jun	18.6	31	0.012	0	88	88
Jul	7.5	12	0.005	0	120	120
Aug	4.2	7	0.003	0	90	90
Sep	4.6	8	0.003	0	69	69
Oct	35.8	59	0.022	0	41	41
Nov	157	260	0.100	93	40	133
Dec	281	464	0.173	99	40	139
Annual	1,300	2,140	0.068	484	770	1255

Table 8. Stocking Lake runoff and withdrawal summary, 10 year return period low runoff.

	Stocking Lake "Natural" Discharge			Consumption from Stocking Lake		
				Ladysmith	Saltair	Total
	mm	dam³	m³/s	dam³	dam³	dam³
Jan	148	244	0.091	100	41	141
Feb	131	215	0.089	90	41	138
Mar	114	189	0.070	103	52	155
Apr	66.5	110	0.042	0	52	52
May	33.3	55	0.020	0	89	89
Jun	11.6	19	0.007	0	88	88
Jul	4.7	8	0.003	0	120	120
Aug	2.6	4	0.002	0	90	90
Sep	2.8	5	0.002	0	69	69
Oct	22.3	37	0.014	0	41	41
Nov	98.2	162	0.062	93	40	133
Dec	176	290	0.108	99	40	139
Annual	811	1,340	0.042	485	770	1255

Table 9. Stocking Lake runoff and withdrawal summary, 25 year return period low runoff.

	Stocking Lake "Natural" Discharge			Consumption from Stocking Lake		
	mm	dam^3	m^3/s	Ladysmith dam^3	Saltair dam^3	Total dam3
Jan	106.	174	0.065	100	41	141
Feb	93.9	154	0.063	90	48	138
Mar	81.8	135	0.050	103	52	155
Apr	47.5	78	0.030	0	52	52
May	23.8	39	0.015	0	89	89
Jun	8.3	14	0.005	0	88	88
Jul	3.4	6	0.002	0	120	120
Aug	1.9	3	0.001	0	90	90
Sep	2.0	3	0.001	0	69	69
Oct	15.9	26	0.010	0	41	41
Nov	70.2	116	0.045	93	40	133
Dec	126.	207	0.077	99	40	139
Annual	580	956	0.030	485	770	1255

Table 10. Stocking Lake runoff and withdrawal summary, 50 year return period low runoff.

	Stocking Lake "Natural" Discharge			Consumption from Stocking Lake		
	mm	dam^3	m^3/s	Ladysmith dam^3	Saltair dam^3	Total dam3
Jan	73.7	122	0.045	100	41	141
Feb	65.5	107	0.044	90	48	138
Mar	57.0	94	0.035	103	52	155
Apr	33.2	55	0.021	0	52	52
May	16.6	27	0.010	0	89	89
Jun	5.8	10	0.004	0	88	88
Jul	2.3	4	0.001	0	120	120
Aug	1.3	2	0.001	0	90	90
Sep	1.4	2	0.001	0	69	69
Oct	11.1	18	0.007	0	41	41
Nov	48.9	81	0.031	93	40	133
Dec	87.5	144	0.054	99	40	139
Annual	404	667	0.021	485	770	1255

Data from regional stations indicate that greater than 80 percent of the annual peak flows occur during December and January.

Return period peak flows were estimated by completing a peak flow frequency analysis for streams in the region, and by using the Rational Formula in conjunction with the precipitation intensity-duration-frequency information in Section 2.4. In the absence of data for other methods, the Rational Formula has been widely used to estimate peak runoff rates for the design of drainage systems in small drainage basins. Using a Rational Formula approach developed by the Hydrology Section of the Water Management Division for British Columbia conditions, mean, 25-year, 50-year and 100-year return period peak flows were estimated for drainage areas of up to 10 km^2. The factors used are listed in Table 11 with the resulting flow estimates. Rainfall amounts are for durations equal to the estimated time of concentration of the drainage area.

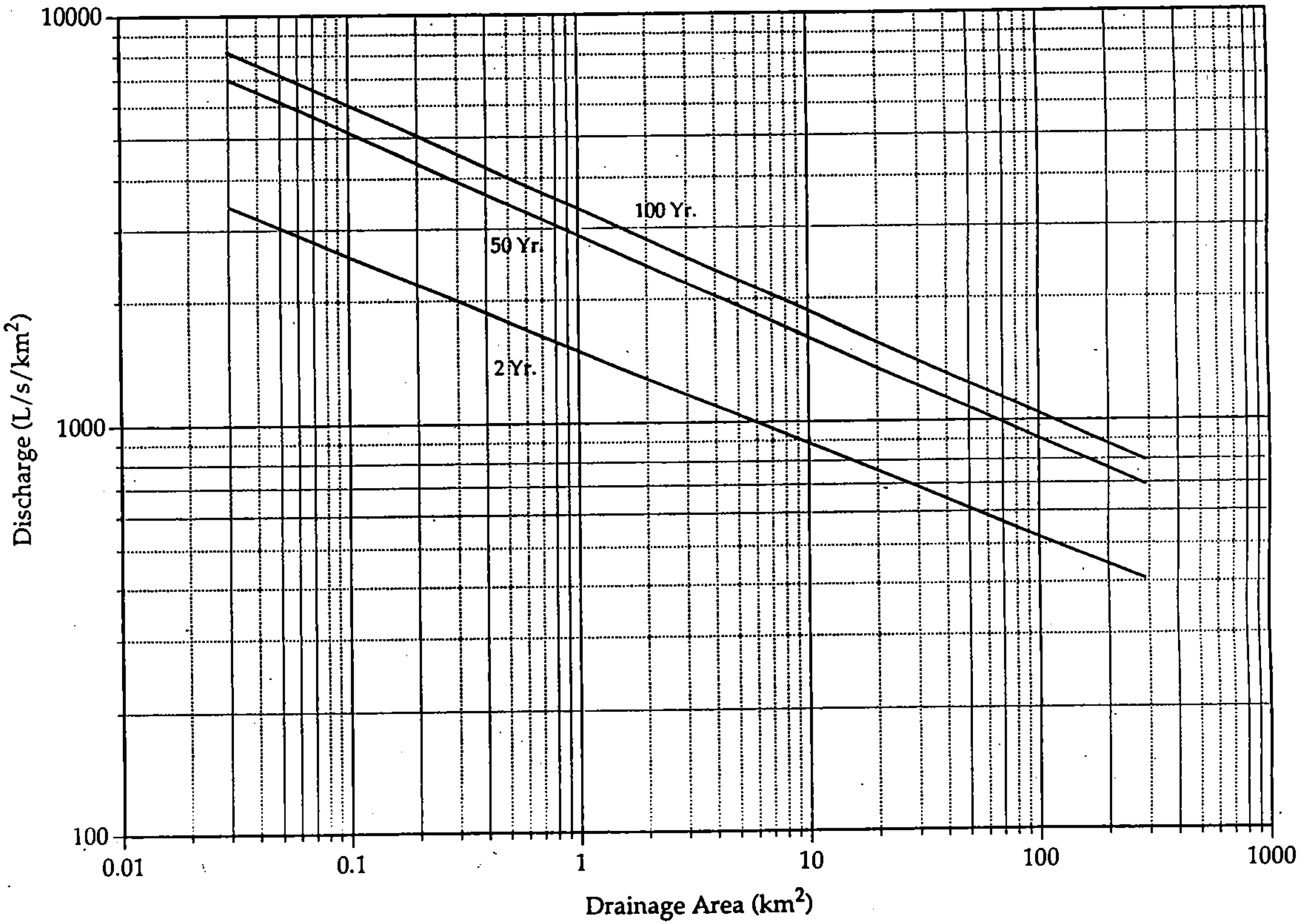
Table 11. Rational formula peak flow estimates

Area	t_c	Precipitation (mm)				Discharge (m^3/s)			
(km^2)	(Hrs)	2 Yr	25 Yr	50 Yr	100 Yr	2 Yr	25 Yr	50 Yr	100 Yr
7.0	6.0	29.9	45.4	49.2	53.0	7.35	11.9	12.9	13.9
0.72	2.0	15.0	22.4	24.2	26.0	1.13	1.81	1.95	2.10
0.14	1.0	10.3	18.0	19.9	21.8	0.303	0.564	0.624	0.684
0.04	0.5	7.7	15.2	17.1	19.0	0.129	0.272	0.306	0.340

Note: A value of 0.75 was used for the coefficient "C" for the 2 year return period estimates, and a value of 0.80 was used for the remaining estimates. The variable t_c is the time of concentration of the drainage area. For information on the Rational Formula method used by the Hydrology Section, refer to *Manual of Operational Hydrology in British Columbia*, Ministry of Environment, Lands and Parks, Water Management Division, Victoria.

Return period peak flow estimates derived from regionalization and the

Figure 9
Return Period Instantaneous Peak Flow Estimates
for the Holland Creek and Stocking Lake Watersheds



Rational Formula are presented graphically in Figure 9.

3.6 Culvert Sizing

Adequately designed and sized culverts are an important aspect of drainage control in watersheds. This section provides guidelines for the proper sizing of culverts for the Holland Creek and Stocking lake watersheds.

The flow capacity of various culvert sizes is obtained from the *Handbook of Steel Drainage and Highway Construction Products*, American and Iron and Steel Institute, 1971. For this study it is assumed that circular corrugated steel or rectangular box culverts are used, and there is no outlet control. The culvert size must be sufficient to carry the 50 year return period instantaneous discharge.

Figure 10 relates the required culvert size directly to drainage area, for 50 year return period instantaneous flows with zero head at the inlet. Indicated also on the figure is the size of culverts required if two equal-sized culverts are considered more desireable than a single larger culvert. For very small drainage areas, a minimum culvert diameter of 500 mm is recomended. As an example, for a drainage area of 1.5 km^2, either a single 1,600 mm culvert or two 1,200 mm culverts are required to transmit the 50 year return period instantaneous discharge.

If rectangular box culverts are more practical to install than steel culverts, Figure 11 indicates the required culvert cross-sectional area (m^2).

Figure 10
Corrugated steel culvert size based on drainage area
for Holland Creek/Stocking Lake sub-basins
50 year return period instantaneous peak flow

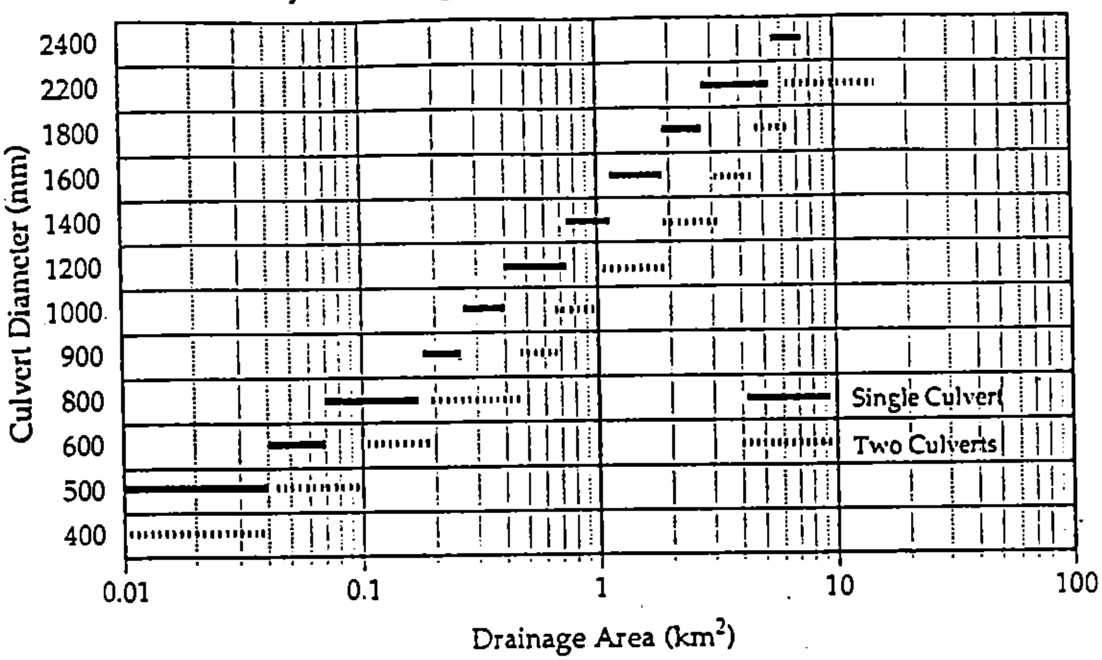
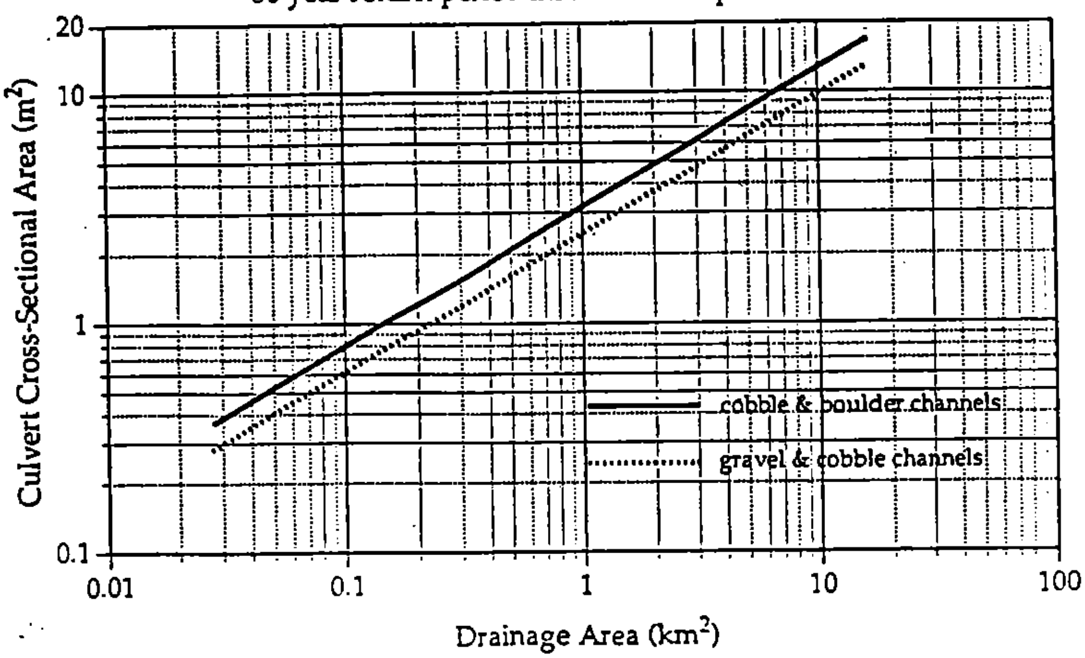


Figure 11
Rectangular box culvert cross-sectional area based on drainage area
for Holland Creek/Stocking Lake sub-basins
50 year return period instantaneous peak flow



4.0 SUMMARY

The information presented in this report summarizes precipitation and streamflow data available for the Holland Creek/Stocking Lake areas. This information can be used to estimate the hydrologic characteristics of sub-basins within the watersheds, and can be used as input to water supply assessment, resource use impact assessment, and for the development of guidelines and prescriptions for various resource use proposals for the watersheds.

The importance of these watersheds as a source of drinking water is apparent in the description of the water supply system and its fairly complex operation.

The report also contains detailed information on the magnitudes of peak flows that can be expected for various return periods from sub-basins within the watersheds which is important for the proper design of drainage structures.

5.0 RECOMMENDATIONS

It is very important that the peak flow estimates and culvert design guidelines provided in this report be used for the design of bridges and culverts along roads within the watersheds to ensure that the integrity of the drainage system is maintained. Also, existing drainage structures should be reviewed to determine their adequacy.

As there are no water quality data for the watersheds, the Water Quality Branch should be requested to assess the need for water quality monitoring.

Lastly, timber harvesting proposals should consider the cumulative watershed effects resulting from past activities.

APPENDIX C

WATER QUALITY ANALYSES

This data was collected for the Integrated Watershed Management Plan, under the direction of L.W.Pommen, Ministry of Environment, Lands and Parks.

TABLE 1
HOLLAND CREEK WATER QUALITY
1992 - 1993

STATION	HOLLAND LAKE OUTFLOW E217163				HOLLAND CREEK, NORTH FORK E217162				HOLLAND CREEK AT CHICKEN LADDER DAM E216974				
DATE	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	Total Coliforms #/100 mL
4-May-92									6.7	12	0.4	25	690
19-May-92												260	770
1-Jun-92												<1	1250
8-Jun-92	6.7	15	0.5	<2	7.0	<5	0.1	<2	7.3	5	0.2	4	56
8-Jun-92	6.7	10	0.4	<2					7.2	5	0.2	6	
8-Jun-92	6.6	10	0.4	<2					7.4	5	0.2		
15-Jun-92												145	760
22-Jun-92	6.7	10	0.7		7.1	5	0.3		7.2	5	0.3	56	410
29-Jun-92												1400	1600
6-Jul-92	7.9	5	0.6	1	7.6	30	0.7	84	7.4	10	0.5	220	520
13-Jul-92												21	55
20-Jul-92												128	2750
27-Jul-92	7.1	5	0.6	<2	7.3	5	0.2	2	7.3	5	0.3	23	892
10-Aug-92	7.2	10	0.5	<2	7.3	5	0.3	4				51	102
17-Aug-92													
24-Aug-92	7.8	10	0.8	<2	7.4	5	0.4	1	7.3	5	0.4	26	41
8-Sep-92	7.6	10	0.4	1	7.4	5	0.3	6	7.0	5	0.3		
21-Sep-92	7.3	10	0.3	<2	7.7	<5	1.4	<2	7.6	5	0.2		
13-Oct-92	7.7	10	0.9	<2	7.3	5	0.6	<2	7.7	5	0.8		
26-Oct-92												9	99
4-Nov-92	6.5	15	1.4	5	6.5	20	0.6	3					
9-Nov-92												2	480
23-Nov-92	7.2	10	0.8	2	6.9	20	0.5	<2	6.6	15	0.6	5	260
30-Nov-92												11	118
7-Dec-92												2	150
9-Dec-92	7.5	30	1.6	2	7.4	20	2.0	1	7.4	20	0.6		
14-Dec-92	7.0	40	0.8		7.6	20	0.6		7.2	30	0.3		
15-Dec-92												4	165
16-Dec-92	7.4	30	0.8	<2	7.2	30	0.3	<2	7.8	10	0.2		
1-Feb-93												<1	100
8-Feb-93												4	132
17-Feb-93									6.6	<5	0.1		
17-Feb-93									6.7	<5	0.1		
26-Feb-93									7	<5	0.2		
1-Mar-93									6.8	<5	0.2		
8-Mar-93									7.9	8	0.4	3	139
15-Mar-93									7.7	5	0.3		
22-Mar-93									6.7	10	0.5		
29-Mar-93									6.5	5	0.2		

* Values in BOLD exceed drinking water quality guidelines.

HOLLAND CREEK WATER QUALITY 1993-94

STATION	HOLLAND LAKE OUTFLOW				HOLLAND CREEK, NORTH FORK				HOLLAND CREEK AT CHICKEN LADDER DAM/RESERVOIR				
DATE	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	pH	True Colour TCU	Turbidity NTU	Fecal Coliforms #/100 mL	Total Coliforms #/100 mL
5-Apr-93	6.8	10	0.5	<2	6.6	15	0.4	1	6.8	10	0.2		
20-Apr-93	7.9	10	0.4	<2	7.5	10	0.3	<2	7.2	<5	0.2		
1-Jun-93	7.2	15	0.3	2	7.2	40	0.3	6	7.2	15	0.2	12	
7-Jun-93									7.7	10	0.3	11#	
22-Jun-93									7.3	10	0.2		
22-Jun-93									7.3	5	0.1		
22-Jun-93									7.3	10	0.1		
23-Jun-93	7.1	10	0.4	<1#	7.0	10	0.1	<1#				10#	
23-Jun-93	7	15	0.3	<1#	7.0	10	0.2	3#				5#	
3-Aug-93												<2	680
13-Aug-93	8.1	5	0.3	<1#	8.1	5	0.1	2#	7.9	5	0.1	7#	
24-Aug-93												2	640
7-Sep-93									7.1	5	<0.1	5, <1#	110
13-Sep-93									7.6	5	0.1	1#	
30-Sep-93	6.9	5	0.5	1#	7.1	<5	0.1	<1#					
14-Oct-93									7.2	5	<0.1	1#	
20-Oct-93									7.1	5	<0.1	4#	
25-Oct-93									7.1	10	0.1	4#	
1-Nov-93										5	0.2	4#	

*Values in BOLD exceed drinking water quality guidelines

#*E. Coli*

APPENDIX D

SELECTED COMPUTER RUNS

PEAK HOUR DEMAND

FOR 6,000 POPULATION

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand 224.70 l/s
Demand South 11.18 l/s
Population 6,000

PIPE TABLE								
INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
1	1	2	20	450	100	206.84	1.30	0.11
2	2	3	1	300	100	206.84	2.93	0.04
3	3	4	5	450	100	206.84	1.30	0.03
4	4	5	3	350	100	86.22	0.90	0.01
5	5	6	1,290	300	110	86.22	1.22	8.72
6	6	7	170	200	110	22.13	0.70	0.67
7	7	8	63	200	110	35.45	1.13	0.59
8	8	9	101	200	110	35.45	1.13	0.95
9	9	10	39	200	110	8.55	0.27	0.03
10	10	11	66	200	110	8.55	0.27	0.04
11	11	12	105	200	110	3.41	0.11	0.01
12	12	13	43	200	110	-1.09	-0.03	0.00
13	13	14	61	200	110	-1.09	-0.03	0.00
14	14	15	122	200	110	-5.48	-0.17	0.04
15	15	16	88	200	110	-7.26	-0.23	0.04
16	16	17	72	200	110	-27.13	-0.86	0.41
17	17	18	82	200	110	-2.25	-0.07	0.00
18	18	19	213	200	110	-2.65	-0.08	0.02
19	19	20	136	200	110	11.85	0.38	0.17
20	20	21	62	200	110	20.63	0.66	0.21
21	21	151	324	200	110	17.81	0.57	0.85
22	151	152	130	200	120	11.80	0.38	0.14
23	6	22	137	200	110	32.61	1.04	1.10
24	22	23	240	200	110	26.64	0.85	1.33
25	23	24	75	200	110	25.84	0.82	0.39
26	24	27	110	200	110	19.88	0.63	0.35
27	27	28	99	200	110	19.88	0.63	0.32
28	28	29	100	200	110	17.11	0.54	0.24
29	29	30	65	200	110	16.71	0.53	0.15
30	30	31	137	200	110	11.53	0.37	0.16
31	31	32	165	150	110	9.13	0.52	0.51
32	32	33	460	150	110	6.74	0.38	0.81
33	33	34	79	100	110	5.14	0.65	0.61
34	34	35	17	100	110	6.28	0.80	0.19
35	35	304	120	100	110	6.28	0.80	1.34
36	6	39	427	200	100	31.48	1.00	3.84
37	39	40	134	200	110	22.78	0.73	0.56
38	40	41	15	200	110	20.18	0.64	0.05
39	41	42	134	200	110	16.84	0.54	0.32
40	42	43	135	200	110	13.57	0.43	0.21
41	43	44	7	200	120	13.57	0.43	0.01
42	152	180	136	100	110	7.86	1.00	2.29
43	41	46	103	200	110	6.39	0.20	0.04
44	46	47	88	200	110	7.09	0.23	0.04
45	47	48	122	200	110	5.89	0.19	0.04
46	48	49	104	200	110	6.67	0.21	0.04
47	49	50	104	200	110	7.71	0.25	0.06
48	50	51	104	150	100	5.29	0.30	0.14
49	51	52	194	150	100	2.92	0.17	0.09
50	52	53	14	200	110	12.58	0.40	0.02
51	53	54	134	200	110	10.28	0.33	0.13
52	54	55	203	200	110	19.04	0.61	0.60
53	55	56	114	200	110	19.04	0.61	0.34
54	56	57	2	200	110	19.04	0.61	0.01
55	57	58	30	200	110	19.04	0.61	0.09
56	56	190	22	200	110	0.00	0.00	0.00
57	190	191	2	100	100	0.00	0.00	0.00
58	191	192	30	200	110	0.00	0.00	0.00
59	57	189	318	200	120	0.00	0.00	0.00
60	55	188	18	100	110	0.00	0.00	0.00
61	42	59	104	200	110	6.67	0.21	0.04
62	46	59	136	100	100	2.47	0.31	0.32
63	59	60	104	200	110	6.57	0.21	0.04
64	60	61	104	200	110	4.40	0.14	0.02
65	61	62	104	200	110	5.01	0.16	0.03
66	62	63	104	200	110	3.62	0.12	0.01
67	63	64	104	200	110	6.10	0.19	0.04
68	64	65	104	200	110	7.51	0.24	0.06
69	65	66	89	200	110	5.86	0.19	0.03
70	66	54	15	200	110	8.76	0.28	0.01
71	52	66	135	150	110	4.98	0.28	0.14
72	65	186	94	100	110	0.00	0.00	0.00
73	51	64	135	100	100	1.57	0.20	0.14
74	50	63	135	150	100	6.15	0.35	0.24
75	49	62	135	100	110	2.55	0.32	0.28
76	48	61	135	100	110	2.64	0.34	0.30
77	47	202	110	100	110	0.80	0.10	0.03

NODE TABLE				
INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
1	140.00	0.00	0	140.0
2	136.00	0.00	38	139.9
3	136.00	0.00	38	139.8
4	136.00	0.00	37	139.8
5	136.00	0.00	37	139.8
6	87.95	0.00	422	131.1
7	93.00	0.00	366	130.4
8	93.00	0.00	361	129.8
9	95.07	0.80	331	128.9
10	93.00	0.00	351	128.8
11	92.00	1.30	360	128.8
12	91.97	0.80	361	128.8
13	90.00	0.00	380	128.8
14	88.00	0.80	399	128.8
15	86.00	0.80	419	128.8
16	85.09	0.80	429	128.9
17	90.00	0.80	385	129.3
18	88.00	0.00	404	129.3
19	86.00	0.00	424	129.3
20	80.00	0.80	481	129.1
21	74.00	1.60	538	128.9
22	82.00	0.80	470	130.0
23	74.00	0.80	535	128.7
24	71.57	0.40	555	128.3
25	68.00	1.20	583	127.5
26	70.00	0.00	567	127.9
27	70.93	0.00	558	127.9
28	65.71	0.00	606	127.6
29	59.00	0.40	669	127.3
30	55.61	1.60	701	127.2
31	54.00	1.20	715	127.0
32	44.21	1.60	806	126.5
33	37.00	1.60	869	125.7
34	36.00	0.80	873	125.1
35	35.00	0.00	880	124.9
37	73.00	0.00	530	127.1
38	75.00	0.00	510	127.1
39	73.00	0.00	531	127.2
40	66.00	0.00	594	126.7
41	66.00	0.80	594	126.6
42	47.00	0.80	777	126.3
43	32.00	0.00	922	126.1
44	31.00	1.80	931	126.1
45	16.50	0.00	1,064	125.2
46	65.47	0.80	599	126.6
47	62.00	0.00	632	126.6
48	58.95	0.80	662	126.5
49	55.00	0.80	700	126.5
50	51.00	0.80	738	126.4
51	54.09	0.80	707	126.3
52	46.40	0.80	781	126.2
53	46.40	0.00	781	126.2
54	35.00	0.00	892	126.0
55	25.00	0.00	984	125.4
56	12.50	0.00	1,103	125.1
57	12.00	0.00	1,107	125.1
58	5.00	19.04	1,175	125.0
59	46.00	0.95	786	126.3
60	47.00	0.80	776	126.2
61	46.00	0.98	785	126.2
62	34.00	1.55	903	126.2
63	34.00	1.76	903	126.2
64	34.00	0.94	902	126.1
65	34.00	0.85	902	126.1
66	34.00	0.89	901	126.1
67	33.00	0.00	911	126.0
68	31.00	0.80	931	126.0
69	99.00	0.00	327	132.4
70	101.00	0.80	309	132.6
71	103.00	0.80	291	132.8
72	103.00	0.80	304	134.1
73	98.00	0.40	349	133.6
74	97.00	0.80	355	133.3
75	96.00	0.00	361	132.9
76	94.00	0.40	377	132.5
77	90.00	1.76	410	131.9
78	87.00	0.40	436	131.5

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand 224.70 l/s
Demand South 11.18 l/s
Population 6,000

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
78	47	203	47	100	110	0.40	0.05	0.00
79	46	161	135	100	110	-3.97	-0.51	0.64
80	48	164	135	100	110	-4.21	-0.54	0.72
81	49	37	113	100	110	-4.39	-0.56	0.65
82	50	38	113	100	110	-4.53	-0.58	0.69
83	172	171	6	150	110	0.00	0.00	0.00
84	165	172	105	150	110	1.50	0.08	0.01
85	164	165	105	150	110	0.24	0.01	0.00
86	162	164	105	150	110	1.68	0.09	0.01
87	161	162	105	150	110	-1.11	-0.06	0.01
88	158	161	105	150	110	0.30	0.02	0.00
89	39	158	15	150	110	1.70	0.10	0.00
90	158	41	134	100	110	3.85	0.49	0.60
91	158	159	111	100	110	-3.24	-0.41	0.36
92	161	160	111	100	110	-3.36	-0.43	0.39
93	162	163	111	100	110	-3.59	-0.46	0.44
94	127	164	134	100	110	3.98	0.51	0.64
95	165	166	11	100	110	-6.44	-0.82	0.13
96	166	167	98	150	110	-6.44	-0.36	0.16
97	128	167	25	100	100	6.44	0.82	0.35
98	168	170	15	150	100	0.00	0.00	0.00
99	168	169	34	100	100	0.00	0.00	0.00
100	129	168	73	150	100	0.80	0.05	0.00
101	116	117	104	100	110	0.80	0.10	0.03
102	116	124	135	100	120	1.23	0.16	0.06
103	115	116	104	150	110	2.99	0.17	0.04
104	112	115	104	150	110	5.83	0.33	0.14
105	111	112	104	150	110	9.22	0.52	0.33
106	111	132	104	150	110	-2.48	-0.14	0.03
107	132	133	104	150	110	-2.23	-0.13	0.02
108	133	134	104	150	110	-2.47	-0.14	0.03
109	134	135	104	150	110	-2.94	-0.17	0.04
110	115	114	111	100	110	0.80	0.10	0.03
111	115	125	135	100	110	1.24	0.16	0.07
112	112	113	111	100	110	0.80	0.10	0.03
113	112	126	135	100	110	1.80	0.23	0.15
114	9	111	119	200	110	26.10	0.83	0.63
115	111	127	135	200	110	18.15	0.58	0.37
116	11	132	119	100	110	3.84	0.49	0.53
117	132	128	135	100	100	2.80	0.36	0.40
118	12	133	119	100	110	3.70	0.47	0.50
119	133	129	135	100	110	3.15	0.40	0.42
120	14	134	119	100	110	3.59	0.46	0.47
121	134	130	135	100	110	3.26	0.41	0.45
122	15	233	22	100	110	0.98	0.13	0.01
123	135	131	135	100	110	3.39	0.43	0.48
124	124	125	103	200	110	-5.35	-0.17	0.03
125	125	126	104	200	110	-8.27	-0.26	0.07
126	126	127	104	200	110	-10.86	-0.35	0.11
127	127	128	104	200	110	2.12	0.07	0.01
128	128	129	104	200	110	-2.32	-0.07	0.01
129	129	130	104	200	110	-0.77	-0.02	0.00
130	130	131	104	200	110	-2.09	-0.07	0.01
131	131	147	89	200	110	-3.32	-0.11	0.01
132	147	137	11	150	110	-13.45	-0.76	0.07
133	137	829	113	150	110	-11.32	-0.64	0.52
134	135	136	89	150	110	-6.15	-0.35	0.13
135	135	233	113	63	100	-0.98	-0.32	0.46
136	136	826	95	200	110	-18.67	-0.59	0.27
137	137	138	663	100	110	-2.13	-0.27	1.00
138	138	813	42	150	110	-4.90	-0.28	0.04
139	139	140	235	25	50	0.00	0.00	0.00
140	4	809	889	350	110	120.62	1.25	5.28
141	72	73	93	300	120	81.14	1.15	0.48
142	73	74	85	300	120	72.83	1.03	0.36
143	74	75	117	300	120	61.71	0.87	0.36
144	75	76	95	300	120	68.03	0.96	0.35
145	76	77	146	300	120	76.75	1.09	0.68
146	77	78	62	250	120	55.73	1.14	0.39
147	78	79	27	250	120	55.33	1.13	0.17
148	79	80	13	250	120	38.83	0.79	0.04
149	79	81	131	150	120	16.50	0.93	1.03
150	81	19	158	150	120	14.50	0.82	0.98
151	81	82	143	150	110	0.80	0.05	0.00
152	18	96	116	150	110	0.40	0.02	0.00
153	17	93	44	150	110	-25.68	-1.45	0.92
154	92	818	111	150	110	1.71	0.10	0.02

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
79	86.00	0.00	444	131.3
80	86.00	0.00	443	131.3
81	92.77	1.20	367	130.3
82	87.00	0.80	424	130.3
83	101.00	0.00	309	132.6
84	103.00	5.59	304	134.1
85	98.50	0.80	341	133.3
86	97.00	0.40	354	133.1
87	97.00	0.80	353	133.0
88	94.00	0.80	378	132.7
89	90.00	0.00	409	131.8
90	87.00	0.00	436	131.5
91	102.70	0.00	286	131.9
92	103.00	0.80	277	131.3
93	95.00	0.80	345	130.2
94	94.00	0.80	357	130.5
95	94.00	0.40	357	130.5
96	101.00	0.40	277	129.3
97	85.00	2.40	435	129.4
98	85.00	0.00	433	129.2
99	57.00	0.00	703	128.8
100	57.00	0.00	703	128.7
101	75.00	3.99	524	128.5
102	71.00	1.60	562	128.4
103	67.00	1.60	601	128.4
104	65.00	2.00	621	128.4
105	73.00	1.60	542	128.4
106	75.00	0.00	523	128.4
107	67.00	0.00	601	128.4
108	67.00	0.00	601	128.4
109	100.00	0.00	312	131.9
110	100.00	1.78	312	131.9
111	92.00	1.20	355	128.2
112	91.00	0.80	361	127.9
113	93.00	0.80	342	127.9
114	92.00	0.80	350	127.7
115	90.00	0.80	370	127.8
116	87.00	0.80	399	127.7
117	87.00	0.80	399	127.7
118	83.00	0.80	438	127.7
119	82.00	0.00	457	128.6
120	82.00	0.80	447	127.7
121	79.00	0.80	477	127.7
122	74.00	0.80	525	127.7
123	78.00	0.80	486	127.7
124	82.76	0.80	440	127.7
125	83.00	0.80	438	127.7
126	86.00	0.80	409	127.8
127	89.69	1.20	374	127.9
128	90.00	0.80	371	127.9
129	91.08	0.80	360	127.9
130	87.00	0.80	400	127.9
131	85.00	0.80	420	127.9
132	92.00	0.80	355	128.3
133	90.00	0.80	375	128.3
134	89.00	0.80	385	128.3
135	86.00	0.80	415	128.4
136	84.00	0.80	436	128.5
137	84.00	0.00	430	128.0
138	68.00	0.80	597	129.0
139	65.00	0.00	627	129.0
140	63.00	0.00	646	129.0
141	74.00	0.00	538	128.9
142	78.00	0.80	498	128.9
143	82.00	0.80	459	128.8
144	82.00	0.80	459	128.8
145	80.00	0.80	478	128.9
146	82.00	0.00	459	128.8
147	84.77	0.80	422	127.9
148	84.77	0.00	422	127.9
149	80.00	0.00	469	127.9
150	78.00	2.04	489	127.9
151	74.41	0.00	525	128.1
152	67.08	1.60	596	127.9
153	74.00	0.00	529	128.1
154	73.00	1.60	539	128.1
155	74.00	0.00	529	128.1

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand 224.70 l/s
Demand South 11.18 l/s
Population 6,000

PIPE TABLE								
INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
155	94	95	49	100	110	0.40	0.05	0.00
156	93	94	104	150	110	-8.69	-0.49	0.29
157	94	92	210	150	110	-9.89	-0.56	0.75
158	92	91	124	150	110	-12.40	-0.70	0.68
159	91	109	155	150	120	1.78	0.10	0.02
160	109	110	63	150	120	1.78	0.10	0.01
161	71	91	140	150	120	14.18	0.80	0.83
162	71	70	96	200	120	16.91	0.54	0.19
163	70	69	104	200	120	15.31	0.49	0.18
164	69	825	171	150	120	15.31	0.87	1.17
165	70	83	23	150	120	0.80	0.05	0.00
166	72	84	30	200	120	6.79	0.22	0.01
167	73	85	145	150	120	7.91	0.45	0.29
168	74	86	47	150	120	10.32	0.58	0.16
169	75	87	93	150	120	-6.32	-0.36	0.12
170	76	88	40	150	120	-9.12	-0.52	0.11
171	77	89	25	200	120	19.27	0.61	0.06
172	78	90	29	150	120	0.00	0.00	0.00
173	141	138	197	150	110	-1.97	-0.11	0.04
174	141	142	142	150	110	3.19	0.18	0.06
175	142	143	125	150	110	1.60	0.09	0.02
176	143	144	138	150	120	0.80	0.05	0.00
177	143	146	10	150	120	0.00	0.00	0.00
178	142	145	68	150	120	0.80	0.05	0.00
179	20	98	104	200	110	-9.58	-0.30	0.09
180	98	97	21	200	110	-31.25	-0.99	0.16
181	810	99	158	200	120	14.77	0.47	0.25
182	99	100	24	200	100	14.77	0.47	0.05
183	100	101	170	200	120	14.77	0.47	0.27
184	101	102	103	200	120	8.38	0.27	0.06
185	102	103	151	200	120	4.85	0.15	0.03
186	103	104	88	200	120	3.59	0.11	0.01
187	102	105	190	150	120	1.94	0.11	0.03
188	105	106	49	150	120	0.00	0.00	0.00
189	105	107	259	150	120	0.34	0.02	0.00
190	103	107	64	150	120	-0.34	-0.02	0.00
191	107	108	29	150	120	0.00	0.00	0.00
192	147	148	13	150	110	9.33	0.53	0.04
193	148	149	175	150	110	-2.38	-0.13	0.04
194	149	150	30	150	110	2.04	0.12	0.01
195	149	151	222	150	110	-4.42	-0.25	0.18
196	151	153	46	150	110	1.60	0.09	0.01
197	153	154	85	150	110	1.60	0.09	0.01
198	154	155	17	150	110	0.00	0.00	0.00
199	154	156	86	150	110	0.00	0.00	0.00
200	153	157	135	25	50	0.00	0.00	0.00
201	130	173	135	100	110	3.79	0.48	0.59
202	175	176	113	100	110	-3.82	-0.49	0.50
203	178	177	113	150	110	-11.71	-0.66	0.55
204	172	173	104	150	110	-3.83	-0.22	0.06
205	173	175	104	150	110	-0.84	-0.05	0.00
206	175	178	90	150	110	2.18	0.12	0.02
207	178	179	10	150	110	13.10	0.74	0.06
208	179	152	404	100	110	-2.35	-0.30	0.73
209	180	181	21	100	110	5.70	0.73	0.20
210	181	182	128	150	110	5.70	0.32	0.17
211	180	183	154	100	110	0.56	0.07	0.02
212	183	184	333	100	110	-1.10	-0.14	0.15
213	53	184	228	100	110	2.30	0.29	0.40
214	173	174	58	100	110	0.00	0.00	0.00
215	175	185	85	25	50	0.00	0.00	0.00
216	52	179	125	150	110	-15.44	-0.87	1.02
217	65	193	30	100	110	0.80	0.10	0.01
218	193	194	93	150	110	0.80	0.05	0.00
219	66	67	36	100	110	1.20	0.15	0.02
220	67	68	47	100	110	0.80	0.10	0.01
221	67	187	220	25	50	0.40	0.81	54.91
222	64	195	30	100	110	-0.77	-0.10	0.01
223	195	196	215	150	110	-0.77	-0.04	0.01
224	196	197	104	150	100	-0.55	-0.03	0.00
225	63	196	140	150	110	1.91	0.11	0.02
226	62	197	140	150	110	2.38	0.13	0.04
227	61	198	140	100	100	1.04	0.13	0.07
228	197	198	104	150	100	0.88	0.05	0.01
229	198	199	104	150	100	0.91	0.05	0.01
230	60	199	140	100	110	1.37	0.17	0.09
231	199	200	125	150	100	0.00	0.00	0.00

NODE TABLE				
INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
156	70.00	0.00	569	128.1
157	68.00	0.00	588	128.1
158	73.00	0.80	531	127.2
159	80.00	0.00	466	127.6
160	82.00	0.00	447	127.6
161	77.00	0.80	492	127.2
162	78.00	0.80	482	127.2
163	85.00	0.00	418	127.7
164	75.85	1.20	503	127.2
165	74.00	0.80	521	127.2
166	75.00	0.00	513	127.4
167	88.00	0.00	387	127.5
168	82.00	0.80	449	127.9
169	82.00	0.00	449	127.9
170	80.00	0.00	469	127.9
171	77.00	0.00	492	127.2
172	77.00	0.80	492	127.2
173	82.00	0.80	443	127.3
174	72.00	0.00	541	127.3
175	75.00	0.80	512	127.3
176	80.00	0.00	468	127.8
177	84.00	0.00	429	127.8
178	69.00	0.80	571	127.3
179	69.00	0.00	570	127.2
180	60.00	1.60	643	125.6
181	61.00	0.00	631	125.4
182	70.00	5.70	541	125.3
183	41.44	1.66	824	125.6
184	53.00	1.20	713	125.8
185	60.00	0.00	659	127.3
186	46.00	0.00	784	126.1
187	35.00	0.40	354	71.1
188	25.00	0.00	984	125.4
189	3.50	0.00	1,191	125.1
190	15.00	0.00	1,078	125.1
191	15.00	0.00	1,078	125.1
192	5.00	0.00	1,176	125.1
193	34.00	0.00	902	126.1
194	33.00	0.80	911	126.1
195	30.81	0.00	934	126.1
196	27.00	1.68	971	126.2
197	27.00	0.95	971	126.2
198	28.00	1.01	961	126.1
199	28.00	0.80	961	126.1
200	11.40	0.00	1,124	126.1
201	30.00	0.80	941	126.1
202	50.00	0.80	749	126.5
203	70.00	0.40	554	126.6
204	65.99	0.80	598	127.0
205	64.00	0.80	615	126.8
206	74.00	0.00	517	126.8
207	74.00	0.00	525	127.6
208	60.60	0.80	647	126.6
209	62.00	0.80	633	126.7
210	49.00	0.80	757	126.3
211	49.00	0.00	757	126.3
212	51.15	0.80	736	126.3
213	50.00	0.00	748	126.3
214	29.00	0.91	952	126.2
215	16.00	0.00	1,079	126.2
216	31.91	0.10	923	126.2
217	45.00	0.00	795	126.2
218	49.00	0.00	764	127.0
219	50.00	0.80	754	127.0
220	46.00	0.40	793	127.0
221	36.00	0.80	886	126.5
222	63.00	0.00	630	127.3
223	49.00	0.00	761	126.7
224	56.00	0.80	692	126.7
225	54.00	1.20	704	125.9
226	59.00	1.60	666	127.0
227	62.00	0.80	640	127.4
228	63.00	1.20	629	127.2
229	63.00	0.00	629	127.2
230	48.00	0.80	757	125.3
231	34.00	0.40	894	125.3
232	30.00	0.00	929	124.9

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand 224.70 l/s
Demand South 11.18 l/s
Population 6,000

PIPE TABLE								
INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
232	199	201	104	150	100	1.49	0.08	0.01
233	44	201	104	150	100	-2.30	-0.13	0.03
234	59	201	140	100	100	1.61	0.20	0.15
235	118	119	115	100	110	-5.17	-0.66	0.89
236	118	123	135	100	110	1.20	0.15	0.07
237	116	118	104	150	110	0.16	0.01	0.00
238	118	121	104	150	110	3.33	0.19	0.05
239	121	120	113	100	110	0.80	0.10	0.03
240	121	122	135	150	110	1.73	0.10	0.02
241	122	123	104	200	110	0.94	0.03	0.00
242	123	124	104	200	110	-2.55	-0.08	0.01
243	123	204	134	100	110	3.89	0.50	0.61
244	204	205	104	150	110	7.07	0.40	0.20
245	39	204	104	150	110	6.99	0.40	0.20
246	204	209	135	100	110	3.01	0.38	0.39
247	209	210	135	100	110	2.73	0.35	0.32
248	40	209	90	150	110	2.60	0.15	0.03
249	42	210	104	200	110	-4.19	-0.13	0.02
250	210	211	92	200	110	-2.26	-0.07	0.01
251	211	212	12	150	110	-2.26	-0.13	0.00
252	208	209	104	150	110	-2.09	-0.12	0.02
253	205	206	117	150	110	0.00	0.00	0.00
254	205	208	134	150	110	6.27	0.35	0.21
255	208	212	134	150	110	7.56	0.43	0.29
256	212	213	12	150	110	4.50	0.25	0.01
257	213	214	129	150	110	4.50	0.25	0.11
258	214	215	145	100	110	0.00	0.00	0.00
259	214	216	104	150	100	3.59	0.20	0.07
260	44	216	104	150	100	-3.49	-0.20	0.06
261	216	217	115	100	100	0.00	0.00	0.00
262	27	26	80	25	50	0.00	0.00	0.00
263	25	227	210	100	110	1.40	0.18	0.15
264	228	229	52	100	110	0.00	0.00	0.00
265	24	25	82	100	110	5.56	0.71	0.73
266	25	228	104	100	110	2.96	0.38	0.29
267	228	226	210	100	110	1.77	0.22	0.22
268	226	227	104	100	110	-3.37	-0.43	0.37
269	227	28	82	100	110	-2.77	-0.35	0.20
270	28	207	183	150	110	0.00	0.00	0.00
271	226	807	276	100	110	3.54	0.45	1.07
272	225	230	185	100	110	3.14	0.40	0.57
273	230	34	162	100	110	1.94	0.25	0.21
274	230	231	194	100	110	0.40	0.05	0.01
275	35	232	88	37	100	0.00	0.00	0.00
276	30	224	122	100	110	3.59	0.46	0.48
277	224	225	335	100	110	2.79	0.36	0.83
278	224	223	68	25	50	0.00	0.00	0.00
279	32	221	140	100	110	0.80	0.10	0.03
280	31	219	98	150	110	1.20	0.07	0.01
281	219	218	104	150	110	0.00	0.00	0.00
282	219	220	93	100	110	0.40	0.05	0.01
283	29	222	90	100	110	0.00	0.00	0.00
284	22	119	5	50	100	5.17	2.63	1.36
285	72	71	203	200	120	31.89	1.02	1.33
286	21	141	12	200	110	1.22	0.04	0.00
287	124	159	20	100	110	3.24	0.41	0.07
288	125	160	20	100	110	3.36	0.43	0.07
289	126	163	20	100	110	3.59	0.46	0.08
290	165	37	20	100	110	4.39	0.56	0.11
291	172	38	20	100	110	4.53	0.58	0.12
292	131	176	20	100	110	3.82	0.49	0.09
293	148	177	5	150	110	11.71	0.66	0.02
301	44	45	435	200	120	17.55	0.56	0.95
302	45	301	8	100	100	1.07	0.14	0.00
303	301	302	2	50	120	1.07	0.55	74.97
304	302	303	120	100	110	0.54	0.07	0.01
305	45	304	814	200	120	16.48	0.52	1.58
306	304	305	47	200	100	22.76	0.72	0.23
307	305	306	2	200	120	22.46	0.71	5.29
308	306	307	184	200	100	22.46	0.71	0.89
309	307	308	10	50	100	1.61	0.82	0.31
310	307	309	107	200	100	20.85	0.66	0.45
311	309	310	311	200	110	20.85	0.66	1.09
312	310	616	165	100	110	0.40	0.05	0.01
313	310	311	194	200	120	19.25	0.61	0.50
314	311	312	130	200	120	7.17	0.23	0.05
315	311	514	82	200	100	12.08	0.38	0.13

NODE TABLE				
INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
233	86.00	0.00	419	128.8
301	16.00	0.00	1,069	125.1
302	16.00	0.53	335	50.2
303	8.00	0.54	413	50.2
304	13.10	0.00	1,082	123.6
305	13.30	0.30	1,078	123.3
306	13.30	0.00	1,026	118.1
307	13.40	0.00	1,016	117.2
308	12.00	1.61	1,027	116.9
309	3.80	0.00	1,106	116.7
310	23.80	1.20	899	115.6
311	16.60	0.00	965	115.1
312	18.00	0.00	951	115.1
401	189.00	0.00	0	189.0
402	140.00	0.00	17	141.7
403	140.00	0.00	1	140.2
404	360.00	0.00	0	360.0
405	352.00	0.00	75	359.7
501	245.00	0.00	0	245.0
502	158.00	0.00	0	158.0
503	126.00	0.00	312	157.9
505	92.00	0.00	644	157.8
506	96.00	0.80	604	157.7
507	90.00	0.80	662	157.6
508	77.00	0.40	789	157.6
509	58.00	0.00	975	157.6
510	58.00	0.00	552	114.3
511	57.00	0.00	561	114.3
512	44.04	2.00	689	114.4
513	30.00	0.52	830	114.7
514	22.00	1.58	911	115.0
515	25.00	0.00	881	115.0
516	29.00	0.40	842	115.0
517	78.86	0.80	771	157.6
518	75.00	0.80	809	157.6
519	62.00	0.00	934	157.3
520	69.00	1.10	865	157.3
521	72.00	0.76	835	157.3
522	51.00	0.40	616	113.9
523	52.00	1.20	606	113.9
524	52.00	0.00	610	114.3
525	56.00	0.00	571	114.3
526	61.00	0.00	522	114.3
527	51.00	1.20	619	114.2
528	36.66	1.20	759	114.2
529	34.36	0.40	782	114.2
530	64.00	1.60	492	114.2
531	74.00	0.00	394	114.2
532	100.00	1.20	564	157.6
533	34.00	0.80	793	115.0
534	52.00	0.00	1,031	157.3
535	66.00	0.80	472	114.2
601	128.00	0.00	294	158.0
604	92.00	0.00	643	157.7
605	83.00	0.80	731	157.6
606	82.00	0.80	737	157.2
607	77.21	0.80	783	157.2
608	52.00	0.80	568	110.0
609	55.50	0.00	534	110.0
613	32.26	0.42	761	110.0
614	25.30	0.80	837	110.8
615	19.00	2.40	939	114.9
616	18.00	0.40	956	115.6
617	99.00	0.80	568	157.1
618	103.00	0.40	529	157.1
619	107.00	0.40	490	157.0
620	103.00	0.80	513	155.4
621	106.00	0.80	484	155.4
622	96.00	0.80	582	155.4
623	95.00	0.80	592	155.4
627	78.86	0.00	771	157.6
628	14.00	0.80	987	114.8
629	10.00	0.40	987	110.8
630	102.00	0.40	523	155.5
800	62.00	0.00	650	128.4
801	59.00	0.80	679	128.4
802	47.00	0.80	797	128.4

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand	**224.70**	**l/s**
Demand South	**11.18**	**l/s**
Population	**6,000**	

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
316	85	87	183	150	120	7.12	0.40	0.30
401	401	402	1,520	300	110	196.59	2.78	47.29
402	401	402	1,520	200	110	67.68	2.15	47.29
403	402	403	4	200	110	264.26	8.41	1.55
404	403	1	2	300	100	297.28	4.21	0.16
405	403	601	2,164	200	110	-33.02	-1.05	17.82
406	404	405	91	490	90	166.11	0.88	0.28
407	405	501	2,073	250	110	166.11	3.38	114.72
501	501	502	1,010	300	110	340.71	4.82	87.00
502	502	503	500	300	130	17.87	0.25	0.13
504	503	505	155	200	110	7.44	0.24	0.08
505	505	506	108	200	110	7.44	0.24	0.06
506	506	507	244	100	110	1.34	0.17	0.16
507	507	508	65	200	110	-0.66	-0.02	0.00
508	508	509	215	200	110	0.00	0.00	0.00
509	509	510	1	150	120	0.00	0.00	0.00
510	510	511	42	200	110	0.00	0.00	0.00
511	511	512	143	200	110	-5.78	-0.18	0.05
512	512	513	119	150	110	-8.78	-0.50	0.34
513	513	514	85	150	110	-9.31	-0.53	0.27
514	514	515	96	150	110	1.20	0.07	0.01
515	515	516	91	150	110	0.40	0.02	0.00
516	515	533	82	100	110	0.80	0.10	0.02
517	506	517	110	150	110	5.30	0.30	0.12
518	517	518	209	200	110	3.72	0.12	0.03
519	518	519	192	100	110	1.86	0.24	0.23
520	519	520	313	150	110	1.86	0.11	0.05
521	520	521	183	100	110	0.76	0.10	0.04
522	520	534	222	150	110	0.00	0.00	0.00
523	523	522	67	100	110	0.40	0.05	0.00
524	523	524	510	100	110	-1.60	-0.20	0.45
525	524	525	30	150	110	-0.59	-0.03	0.00
526	524	512	130	100	110	-1.01	-0.13	0.05
527	525	526	70	150	110	0.00	0.00	0.00
528	507	532	290	150	110	1.20	0.07	0.02
529	511	525	12	100	110	0.59	0.07	0.00
530	511	527	105	150	110	5.19	0.29	0.11
531	527	528	256	150	110	1.56	0.09	0.03
532	528	529	106	150	110	0.40	0.02	0.00
533	530	535	160	150	110	0.83	0.05	0.01
534	527	530	91	150	110	2.43	0.14	0.02
535	530	531	102	150	110	0.00	0.00	0.00
536	508	518	53	200	110	-1.06	-0.03	0.00
537	528	535	230	150	110	-0.03	0.00	0.00
601	502	601	2	200	110	33.02	1.05	0.02
604	503	604	155	200	110	10.43	0.33	0.15
605	604	605	114	200	110	10.43	0.33	0.11
606	836	606	200	200	110	8.02	0.26	0.12
607	606	607	213	200	110	5.62	0.18	0.07
608	843	608	225	200	110	0.03	0.00	0.00
609	608	609	115	200	110	0.00	0.00	0.00
614	613	614	305	100	110	-2.78	-0.35	0.75
615	614	615	855	100	110	-3.98	-0.51	4.09
616	312	615	15	100	110	7.17	0.91	0.21
617	517	627	1	200	100	0.78	0.02	0.00
618	605	627	130	200	110	-0.78	-0.02	0.00
619	606	617	205	100	110	1.60	0.20	0.18
620	617	618	55	100	110	0.40	0.05	0.00
621	617	619	137	100	110	0.40	0.05	0.01
622	607	630	433	100	110	3.59	0.46	1.72
623	620	621	102	150	120	1.60	0.09	0.01
624	621	622	160	150	120	0.80	0.05	0.00
625	620	623	160	150	120	0.80	0.05	0.00
626	608	847	178	200	110	0.00	0.00	0.00
629	614	629	120	100	110	0.40	0.05	0.01
630	615	628	245	100	110	0.80	0.10	0.06
631	630	620	60	150	120	3.19	0.18	0.02
800	86	88	148	150	120	9.92	0.56	0.45
801	104	800	54	200	120	1.60	0.05	0.00
802	800	801	57	150	120	0.80	0.05	0.00
803	800	802	136	200	120	0.80	0.03	0.00
804	80	803	30	250	120	38.83	0.79	0.10
805	803	804	175	250	120	2.00	0.04	0.00
806	803	805	95	200	120	36.04	1.15	0.78
807	805	806	23	200	120	0.00	0.00	0.00
808	805	97	140	200	120	33.64	1.07	1.02
809	807	808	176	150	120	0.40	0.02	0.00

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
803	85.00	0.80	452	131.2
804	85.00	2.00	452	131.2
805	84.00	2.40	454	130.4
806	84.00	0.00	454	130.4
807	53.00	1.60	714	126.0
808	54.00	0.40	705	126.0
809	107.00	0.00	270	134.5
810	81.00	0.00	470	129.0
811	77.00	0.00	509	129.0
812	78.00	0.80	500	129.0
813	70.00	0.00	578	129.0
814	68.00	0.40	597	129.0
815	72.00	0.80	558	129.0
816	95.00	0.80	359	131.7
817	99.00	0.80	318	131.5
818	102.00	0.80	286	131.2
819	96.00	0.00	348	131.5
820	95.00	0.80	359	131.7
821	77.00	1.20	504	128.5
822	75.00	1.20	524	128.5
823	91.00	0.00	394	131.2
824	94.00	0.00	364	131.2
825	95.00	2.00	355	131.2
826	85.00	0.00	429	128.8
827	84.00	0.40	438	128.8
828	83.00	0.40	445	128.5
829	86.00	0.00	416	128.5
830	109.00	0.40	246	134.1
831	105.00	0.80	285	134.1
832	34.00	0.80	744	110.0
833	12.00	0.80	960	110.0
834	12.00	0.00	960	110.0
835	12.00	0.00	960	110.0
836	87.00	0.80	689	157.4
837	92.00	0.80	640	157.4
838	98.00	0.00	581	157.4
839	115.00	0.80	415	157.4
840	116.00	0.00	405	157.4
841	110.00	0.00	464	157.4
842	70.00	0.00	854	157.2
843	70.00	0.00	392	110.0
844	105.00	0.80	270	132.6
845	105.00	0.00	270	132.6
846	52.00	0.00	568	110.0
847	38.00	0.00	705	110.0
848	38.00	0.40	1,167	157.2
849	34.00	0.80	1,206	157.2

Town of Ladysmith
PeakHour Demand
7-Feb-95
File: 6PH

Total Demand 224.70 l/s
Demand South 11.18 l/s
Population 6,000

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
810	807	225	105	100	120	1.55	0.20	0.07
811	83	844	247	150	120	0.29	0.02	0.00
812	809	72	86	350	120	120.62	1.25	0.44
813	98	810	55	200	120	21.67	0.69	0.18
814	810	811	45	200	120	6.90	0.22	0.02
815	811	812	43	200	120	0.80	0.03	0.00
816	811	813	96	200	120	6.10	0.19	0.03
817	813	814	79	150	120	1.20	0.07	0.00
818	814	815	64	150	120	0.80	0.05	0.00
819	814	139	63	150	120	0.00	0.00	0.00
820	89	816	37	200	120	19.27	0.61	0.10
821	816	817	83	200	120	17.67	0.56	0.18
822	817	818	142	200	120	16.87	0.54	0.29
823	818	93	114	150	120	17.78	1.01	1.03
824	817	819	56	150	120	0.00	0.00	0.00
825	816	820	175	150	120	0.80	0.05	0.01
826	101	821	50	100	120	1.20	0.15	0.02
827	101	822	50	200	120	1.20	0.04	0.00
828	824	823	112	75	120	0.00	0.00	0.00
829	824	823	57	75	120	0.00	0.00	0.00
830	825	824	36	150	120	0.00	0.00	0.00
831	825	7	152	150	120	13.32	0.75	0.80
832	16	826	42	200	120	19.07	0.61	0.11
833	826	827	71	150	120	0.40	0.02	0.00
834	829	828	70	150	120	0.40	0.02	0.00
835	829	136	12	200	120	-11.72	-0.37	0.01
836	84	830	114	200	120	0.40	0.01	0.00
837	84	831	128	200	120	0.80	0.03	0.00
838	832	613	60	200	120	-1.60	-0.05	0.00
839	832	833	214	200	120	0.80	0.03	0.00
840	833	834	45	200	120	0.00	0.00	0.00
841	833	835	50	200	120	0.00	0.00	0.00
842	605	836	300	200	120	10.41	0.33	0.25
843	836	837	68	200	120	1.60	0.05	0.00
844	837	838	40	200	120	0.00	0.00	0.00
845	837	839	212	200	120	0.80	0.03	0.00
846	839	840	21	200	120	0.00	0.00	0.00
847	839	841	58	200	120	0.00	0.00	0.00
848	842	843	5	200	120	0.03	0.00	47.15
849	607	842	90	200	120	1.23	0.04	0.00
850	846	613	220	200	120	-0.77	-0.02	0.00
851	83	844	90	150	120	0.51	0.03	0.00
852	844	845	50	150	120	0.00	0.00	0.00
853	608	846	86	200	120	-0.77	-0.02	0.00
854	842	848	125	200	120	1.20	0.04	0.00
855	848	849	525	200	120	0.80	0.03	0.00

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m

PUMPED SOURCES TABLE

INPUT				OUTPUT	
Node	Pumps	OpCurve	Estimate	Actual	Inflow l/s
1	1	Pump1	0.40	-0.40	90.45
401	1	Pump1	0.1	1.18	-264.26
404	1	Pump1	0.1	0.74	-166.11
501	1	Pump1	0.1	0.78	-174.61
502	1	Pump1	0.4	-1.29	289.83

REDUCING (PRV) TABLE

INPUT					OUTPUT	
Pipe	Source	Pressure kPa	OpenK m	CKV	PRVLoss kPa	CKVState
303	1	335.20	0.00	Yes	74.95	Open
307	1	1027.26	0.00	Yes	5.29	Open
509	502	517.01	0.00	Yes	47.11	Closed
848	502	392.40	0.00	Yes	47.15	Open

PEAK HOUR DEMAND

FOR 18,000 POPULATION

WITH NEW PRESSURE ZONE ARRANGEMENT

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand 518.10 l/s
Demand South 48.02 l/s
Population 18,000

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
1	1	2	20	450	100	414.01	2.60	0.41
2	2	3	1	300	100	414.01	5.86	0.15
3	3	4	5	450	100	414.01	2.60	0.10
4	4	5	3	350	100	165.62	1.72	0.04
5	5	6	1,290	300	110	165.62	2.34	48.37
6	6	7	170	200	110	50.91	1.62	3.12
7	7	8	63	200	110	63.22	2.01	1.73
8	8	9	101	200	110	63.22	2.01	2.77
9	9	10	39	200	110	11.13	0.35	0.04
10	10	11	66	200	110	11.13	0.35	0.07
11	11	12	105	200	110	0.65	0.02	0.00
12	12	13	43	200	110	-8.49	-0.27	0.03
13	13	14	61	200	110	-8.49	-0.27	0.04
14	14	15	122	200	110	-17.48	-0.56	0.38
15	15	16	88	200	110	-21.29	-0.68	0.32
16	16	17	72	200	110	-64.30	-2.05	2.04
17	17	18	82	200	110	17.29	0.55	0.20
18	18	19	213	200	110	17.29	0.55	0.53
19	19	20	136	200	110	38.32	1.22	1.48
20	20	21	62	200	110	43.99	1.40	0.87
21	21	151	324	200	110	35.58	1.13	3.06
22	151	152	130	200	120	27.91	0.89	1.16
23	6	22	137	200	110	53.78	1.71	2.79
24	22	23	240	200	110	41.28	1.31	2.99
25	23	24	75	200	110	39.53	1.26	0.86
26	24	27	110	200	110	30.64	0.98	0.79
27	27	28	99	200	110	30.64	0.98	0.71
28	28	29	100	200	110	28.11	0.89	32.79
29	29	30	65	200	110	27.23	0.87	0.37
30	30	31	137	200	110	17.21	0.55	0.34
31	31	32	165	150	110	11.94	0.68	0.84
32	32	33	460	150	110	6.67	0.38	0.79
33	33	34	79	100	110	3.15	0.40	0.39
34	34	35	17	100	110	-3.52	-0.45	0.06
35	35	304	120	100	110	-3.52	-0.45	0.46
36	6	39	427	200	100	60.92	1.94	13.04
37	39	40	134	200	110	49.08	1.56	2.30
38	40	41	15	200	110	61.31	1.95	0.39
39	41	42	134	200	110	49.33	1.57	25.14
40	42	43	135	200	110	19.93	0.63	0.44
41	43	44	7	200	120	19.93	0.63	0.02
42	152	180	136	100	110	20.14	2.57	13.12
43	41	46	103	200	110	18.85	0.60	0.30
44	46	47	88	200	110	26.35	0.84	0.48
45	47	48	122	200	110	23.71	0.75	24.35
46	48	49	104	200	110	18.05	0.57	0.28
47	49	50	104	200	110	12.98	0.41	0.15
48	50	51	104	150	100	3.31	0.19	0.06
49	51	52	194	150	100	-1.35	-0.08	0.02
50	52	53	14	200	110	26.23	0.84	0.08
51	53	54	134	200	110	24.77	0.79	0.65
52	54	55	203	200	110	41.90	1.33	2.60
53	55	56	114	200	110	41.90	1.33	1.46
54	56	57	2	200	110	41.90	1.33	0.03
55	57	58	30	200	110	41.90	1.33	0.38
56	56	190	22	250	110	0.00	0.00	0.00
57	190	191	2	250	100	0.00	0.00	0.00
58	191	192	30	250	110	0.00	0.00	0.00
59	57	189	318	200	120	0.00	0.00	0.00
60	55	188	18	100	110	0.00	0.00	0.00
61	42	59	104	200	110	18.54	0.59	0.29
63	59	60	104	200	110	14.39	0.46	0.18
64	60	61	104	200	110	10.96	0.35	0.11
65	61	62	104	200	110	11.35	0.36	0.12
66	62	63	104	200	110	8.76	0.28	0.07
67	63	64	104	200	110	10.63	0.34	0.11
68	64	65	104	200	110	13.40	0.43	0.16
69	65	66	89	200	110	9.78	0.31	0.10
70	66	54	15	200	110	17.13	0.55	0.04
71	52	66	135	150	110	11.94	0.68	0.69
72	65	186	94	100	110	0.00	0.00	0.00
73	51	64	135	100	100	2.90	0.37	0.40
74	50	63	135	150	100	7.91	0.45	0.36
75	49	62	135	100	110	3.32	0.42	0.44
76	48	61	135	100	110	3.90	0.50	0.60
77	47	202	110	100	110	1.76	0.22	0.12
78	47	203	47	100	110	0.88	0.11	0.01

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
1	180.00	0.00	0	180.0
2	136.00	0.00	427	179.6
3	136.00	0.00	425	179.4
4	136.00	0.00	424	179.3
5	136.00	0.00	424	179.3
6	87.95	0.00	421	130.9
7	93.00	0.00	341	127.8
8	93.00	0.00	324	126.1
9	95.07	1.76	277	123.3
10	93.00	0.00	296	123.3
11	92.00	2.86	305	123.2
12	91.97	1.76	306	123.2
13	90.00	0.00	325	123.2
14	88.00	1.76	345	123.3
15	86.00	1.76	369	123.6
16	85.09	1.76	381	124.0
17	90.00	1.76	353	126.0
18	88.00	0.00	370	125.8
19	86.00	0.00	385	125.3
20	80.00	1.76	429	123.8
21	74.00	3.51	479	122.9
22	82.00	1.76	452	128.1
23	74.00	1.76	501	125.2
24	71.57	0.88	516	124.3
25	68.00	2.64	537	122.9
26	70.00	0.00	524	123.5
27	70.93	0.00	515	123.5
28	65.71	0.00	559	122.8
29	59.00	0.88	304	90.0
30	55.61	3.51	333	89.6
31	54.00	2.64	346	89.3
32	44.21	3.51	433	88.5
33	37.00	3.51	496	87.7
34	36.00	1.76	502	87.3
35	35.00	0.00	512	87.3
37	73.00	0.00	446	118.5
38	75.00	0.00	425	118.4
39	73.00	0.00	440	117.9
40	66.00	0.00	486	115.6
41	66.00	1.76	482	115.2
42	47.00	1.76	422	90.1
43	32.00	0.00	564	89.6
44	31.00	3.97	574	89.6
45	16.50	0.00	708	88.8
46	65.47	1.76	484	114.9
47	62.00	0.00	513	114.4
48	58.95	1.76	305	90.1
49	55.00	1.76	341	89.8
50	51.00	1.76	378	89.6
51	54.09	1.76	347	89.6
52	46.40	1.76	423	89.6
53	46.40	0.00	422	89.5
54	35.00	0.00	528	88.9
55	25.00	0.00	600	86.3
56	12.50	0.00	708	84.8
57	12.00	0.00	713	84.8
58	5.00	41.90	778	84.4
59	46.00	2.10	429	89.8
60	47.00	1.76	417	89.6
61	46.00	2.16	426	89.5
62	34.00	3.42	542	89.4
63	34.00	3.88	541	89.3
64	34.00	2.06	540	89.2
65	34.00	1.87	539	89.0
66	34.00	1.95	538	88.9
67	33.00	0.88	547	88.8
68	31.00	1.76	566	88.8
69	99.00	0.00	302	129.9
70	101.00	1.76	508	152.8
71	103.00	1.76	491	153.1
72	103.00	1.76	534	157.6
73	98.00	0.88	565	155.7
74	97.00	1.76	560	154.2
75	96.00	0.00	556	152.8
76	94.00	0.88	562	151.4
77	90.00	3.87	575	148.7
78	87.00	0.88	421	130.0

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand	**518.10 l/s**
Demand South	**48.02 l/s**
Population	**18,000**

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
79	46	161	135	100	110	-9.25	-1.18	3.08
83	172	171	6	150	110	0.00	0.00	0.00
84	165	172	105	150	110	5.85	0.33	0.14
85	164	165	105	150	110	-2.21	-0.13	0.02
86	162	164	105	150	110	-5.75	-0.33	0.14
87	161	162	105	150	110	-9.70	-0.55	0.36
88	158	161	105	150	110	-4.72	-0.27	0.10
89	39	158	15	150	110	-0.34	-0.02	0.00
90	158	41	134	100	110	8.63	1.10	2.69
91	158	159	111	100	110	-6.00	-0.76	1.14
92	161	160	111	100	110	-6.03	-0.77	1.15
93	162	163	111	100	110	-5.71	-0.73	1.04
94	127	164	134	100	110	6.17	0.79	1.44
95	165	166	11	100	110	-9.82	-1.25	0.28
96	166	167	98	150	110	-9.82	-0.56	0.35
97	128	167	25	100	100	9.82	1.25	0.76
98	168	170	15	150	100	0.00	0.00	0.00
99	168	169	34	100	100	0.00	0.00	0.00
100	129	168	73	150	100	1.76	0.10	0.01
101	116	117	104	100	110	1.76	0.22	0.11
102	116	124	135	100	120	2.28	0.29	0.20
103	115	116	104	150	110	5.56	0.31	0.13
104	112	115	104	150	110	11.28	0.64	0.48
105	111	112	104	150	110	18.10	1.02	1.14
106	111	132	104	150	110	-5.48	-0.31	0.12
107	132	133	104	150	110	-5.11	-0.29	0.11
108	133	134	104	150	110	-5.78	-0.33	0.14
109	134	135	104	150	110	-6.92	-0.39	0.19
110	115	114	111	100	110	1.76	0.22	0.12
111	115	125	135	100	110	2.21	0.28	0.22
112	112	113	111	100	110	1.76	0.22	0.12
113	112	126	135	100	110	3.30	0.42	0.46
114	9	111	119	200	110	50.33	1.60	2.14
115	111	127	135	200	110	35.08	1.12	1.24
116	11	132	119	100	110	7.62	0.97	1.90
117	132	128	135	100	100	5.50	0.70	1.40
118	12	133	119	100	110	7.38	0.94	1.79
119	133	129	135	100	110	6.30	0.80	1.51
120	14	134	119	100	110	7.23	0.92	1.72
121	134	130	135	100	110	6.61	0.84	1.66
122	15	233	22	100	110	2.06	0.26	0.11
123	135	131	135	100	110	7.02	0.89	1.85
124	124	125	103	200	110	-10.83	-0.34	0.11
125	125	126	104	200	110	-16.41	-0.52	0.23
126	126	127	104	200	110	-20.58	-0.65	0.36
127	127	128	104	200	110	5.70	0.18	0.03
128	128	129	104	200	110	-0.39	-0.01	0.00
129	129	130	104	200	110	2.39	0.08	0.01
130	130	131	104	200	110	0.76	0.02	0.00
131	131	147	89	200	110	-1.15	-0.04	0.00
132	147	137	11	150	110	-27.77	-1.57	0.27
133	137	829	113	150	110	-24.10	-1.36	2.11
134	135	136	89	150	110	-13.64	-0.77	0.58
135	135	233	113	63	100	-2.06	-0.66	1.81
136	136	826	95	200	110	-40.37	-1.29	1.21
137	137	138	663	100	110	-3.67	-0.47	2.74
138	138	813	42	150	110	-7.56	-0.43	0.09
139	139	140	235	25	50	0.00	0.00	0.00
140	4	809	889	350	110	248.39	2.58	20.13
141	72	73	93	300	120	170.71	2.42	1.90
142	73	74	85	300	120	153.13	2.17	1.42
143	74	75	117	300	120	129.65	1.83	1.43
144	75	76	95	300	120	142.84	2.02	1.39
145	76	77	146	300	120	161.05	2.28	2.67
146	77	78	62	250	120	94.88	1.93	18.73
147	78	79	27	250	120	94.00	1.92	0.44
148	79	80	13	250	120	68.57	1.40	0.12
149	79	81	131	150	120	25.42	1.44	2.30
150	81	19	158	150	120	21.03	1.19	1.99
151	81	82	143	150	110	1.76	0.10	0.02
153	93	17	44	150	110	83.34	4.72	8.17
154	92	818	111	150	110	2.34	0.13	0.03
155	94	95	49	100	110	0.88	0.11	0.01
156	93	94	104	150	110	-28.36	-1.61	2.62
157	94	92	210	150	110	-31.00	-1.75	6.25
158	92	91	124	150	110	-35.09	-1.99	4.64
159	91	109	155	150	120	3.92	0.22	0.09
160	109	110	63	150	120	3.92	0.22	0.03

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
79	86.00	0.00	427	129.6
80	86.00	0.00	425	129.4
81	92.77	2.64	338	127.3
82	87.00	1.76	394	127.2
83	101.00	0.00	508	152.8
84	103.00	12.30	534	157.5
85	98.50	1.76	548	154.5
86	97.00	0.88	554	153.6
87	97.00	1.76	551	153.3
88	94.00	1.76	566	151.8
89	90.00	0.00	570	148.2
90	87.00	0.00	421	130.0
91	102.70	0.00	441	147.7
92	103.00	1.76	392	143.1
93	95.00	1.76	384	134.2
94	94.00	1.76	419	136.8
95	94.00	0.88	419	136.8
96	101.00	0.88	453	147.3
97	85.00	5.27	385	124.3
98	85.00	0.00	380	123.9
99	57.00	0.00	638	122.1
100	57.00	0.00	635	121.9
101	75.00	8.78	448	120.7
102	71.00	3.51	484	120.5
103	67.00	3.51	522	120.3
104	65.00	4.39	542	120.3
105	73.00	3.51	464	120.4
106	75.00	0.00	444	120.4
107	67.00	0.00	522	120.3
108	67.00	0.00	522	120.3
109	100.00	0.00	466	147.6
110	100.00	3.92	466	147.6
111	92.00	2.64	286	121.2
112	91.00	1.76	284	120.0
113	93.00	1.76	264	119.9
114	92.00	1.76	269	119.4
115	90.00	1.76	289	119.6
116	87.00	1.76	317	119.4
117	87.00	1.76	316	119.3
118	83.00	1.76	357	119.4
119	82.00	0.00	400	122.9
120	82.00	1.76	364	119.1
121	79.00	1.76	394	119.3
122	74.00	1.76	443	119.2
123	78.00	1.76	403	119.2
124	82.76	1.76	357	119.2
125	83.00	1.76	356	119.3
126	86.00	1.76	329	119.6
127	89.69	2.64	296	119.9
128	90.00	1.76	293	119.9
129	91.08	1.76	282	119.9
130	87.00	1.76	322	119.9
131	85.00	1.76	342	119.9
132	92.00	1.76	287	121.3
133	90.00	1.76	308	121.4
134	89.00	1.76	319	121.5
135	86.00	1.76	350	121.7
136	84.00	1.76	375	122.3
137	84.00	0.00	354	120.2
138	68.00	1.76	538	122.9
139	65.00	0.00	568	123.0
140	63.00	0.00	587	123.0
141	74.00	0.00	479	122.9
142	78.00	1.76	437	122.7
143	82.00	1.76	397	122.6
144	82.00	1.76	397	122.6
145	80.00	1.76	418	122.6
146	82.00	0.00	397	122.6
147	84.77	1.76	344	119.9
148	84.77	0.00	341	119.6
149	80.00	0.00	388	119.6
150	78.00	4.48	407	119.6
151	74.41	0.00	445	119.9
152	67.08	3.51	506	118.7
153	74.00	0.00	449	119.8
154	73.00	3.51	458	119.8
155	74.00	0.00	448	119.8
156	70.00	0.00	488	119.8

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand	**518.10 l/s**
Demand South	**48.02 l/s**
Population	**18,000**

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
161	71	91	140	150	120	39.01	2.21	5.43
162	71	70	96	200	120	20.21	0.64	0.27
163	70	69	104	200	120	16.70	0.53	22.97
164	69	825	171	150	120	16.70	0.95	1.38
165	70	83	23	150	120	1.76	0.10	0.00
166	72	84	30	200	120	14.93	0.48	0.05
167	73	85	145	150	120	16.70	0.95	1.17
168	74	86	47	150	120	21.72	1.23	0.62
169	75	87	93	150	120	-13.18	-0.75	0.48
170	76	88	40	150	120	-19.09	-1.08	0.41
171	77	89	25	200	120	62.31	1.98	0.57
172	78	90	29	150	120	0.00	0.00	0.00
173	141	138	197	150	110	-2.13	-0.12	0.03
174	141	142	142	150	110	7.03	0.40	0.27
175	142	143	125	150	110	3.51	0.20	0.07
176	143	144	138	150	120	1.76	0.10	0.02
177	143	146	10	150	120	0.00	0.00	0.00
178	142	145	68	150	120	1.76	0.10	0.01
179	20	98	104	200	110	-7.43	-0.24	0.05
180	98	97	21	200	110	-51.88	-1.65	0.44
181	810	99	158	200	120	32.50	1.03	1.08
182	99	100	24	200	100	32.50	1.03	0.23
183	100	101	170	200	120	32.50	1.03	1.16
184	101	102	103	200	120	18.45	0.59	0.25
185	102	103	151	200	120	10.67	0.34	0.13
186	103	104	88	200	120	7.91	0.25	0.04
187	102	105	190	150	120	4.27	0.24	0.12
188	105	106	49	150	120	0.00	0.00	0.00
189	105	107	259	150	120	0.75	0.04	0.01
190	103	107	64	150	120	-0.75	-0.04	0.00
191	107	108	29	150	120	0.00	0.00	0.00
192	147	148	13	150	110	24.86	1.41	0.26
193	148	149	175	150	110	0.32	0.02	0.00
194	149	150	30	150	110	4.48	0.25	0.02
195	149	151	222	150	110	-4.16	-0.24	0.23
196	151	153	46	150	110	3.51	0.20	0.02
197	153	154	85	150	110	3.51	0.20	0.04
198	154	155	17	150	110	0.00	0.00	0.00
199	154	156	86	150	110	0.00	0.00	0.00
200	153	157	135	25	50	0.00	0.00	0.00
201	130	173	135	100	110	6.49	0.83	1.60
202	175	176	113	100	110	-7.18	-0.91	1.61
203	178	177	113	150	110	-24.54	-1.39	2.18
204	172	173	104	150	110	4.10	0.23	0.07
205	173	175	104	150	110	8.83	0.50	0.30
206	175	178	90	150	110	14.25	0.81	0.63
207	178	179	10	150	110	37.03	2.10	0.83
208	179	152	404	100	110	-4.25	-0.54	2.18
209	180	181	21	100	110	11.80	1.50	0.75
210	181	182	128	150	110	11.80	0.67	0.64
211	180	183	154	100	110	4.83	0.61	16.07
212	183	184	333	100	110	1.17	0.15	0.17
213	53	184	228	100	110	1.46	0.19	0.17
214	173	174	58	100	110	0.00	0.00	0.00
215	175	185	85	25	50	0.00	0.00	0.00
216	179	52	125	150	110	41.28	2.34	26.93
217	65	193	30	100	110	1.76	0.22	0.03
218	193	194	93	150	110	1.76	0.10	0.01
219	66	67	36	100	110	2.64	0.34	0.08
220	67	68	47	100	110	1.76	0.22	0.05
221	67	187	220	25	50	0.00	0.00	0.00
222	64	195	30	100	110	-1.93	-0.25	0.04
223	195	196	215	150	110	-1.93	-0.11	0.04
224	196	197	104	150	100	-3.47	-0.20	0.06
225	63	196	140	150	110	2.16	0.12	0.03
226	62	197	140	150	110	2.50	0.14	0.04
227	61	198	140	100	100	1.34	0.17	0.11
228	197	198	104	150	100	-3.08	-0.17	0.05
229	198	199	104	150	100	-3.97	-0.22	0.08
230	60	199	140	100	110	1.68	0.21	0.14
231	199	200	125	150	100	0.00	0.00	0.00
232	199	201	104	150	100	-4.04	-0.23	0.08
233	44	201	104	150	100	3.74	0.21	0.07
234	59	201	140	100	100	2.05	0.26	0.24
235	118	119	115	100	110	-10.74	-1.37	3.46
236	118	123	135	100	110	2.26	0.29	0.23
237	116	118	104	150	110	-0.23	-0.01	0.00
238	118	121	104	150	110	6.50	0.37	0.17

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
157	68.00	0.00	508	119.8
158	73.00	1.76	440	117.9
159	80.00	0.00	382	119.0
160	82.00	0.00	364	119.1
161	77.00	1.76	401	118.0
162	78.00	1.76	395	118.3
163	85.00	0.00	337	119.4
164	75.85	2.64	417	118.5
165	74.00	1.76	436	118.5
166	75.00	0.00	429	118.8
167	88.00	0.00	305	119.1
168	82.00	1.76	371	119.9
169	82.00	0.00	371	119.9
170	80.00	0.00	391	119.9
171	77.00	0.00	405	118.4
172	77.00	1.76	405	118.4
173	82.00	1.76	355	118.3
174	72.00	0.00	453	118.3
175	75.00	1.76	421	118.0
176	80.00	0.00	388	119.6
177	84.00	0.00	348	119.5
178	69.00	1.76	473	117.4
179	69.00	0.00	465	116.5
180	60.00	3.51	446	105.6
181	61.00	0.00	429	104.8
182	70.00	11.80	335	104.2
183	41.44	3.66	471	89.5
184	53.00	2.64	356	89.4
185	60.00	0.00	568	118.0
186	46.00	0.00	421	89.0
187	35.00	0.00	527	88.8
188	25.00	0.00	600	86.3
189	3.50	0.00	796	84.8
190	15.00	0.00	684	84.8
191	15.00	0.00	684	84.8
192	5.00	0.00	782	84.8
193	34.00	0.00	538	89.0
194	33.00	1.76	548	89.0
195	30.81	0.00	572	89.2
196	27.00	3.70	610	89.2
197	27.00	2.10	610	89.3
198	28.00	2.23	601	89.4
199	28.00	1.76	602	89.4
200	11.40	0.00	764	89.4
201	30.00	1.76	583	89.5
202	50.00	1.76	630	114.3
203	70.00	0.88	435	114.4
204	65.99	1.76	503	117.3
205	64.00	1.76	517	116.8
206	74.00	0.00	419	116.8
207	74.00	0.00	478	122.8
208	60.60	1.76	546	116.3
209	62.00	1.76	529	116.1
210	49.00	1.76	401	90.0
211	49.00	0.00	401	89.9
212	51.15	1.76	380	89.9
213	50.00	0.00	391	89.9
214	29.00	1.99	595	89.7
215	16.00	0.00	722	89.7
216	31.91	0.21	566	89.7
217	45.00	0.00	437	89.7
218	49.00	0.00	394	89.3
219	50.00	1.76	385	89.3
220	46.00	0.88	423	89.2
221	36.00	1.76	512	88.3
222	63.00	0.00	264	90.0
223	49.00	0.00	384	88.2
224	56.00	1.76	315	88.2
225	54.00	2.64	313	86.0
226	59.00	3.51	621	122.4
227	62.00	1.76	594	122.6
228	63.00	2.64	582	122.5
229	63.00	0.00	582	122.5
230	48.00	1.76	375	86.3
231	34.00	0.88	511	86.2
232	30.00	0.00	561	87.3
233	86.00	0.00	368	123.5
301	16.00	0.00	713	88.8

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand 518.10 l/s
Demand South 48.02 l/s
Population 18,000

PIPE TABLE								
INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
239	121	120	113	100	110	1.76	0.22	0.12
240	121	122	135	150	110	2.98	0.17	0.05
241	122	123	104	200	110	1.23	0.04	0.00
242	123	124	104	200	110	-5.35	-0.17	0.03
243	123	204	134	100	110	7.07	0.90	1.86
244	204	205	104	150	110	11.76	0.67	0.51
245	39	204	104	150	110	12.18	0.69	0.55
246	204	209	135	100	110	5.74	0.73	1.27
248	40	209	90	150	110	-12.23	-0.69	0.48
249	42	210	104	200	110	9.10	0.29	0.08
250	210	211	92	200	110	7.35	0.23	0.05
251	211	212	12	150	110	7.35	0.42	0.02
252	208	209	104	150	110	8.25	0.47	0.27
253	205	206	117	150	110	0.00	0.00	0.00
254	205	208	134	150	110	10.01	0.57	0.49
256	212	213	12	150	110	5.59	0.32	0.01
257	213	214	129	150	110	5.59	0.32	0.16
258	214	215	145	100	110	0.00	0.00	0.00
259	214	216	104	150	100	3.60	0.20	0.07
260	44	216	104	150	100	-3.38	-0.19	0.06
261	216	217	115	100	100	0.00	0.00	0.00
262	27	26	80	25	50	0.00	0.00	0.00
263	25	227	210	100	110	1.83	0.23	0.24
264	228	229	52	100	110	0.00	0.00	0.00
265	24	25	82	100	110	8.00	1.02	1.43
266	25	228	104	100	110	3.54	0.45	0.40
267	228	226	210	100	110	0.91	0.12	0.06
268	226	227	104	100	110	-2.61	-0.33	0.23
269	227	28	82	100	110	-2.54	-0.32	0.17
270	28	207	183	150	110	0.00	0.00	0.00
272	225	230	185	100	110	-2.28	-0.29	0.32
273	230	34	162	100	110	-4.91	-0.63	1.00
274	230	231	194	100	110	0.88	0.11	0.06
275	35	232	88	37	100	0.00	0.00	0.00
276	30	224	122	100	110	6.51	0.83	1.45
277	224	225	335	100	110	4.75	0.60	2.23
278	224	223	68	25	50	0.00	0.00	0.00
279	32	221	140	100	110	1.76	0.22	0.15
280	31	219	98	150	110	2.64	0.15	0.03
281	219	218	104	150	110	0.00	0.00	0.00
282	219	220	93	100	110	0.88	0.11	0.03
283	29	222	90	100	110	0.00	0.00	0.00
284	22	119	5	50	100	10.74	5.47	5.26
285	72	71	203	200	120	60.99	1.94	4.43
286	21	141	12	200	110	4.90	0.16	0.00
287	124	159	20	100	110	6.00	0.76	0.20
288	125	160	20	100	110	6.03	0.77	0.21
289	126	163	20	100	110	5.71	0.73	0.19
290	165	37	20	100	110	0.00	0.00	0.00
291	172	38	20	100	110	0.00	0.00	0.00
292	131	176	20	100	110	7.18	0.91	0.29
293	148	177	5	150	110	24.54	1.39	0.10
301	44	45	435	200	120	15.60	0.50	0.76
302	45	301	8	100	100	2.36	0.30	0.02
303	301	302	2	50	120	2.36	1.20	0.09
304	302	303	120	100	110	1.19	0.15	0.06
305	45	304	814	200	120	13.24	0.42	1.05
306	304	305	47	200	100	9.72	0.31	0.05
307	305	306	2	200	120	9.06	0.29	0.27
308	306	307	184	200	100	9.06	0.29	0.16
309	307	308	10	50	100	3.54	1.80	1.35
310	307	309	107	200	100	5.52	0.18	0.04
311	309	310	311	200	110	5.52	0.18	0.09
312	310	616	165	100	110	0.88	0.11	0.05
313	310	311	194	200	120	2.00	0.06	0.01
314	311	312	130	200	120	10.45	0.33	0.11
315	311	514	82	200	100	-8.45	-0.27	0.06
316	85	87	183	150	120	14.94	0.85	1.20
405	1	601	1,812	200	110	49.68	1.58	31.80
406	404	405	91	490	90	166.11	0.88	0.28
407	405	501	2,073	250	110	166.11	3.38	114.72
501	501	502	1,010	300	110	340.71	4.82	87.00
502	502	503	500	300	130	24.75	0.35	0.25
505	505	506	108	200	110	0.00	0.00	0.00
506	506	507	244	100	110	-3.33	-0.42	0.84
507	507	508	65	200	110	41.95	1.34	0.83
508	508	509	215	200	110	29.76	0.95	1.46
509	509	510	1	150	120	29.76	1.68	37.65

NODE TABLE				
INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
302	16.00	1.17	712	88.7
303	8.00	1.19	790	88.7
304	13.10	0.00	731	87.8
305	13.30	0.67	729	87.7
306	13.30	0.00	732	88.0
307	13.40	0.00	729	87.9
308	12.00	3.54	730	86.5
309	3.80	0.00	823	87.8
310	23.80	2.64	626	87.7
311	16.60	0.00	696	87.7
312	18.00	0.00	682	87.6
401	189.00	0.00	0	189.0
404	360.00	0.00	0	360.1
405	352.00	0.00	76	359.8
501	245.00	0.00	0	245.1
502	158.00	0.00	0	158.1
503	126.00	0.00	311	157.8
505	92.00	0.00	364	129.2
506	96.00	1.76	325	129.2
507	90.00	1.76	392	130.0
508	77.00	0.88	511	129.2
509	58.00	0.00	683	127.7
510	58.00	0.00	314	90.1
511	57.00	0.00	321	89.8
512	44.04	4.39	444	89.4
513	30.00	1.15	572	88.4
514	22.00	3.47	644	87.8
515	25.00	0.00	614	87.7
516	29.00	0.88	575	87.7
517	78.86	1.76	493	129.2
518	75.00	1.76	530	129.2
519	62.00	0.00	648	128.2
520	69.00	2.43	577	128.0
521	72.00	1.67	546	127.8
522	51.00	0.88	359	87.7
523	52.00	2.64	349	87.7
524	52.00	0.00	368	89.6
525	56.00	0.00	330	89.7
526	61.00	0.00	281	89.7
527	51.00	2.64	378	89.6
528	36.66	2.64	517	89.5
529	34.36	0.88	540	89.5
530	64.00	3.51	638	129.2
531	74.00	0.00	540	129.2
532	100.00	2.64	293	129.9
533	34.00	1.76	525	87.7
534	52.00	0.00	744	128.0
535	66.00	1.76	618	129.1
601	128.00	0.00	198	148.2
604	92.00	0.00	637	157.1
605	83.00	3.43	720	156.5
606	82.00	3.43	718	155.4
607	77.21	3.43	764	155.2
608	52.00	1.76	314	84.0
609	55.50	0.00	280	84.0
613	32.26	0.92	507	84.0
614	25.30	1.76	576	84.1
615	19.00	5.27	668	87.2
616	18.00	0.88	682	87.7
617	99.00	3.43	552	155.4
618	103.00	4.29	518	155.9
619	107.00	1.71	472	155.2
620	103.00	3.43	511	155.2
621	106.00	6.00	479	154.9
622	96.00	3.43	576	154.8
623	95.00	3.43	588	155.1
627	78.86	0.00	760	156.5
628	14.00	1.76	714	86.9
629	10.00	0.88	725	84.0
630	102.00	1.71	525	155.6
800	62.00	0.00	571	120.3
801	59.00	1.76	600	120.3
802	47.00	1.76	718	120.3
803	85.00	1.76	433	129.2
804	85.00	4.39	432	129.2
805	84.00	5.27	421	127.0
806	84.00	0.00	421	127.0
807	53.00	3.51	318	85.4

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand 518.10 l/s
Demand South 48.02 l/s
Population 18,000

PIPE TABLE

INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
510	510	511	42	200	110	29.76	0.95	0.29
511	511	512	143	200	110	17.82	0.57	0.38
512	512	513	119	150	110	15.71	0.89	1.01
513	513	514	85	150	110	14.56	0.82	0.62
514	514	515	96	150	110	2.64	0.15	0.03
515	515	516	91	150	110	0.88	0.05	0.00
516	515	533	82	100	110	1.76	0.22	0.09
517	506	517	110	150	110	1.57	0.09	0.01
518	517	518	209	200	110	-0.18	-0.01	0.00
519	518	519	192	100	110	4.10	0.52	0.97
520	519	520	313	150	110	4.10	0.23	0.22
521	520	521	183	100	110	1.67	0.21	0.18
522	- 520	534	222	150	110	0.00	0.00	0.00
523	523	522	67	100	110	0.88	0.11	0.02
524	523	524	510	100	110	-3.51	-0.45	1.94
525	524	525	30	150	110	-5.79	-0.33	0.04
526	524	512	130	100	110	2.28	0.29	0.22
527	525	526	70	150	110	0.00	0.00	0.00
528	507	532	290	150	110	2.64	0.15	0.09
529	511	525	12	100	110	5.79	0.74	0.12
530	511	527	105	150	110	6.15	0.35	0.16
531	527	528	256	150	110	3.51	0.20	0.14
532	528	529	106	150	110	0.88	0.05	0.00
533	530	535	160	150	110	1.76	0.10	0.02
535	530	531	102	150	110	0.00	0.00	0.00
536	508	518	53	200	110	6.04	0.19	0.02
604	503	604	155	200	110	24.75	0.79	0.75
605	604	605	114	200	110	24.75	0.79	0.55
606	836	606	200	200	110	11.03	0.35	0.22
607	606	607	213	200	110	8.20	0.26	0.13
608	843	608	225	200	110	5.40	0.17	0.06
609	608	609	115	200	110	0.00	0.00	0.00
614	613	614	305	100	110	-0.79	-0.10	0.07
615	614	615	855	100	110	-3.42	-0.44	3.09
616	312	615	15	100	110	10.45	1.33	0.43
617	627	517	1	200	100	0.00	0.00	0.00
618	605	627	130	200	110	0.00	0.00	0.00
619	606	617	205	100	110	-0.60	-0.08	0.03
620	617	618	55	100	110	-5.75	-0.73	0.52
621	617	619	137	100	110	1.72	0.22	0.14
622	607	630	433	100	110	-1.63	-0.21	0.40
623	620	621	102	150	120	9.43	0.53	0.29
624	621	622	160	150	120	3.43	0.19	0.07
625	620	623	160	150	120	3.43	0.19	0.07
626	608	847	178	200	110	0.00	0.00	0.00
629	614	629	120	100	110	0.88	0.11	0.04
630	615	628	245	100	110	1.76	0.22	0.26
631	630	620	60	150	120	16.29	0.92	0.46
800	86	88	148	150	120	20.84	1.18	1.80
801	104	800	54	200	120	3.51	0.11	0.01
802	800	801	57	150	120	1.76	0.10	0.01
803	800	802	136	200	120	1.76	0.06	0.00
804	80	803	30	250	120	68.57	1.40	0.27
805	803	804	175	250	120	4.39	0.09	0.01
806	803	805	95	200	120	62.42	1.99	2.17
807	805	806	23	200	120	0.00	0.00	0.00
808	805	97	140	200	120	57.15	1.82	2.71
809	807	808	176	150	120	0.88	0.05	0.01
810	807	225	105	100	120	-4.39	-0.56	0.51
811	83	844	247	150	120	0.64	0.04	0.00
812	809	72	86	350	120	248.39	2.58	1.66
813	98	810	55	200	120	44.45	1.42	0.67
814	810	811	45	200	120	11.95	0.38	0.05
815	811	812	43	200	120	1.76	0.06	0.00
816	811	813	96	200	120	10.19	0.32	0.15
817	813	814	79	150	120	2.64	0.15	0.02
818	814	815	64	150	120	1.76	0.10	0.01
819	814	139	63	150	120	0.00	0.00	0.00
820	89	816	37	200	120	62.31	1.98	0.84
821	816	817	83	200	120	57.91	1.84	1.65
822	817	818	142	200	120	56.16	1.79	2.66
823	818	93	114	150	120	56.74	3.21	8.84
824	817	819	56	150	120	0.00	0.00	0.00
825	816	820	175	150	120	2.64	0.15	0.05
826	101	821	50	100	120	2.64	0.34	0.10
827	101	822	50	200	120	2.64	0.08	0.00
828	824	823	112	75	120	0.00	0.00	0.00

NODE TABLE

INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m
808	54.00	0.88	308	85.4
809	107.00	0.00	511	159.2
810	81.00	0.00	413	123.2
811	77.00	0.00	452	123.1
812	78.00	1.76	442	123.1
813	70.00	0.00	519	123.0
814	68.00	0.88	538	123.0
815	72.00	1.76	499	123.0
816	95.00	1.76	512	147.3
817	99.00	1.76	457	145.7
818	102.00	1.76	402	143.0
819	96.00	0.00	487	145.7
820	95.00	1.76	512	147.3
821	77.00	2.64	427	120.6
822	75.00	2.64	448	120.7
823	91.00	0.00	367	128.5
824	94.00	0.00	338	128.5
825	95.00	4.39	328	128.5
826	85.00	0.00	377	123.5
827	84.00	0.88	387	123.5
828	83.00	0.88	384	122.3
829	86.00	0.00	355	122.3
830	109.00	0.88	475	157.5
831	105.00	1.76	514	157.5
832	34.00	1.76	490	84.0
833	12.00	1.76	705	84.0
834	12.00	0.00	705	84.0
835	12.00	0.00	705	84.0
836	87.00	3.43	671	155.6
837	92.00	3.43	622	155.5
838	98.00	0.00	563	155.5
839	115.00	3.43	397	155.5
840	116.00	0.00	387	155.5
841	110.00	0.00	446	155.5
842	70.00	0.00	834	155.2
843	70.00	0.00	138	84.1
844	105.00	1.76	468	152.8
845	105.00	0.00	468	152.8
846	52.00	0.00	314	84.0
847	38.00	0.00	451	84.0
848	38.00	0.50	452	84.1
849	34.00	0.50	491	84.1
900	115.00	0.00	402	156.0

Town of Ladysmith (New Pressure Zones)
Peak Hour Demand
7-Feb-95
File: PZ18P

Total Demand 518.10 l/s
Demand South 48.02 l/s
Population 18,000

PIPE TABLE								
INPUT						OUTPUT		
Pipe	UpNode	DnNode	Length m	Diameter mm	Roughness	Flow l/s	Velocity m/s	HeadLoss m
829	824	823	57	75	120	0.00	0.00	0.00
830	825	824	36	150	120	0.00	0.00	0.00
831	825	7	152	150	120	12.31	0.70	0.70
832	16	826	42	200	120	41.25	1.31	0.44
833	826	827	71	150	120	0.88	0.05	0.00
834	829	828	70	150	120	0.88	0.05	0.00
835	829	136	12	200	120	-24.98	-0.80	0.05
836	84	830	114	200	120	0.88	0.03	0.00
837	84	831	128	200	120	1.76	0.06	0.00
838	832	613	60	200	120	-3.51	-0.11	0.01
839	832	833	214	200	120	1.76	0.06	0.01
840	833	834	45	200	120	0.00	0.00	0.00
841	833	835	50	200	120	0.00	0.00	0.00
842	605	836	300	200	120	21.32	0.68	0.94
843	836	837	68	200	120	6.86	0.22	0.03
844	837	838	40	200	120	0.00	0.00	0.00
845	837	839	212	200	120	3.43	0.11	0.02
846	839	840	21	200	120	0.00	0.00	0.00
847	839	841	58	200	120	0.00	0.00	0.00
848	842	843	5	200	120	6.40	0.20	71.08
849	607	842	90	200	120	6.40	0.20	0.03
850	846	613	220	200	120	3.64	0.12	0.03
851	83	844	90	150	120	1.11	0.06	0.00
852	844	845	50	150	120	0.00	0.00	0.00
853	608	846	86	200	120	3.64	0.12	0.01
854	843	848	125	200	120	1.00	0.03	0.00
855	848	849	525	200	120	0.50	0.02	0.00
900	601	507	155	200	140	49.68	1.58	18.19
901	820	96	80	200	140	0.88	0.03	0.00
902	508	530	140	200	140	5.27	0.17	0.02
903	502	900	470	200	140	29.67	0.94	2.03
904	900	618	200	200	140	10.03	0.32	0.12
905	900	630	200	200	140	19.64	0.63	0.40
1000	401	1	1,600	450	140	288.59	1.81	9.00

NODE TABLE				
INPUT			OUTPUT	
Node	Elevation m	Demand l/s	Pressure kPa	HGL m

PUMPED SOURCES TABLE

INPUT				OUTPUT	
Node	Pumps	OpCurve	Estimate	Actual	Inflow l/s
1	1	Pump1	-1.40	0.34	-175.09
401	1	Pump1	2	0.56	-288.59
404	1	Pump1	1.4	0.32	-166.11
501	1	Pump1	1.4	0.34	-174.61
502	1	Pump1	-2	-0.55	286.30

REDUCING (PRV) TABLE

INPUT					OUTPUT	
Pipe	Source	Pressure kPa	OpenK m	CKV	PRVLoss kPa	CKVState
5	1	421.51	0.00	Yes	19.15	Open
28	1	304.11	0.00	Yes	32.17	Open
39	1	421.83	0.00	Yes	22.82	Open
45	1	304.60	0.00	Yes	23.81	Open
146	1	421.83	0.00	Yes	17.70	Open
153	1	392.40	0.00	Yes	0.00	Open
163	1	304.11	0.00	Yes	22.64	Open
211	1	476.37	0.00	Yes	15.05	Open
216	1	427.72	0.00	Yes	20.61	Open
509	1	313.92	0.00	Yes	37.63	Open
617	502	413.66	0.00	Yes	36.50	Closed
848	502	137.89	0.00	Yes	71.08	Open
900	1	392.40	0.00	Yes	16.45	Open

APPENDIX E

REPORT BY EBA ENGINEERING LTD

EBA Engineering Ltd.

KOERS & ASSOCIATES ENGINEERING LTD.
PO Box 1289
182 Memorial Avenue
Parksville, BC V9P 2H3

October 12, 1994
File No: 0802-82491

ATTENTION: **Norm Winton, P.Eng.**

Ladysmith Water Resource Study — Water Retention Structures

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. (EBA) were commissioned to undertake an assessment of existing earthfill retention structures and to provide comments on the geotechnical aspects of options for increasing reservoir capacity.

This letter report presents the results of the study and gives recommendations for future work.

2.0 DATA COLLECTION

During the study, the following documents were made available to EBA:

Thurber Consultants Ltd., October 1978
"Holland Lake Reservoir — Geotechnical Investigation"

Willis Cunliffe Tait & Company Ltd., 1979
"Town of Ladysmith, Holland Lake Reservoir,
Earthfill Dam and Appurtenances — Contract Documents"

Willis Cunliffe Tait & Company Ltd., December 1980
"Town of Ladysmith, Holland Lake Reservoir. As Built Drawings"
Sheets 1 through 7.

BC Ministry of Environment, October 1982
"Conditional Water License 50156 — Holland Lake Dams"

BC Ministry of Environment, February 1985
"Instrumentation Analysis — Holland Lake Dam"

BC Ministry of Environment, October 1991
"Holland Lake Dam — Dam Inspection Report"

#1 - 4376 Boban Drive, Nanaimo, B.C. V9T 5V1
• Telephone (604) 756-2256 • FAX (604) 756-2686 •

BC Ministry of Forests, 1:10,000 Scale Topographic Map
"Stocking Lake — Holland Creek Watershed Project"

On September 20, 1994, an EBA senior geotechnical engineer accompanied Norm Winton. P.Eng., of Koers & Associates Engineering Ltd. and personnel from the Town of Ladysmith to the Holland Lake Dam.

3.0 HOLLAND LAKE DAM

3.1 History

In 1978, a study was undertaken to assess options for increasing the capacity of the water supply to Ladysmith. At that time, there were 2 low embankments which formed Upper and Lower Holland Lakes located in a saddle between the Holland Creek catchment area and the Banon Creek catchment. These lakes diverted runoff from North Banon Creek to Holland Creek.

Two new embankments were constructed in 1980 to form one large lake. The east dam has a crest length of about 915m and the west about 460m. The average height of the embankments is 4.6m and the maximum height at centerline is 7.6m.

A positive cutoff was formed below the dam between the dam fill and the underlying glacial till. This till was borrowed locally for use as embankment fill.

The impervious zone of the dam has a 3 horizontal to 1 vertical (3H:1V) upstream slope, a 6m crest width and a 2H:1V downstream slope. A cutoff extends below the crest a minimum of 2m into glacial till.

The upstream slope is armoured with rip-rap which rests on bedding gravel. The crest has a 0.5m thickness of road topping.

The downstream slope is flattened to 4H:1V with silty, sandy gravel with a maximum fines content of 20%.

There is an inlet to the dam from North Banon Creek near the south abutment of the east embankment.

A low level outlet at the central area of the west abutment releases water into Holland Creek. There is an overflow spillway near the south abutment of the west embankment.

3.2 Condition

Monitoring of piezometric levels in the embankment fill was carried out until 1985 by the Ministry of Environment. This data indicates that the water level in the impervious zone is near that of the reservoir water level.

The following observations were made during the September 20, 1994:

- The upstream slopes of both embankments appear in good condition. There were no signs of subsidence, beaching or degradation of the rip-rap.
- Alder trees were growing near the top of the upstream slope.
- The crest was in good condition with no areas of subsidence, rutting or erosion evident.
- The downstream slopes had many areas covered in alder trees and thus were difficult to observe. The areas which were visible were grassed and no seepage was apparent.
- At the toe of the downstream slope of both embankments, there are signs of seepage. It appears a swale was formed in this area during surface preparation and it serves to channel surface water and seepage flows. No evidence or migration of fines from the embankment was found.
- The concrete of the overflow spillway and the outlet of the discharge from North Banon Creek and the low level conduit appeared to be in good condition.

The Town of Ladysmith was sending a crew to Holland Lake during September to remove the alders from the embankments.

3.3 Discussion

The two embankments appear to be performing satisfactorily. Efforts should be made to remove the alder growth on a yearly basis.

4.0 PREVOST LAKE DAM

This dam was not visited due to difficult access. It is understood that the dam is a low embankment constructed during logging operations. The outlet is left open and the reservoir is thus not deep and has significant vegetation growing in it.

It is understood that the road to this area may be upgraded in the near future.

5.0 INCREASING RESERVOIR CAPACITY

5.1 General

The Town of Ladysmith has determined that increased water supply is necessary. Several options are being assessed to provide the additional capacity. Those relevant to the EBA portion of the study include the following:

- Increasing the reservoir capacity at Holland Lake;
- Increasing the reservoir capacity at Prevost Lake; and
- Constructing an embankment to form a new reservoir.

5.2 Holland Lake

The capacity of Holland Lake can be increased by dredging the existing lake bottom and/or raising the embankment.

The cost of removal of the material from within the reservoir compared to the gain in capacity would likely render this option uneconomical. If the excavated material could be used in raising the embankment, this would reduce the cost of dredging. However, the original tender drawings did not identify any potential borrow within the reservoir area. This may indicate that the soils are unsuitable or discontinuous.

Therefore, without doing additional investigations, it does not appear that dredging is a feasible option for increasing the reservoir capacity.

The existing embankments have performed well since their construction in 1980. EBA carried out and assessment of the stability of the highest section of the dam to determine if raising the embankments was possible. A high piezometer level was assumed in the impervious zone based on the MoE data and also in the downstream zone due to the possible high fines content (up to 20%). This resulted in a Factor of Safety (F of S) against failure of the downstream shell of 1.52. The normally accepted value for these conditions is 1.5.

The increase in the embankment height was modelled by continuing the 3H:1V upstream slope up 1m (measured vertically), extending the core and using a 3H:1V upper slope downstream of the crest. This reduced the F of S to 1.3 which is below that normally acceptable. This F of S could be increased by flattening the downstream slope and/or provide increased drainage to reduce the water level in the downstream shell.

These measures would also be needed to ensure the stability under seismic loading was adequate.

Based on our preliminary assessment, it appears that raising the embankments 1m would be possible. An investigation would be required to more accurately determine the piezometric level in and under the embankment. This could be accomplished by monitoring the existing piezometers and possibly newly installed ones. As well, a series of test holes in the downstream shell would be necessary to access the permeability of the silty, sandy gravel zone. This may be supplemented by construction records if grain size analyses were carried out.

If the embankment was raised, the inlet to the overflow spillway would have to be raised as would controls for the low level conduit.

A preliminary estimate of the cost of raising these embankments has been completed and totals $2,200,000.00. This figure does not include the cost of upgrading the access road to Holland Lake.

Diversion form North Banon Creek would be necessary to fill this reservoir as the catchment area for Holland Lake is small.

5.3 Prevost Lake

Based on the available topography, it appears that this embankment could be raised or reconstructed to a higher level to increase the capacity of this lake.

This would require that the access road be upgraded.

The catchment area for this lake is of limited size and monitoring of precipitation is recommended if this option is being considered. There does not appear to be a possibility of diversion from another catchment area into this lake.

5.4 New Embankment

The available topography was used to assess the possibility of constructing an embankment to create a new reservoir. Two locations were identified:

- Near the confluence of the two main branches of Holland Creek; and
- Near the Chicken Ladder intake structure.

A reservoir just downstream of the confluence on Holland Creek would have to be over 1km in length and at least 30m high to create a reservoir similar in area to Holland Lake. This reservoir would be fed by a large catchment area and its location may allow the discharge to be piped to the Town distribution system.

There is currently no access to this area, therefore a road approximately 2km long would have to be upgraded.

The Holland Creek valley becomes very narrow and the gradient increases near the Chicken Ladder intake structure. This renders the potential reservoir capacity small in relation to the height of dam required.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the available data and our observations, the existing embankments at Holland Lake are performing well. The alders on the slopes and crest should be removed and the seepage at the downstream toe monitored to ensure migration of fines from the embankment is not occurring.

A preliminary assessment indicated that these embankments would be raised, although it may be necessary to upgrade internal drainage systems.

Further site investigation to determine the actual composition of the fill and foundation as well as the piezometer levels would be necessary prior to undertaking a more detailed analysis.

The available topography indicates that Prevost Lake may be a suitable site for raising the reservoir level. Information on precipitation in the catchment area, the costs for upgrading access roads and the availability of construction materials at the site will be necessary to accurately assess this feasibility.

A possible dam site downstream of the confluence of the two main branches of Holland Creek has been identified. This area has the advantage of a large catchment as well as close proximity to the inlet to the Town water supply. The required length and height of dam may render this option uneconomical.

No other location in the Holland Creek watershed appears to provide a potential reservoir site.

7.0 CLOSURE

The comments and recommendations made are based on the data provided and observations made at Holland Lake Dam. Analyses carried out must be considered preliminary in nature due to the lack of specific soil and groundwater data.

EBA trusts the above is sufficient for the purposes of the Water Resource Study at this time. Should additional information be required, please contact Bob Patrick at 756-2256.

Yours truly

EBA ENGINEERING CONSULTANTS LTD.

R.A. Patrick, M.Sc., P.Eng.

Reviewed by:

R.L. Kennett, P.Eng.

smo

APPENDIX F

REPORT BY PACIFIC HYDROLOGY CONSULTANTS LTD

Project Number K701105

HYDROGEOLOGICAL EVALUATION OF GROUNDWATER SUPPLY POTENTIAL IN THE LADYSMITH AREA OF VANCOUVER ISLAND, B.C.

Prepared for

KOERS & ASSOCIATES ENGINEERING LTD.
182 Memorial Avenue
P.O. Box 1289
PARKSVILLE, B.C. V9P 2H3

Prepared by

PACIFIC HYDROLOGY CONSULTANTS LTD.
330 - 580 Hornby Street
VANCOUVER, B.C. V6C 3B6

NOVEMBER 9, 1994

PACIFIC HYDROLOGY CONSULTANTS LTD. Consulting Hydrogeologists
Suite 330, 580 Hornby Street, Vancouver, B.C., Canada V6C 3B6
Phone: (604) 683-9612 Fax: (604) 683-9676

Project No. K701105

November 9, 1994

Koers & Associates Engineering Ltd.
182 Memorial Avenue
P.O. Box 1289
PARKSVILLE, B.C. V9P 2H3

Attention: Mr. Norman Winton, P. Eng.

Subject: **Hydrogeological Evaluation of Groundwater Supply Potential in the Ladysmith Area of Vancouver Island, B.C.**

Dear Sirs:

We are herewith submitting our report covering our evaluation of hydrogeological conditions in the Ladysmith area as they affect the feasibility of developing a supply of groundwater for the Town.

We trust that the report meets your expectations and provides the information required at this time for making a decision about proceeding further to confirm and/or explore the groundwater resources of several potential aquifers. We would be pleased to further discuss any aspect of the report and please do not hesitate to contact either of the undersigned or Ed Livingston, P. Eng., Associate Consultant for further discussion of any aspect of the contents.

Yours truly,
PACIFIC HYDROLOGY CONSULTANTS LTD.

Joseph T. Arengi, M.Sc., P. Geo.
Hydrogeologist

Reviewed by
Ann Badry, P. Geo.
Hydrogeologist and Manager

PROFESSIONAL PROVINCE OF A. M. BADRY BRITISH COLUMBIA GEOSCIENTIST
11/10/94

HYDROGEOLOGICAL EVALUATION OF GROUNDWATER SUPPLY POTENTIAL IN THE LADYSMITH AREA OF VANCOUVER ISLAND, B.C.

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EXECUTIVE SUMMARY

An hydrogeological investigation was carried out by Pacific Hydrology Consultants Ltd. in the Ladysmith area on Vancouver Island, B.C. in order to evaluate the feasibility of developing a satisfactory source of groundwater for the Town of Ladysmith. The study area was defined as the economic limit for a water supply source for connection to the existing water supply system at Ladysmith.

The hydrogeological evaluation shows that the Cassidy Aquifer, a complex aquifer system consisting of a sequence of interbedded sand and sand and gravel, represents a known aquifer with considerable potential. Several high capacity wells which exceed 44.2 *l*/sec (700 USgpm) have been successfully completed in this Aquifer. Other lower priority, and higher risk potential aquifers, include permeable zones within thick sections of sand and/or gravel along Rocky Creek and the Davis Lagoon area.

Experience in the subject Ladysmith area indicates that a sufficient quantity of good quality groundwater can almost certainly be developed from the Cassidy Aquifer; however, test-production drilling to confirm local conditions may be required. The estimated minimum cost for a successful groundwater exploration/development program, in which three 150 mm (6") diameter test wells are drilled to locate favourable conditions followed by completion of a 400 mm (16") diameter production well in the Cassidy Aquifer, is $57,800. The maximum cost of a groundwater exploration program, in which three unsuccessful 200 mm (8") diameter test wells are drilled in each of the Rocky Creek and Davis Lagoon areas, followed by a successful program in the Cassidy Aquifer, is estimated to be $107,600.

1.0 INTRODUCTION

1.1 Purpose and Scope

Pacific Hydrology Consultants Ltd. (PHCL) was authorized by Koers & Associates Engineering Ltd. (KAEL) in a letter dated June 28, 1994 to proceed with an evaluation of the feasibility of developing a groundwater source for the Town of Ladysmith on Vancouver Island, B.C. The study area is defined as the economic limit for a water source, taken as the area within a 4.8 km (3 mile) radius of the Town as discussed in an internal B.C. Ministry of Environment (BCMOE), Groundwater Section Memorandum dated September 14, 1976 to J.C. Foweraker from A.P. Kohut regarding a "Ladysmith Groundwater Study". As instructed by KAEL, the study area has been modified to exclude the area northeast of Ladysmith Harbour and to include the area south of Nanaimo Airport.

1.2 Background

On the basis of discussions in June 1994 between David Shillabeer, P. Eng., and/or Norman Winton, P. Eng., of KAEL, and Ann Badry, P. Geo., Hydrogeologist/Manager of PHCL, as well as to later discussions between Norman Winton (KAEL) and Joseph Arengi, P. Geo., Hydrogeologist of PHCL, following a site visit by Ed Livingston, P. Eng. (PHCL), and Joseph Arengi on August 30, 1994, the situation concerning the groundwater supply potential study for the Town of Ladysmith was understood to be as follows:

1. The required capacity for a groundwater source is 88 *l*/sec (1390 USgpm; 1160 igpm).
2. The study is to be carried out in the area within the modified "economic limit for a water source" discussed in Section 1.1.

Along with the field reconnaissance by Arengi and Livingston mentioned above, the following published and unpublished maps and reports were considered in preparation of this report:

1. Geological Survey of Canada Paper 65-24, **Surficial Geology of Duncan and Shawnigan Map - Areas, British Columbia**, by E.C. Halstead, 1966, 3 pp.

2. A report by PHCL titled "Completion Report Construction and Testing of a Fire Protection Well at the Nanaimo Airport Air Terminal Complex for Public Works (Air Transportation Sector)", dated August 24, 1990, 10 pp.

3. A report by PHCL titled "Completion Report Construction and Testing of a 200 mm (8") Diameter Test-Production Well South of the Nanaimo (Cassidy Airport)", dated January 15, 1987, 16 pp.

4. N.T.S. Topographic Maps 92B/13, **Duncan** and 92 G/4, **Nanaimo**, both of scale 1:50,000 and with contour intervals of 20 metres.

5. Aerial photographs Roll BC7408, No.'s. 033 to 039.

6. B.C. Ministry of Agriculture and Food Report titled "Regional Groundwater Potential for Supply Irrigation Water: 1985 Duncan to Nanoose Bay", by K.D. Ronneseth, 1985, 21 pp.

7. B.C. Ministry of Environment, Lands and Parks, various unpublished reports, memorandums and maps - in particular, the following:
   - An internal B.C. Ministry of Environment, Groundwater Section Memorandum from A.P. Kohut, Senior Geological Engineer, Groundwater Section, to J.C. Foweraker, Head, Groundwater Section, dated September 14, 1976, File 0239013, on the subject "Ladysmith Groundwater Study".
   - An internal B.C. Ministry of Environment, Water Investigation Branch Memorandum, from A.Kohut, Senior Geological Engineer, Groundwater Section, to Dr. J.C. Foweraker, Head, Groundwater Section, dated April 20, 1979, File 92G4 #26, "Re: Cowichan Valley Regional District - North Oyster Diamond Settlement Plan - Cassidy Aquifer".

8. B.C. Ministry of Environment, Lands and Parks Water Well Location Maps, Bright District 23, Sheet 1; Oyster District 22 (North), Sheet 1; and Oyster District 22 (South), Sheet 2; of scales 1" = 1000' with contour intervals of 50 ft.

9. "Petrologic Evolution and Paleogeography of the Late Cretaceous Nanaimo Basin, Washington and British Columbia; Implications for Cretaceous Tectonics"; by J.A. Pacht, 1984, in **Geological Society of America Bulletin**, Vol. 95, 766 - 778 pp.

The area and well location map is shown on Figure 1 in Appendix A (Page A - 1), and details for selected wells are provided in Table 1 in Appendix B (Pages B - 1 to B - 6).

1.3 Acknowledgement

Numerous unpublished maps, reports, memorandum and aerial photographs of the study area were loaned by Groundwater Section of B.C. Environment. The cooperation and assistance of Groundwater Section in providing this information was much appreciated.

2.0 GEOLOGY AND HYDROGEOLOGY

Bedrock in the Ladysmith area consists of interbedded siltstone, sandstone, conglomerate and minor coal of the Cretaceous-aged Nanaimo Group. Bedrock outcrop predominates in the area south and west of Ladysmith between Stocking Lake and north of Rocky Creek (Tyee Creek). Elsewhere bedrock is overlain by a variable thickness of unconsolidated sediments consisting mainly of marine and glaciomarine clay, silt, sand and stony clay; till, and lesser fluvial and glaciofluvial sand and gravel as shown on Geological Survey of Canada Map 14-1965, **Surficial Geology Duncan, British Columbia** (Background Reference No. 1, Section 1.2).

Driller's lithologs for wells drilled in the area show that the unconsolidated sediments are up to 66.2 m (217 ft) thick in the north part of the study area, south of the Nanaimo Airport within the area defined as the Cassidy Aquifer. Areas of thin overburden - <3 m (<10 ft) - occur between bedrock outcrop areas and as apparent isolated areas within the Town of Ladysmith and north and east to Ladysmith Harbour.

Groundwater originates as precipitation, snowmelt, and to a lesser extent, leakage from surface water in the uplands to the west and southwest as well as along the coastal plain between the uplands and Ladysmith Harbour. In the uplands, groundwater is conveyed mainly via interconnected saturated bedrock fractures which migrate via gravity flow toward lower elevations and discharge to surface water or provide recharge to aquifers within the unconsolidated sediments. Groundwater in the overburden also migrates via gravity flow and shallow groundwater may discharge as local springs or provide baseflow to creeks whereas deeper groundwater discharges into Ladysmith Harbour. Such groundwater discharge phenomena can be seen at the head of Ladysmith Harbour and is manifest in a public spring along the Island Highway north of Ladysmith.

A thick sequence of shallow and deep saturated permeable sand and sand and gravel, collectively referred to as the Cassidy Aquifer, occurs along the continuation of the northwest trend of Ladysmith Harbour. Figure 2 in Appendix A (Page A - 2) is a map of the interpreted boundary of the Cassidy Aquifer and Figure 3 (Page A - 3) is a map showing interpreted geology and favourable areas for development of substantial quantities of groundwater as required to supply the Town of Ladysmith. Figure 3 also shows the extent of bedrock and interpreted shallow overburden in the study area.

3.0 GROUNDWATER POTENTIAL

There are two potential sources of groundwater in the study area:

- saturated fractured bedrock;
- permeable zones within the unconsolidated sediments.

Experience in the area shows that saturated fractured bedrock is capable of providing well capacities suitable for individual domestic demands or several users but it is not considered to be an aquifer(s) favourable for developing the required capacity of 88 *l*/sec (1390 USgpm; 1160 igpm). An aquifer capable of yielding the required groundwater source is saturated permeable sediments - in particular, the Cassidy Aquifer, the Rocky Creek/Grouhel Road area, the Davis Lagoon area and the vicinity of the public spring along the Island Highway north of Ladysmith.

3.1 Cassidy Aquifer

Kohut (1979) has divided the Cassidy Aquifer into an Upper and Lower Aquifer in areas of thick overburden, i.e. >24 m (>80 ft). The aquifers are separated by 6 to 30 m (20 to 100 ft) of clay till; however, driller's lithologs of drilled wells within the Cassidy Aquifer which are provided in Table 1 (Pages B - 1 to B - 6) along with a map showing the interpreted distribution of the aquifer is provided in Figure 2 in Appendix A (Page A - 2). They indicate that these conditions are not present everywhere owing to lateral and vertical permeability contrasts. Most of the wells in the area obtain water from permeable saturated sand and gravel zones at a depth of 24 m (80 ft) or less. The high permeability of the saturated sediments and an aquifer thickness of 6 m (20 ft) or more results in a highly productive aquifer which is capable of yielding up to 86.4 *l*/sec (1370 USgpm) or more in the study area.

Of particular interest is Well 2 (see Table 1 in Appendix B); this well was a 200 mm (8") diameter well drilled for Pacific Aqua Foods Ltd. in 1986. PHCL rated the capacity of this well at 44 *l*/sec (700 USgpm) based on a 4000 minute pumping test. The well was not placed into production and the casing was located during the preliminary field reconnaissance. This well represents a proven source of groundwater. Another area within the Cassidy Aquifer considered favourable for developing the desired groundwater source capacity is along the head of Ladysmith Harbour where there is evidence of significant discharge. There is no subsurface information in this portion of the Aquifer consequently test drilling and testing is required to verify sufficient thickness and permeability.

3.2 Rocky Creek/Grouhel Road Area

Details of drilled wells in the area south of the Cassidy Aquifer are provided in Table 1 in Appendix B. This information, together with air photo interpretation and field observations has lead to the identification of an area of possible potential.

This area is shown on Figure 3 in Appendix A (Page A - 3).

Potential thick accumulations of the fluvial/glaciofluvial sediments are interpreted to be present in the lower reaches of Rocky Creek west of the Town of Ladysmith. There is a lack of subsurface information in the vicinity of the creek valley; however, from field observations - specifically, the hummocky terrain evident in the area - there are indications of thicknesses of overburden sediments of glacial origin. An exposure along the bank of an old gravel pit on the forest access road west of Rocky Creek shows crossbedded fine gravel overlain by till; and, an exposure along a road cut along a new bridge near the Rocky Creek area shows varved clay with dropstones overlain by till. Bedrock outcrop was observed along the forest access road north of Rocky Creek where the road curves to the west and west of the junction of Cristie Road and Pictou Road. Well 13 on Table 1 is located in this area; it encountered bedrock at 7.6 m (25 ft).

3.3 Davis Lagoon Area

Water Well records for two wells, (Wells 15 and 16 in Table 1, Appendix B) indicate up to 37.2 m (122 ft) of unconsolidated sediments. Well 15 is actually two wells which have subsequently been abandoned. Both wells intersected significant thickness of favourable sand and gravel. Of particular interest is Well 16 which intersected at least 5.2 m (17.0 ft) of sand and ended in coarse sand and gravel. Although these wells have driller estimated capacities of less than 1.9 *l*/sec (30 USgpm), the favourable conditions warrant exploration drilling to better evaluate whether there are permeable horizons capable of yielding the required capacity.

3.4 Island Highway Public Spring

Although there is evidence of significant groundwater discharge in the area, it is doubtful that the required capacity can be developed and therefore further consideration of this source is not recommended.

4.0 GROUNDWATER QUALITY

Groundwater samples from 20 drilled wells collected at various depths in the Cassidy Aquifer by A.P. Kohut (1976) indicate that the groundwater is soft and low in total dissolved solids. An analysis of groundwater from the Aquifer north of the study area which is provided in Table 3 in Appendix C (Page C - 1) indicates similar chemistry quality. The groundwater can be classified as a calcium + sodium/bicarbonate type.

There is no information with respect to groundwater quality from the other areas identified as having potential; however, there is no reason to anticipate poor groundwater quality in this large discharge area, although a higher mineralized component could be present in aquifers which are less permeable than the Cassidy Aquifer and in which groundwater travels at a much slower rate. Obviously, high capacity wells within coastal plain sediments near the saltwater/freshwater interface would require careful monitoring during testing to ensure that saltwater capture will not occur.

A possible concern in the Davis Lagoon area is the impact of existing development on groundwater quality. Possible sources of contamination include ground disposal of septic effluent in this unsewered area and hydrocarbons from industrial and residential sources. Information from two drilled wells in the area indicate the presence of a thick, low permeability till (hardpan, cemented sand and gravel) which would serve as a protective barrier from downward migrating contaminants. Although a deep aquifer would not likely be impacted from near-surface contaminants, it would be prudent to characterize groundwater quality in any test-production well prior to well development to determine if any contaminants are present. At the time of selection of sites for test-production drilling, issues should be addressed prior to drilling; these include:

- delineating a wellhead protection area;
- conducting an inventory in the wellhead protection area to ensure that there are no potential sources of contamination in the probable aquifer recharge area.

5.0 GROUNDWATER EXPLORATION

5.1 Objectives

The Cassidy Aquifer is considered to be the area with the greatest potential and lowest risk based on information from water wells in the area. The potential for completing a well(s) capable of meeting the required capacity of good quality water is considered very good. One of the main objectives of test drilling is to locate a well which will not cause any adverse impacts on water levels in surrounding wells as well as to characterize groundwater quality and define aquifer thickness. The obvious disadvantage is the distance to the existing Ladysmith water system and attendant high connection costs.

In the Rocky Creek/Grouhel Road area more detailed field work is required to locate suitable areas for exploratory drilling. Given the lack of subsurface information, this area has a considerably higher risk; even so, exploratory drilling of two or three test wells can be justified if warranted by system design. An obvious advantage to locating a production well(s) in this area is the proximity to the existing water system.

The Davis Lagoon area is also considered to be high risk; however, as with the Rocky Creek area because of the proximity to the existing water system and attendant cost saving, exploratory drilling of two or three test wells is likely warranted. A disadvantage of this area is accessability of well sites in this highly developed residential area.

The objective of test drilling in the Rocky Creek and Davis Lagoon areas will be to locate and define saturated permeable horizons which are capable of providing the required capacity as well as to characterize groundwater quality in areas where little information is known.

5.2 Test-Production Drilling and Testing

In order to complete the objectives for test-production drilling and to properly evaluate aquifer potential, as many as three 150 mm (6") diameter test wells may be required in the Cassidy Aquifer, and as many as three 200 mm (8") diameter test wells may be required in each of the Rocky Creek and Davis Lagoon areas, with depths as great as 45 m (150 ft). A 400 mm (16") diameter production well will be required to provide the required capacity of 88 l/sec (1390 USgpm; 1160 igpm) from a single well. Alternatively, a series of up to three 200 mm (8") diameter production wells could provide the required capacity, with successful 200 mm (8") diameter exploration wells retained as production wells.

As summarized in Table 4 in Appendix D, the estimated cost of a successful screened and tested 200 mm (8") diameter well drilled to a depth of 45 m (150 ft) is $22,000., or $44,000 for two such production wells. The estimated cost for a single 400 mm (16") diameter production well is $38,700., with an estimated "risk" cost of unsuccessful 200 mm (8") diameter test wells of about $9,000. each. As outlined in Table 4, these estimates do not include the cost of hydrogeological consulting services.

Estimated costs of hydrogeological consulting services are shown in Table 5 in Appendix D (Page D - 3). Such services are divided into groundwater exploration and evaluation/reporting. The former includes preparation of contract documents, supervision during well construction and pumping tests, sieve analyses, screen design and water quality analysis at a total estimated cost of $5,000. The latter includes data analysis, computer modelling, draft and final reports at a cost of $7,000., for a total estimated cost of hydrogeological consulting services of $12,000., assuming a maximum program of groundwater exploration as outlined.

The issue of water treatment has not been addressed in this report, as costs will depend on the type and concentration of the parameter to be treated. As noted in Section 4.0, the quality of groundwater in the Cassidy Aquifer is suitable for domestic use and there are no known quality problems that would require treatment.

6.0 CONCLUSIONS

Based on our evaluation of hydrogeological conditions in the Ladysmith area, we conclude the following with respect to groundwater supply potential, exploration and development in the area defined as being the economic limit for a water source to supply the Town of Ladysmith:

1. Hydrogeologic conditions in three parts of the study area are favourable for developing the desired source capacity of 88 *l*/sec (1390 USgpm; 1160 igpm) and test-production drilling to "prove up" the source can be justified.

2. The well-known Cassidy Aquifer is an obvious source but is the furthest from Ladysmith; other potential aquifers are permeable sand and gravel within the glaciofluvial sediments along Rocky Creek and permeable sand and/or gravel in coastal plain sediments near Davis Lagoon.

3. In regard to the Cassidy Aquifer, the objective is locate suitable conditions as close as possible to the existing or proposed water distribution system; additional detailed field work is required to locate drill sites in the Rocky Creek and Davis Lagoon areas. The exploration risks are higher at Rocky Creek and Davis Lagoon than at the Cassidy Aquifer. A disadvantage of the Davis Lagoon area is the accessibility of well sites in this highly developed residential area.

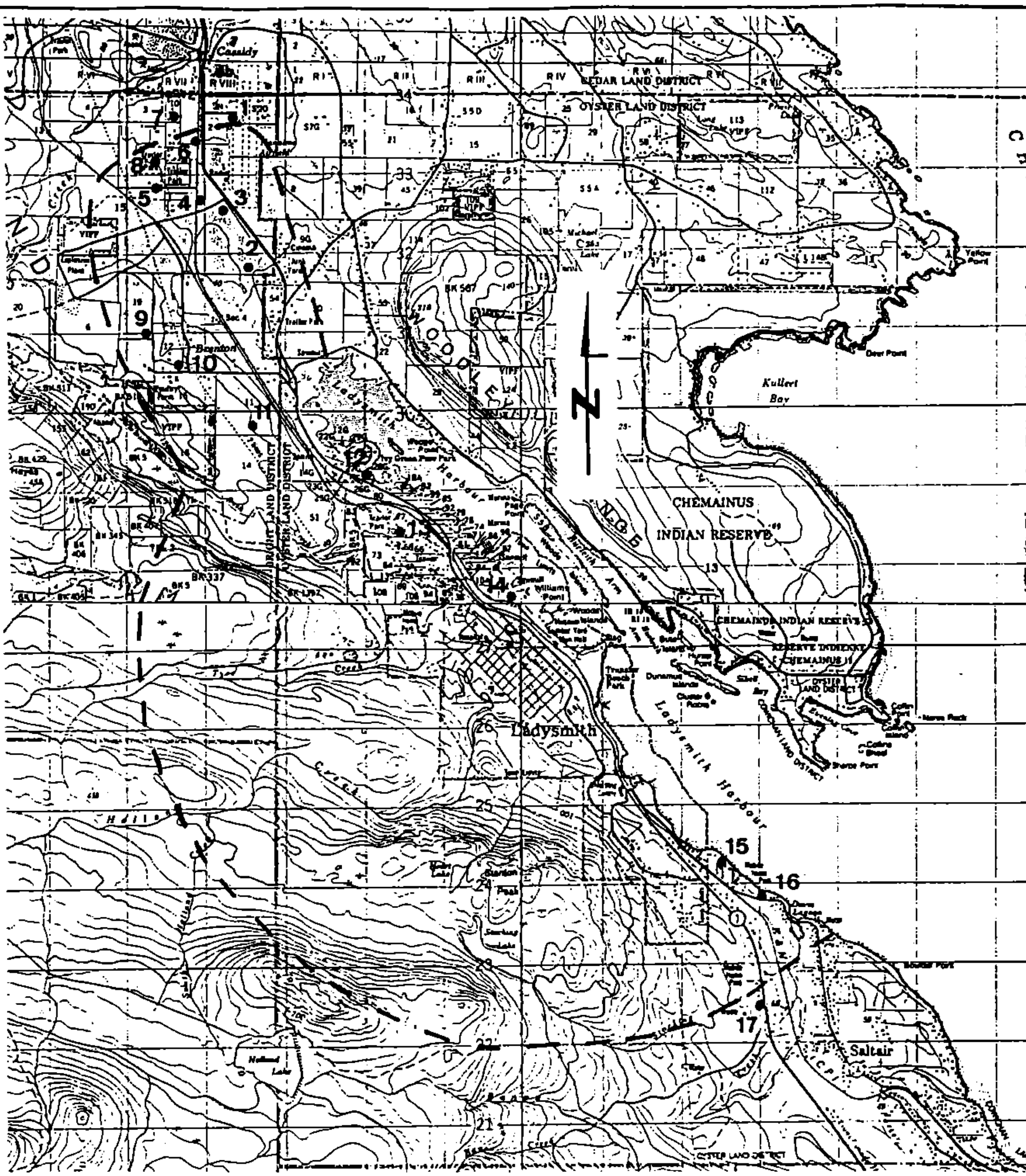
4. Under favourable aquifer conditions, up to three 200 mm (8") diameter drilled wells or a single 400 mm (16") diameter drill well will be capable of supplying the required 88 *l*/sec (1390 USgpm; 1160 igpm). Ideally, drilling should be carried out with a cable tool rig in order to facilitate optimum screen size selection and location, especially in the Rocky Creek and Davis Lagoon areas.

5. Groundwater in the Cassidy Aquifer and other potential aquifers to the south is anticipated to be of good quality for domestic consumption.

6. Groundwater exploration costs are somewhat uncertain in the Rocky Creek and Davis Lagoon areas due to lack of subsurface information. Table 4 in Appendix D reflects various scenarios of groundwater exploration and development. The cost of an unsuccessful groundwater exploration program in both Rocky Creek and Davis Lagoon, which are considered high risk, is $48,800. The cost of successful groundwater exploration and development in the relatively low-risk Cassidy Aquifer is $58,800. The estimated cost of hydrogeological consulting is $12,000.

APPENDIX A

AREA, WELL LOCATION, AND CASSIDY AQUIFER MAPS



Notes:

1. The base map is prepared from topographic maps N.T.S. 92B/13, **Duncan**, and 92G/4, **Nanaimo**, of scale 1:50,000 reduced to an approximate scale of 1:75,000 with contour intervals of 20 metres.
2. — — — outlines the aera of economic limit for groundwater supply.
3. • denotes unsurveyed location of a drilled well (see Table 1 in Appendix B).

PROJECT No: K701105

PROJECT:

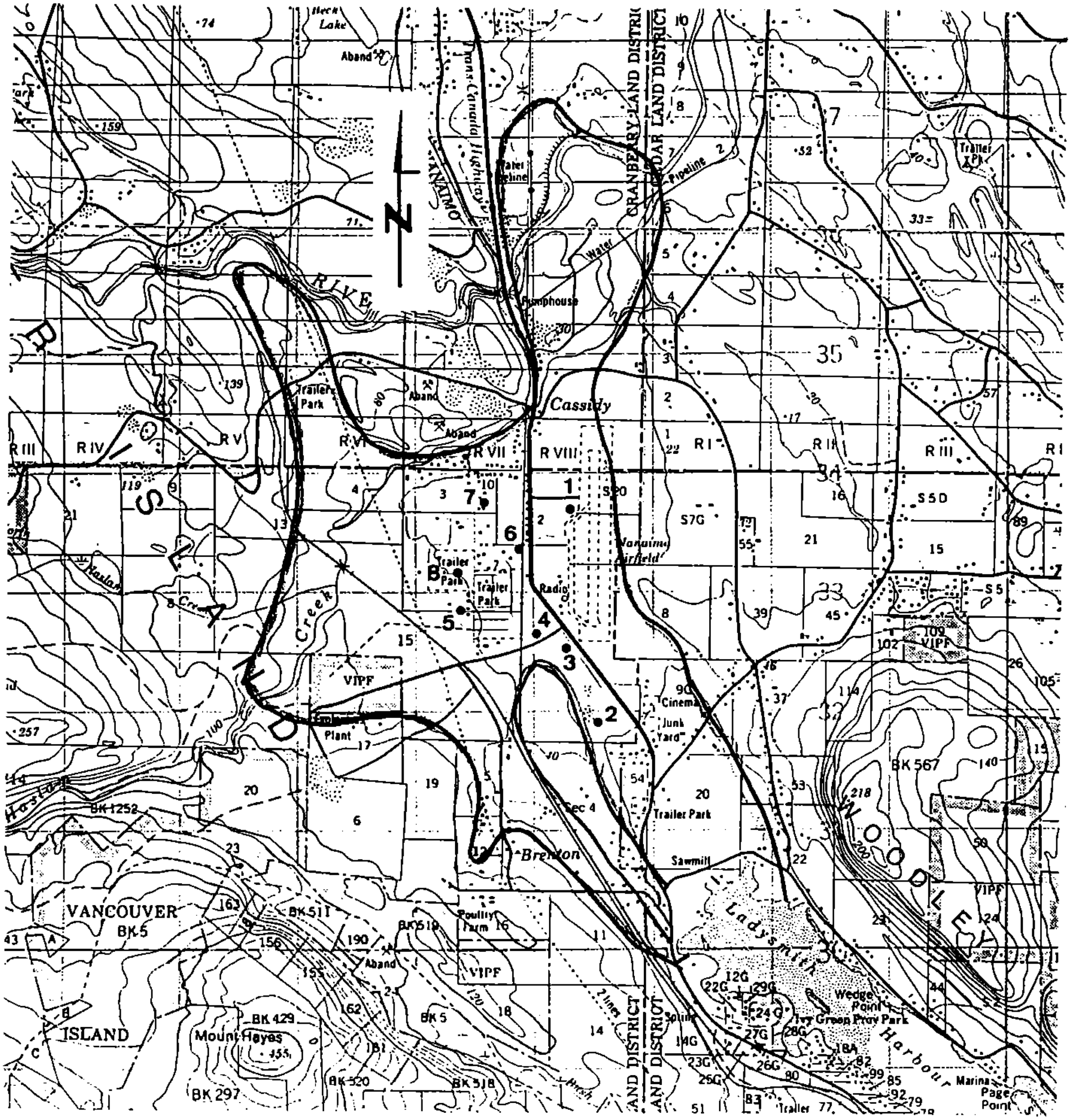
LADYSMITH GROUNDWATER POTENTIAL EVALUATION

LOCATION: Ladysmith, B.C.

PACIFIC HYDROLOGY CONSULTANTS LTD.
CONSULTING HYDROGEOLOGISTS

AREA AND WELL LOCATION MAP

DATE:	DRAWN BY:	FIGURE:
09/08/94	J.T.A.	1



Notes:

1. The base map is prepared from topographic map N.T.S. 92G/4, **Nanaimo**, of scale 1:50,000 with contour interval of 20 metres.
2. ▬▬ outlines the interpreted extent of the Cassidy Aquifer.
3. • denotes unsurveyed location of a drilled well (see Table 1 in Appendix B).

PROJECT No: K701105

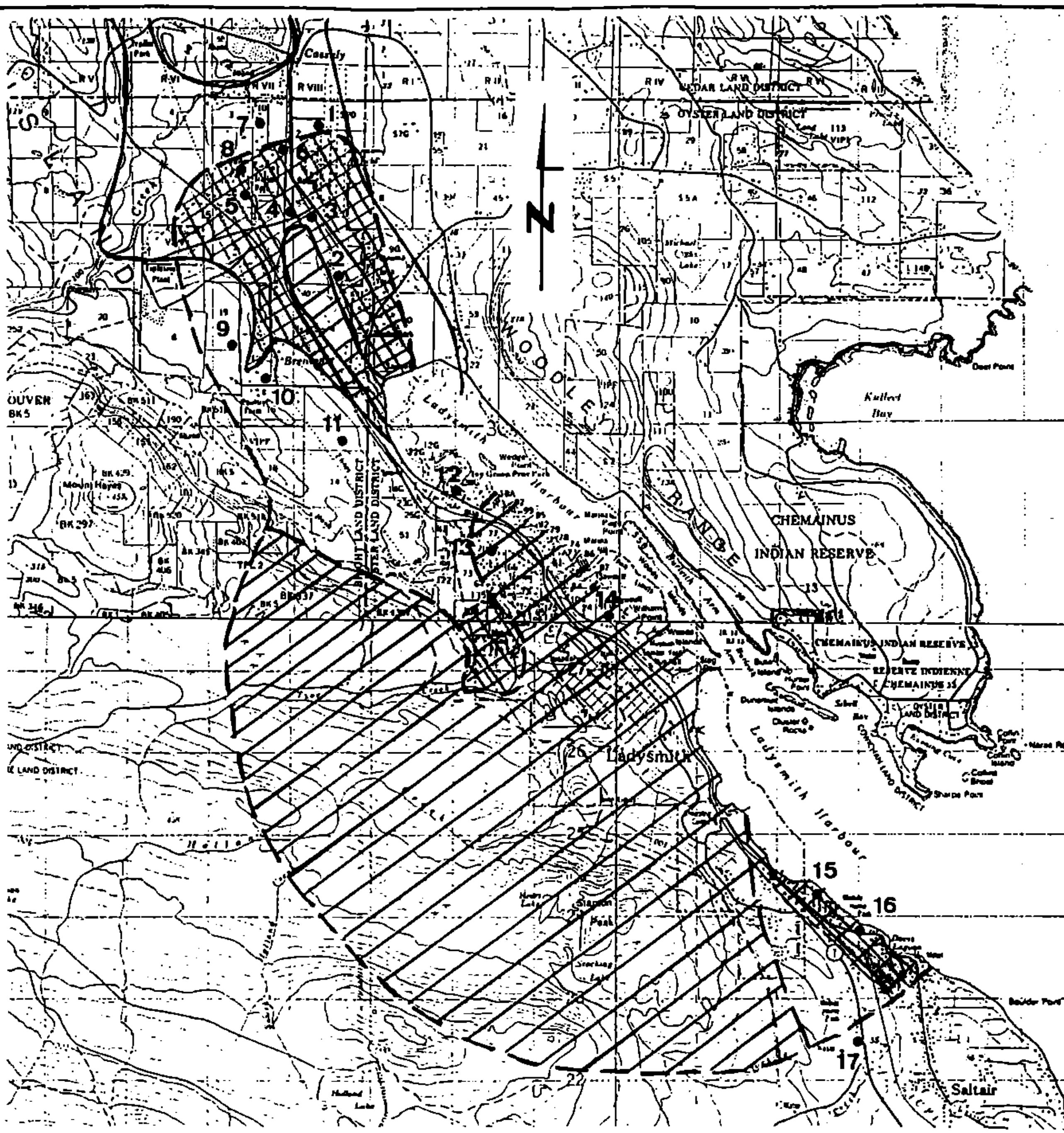
PROJECT: **LADYSMITH GROUNDWATER POTENTIAL EVALUATION**

LOCATION: Ladysmith, B.C.

PACIFIC HYDROLOGY CONSULTANTS LTD.
CONSULTING HYDROGEOLOGISTS

DELINEATION OF CASSIDY AQUIFER

DATE:	DRAWN BY:	FIGURE:
09/08/94	J.T.A.	2



Notes:

1. The base map is prepared from topographic maps N.T.S. 92B/13, **Duncan**, and 92G/4, **Nanaimo**, of scale 1:50,000 reduced to an approximate scale of 1:75,000; contour interval is 20 metres.
2. (symbol) outlines areas of bedrock outcrop or shallow overburden.
3. (symbol) outlines Cassidy Aquifer.
4. (symbol) indicates favourable groundwater exploration area.
5. ● denotes unsurveyed location of a drilled well (see Table 1 in Appendix B).

PROJECT No: K701105

PROJECT: **LADYSMITH GROUNDWATER POTENTIAL EVALUATION**

LOCATION: Ladysmith, B.C.

PACIFIC HYDROLOGY CONSULTANTS LTD.
CONSULTING HYDROGEOLOGISTS

INTERPRETED GEOLOGY AND FAVOURABLE EXPLORATION AREAS

DATE:	DRAWN BY:	FIGURE:
08/08/94	J.T.A.	**3**

APPENDIX B

SELECTED DETAILS OF DRILLED WELLS IN THE LADYSMITH AREA

Table 1. **Selected Details of Drilled Wells in the Ladysmith area**

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Completion	Driller's Litholog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
1	19.4	63.7	5.1	16.7	Coarse gravel and sand; completed with a 6.9 m (22.8 ft) long screen assembly of 1.52, 0.30 and 5.08 mm (0.060", 0.120" and 0.200") slot screen set between 12.5 and 19.4 m (40.9 and 63.7 ft).	0 - 0.3	0 - 1	brown silty sand	[1370]	400 mm (16") diameter well in the Cassidy Aquifer used for fire protection at Nanaimo Airport, sulphur odour noted from 18.6 to 19.5 m (61 to 64 ft) during drilling but no indication that water quality is affected; location - west side of Airport 42.7 m (140 ft) south of Terminal.
						0.3 - 4.6	1 - 15	brown silty sand and gravel		
						4.6 - 5.5	15 - 18	coarse sand and gravel; dry wood		
						5.5 - 6.7	18 - 22	grey silty sand with wood		
						6.7 - 7.0	22 - 23	brown coarse sand and gravel with bits of wood; water-bearing		
						7.0 - 8.8	23 - 29	brown coarse gravel and sand with clasts of silt; water-bearing		
						8.8 - 9.8	29 - 32	brown coarse gravel and sand with clasts of silt; water-bearing		
						9.8 - 18.0	32 - 59	brown coarse gravel and sand with boulders; water-bearing		
						18.0 - 18.6	59 - 61	brown coarse sand, some gravel; water-bearing		
						18.6 - 19.5	61 - 64	grey silty sand, sulphur smell.		
2	25.0	82.0	9.4	30.8	Coarse gravel; completed with 4.9 m (16 ft) of 3.81 mm (0.150") slot screen set between 20.1 and 25 m (66 and 82 ft).	0 - 9.1	0 - 30	coarse gravel with abundant large cobbles and boulders	[700]	200 mm (8") diameter well in the Cassidy Aquifer, bedrock intersected at 26.5 m (87 ft), well drilled for Pacific Aqua Foods Ltd. in 1986; location - Lot 1, D.L. 15, Bright Land District.
						9.1 - 9.8	30 - 32	brown silt		
						9.8 - 13.7	32 - 45	grey silt with sand		
						13.7 - 14.6	45 - 48	brown silt with sand and gravel		
						14.6 - 17.4	48 - 57	brown silty gravel		
						17.4 - 19.2	57 - 63	brown coarse sand		
						19.2 - 25.3	63 - 83	brown coarse gravel		
						25.3 - 26.5	83 - 87	brown silt with sand and gravel layers		
						at 26.5	at 87	sandstone bedrock.		

Note: Location refers to that shown on B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

Table 1. Selected Details of Drilled Wells in the Ladysmith Area (cont'd)

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Completion	Driller's Litholog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
3	66.5	218	9.4	31.0	Sand and gravel; completed as open-end casing below 49.7 m (163 ft).	0.0 - 12.5	0 - 41	gravel and boulders	-	200 mm (8") diameter test well in the Cassidy Aquifer used as Provincial Observation Well since 1978; hydrograph shows a water level fluctuation of 4.3 to 4.9 m (14 to 15 ft); location - Bright District 23, sheet 1, X5, Y5, No. 24.
						12.5 - 22.9	41 - 75	clean gravel; water-bearing		
						22.9 - 23.8	75 - 78	yellow clay		
						23.8 - 24.3	78 - 80	gravel		
						24.3 - 25.3	80 - 83	yellow clay		
						25.3 - 25.9	83 - 85	gravel		
						25.9 - 32.9	85 - 108	blue clay		
						32.9 - 33.8	108 - 111	gravel; hard packed		
						33.8 - 39.0	111 - 128	stratas of yellow clay and gravel		
						39.0 - 45.7	128 - 150	clean sand and gravel, note on record states sand and gravel raised 9.1 m (30 ft) in casing when this level was reached; water-bearing		
						45.7 - 46.6	150 - 153	hard-packed sand and gravel		
						46.6 - 59.5	153 - 195	fine gravel and sand; hard packed		
						59.5 - 64.0	195 - 210	sand and gravel with signs of coal float; hard-packed		
						64.0 - 66.5	210 - 218	sandstone.		
4	66.1	217	-	-	-	0 - 15.2	0 - 50	gravel and boulders	-	200 mm (8")(?) diameter test well in the Cassidy Aquifer; location - Bright District 23, Sheet 1, X5, Y5, No. 25.
						15.2 - 17.7	50 - 58	fine gravel		
						17.7 - 18.6	58 - 61	gravel		
						18.6 - 21.0	61 - 69	sandy clay		
						21.0 - 29.0	69 - 95	blue clay		
						29.0 - 38.1	95 - 96	gravel		
						38.1 - 45.7	96 - 150	blue clay and small boulders		
						45.7 - 60.4	150 - 198	gravel and small boulders		
						60.4 - 65.9	198 - 216	blue clay and small boulders		
						65.9 - 66.2	216 - 217	coarse sand		
						at 66.2	at 217	shale.		

Note: Location refers to that shown on B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

Table 1. Selected Details of Drilled Wells in the Ladysmith Area (cont'd)

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Completion	Driller's Litholog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
5	15.8	52.0	12.8	42.0	Sand(?); open-end casing(?)	0 - 7.6 7.6 - 8.5 8.5 - 12.8 12.8 - 15.9	0 - 25 25 - 28 28 - 42 42 - 52	cobble rock sand and gravel clay sand.	58	200 mm (8") diameter well in the Cassidy Aquifer, completion details not available; location - Bright District 23, Sheet 1, X5, Y5, No. 32.
6	16.5	54.0	5.2	17.0	Coarse gravel with sand(?); open-end casing(?)	0 - 9.5 9.5 - 11.9 11.9 - 14.3 14.3 - 16.5	0 - 31 31 - 39 39 - 47 47 - 54	coarse gravel and boulders coarse gravel with brown clay lenses; water-bearing coarse clean gravel; water-bearing coarse clean gravel with clean brown sand; water-bearing.	40	150 mm (6") diameter well in the Cassidy Aquifer, completion details not available; location - Bright District 23, Sheet 1, X5, Y5, No. 42.
7	21.3	70.0	9.0	29.5	Coarse sand and gravel; completed with 1.5 m (5 ft) of 2.03 mm (0.080") and 1.5 m (5 ft) of 2.54 mm (0.100") slot screen with the assembly set between 18.6 and 21.3 m (61 and 70 ft).	0 - 0.6 0.6 - 10.9 10.9 - 18.9 18.9 - 21.6 21.6 - 22.0	0 - 2 2 - 36 36 - 62 62 - 71 71 - 72	brown loam dry sand and gravel with boulders coarse sand and gravel with layers of brown clay; water-bearing coarse, clean sand and gravel; water-bearing gray silt and wood with clay.	1200	150 mm (6")(?) diameter well in the Cassidy Aquifer; location - Bright District 23, Sheet 1, X5, Y5, No. 60.
8	17.7	58.0	3.5	11.5	Sand and gravel; completed as open-end casing at 17.7 m (58 ft).	0 - 10.7 10.7 - 14.3 14.3 - 15.5 15.5 - 16.2 16.2 - 17.7 at 17.7	0 - 35 35 - 47 47 - 51 51 - 53 53 - 58 at 58	coarse, dry sand and gravel with cobbles and boulders blue silt and clay brown clay with small sand lenses brown, silty sand and gravel coarse, clean sand and gravel; water-bearing, very loose.	50	150 mm (6") diameter well in the Cassidy Aquifer; location - Bright District 23, Sheet, X5, Y5, No. 77.

Note: Location refers to that shown on B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

Table 1. Selected Details of Drilled Wells in the Ladysmith area (cont'd)

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Construction	Driller's Lithlog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
9	41.1	135	22.9	75	Sand and gravel; open-end casing(?).	0 - 3.0 3.0 - 18.3 18.3 - 27.4 27.4 - 31.1 31.1 - 32.3 32.3 - 38.7 38.7 - 41.2	0 - 10 10 - 60 60 - 90 90 - 102 102 - 106 106 - 127 127 - 135	brown hardpan and gravel blue hardpan dry silty gravel sitly gravel; water-bearing loose clean dry gravel tight silty gravel coarse clean sand and gravel; water-bearing.	15	150 mm (6") diameter well; location - Bright District 23, Sheet 1, X5, Y4, No. 18.
10	24.7 (?)	81.0 (?)	17.4	57	Coarse sand and gravel; open-end casing(?)	0 - 12.5 12.5 - 14.3 14.3 - 15.5 15.5 - 16.5 16.5 - 18.0 18.0 - 18.3 18.3 - 23.2 23.2 - 24.7	0 - 41 41 - 47 47 - 51 51 - 54 54 - 59 59 - 60 60 - 76 76 - 81	dug well coarse sand and gravel; dry clayey and brown sand clay, sand and gravel coarse loose sand and gravel coarse sand and gravel; water-bearing gravelly hardpan very tight coarse sandy gravel.	1	150 mm (6") diameter well, location - Bright District 23, Sheet 1, X5, Y3, No. 6.
11	55.8 (?)	18.3 (?)	47.9	157	Sand(?); open-end casing(?).	0 - 0.9 0.9 - 22.6 22.6 - 35.4 35.4 - 38.4 38.4 - 41.5 41.5 - 49.4 49.4 - 51.2 51.2 - 51.5 51.5 - 53.7 53.7 - 55.8	0 - 3 3 - 74 74 - 116 116 - 126 126 - 136 136 - 162 162 - 168 168 - 169 169 - 176 176 - 183	gravelly till stoney clay (hardpan) grey, silty sand very tight silty sand grey clay and silt blue clay grey, coarse sand and gravel with lenses of clay throughout; water-bearing cemented sand and gravel fine sand and gravel; water-bearing grey, fine sand; water-bearing.	8	Well diameter and completion; location - Bright District 23, Sheet 1, X5, Y3, No. 18.

Note: Location refers to that shown on B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

Table 1. Selected Details of Drilled Wells in the Ladysmith Area (cont'd)

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Construction	Driller's Lithlog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
12	21.5	70.5 (?)	0.3	1	Gravel; completed with open-end casing at a depth of 21.3 m (70.3 ft).	0 - 1.5 1.5 - 6.0 6.0 - 18.3 18.3 - 18.6 18.6 - 20.1 20.1 - 21.1 21.1 - 22.6	0 - 5 5 - 18 18 - 60 60 - 61 61 - 66 66 - 69¼ 69¼ - 74	clay, some stones(?) stony clay hard clay stony gravel; water-bearing sandstone.	25	150 mm (6") diameter well, completion details unavailable; location - Oyster District 22 (North), Sheet 1, X1, Y6, No. 6.
13	15.2	50.0	8.8	29	Fractured bedrock.	0 - 7.6 7.6 - 15.2	0 - 25 25 - 50	dug bedrock.	10	200 mm (8") diameter well; location - Oyster District 22 (North), Sheet 1, X2, Y5, No. 1.
14	15.9	5.2	12.2	40	Gravel; open-end casing(?).	0 - 6.1 6.1 - 12.2 12.2 - 15.9	0 - 20 20 - 40 40 - 52	blue clay and gravel clay and coarse gravel clay and fine gravel.	5	Well diameter details unavailable; location - Oyster District 22 (North), Sheet 1, X2, Y5, No. 17.
15	19.2	63	12.2	40	Sand, sand and gravel; completed with 1.5 m (5 ft) of perforated casing between 17.7 and 19.2 m (58 and 63 ft).	0 - 15.2 15.2 - 18.3 18.3 - 19.2 0 - 9.1 9.1 - 12.2 12.2 - 14.6	0 - 50 50 - 60 60 - 63 0 - 30 30 - 40 40 - 48	cemented sand and gravel sand and gravel sand. cemented grey gravel gravel and sand more sand less gravel.	27	Two wells; well diameters and completion details unavailable, wells abandoned; location - Oyster District 22 (South), Sheet 2, X4, Y3, No. 3.
16	37.1	121.6	15.2	50	sand and gravel; completed with 0.6 m (2.0 ft) of perforated screen set between 36.5 and 37.1 m (119.6 and 121.6 ft).	0 - 3.0 3.0 - 32.0 32.0 - 34.1 34.1 - 35.7 35.7 - 36.3 36.3 - 37.2	0 - 10 10 - 105 105 - 112 112 - 117 117 - 119 119 - 122	tight sand and gravel with boulders hardpan brown, "gooie" sand; water-bearing brown, hard packed sand with small amount of clay brown, hardpacked sand coarse sand and gravel up to 0.5 m (1.5 ft).	8	Well diameter unavailable; location - Oyster District 22 (south), Sheet 2, X4, Y3, No. 2.

Note: Location refers to that shown on B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

Table 1. Selected Details of Drilled Wells in the Ladysmith Area (cont'd)

Well No.	Completed Depth		Static Water Level		Aquifer Materials and Well Construction	Driller's Lithlog			Estimated or [tested] Capacity (USgpm)	Remarks
	m	ft	m	ft		m	ft	Description		
17	-	-	-	-		0 - 6.6	0 - 21	dug hole	-	Well diameter and completion details unavailable; location - Oyster District 22 (South), Sheet 2, X4, Y2, No. 1.
						6.6 - 14.6	21 - 48	boulders		
						14.6 - 19.5	48 - 64	brown, silty sand		
						19.5 - 25.3	64 - 83	gravel with clay binder		
						25.3 - 28.4	83 - 93	brown, silty sand		
						28.4 - 35.4	93 - 116	brown, silty sand, some gravel		
						35.4 - 38.4	116 - 126	light brown gravel, some boulders		
						38.4 - 44.2	126 - 145	grey-brown, tight gravel and boulders.		

Note: Location refers to B.C. Ministry of Environment, Lands and Parks (formerly Department of Lands, Forests and Water Resources) Water Well Location Map

APPENDIX C

CHEMISTRY OF GROUNDWATER IN THE CASSIDY AQUIFER NORTH OF THE STUDY AREA

Table 2. Chemistry of Groundwater in the Cassidy Aquifer from a Well North of the Study Area

Parameter		Cassidy Aquifer Well	Drinking Water Guideline[1]
Physical Tests			
pH		7.32	6.5 - 8.5
Conductivity (umhos/cm)		63.6	-
Colour (CU)		<5.0	15.
Turbidity (JTU)		0.20	5.
Total Dissolved Solids (mg/l)		<1.0	-
Total Suspended Solids (mg/l)		40.	500.
Total Hardness (mg/l)	$CaCO_3$	22.3	-
Dissolved Anions (mg/l)			
Alkalinity	$CaCO_3$	17.5	-
Sulfate	SO_4	4.1	500.
Chloride	Cl	3.8	250.
Fluoride	F	<0.02	1.5
Silicate	SiO_2	7.5	-
NO_3/NO_2	N	<0.005	10.0
Dissolved Metals (mg/l)			
Arsenic	As	<0.0001	0.05
Barium	Ba	<0.010	1.0
Cadium	Cd	<0.0002	0.005
Chromium	Cr	<0.015	0.05
Copper	Cu	<0.010	1.0
Iron	Fe	<0.030	-
Lead	Pb	<0.001	0.05
Manganese	Mn	<0.005	-
Zinc	Zn	<0.005	5.0
Calcium	Ca	6.82	-
Magnesium	Mg	1.26	-
Potassium	K	0.13	-
Sodium	Na	3.18	-
Total Metals (mg/l)			
Iron	Fe	<0.030	0.30
Manganese	Mn	0.010	0.05
Bacteriological Tests[3]			
Coliform Total		2.	-
Coliform Total		13.	-

Notes:

1. Maximum acceptable concentration as specified by Health & Welfare Canada (1993) and B.C. Ministry of Health (1982).
2. Results expressed as milligrams per litre except for pH, conductivity (uhmos/cm), colour (CU), turbidity (JTU), and coliform bacteria (colonies/100 ml).
3. The original report by Analytical Service Laboratories Ltd. (File 4075B dated December 14, 1990) has not distinguished between total and fecal coliforms; the first is believed to be fecal.

APPENDIX D

GROUNDWATER EXPLORATION AND DEVELOPMENT COSTS

Table 5. Hydrogeological Consulting Costs for Ladysmith Groundwater Exploration/Development

Task	Description	Time (hrs)	Fees ($)	Disbursements ($)	Total ($)
	Phase 1 - Groundwater Exploration				
1	Prepare draft contract documents, issue tender call, evaluate results and recommend contractors	5	450.	150.	600.
2	Provide engineering supervision	10	1,000.	50.	1,050.
3	Carry out sieve analysis and design screens	20	1,350.	100.	1,450.
4	Supervise pumping tests onsite and collect water samples	20	1,400.	500.	1,900.
	Subtotal for Phase 1, Ladysmith Groundwater Exploration/Development				**5,000.**
	Phase 2 - Evaluation and Final Report				
1	Evaluate results and provide a draft report; disbursements include cost of basic drinking water analyses	50	4,000.	1,000.	5,000.
2	Discuss draft report with Koers & Associates and/or Town of Ladysmith	6	600.	100.	700.
3	Revise and submit final report	15	1,000.	300.	1,300.
	Subtotal for Phase 2, Ladysmith Groundwater Exploration/Development				**7,000.**
	Total Estimated Hydrogeological Consulting Costs				**$12,000.**

Notes:

1. The fee item may include several different rate categories.
2. G.S.T. is not included.

KOERS
& ASSOCIATES
ENGINEERING LTD.
Consulting Engineers

LADYSMITH WATER STUDY
PIPE AND NODE DIAGRAM

FIG. 3