CITY OF DAWSON CREEK

WATER QUALITY ASSURANCE PLAN

February 2001

Table of Contents

1.0 INTRODUCTION

1.1 Authorization

The following report was commissioned in August 2000 by the City of Dawson Creek. It represents the first stage of a planning process to ensure that the City maintains adequate high quality water supply for the long-term future.

A review of the Dawson Creek Waterworks was carried out by Bob Watson, P.Eng., the Regional Public Health Engineer in October 1999. His report is included as Appendix I. Consequently, the City applied to the Ministry of Municipal Affairs for study funding assistance and was later awarded a $10,000 study grant to undertake the work.

1.2 Purpose and Scope

The purpose of this study is to review and assess the City's overall waterworks system and develop a framework of capital improvements for source extraction, transmission, treatment and delivery of safe potable water for the long-term.

The study is limited in depth as funding did not allow for more costly investigations such as alternate groundwater sources, watershed management and other in-depth assessments. Nevertheless, it does attempt to provide a clear evaluation of the system's major components, namely:

1. The Source – Kiskatinaw River
2. Pumping, Storage and Transmission Systems
3. The Water Filtration Plant
4. The Distribution System

2.0 SOURCE WATER

2.1 Kiskatinaw River

The City of Dawson Creek has been drawing water from the Kiskatinaw River since the mid 1940's using an intake and pumphouse located at Arras, about 16 km west of the City limits.

The headwaters of the Kiskatinaw River originate over 60 km south of the City at Bear Hole Lake. Two arms, West Arm and East Arm confluence near One Island Lake and flow north, eventually discharging into the Peace River. Figure 2.1 depicts the overall watershed boundary.

At the intake location at Arras, the contributing watershed forms an area of approximately 2,800 km^2.

Flows in the River have been recorded by the Water Survey of Canada since 1945 at Station 07FD001. The station is near Kiskatinaw Park at the Highway 97 crossing north of Farmington.

The relevant extreme **low flows** at this station are:

a) The extreme low flow (one day):
145 Igpm on September 16, 1945

b) The average of all low flows over 32 years:
5,900 Igpm

c) Lowest single month average - February 1989
1,680 Igpm

Extreme low flow days have occurred in the months of September, March, August, December, January and February on various years. An extremely low flow was observed in late summer 1992. Immediate action was taken to construct a weir downstream of the intake at Arras to prevent total freeze-up of the river and intake pipe. This weir is still in place and has alleviated concerns over a "high and dry" intake.

A low flow frequency analysis was conducted by the Ministry of Environment in 1990 (based on the Farmington records), and yielded the following projections*: (Note that all flow rates are Igpm – Imperial gallons per minute)*.

Table 2.1
Return Period Low Flows (October – May)

Duration (Days)	Mean	Return Period (Years)			
		5	10	20	30
1	7,600	1,980	1,040	580	420
7	7,850	2,170	1,150	650	480
14	8,100	2,340	1,260	710	520
30	8,640	2,720	1,480	830	610
60	9,400	3,330	1,900	1,120	850

Table 2.2
Return Period Low Flows (June – September)

Duration (Days)	Mean	Return Period (Years)			
		5	10	20	30
1	22,200	4,900	1,900	750	450
7	25,240	6,100	2,660	1,220	780
14	29,200	6,900	3,200	1,560	1,040
30	38,300	9,100	4,320	2,170	1,480
60	69,000	15,200	8,060	4,600	3,400

River flows at the Arras location can be expected to be in proportion to the relative catchment areas:

Catchment area at Farmington station: 3,660 km^2
Catchment area at Arras: 2,820 km^2

Ratio: $\frac{2,820}{3,660} = 77\%$

2.1.1 Security of Supply

When adequate records are available, a 100-year return frequency drought can form the basis of a City's water supply. However, the records only allow a reasonably confident projection of a 30-year return frequency.

The City currently has approximately 20 days of pumped water storage, so the critical 30-year return drought flow should be taken as a 14-day duration. A one-day low flow is not significant because of the available storage. The projected 30-year return drought flows (14-day duration) are:

October – May: 520 x 0.77 = 400 Igpm

June – September: 1,040 x 0.77 = 800 Igpm

It is evident that to satisfy a demand of approximately 2,000 Igpm on a consistent basis, additional storage is required. The only river flows that come close to satisfying the demand are 5-year return frequency flows.

2.1.2 Potential Storage

The City currently has the ability to draw at a rate of 2,000 Igpm from the River. It can therefore be expected that for a 1:30 year return frequency drought, the River will not provide sufficient water. A minimum 60 day storage would alleviate this problem in the June – September period, but over 120 days would be required for the October – May period.

In order to provide security for the drought years, it's prudent to consider storage. This can take the form of:

a) Creating impoundment on the River with a controlled outlet.
b) Creating off-line storage to be used as necessary.
c) Creating a control structure at Bear Hole Lake.

The size of the required storage is difficult to determine. Most years show a tendency to recover from a low monthly flow one or two months after. The 1989 months of January, February, and March were particularly low, averaging no more than 2,500 Igpm over the three-month period.

Therefore, the minimum prudent storage capacity would be three months at the City's consumption rate of 2,000 Igpm, or about 260 M Gals. In-stream or off-stream storage of this size would incur a considerable expense and would require a comprehensive environmental impact assessment.

A control structure at Bear Hole Lake could provide such storage and an effectively operated controlled release could supply the City's requirements for the drought periods. An approximate calculation shows that Bear Hole Lake could store some 100 M Gals with each additional foot of water level increase.

The City's Water Licence allows it to draw an average of 2 M Gals/day over the year. It is also suggested that this Licence be amended to 3 M Gals/day.

2.2 River Water Quality

The Kiskatinaw River has always been subject to high turbidity levels since much of its banks consist of erodible silts and clays. Spring freshet and heavy rains usually result in turbidities in excess of 3,000 NTU (Nepthalometric Turbidity Units).

More recent years have seen noticeable increases in turbidity spikes, often reaching 8,000 to 10,000 NTU. This gradual deterioration is often attributed to increased logging and hard-surface developments in the watershed which increase both the quantity and velocity of runoff.

A scan of maximum daily discharges and instantaneous flows shows a gradual increase from the 1960's to the 1990's. Where the recorded maximums in the 1960's through the 1980's ran at under 87,000 Igpm, the 1990's have recorded maximum flows in excess of 130,000 Igpm.

This is an indication that as development occurs in the watershed, the high flows get higher and the low flows get lower. Higher flows lead to increased erosion and higher turbidity. Faster runoff and more rapid entry of agricultural wastes to the River increase the level of microbiological contamination.

The watershed is relatively large and there are numerous interests in land use and economic development.

While the City is not the only interested party in the watershed, it has a very important stake in protecting water quality for over 12,000 residents. A watershed management plan was completed in 1991 and endorsed by the Regional District of Peace River, the Ministries of Health, Environment, Forests, Agriculture, Mines and Transportation. However, specific actions to manage land use and implement the recommendations have been put off.

Given the increasing risks and the advent of Provincial Water Protection Plans, it will be prudent for the City to re-start the watershed management process in co-operation with other stakeholders. This process should not so much restrict economic development, but rather develop consensus on development standards to attenuate and manage runoff to the River, and provide better long-term protection from erosion and contamination.

2.3 Risk of Accidental Spills

Accidental spills of hazardous materials can occur at road crossings and pipeline crossings.

Evidence of an accidental pipeline break occurred recently at Chetwynd. The result forced the Municipality to access another water source, since the Pine River may remain contaminated for several years.

The approach to managing these risks is threefold:

a) Prevention and Early Warning
b) Storage
c) Alternate emergency source

Prevention and early warning can be part of the watershed management plan process and specific guidelines can be developed for spill detection and reporting procedures.

The City currently has approximately 80 M Gals of usable pumped water storage en-route between the Arras pumphouse and the water treatment plant.

At restricted consumption rates during emergency conditions this stored water could suffice for 40 to 50 days.

For the future, it is prudent to purchase and set aside land for additional pumped water storage in case of longer duration emergency conditions. The land should preferably be located in the vicinity of the pipeline route from Arras to the water treatment plant.

The ideal location for such storage is at an elevation of 2,340 ft. This would allow the existing low lift pumps at Arras to pump river water to the storage pond. The high lift pumps could be relocated to the pond and pump directly to the Hart reservoir.

The ideal size for such a pond would provide 60 M Gals of usable storage. Combined with 80 M Gals at the Trail reservoir and 6 M Gals at the Hart reservoir, the system could provide in excess of 60 days of pumped water should an accidental spill occur.

Other advantages of a storage pond in the vicinity of the Arras pumphouse include:

- Provision of sedimentation would significantly increase the life of the high lift pumps. The current direct pumping of gritty water from the river severely shortens the life of the high lift pumps. The low lift pumps use open hardened impellers and are more resistant to abrasion.
- Using the high-lift pumps at a higher elevation would eliminate the need for the intermediate booster pump at Deveraux, thereby reducing both energy and maintenance costs.
- Pumping cleaner water will also extend the life of the transmission pipeline, as abrasion from grit and sand will be significantly reduced.

If land at the 2,340 ft. elevation is not available, a higher elevation can also be utilized by increasing the capacity of the low lift pumps, either with larger pumps or by tandem pumping from the upper floor at the Arras pumphouse.

Secondary sources of emergency supply could include other rivers such as the Pouce Coupe River or the Murray River. However, these are very remote from the plant and would incur very high capital costs for transmission mains. Another emergency source may be groundwater, and the City is currently conducting an overview study to determine the potential of finding sufficient groundwater for emergency use.

3.0 INTAKE FACILITIES

3.1 River Intake

The existing river intake is a 24-inch diameter steel pipe installed in the 1960's. It has a coarse trash screen and leads directly into the pumphouse wet well. The condition of the pipe is not known with certainty, but after 40 years of operation, it can be anticipated that the steel pipe has deteriorated.

The coarse screen keeps out larger debris but does not meet the requirements of the Department of Fisheries and Oceans (DFO) for prevention of fish entry. The pipe at the bottom of the river also presents some operational difficulties:

- Siltation of the entry requiring regular backflushing.
- Unstable riverbank slope creating frequent plugging of the inlet.
- No access to inlet except with expensive diving crew.
- Sticks and other debris regularly clog the pumps.

It is recommended that this intake be reconfigured to comply with DFO regulations, stabilize the riverbank and afford convenient access for cleaning and maintenance. A capital cost estimate is presented in a later section.

3.2 Level Control Weir

The level control weir was quickly built in the fall of 1992 in response to a very low flow situation. The weir consists of steel sheet piling with rock rip-rap placed on the downstream side. An appropriate fishway is included.

The weir was equipped with a stop-log system to afford regular flushing of accumulated sediments behind the weir. These stop logs are currently inoperable because of timber saturation.

The solution to this problem is beyond the scope of this report and will require input of a structural and hydraulics engineering team to develop a practical method for correcting the situation.

4.0 TRANSMISSION FACILITIES

4.1 Arras Pumphouse

The Arras pumphouse was recently upgraded and refurbished in 1999 and this facility should provide adequate service for the next 25 years. The pumps can pump in excess of 2,000 Igpm (or 2.8 M Gals/day), which would supply a population of 15,000 under maximum demand conditions.

4.2 Pipeline: Arras to Hart Reservoir

This pipeline was replaced in 1998 with a 14-inch diameter PVC watermain. The pipeline will pass in excess of 2,000 Igpm and should be adequate for the long-term.

A booster pump station exists at Deveraux, and this pump was also replaced in 1996. Other than regular maintenance and replacement of wearable parts, this pump station does not require any major investment. Operation of the booster pump can be improved considerably by the addition of a variable speed drive in order to reduce energy consumption.

4.3 Hart Reservoir

This is a two-cell earth reservoir intended to act as initial settling ponds. The current capacity of the ponds is 3 M Gals each, for a total capacity of 6 M Gals.

The ponds have never been cleaned since inception and there is a significant accumulation of silt in Pond No. 1, reducing its capacity to less than 2 M Gals. There is also evidence of water rooted weed growth in the ponds and this may be adding to water quality deterioration. It is recommended that Pond No. 1 be emptied and cleaned out in the near future. The material removed, after analysis, could possibly be used to raise the berms and add capacity. Pond No. 2 can be cleaned at a later date.

4.4 Pipeline: Hart Reservoir to Trail Reservoir

This pipeline is the remaining piece of the original steel pipeline constructed in the 1950's. The 12-inch steel pipeline has a limiting capacity of 1,300 Igpm and is subject to corrosion. After close to 50 years of service it should be considered for replacement. Extensive cathodic protection has increased its life, and replacement is not urgent.

Since there are users on this line, attempts to increase flows in the line result in unacceptably low pressures to some users. An intermediate step to correct this problem involves upgrading the inlet valve arrangement at the Trail Reservoir. This would allow nominally greater flow in the pipe while maintaining adequate pressures for en-route raw water users.

For the long-term, however, the pipeline should be replaced with a 14-inch non-corrosive pipeline within the next five years.

4.5 Trail Reservoir Operation

The Trail Reservoir comprises two cells, each of approximately 50 M Gal total capacity. The reservoirs achieve the following:

- Provide sedimentation for silts and clays which do not settle in the Hart reservoir.
- Provide a significant quantity of stored water when the Arras pumps are turned off because of extremely high turbidity. They can provide approximately 40 days of water supply with River pumps shut off.
- Provide a pressure break so that the filtration plant operates at a reliable and relatively constant inlet pressure.

Some difficulties experienced with the Trail reservoirs include:

- Wind action increases the water's turbidity if the water level is below the rock rip-rap embankment. Rip-rap was originally placed on the berms to stabilize them and prevent erosion. However, the rip-rap only extends part way down the berms, the remainder being earth fill.

  When water levels are lower than the rip-rap, wave action erodes the lower portion of the berms and re-introduces turbidity. With the new pump station at Arras and higher pumping capacity, this problem has been resolved for most circumstances. Of course when the River remains turbid for more than 2 – 3 weeks, the water level drops and the problem re-occurs.

- Organics have been a problem seasonally, often through the winter and spring seasons One of the cells has recently been retrofitted with submerged air diffusion in an effort to control organics. Since this is a recent modification, its effect will need to be monitored over the next year.

  The organics have also had a tendency to reduce filter runs at the plant, and often create nuisance taste and odour problems. Taste and odour have been controlled by the introduction of Powdered Activated Carbon (P.A.C.) at the plant prior to filtration.
- The intake location at the bottom of the pond may be the source of sulfate reducing bacteria arising from the bottom sediments. A variable level intake to enable drawing from a higher level during winter months (when ice cover is a factor) may be effective in reducing taste/odour problems.
- The 18-inch diameter steel transfer pipes from Cell No. 1 to Cell No. 2 are suspected to be corroded. Corrosion and leakage from these pipes can have a devastating impact on the berm between the two cells.

  Undetected leakage can destabilize the berm and destroy the structure. It will therefore be prudent to replace these transfer pipes with non-corrodable material.

  Excavation and replacement is not possible without compromising the integrity of the berm. The safest method will involve insertion of a new (and necessarily smaller) pipe into the existing pipe. A high density polyethylene insertion pipe or other form of on-site restoration will prevent any leakage from the corroded steel pipes.
- As noted in Section 4.3, the addition of an automatic inlet flow control valve will resolve the problem of low pressures to en-route raw water users.

4.6 Pipeline: Trail Reservoir to Plant

This pipeline is an 18-inch Asbestos-Cement pipe with a limiting capacity of 5,000 Igpm. It was installed in the mid-1970's and by all accounts is in good condition.

All of the above elements are depicted schematically on Figure 4.1. Figure 4.2 shows the proposed upgrades.

4.7 Water Consumption

Flow records for the year 2000 indicate the following:

a) Highest single month consumption: 42.2 M Gals in August. Month Average: 1.4 Mgd
b) Highest single day consumption: 1.9 Mgd on June 27th
c) Average for Year 2000: 1.22 Mgd.

Figure 4.3 plots monthly consumption for year 2000.

The summer of Year 2000 was relatively cool and wet. Other years with hot dry summers have recorded daily consumption in excess of **2.2 Mgd**. In recent years, winter consumption has been increasing, likely due to increasing oil and gas exploration with hotels and motels fully booked through the winter months. Tourism has also been on the rise and summer visitation of Alaska Highway travellers has been steadily increasing.

Population growth (from Statistic Canada Census) has been as follows:

1981: 12,197 (including Pouce Coupe)

1986: 11,762 (including Pouce Coupe)

1991: 11,966 (including Pouce Coupe)

1996: 12,452 (including Pouce Coupe)

2000: 12,712 (estimate)

The consumption figures indicate the following:

Per capita consumption on a Maximum Day: 190 Igcd (I gals/capita/day)

Per capita consumption on Average Day: 115 Igcd (I gals/capita/day)

It is difficult to predict future growth on the basis of past population swings, but a design population horizon of 15,000 would appear reasonable. This yields the following projected demand:

15,000 people @ 190 Igcd = **2.85 Mgd**

5.0 TREATMENT PLANT FACILITIES

5.1 Existing Process Train

The filtration plant utilizes a conventional coagulation, flocculation, clarification, filtration train. Various coagulants have been used over the years, and the optimum performance was found to be with Poly Aluminum Chloride (trade name Clear PAC).

The original gravity clarifier was retrofitted with tube settlers in 1982 to improve performance. The upflow adsorption clarifier was added in 1991. The filters were refurbished with new triple media (anthracite, sand, garnet) in 1990 but were not expanded.

The respective surface areas of these units, and their recommended loading rates are as follows:

	Surface Area	Recommended Loading Range
Gravity Clarifier (with tubes)	970 ft^2	1 – 1.5 $Igpm/ft^2$
Upflow Clarifier	140 ft^2	5 – 8 $Igpm/ft^2$
Filters	640 ft^2	1.5 –3 $Igpm/ft^2$

The respective processing capabilities (in Igpm) of the units at either the low loading rate or high loading rate are as follows:

	Capacity @ Low Rate (Igpm)	Capacity @ High Rate (Igpm)
Gravity Clarifier	970	1,460
Upflow Clarifier	700	1,120
Filters	1,280	2,560

The best performance for these processes is expected at the lowest loading rate. Using a target objective of processing water for 15,000 people (2.85 Mgd), yields a flow rate of approximately 2,000 Igpm.

Therefore, if both clarifiers are operated at 1,000 Igpm, their total throughput can be 2,000 Igpm, with the gravity clarifier loaded at 1.03 $Igpm/ft^2$ (acceptable) and the adsorption clarifier loaded at 7.1 $Igpm/ft^2$ (also acceptable).

Loading of the filters at 2,000 Igpm represents a rate of 3.1 $Igpm/ft^2$, which is above the recommended range.

5.2 Plant Performance

Plant performance has been monitored since 1992 for numerous parameters. One of the key parameters of concern is Turbidity. Turbidity provides an indication of particulate matter in the water and, by extrapolation, the risk of micro-organism breakthrough.

5.2.1 Turbidity

Turbidity is a measure of particulate matter concentration in the water. It is measured by means of light scatter through a water sample in Nepthalometric Turbidity Units (NTU). When the 1991 upgrade was completed, the target maximum turbidity from the Canadian Drinking Water Guidelines **was 5.0 NTU**. Since then, Health Canada has revised the maximum acceptable turbidity to **1.0 NTU**. US EPA uses a maximum of 0.1 NTU and various other provinces in Canada such as Alberta and Ontario use maximums ranging from 0.1 NTU to 0.5 NTU.

Plant performance was tracked from 1992 to 2000 on the basis of finished water turbidity, with the following results:

Days with turbidity **greater than 5 NTU:**	**11** out of 2,920 days (0.3%)
Days with turbidity **greater than 1 NTU:**	**740** out of 2,920 days (25.3%)
Days with turbidity **less than 1 NTU:**	**2,169** out of 2,920 days (74.3%)

Finished water turbidity exceeded the current Canadian Guideline of 1 NTU for approximately 750 days out of 2,920, or 26% of the time. Typically however, under normal loadings and flows, the plant can produce turbidity of 1.0 NTU or less.

Its ability to consistently produce below 0.5 NTU depends on the raw water turbidity and the clarifier and filter loading rates.

5.2.2 Loading Rates

(a) Clarifiers

Appropriate surface loading rates for clarifiers are highly dependent on raw water turbidity. It has been observed that the upflow adsorption clarifier, begins to perform poorly when raw water turbidity exceeds 30 – 40 NTU. The gravity clarifier, with a much larger surface area, can adequately deal with raw water turbidity in the 60 – 70 NTU range.

The two existing clarifiers could process up to 2.9 Mgd provided that incoming raw water turbidity is kept between 30 – 60 NTU. One way to control incoming water turbidity is to pass all raw water through a settling pond. A "pre-plant" settling pond can be implemented in several possible locations:

a) At the Trail reservoir site.
b) En-route between Trail reservoir and the plant.
c) At the Lungul reservoir on the existing plant site.

The Lungul reservoir is a nominal 5 M Gal earth pond that is currently used to store water for emergencies. Unfortunately it is constructed at the same level as the plant, and water must be pumped to get through the plant. In order to operate by gravity, the berms must be raised in the order of 25 ft. at relatively high cost.

These three options are costed in Section 7 of this report. The base criteria is to achieve 2 to 3 days of settling time prior to the plant.

(b) Filters

The operating records on the existing filters indicate that filtered water turbidity can be kept below 1 NTU when the filters are loaded at or below 2 $Igpm/ft^2$ or 1300 Igpm. As loadings increase, additional turbidity begins to break through. While this has rarely exceeded the previous target of 5 NTU, it is higher than the current Canadian standard of 1 NTU.

The BC Ministry of Health has strongly suggested that the target be set at a maximum of 1 NTU, requiring a target average of 0.5 NTU.

With increasing concerns over water quality and safety, it can be anticipated that in the long-term a target turbidity maximum of **0.1 NTU** may become the standard in BC.

The 1991 plant upgrade provided additional building space, and an area was set aside for future installation of additional filters. The floor space available for additional filtration is approximately 400 ft^2. Using a loading rate of 2.25 $Igpm/ft^2$, this filter could process 900 Igpm.

With the use of an additional multi-media filter (two bays for backwash), piping can be re-configured such that the adsorption clarifier operates with the new filters.

That is,

• Adsorption clarifier and new filters @		900 Igpm
• Gravity clarifier and existing filters @		1,100 Igpm
	Total	2,000 Igpm

This scheme would ensure all units are operating at low loading rates to achieve the targetted 1.0 NTU maximum turbidity.

(c) Membrane Filtration

An alternative scheme would retain the existing process train with no modifications and no concern over filtered water turbidity. All filtered water would then be passed through a membrane (microfiltration) filter. Microfiltration will typically produce water at less than 0.1 NTU, and with a membrane nominal pore size of 0.2 microns will substantially reduce the risk of Giardia cyst (4 – 6 microns) or Cryptosporidium oocyst (1 – 2 microns) breakthrough.

Membrane filters require pressure to operate effectively (or vacuum in some configurations), and this scheme would incur pumping out of the existing clearwell. Membrane filter backwash requirements are also significant, with 20 – 30% of the filtered water used for backwash (or 1 – 2 minutes every hour).

In this instance, the membrane filter would process all the finished water and would have a capacity of 2,000 Igpm. Each filter unit has bundled modules of hollow-fibre membranes with a filtration surface area of 500 – 700 ft^2 (depending on the manufacturer). The loading rate is 0.01 to 0.03 $Igpm/ft^2$. At 2,000 Igpm, approximately 100,000 ft^2 of fibre area is required, or approximately 140 modules. Modular units typically contain 60 – 70 modules/unit; therefore two module blocks would be required.

The footprint for two module blocks is approximately 30 ft. x 16 ft, or 480 ft^2. The spare space available in the existing building is approximately 400 ft^2, with 4 feet perimeter access. If the access is narrowed to 3 feet, the membrane filter banks could be accommodated.

Sludge pond decant return water need not be pre-filtered if membranes are used as final filtration, since they will provide sufficient barrier for protozoa breakthrough.

(d) Membrane Filtration without Pre-filtration

Membrane filter manufacturers claim that membranes can be used directly on some source waters. The water arriving at the plant has sufficient pressure to apply to a membrane filtration system, and this is an option that could be considered. This option could potentially render the existing clarifiers and filters redundant, and thereby reduce the attendant operating and chemical costs.

However, the raw water turbidity is such that it might easily plug the membrane filter and lead to unacceptable backwash frequencies. If this option is to be explored, a pilot membrane plant should be operated and monitored for a full year to determine the feasibility of direct filtration with membranes.

The pilot plant will reveal the necessary operating parameters and might conclude with any of several options:

a) Direct filtration with membranes is feasible and cost effective; or

b) Use of the existing clarifiers is sufficient to protect the membranes from overload; or

c) Both clarification and pre-filtration are required to ensure acceptable membrane operation.

Given the known levels of current raw water turbidity, it is unlikely that membrane filtration would be successful without a nominal size roughing filter.

5.3 Filtered Water Storage

Filtered water storage in an enclosed concrete tank is currently provided by the concrete wet well below the filters. This tank has a nominal 170,000 gallon capacity; this water is also used for backwashing.

The main treated water storage facility is an open earth reservoir, known as the Ridge Reservoir. This open reservoir stores approximately 1.5 M Gals and acts as a balancing storage for the daily output of the plant and the peak hourly demand of the City.

Peak hourly demands are usually up to 2 times the daily consumption rate and typically occur between 6:00 a.m. to 9:00 a.m. and 5:00 p.m. to 8:00 p.m.

The open reservoir has long been a source of concern, as the disinfected filtered water is again exposed to the elements for potential re-contamination from:

- Waterfowl and birds.
- Rodents and other animals.
- Leaves and other organic debris.

To reduce this risk, a second chlorination station is currently located at the Ridge reservoir outlet. This second chlorinator incurs an appreciable additional cost which would otherwise be unnecessary with a closed tank.

The Health authorities recommend that this problem be corrected as soon as possible with the addition of a closed concrete storage tank for filtered, disinfected water. The size of this tank should be sufficient to make up the difference between plant output capacity and the peak hourly demand for a period of at least three hours, and more desirably for a period of 5 hours.

5.3.1 Available CT

Conventional rapid sand filtration is credited with 2-log (99%) removal of Giardia cysts (US EPA). The BC Health Ministry encourages a target removal of 3-log (99.9%) of Giardia cysts. Therefore, chlorination must achieve the remaining 1-log.

The required CT values for 1-log Giardia inactivation with free chlorine for water are given by US EPA for the following conditions:

pH = 8.0; Chlorine concentration at end of contact: 0.8 mg/L

temp: 0.5^{o}C: CT = 98 (required)
temp: 10^{o}C: CT = 53 (required)

The available CT in the existing clearwell is given by:

Contact volume: 170,000 gals x 0.3 = 51,000 Gals
(0.3 is the **effective** volume for an unbaffled tank)
Contact time: 51,000/2,000 Igpm = 25.5 minutes
CT: 0.8 x 25.5 = **20**

Additional contact time is available in the Ridge reservoir, but since this is an open reservoir, the CT credit is effectively zero. Re-chlorination takes place at the Ridge outlet and contact time is available in the pipeline into town. The split is approximately 50% of the flow into each pipeline (1000 Igpm in each), and an available contact time of 40 minutes (pipelines can be considered plug flow). The CT value is therefore 0.8 x 40 = 32. The **total CT** available is **52**. This is marginally below the required CT at a summer water temperature of 10^{o}C and significantly below the requirement at the winter temperature of 0.5^{o}C.

CT values can be increased by increasing the chlorine dosage. A finished water concentration of 1.5 mg/L would meet the requirement, but this would mean dosing at a rate in excess of 2 mg/L. In addition to the higher chlorine consumption (and cost), this dosage could lead to greater taste/odour complaints and greater THM levels.

In order to meet the required CT values, more contact time in an enclosed tank is required. The additional volume required for the more critical winter temperature is:

Unbaffled reservoir: $\frac{195{,}000 \text{ I gals}}{0.3}$ = 650,000 I gals

Partially baffled reservoir: $\frac{195{,}000 \text{ I gals}}{0.5}$ = 390,000 I gals

Fully baffled reservoir: $\frac{195{,}000 \text{ I gals}}{0.7}$ = 280,000 I gals

5.3.2 Storage for Peak Hour Balancing

The comparative required volumes are calculated as follows:

		Plant Output Capacity (gpm)	Peak Hour Rate (gpm)	Minimum Storage Required for 3 Hours (Gals) (a)	Desirable Storage Required for 5 Hours (Gals) (b)	Effective Existing Volume (Gals)	Net Size of New Tank (Gals) (a)	Net Size of New Tank (Gals) (b)
1.	With no added filtration	1,300	4,000	500,000	810,000	100,000	400,000	710,000
2.	With additional filter	2,000	4,000	360,000	600,000	100,000	260,000	500,000

Notes:

- The plant output capacity is the safe filter loading rate to ensure less than 1 NTU filtered water turbidity. It is currently 1,300 Igpm, and would be expanded to 2,000 Igpm with additional filtration.
- The peak hour rate is the projected demand for 15,000 people (2.85 MG/d), or 1,980 gpm times 2, or approximately 4,000 gpm.
- The existing storage is the volume of the existing wet well (170,000 gallons) less 70,000 gallons used for filter backwash operation.
- Case (a) is the **minimum** storage required; 3 hrs); case (b) is the **desirable** storage required (5 hrs).

The optimum size of additional new storage is **500,000 gals**. This would suffice for the minimum 3-hour peak event if no additional filtration were provided. It would also provide storage for the more desirable 5 hours if additional filtration were provided. Partially baffled, it would also provide the required CT for Giardia inactivation.

5.4 Sludge Management

The plant produces wastewater from three sources:

a) Filter backwash water.

b) Gravity clarifier sludge.

c) Adsorption clarifier scour and waste.

All of these wastewater streams are currently directed to a single sludge pond. The larger materials are allowed to settle and the decant water is pumped back to the plant.

There are several operating problems and some risks associated with this procedure:

5.4.1 Operating Problems

Use of a single pond does not provide the ability to dewater the settled sludge. Discharge of this sludge to streams or surface drainage is not permitted. As a consequence, the plant needs to undergo a major operation twice per year to pump and haul the pond sludge to landfill.

This problem could be alleviated by having **two** sludge ponds. One pond can then be shut down through the winter months and the sludge allowed to "freeze-dry", making it more manageable and transportable. This drying process would increase solids content from 4% to 24%, and therefore incur 6 times less loads to landfill.

If the Ridge Reservoir is decommissioned and replaced with a concrete storage tank, it can be converted to a second sludge pond. This modification is consistent with the long range plan of 1988. (Water Treatment Upgrading Options Report).

5.4.2 Risks

Return of decant water from the sludge pond represents a risk to the water supply, as the decant water is turbid and may often have a high concentration of micro-organisms such as Giardia and/or Cryptosporidium. This decant water can sometimes be wasted to a suitable watercourse if there is adequate dilution.

At this site, however, there are no suitable watercourses and the water must be returned to the plant.

There are several potential approaches to dealing with this return water and reducing the risk:

a) Pass the return water through a separate filtration unit. A packaged membrane filter, or cartridge filter combination would be suitable for this purpose.

b) If the Lungul Reservoir is modified and placed "on-line" as a pre-sedimentation pond, the sludge pond decant can be returned to the Lungul Reservoir for further settling and blending with raw water.

c) Use of Dissolved Air Flotation (DAF) prior to return to the main plant process train.

5.5 Other Water Quality Concerns

5.5.1 Taste/Odour

As previously stated, seasonal organics in the Trail Reservoir often lead to taste and odour problems in the water. Historically, this has been managed by the addition of a Powdered Activated Carbon (PAC) slurry to the raw water.

Addition of PAC just prior to the entry to the clarifiers does not provide adequate contact time and the quantities of PAC used have been significant. A different application point further upstream to allow for sufficient contact time is required. Again, if the Lungul Reservoir is put on-line as a pre-sedimentation pond, application of PAC at this point would be effective.

The existing PAC feeder unit is inoperable after 40 years of service and a new feeder is required. Powdered Activated Carbon can be a hazard to workers because of the dust and potential for explosion. It should be located in an isolated building.

Taste and odour can also be controlled by the use of Chlorine Dioxide. Chlorine Dioxide is commonly applied to control tastes and odours associated with algae and decaying vegetation as well as phenolic compounds. It is typically applied prior to filtration, which also serves to keep filter media disinfected. Chlorine Dioxide must be produced on-site and can be considered as an alternative to Powdered Activated Carbon.

Modern Chlorine Dioxide generators use dilute forms of Sodium Chlorite and Hydrochloric Acid and pose very little hazard for plant operators.

5.5.2 Disinfection By-Products

Nominal sampling for Trihalomethanes (THM's) has shown finished water Chloroform levels in the range of **0.1 mg/L to 0.2 mg/L**. Other THM's such as Bromoform were not detected. The current Canadian acceptable limit for these compounds is **0.1 mg/L**, but this is anticipated to be adjusted downwards to the US limit of 0.04 mg/L or the European limit of 0.001 mg/L.

While disinfection by-products do not appear excessive, some techniques for management can be improved.

These include:

- Elimination of the open filtered water reservoir and the re-chlorination system.
- More consistent application of PAC to reduce organics and reduce Total Organic Carbon. (Activated Carbon is known to reduce THM Precursors).
- Use of Chlorine Dioxide, which does not produce chlorine by-products.
- Improved filtration with lower loading rates.
- Use of Ultra-Violet radiation as the primary disinfectant.

The THM levels should continue to be monitored over the next several years after plant upgrades are implemented. If high levels persist, the City should consider changing the disinfection system to Ultra-Violet or Chlorine Dioxide.

Figure 5.1 depicts schematically the existing process train. Figure 5.2 depicts the proposed improvements using an additional triple media filter. Figure 5.3 depicts the option of using membrane filters.

5.5.3 Cryptosporidium Parvum

Cryptosporidium infestation is of concern because of agricultural activities in the watershed. There is no official rating for conventional filtration and Cryptosporidium removal, although 1-log (90%) to 2-log (99%) can be anticipated. Chlorination by free chlorine is ineffective on Cryptosporidium and no further removal can be expected.

Three disinfectants have been found to inactivate Cryptosporidium oocysts:

a) Ozone
b) Chlorine Dioxide
c) Ultra-violet radiation

Research to determine effective CT values on Cryptosporidium for the above disinfectants is ongoing and no official values have yet been published. Given that an ozonation system for this size of plant would incur a capital cost in excess of $2M, it is recommended that the City focus on Chlorine Dioxide and UV radiation.

Chlorine Dioxide is already proposed as a pre-filtration aid to substitute for Powdered Activated Carbon in the control of tastes and odours, and would also present a nominal barrier for Cryptosporidium breakthrough.

More recent research reveals that UV light, with either low or medium pressure lamps, is very effective at Cryptosporidium inactivation, achieving from 2-log to 4-log reductions. It will therefore be prudent to consider installation of a UV contactor as a final barrier for both Giardia and Cryptosporidium protection. It will also have the added benefit of reducing chlorine dosage and consequent chlorine by-products.

6.0 DISTRIBUTION NETWORK

6.1 Piped System

Filtered water delivery to town is via two 14" mains. These are adequate for long-term demand. The distribution network consists of a variety of 10", 8" and 6" mains and hydraulic modelling has indicated that adequate fire flows are available at all hydrants.

City crews carry out meticulous maintenance on the system with regular flushing and valve and hydrant exercising. Area soils are highly corrosive and badly corroded metal pipes are replaced as necessary on an annual basis. A significant portion of metal pipes has already been replaced through an annual rehabilitation program.

A minor bottleneck for fire flow has been identified between Parkhill reservoir and the downtown area, and a section of pipe crossing the Alaska Highway should be replaced with a larger pipe.

6.2 In-Town Storage

In-town storage for fire and emergency conditions is at the Parkhill Reservoir. This reservoir was reconstructed in 1997 and has a storage capacity of 1.7 M Gals. This volume is sufficient for all fire flow and emergency demands.

The Parkhill Reservoir currently operates at an elevation of 2,352 ft. It services two zones above this elevation by pumping directly into the zones. One of these zones, the Loran zone, was previously serviced by the Loran reservoir, which was decommissioned in 1997 after the roof collapsed.

The pump system operates effectively and a large fire pump is available to provide fire flows to the upper zones. Current operation of the fire pump is manual, but this will be automated with the implementation of a City-wide SCADA system.

6.3 Pouce Coupe Connection

The bulk water supply line to Pouce Coupe is reportedly in good condition. However, the metering and control chamber is very old and requires upgrading. Remote telemetry would cut down on operating and maintenance costs and a refurbishment of this facility should be considered.

7.0 CAPITAL COST ESTIMATES

The following is a summary of estimated capital costs to implement the major elements of the water quality assurance plan.

7.1 Source Water

1.	Increase storage at Bear Hole Lake by raising control weir by 3 feet	$90,000
2.	Construct new river intake at Arras	90,000
3.	Allowance to correct stop log problem at Kiskatinaw weir	50,000
4.	Update Watershed Management Plan and Amend Water Licence	36,000
5.	Install water quality and gas monitoring devices at Arras	40,000

7.2 Raw Water Transmission and Storage

1.	Clean out and upgrade Hart Reservoir cells	$50,000
2.	Construct sedimentation pond near Arras (assumed land cost of $50,000)	850,000
3.	Construct high lift pumphouse	120,000
4.	Add variable speed drive at Deveraux booster	70,000
5.	Replace steel pipeline from Hart to Trail Reservoir (8,000m)	1,400,000
6.	Flow control valving at Trail Reservoir	60,000
7.	Piping rehabilitation at Trail Reservoir	70,000
8.	Settling pond at Trail Reservoir	150,000

7.3 Treatment Plant Upgrades

1.	Install new PAC feeder	$70,000
2.	Install Chlorine Dioxide feeder	50,000
3.	Install additional filter at plant (multi-media)	550,000
4.	Install membrane filter at plant	1,800,000
5.	Install 500,000 gallon finished water reservoir	600,000
6.	Install UV disinfection	90,000
7.	Convert Ridge reservoir to sludge pond (including piping)	80,000
8.	Re-pipe sludge decant from Ridge	20,000
9.	Install filtration for sludge decant	200,000
10.	Install DAF for sludge decant	200,000
11.	Emergency Response Plan	8,000
12.	Upgrade laboratory	15,000
13.	Lungul reservoir pumphouse	180,000

7.4 Distribution Network

1.	Upgrade Pouce Coupe metering chamber and add remote telemetry	40,000
2.	Upsize Parkhill Reservoir feed line	200,000

7.5 Option Comparison

Items under 7.3 present a listing of capital cost estimates for both additional media filtration and membrane filtration, as well as optimal reservoir sizes with and without added filtration.

To enable some choices, the following can be considered:

a) Finished Water Storage

The provision of greater finished water storage will partly mitigate the plant's shortfall in production capacity. However, it is inevitable that as the City continues to grow, the plant will need to produce more water, and additional filtration will be required.

It is therefore recommended that the 500,000 Gal reservoir be selected and provision made for additional filtration.

b) Type of Filter

It can be anticipated that use of a membrane filter for secondary filtration will not require either of the taste/odour control systems, nor the sludge decant filtration.

The capital cost comparison is as follows:

Membrane Filtration	Media Filtration	
$1,800,000 (filter and pumps)	550,000	(filter)
	50,000	(taste/odour control)
	200,000	(decant filtration)
	$800,000	

While membrane filtration offers much better finished water, it comes at a significant premium over conventional media filtration.

If membrane filtration without pre-filtration is feasible, the attendant annual cost saving in chemicals is in excess of $20,000/year. The Present Worth of such a saving (using 5%/annum compound interest over 20 years) is approximately $250,000. This is still too low to justify the additional $1.0 M extra cost.

The expected life of membranes is also the subject of some debate. While some manufacturers warranty the membranes for 5 years, the maximum expected life could be at best 8 – 10 years. Replacement costs for membranes are relatively high and the savings in coagulant chemicals would be negated.

It is therefore recommended that additional filtration capacity be achieved with conventional media filters.

c) Taste/Odour Control

The capital cost estimates indicate that Chlorine Dioxide is roughly half the cost of Powdered Activated Carbon. Operating costs will also be less.

It is therefore recommended that Chlorine Dioxide be considered for taste/odour control. Since all waters have their own peculiar chemistry, trial testing with Chlorine Dioxide is recommended prior to full-scale installation.

d) Pre-Plant Settling

The capital cost of pre-plant settling options are:

Settling pond near Trail reservoir:	$150,000
Use Lungul and construct pump station:	$180,000

It is evident that the more economical option is to use a settling pond at the Trail site. In addition to the higher cost, a pump system at Lungul would incur annual power consumption costs.

A third option is to utilize coarse roughing filters at the plant prior to entry to the main plant units. Roughing filters can be of two varieties:

- Pressure tanks (downflow or upflow)
- Gravity tank (downflow or upflow)

Pressure tanks are limited in the available size of each tank (to about 6 ft. diameter). Approximately 8 tanks would be required within a 600 $ft.^2$ building. Gravity tanks would occupy somewhat less space and provide easier access for maintenance. The estimated capital costs are:

- Pressure filters (bank of 8): $300,000
- Gravity filters (bank of 2): $260,000

In terms of overall cost, the settling pond at Trail presents the lowest cost option.

e) Deveraux Booster Upgrade

This $70,000 investment is warranted only if land cannot be found for a storage pond near Arras. If the storage pond can be implemented, the Deveraux booster pumphouse can be eliminated.

f) Sludge Decant Filtration

The costs of filtering sludge decant by either membrane filtration or DAF are roughly equivalent. While the DAF is a lower cost unit, its footprint would require a building extension and this adds considerably to the cost. Ultrafiltration will achieve 4-log removal of protozoa and the filtrate can be directed to the clearwell for disinfection without reprocessing. It is therefore recommended that membrane filtration be selected for sludge decant return.

7.6 Priority Rankings and Plan Phase-In

The following is an attempt to prioritize the Water Quality Assurance Plan investments based on the urgency of implementation to protect water quality. It is based on a 4-year program of investments in order to culminate with a 20-year capacity for both quantity and safe quality.

The suggested priority rankings for all the investment items is as follows:

YEAR 1

7.1.2	New River Intake		$90,000
7.1.5	Monitoring devices at Arras		40,000
7.2.6	Flow control valving at Trail		60,000
7.2.7	Piping rehabilitation at Trail		70,000
7.3.3	Install new filters		550,000
7.3.6	500,000 Gal reservoir at Ridge		600,000
		Subtotal	$1,410,000
		E & C (30%)	423,000
		Admin (10%)	141,000
		GST (7%)	128,000
		Total	**$2,102,000**

YEAR 2

7.1.1	Bear Hole Lake impoundment		$90,000
7.1.4	Watershed Management Plan		36,000
7.2.1	Upgrade Hart Reservoirs		50,000
7.3.9	Install filtration for sludge decant		200,000
7.3.10	Emergency Response Plan		8,000
7.1.3	Correct stop logs at Kiskatinaw weir		50,000
7.2.8	Settling pond at Trail Reservoir		150,000
7.3.2	Install Chlorine Dioxide Unit		50,000
7.3.7	Convert Ridge to sludge pond		80,000
7.3.8	Re-pipe sludge decant from Ridge		20,000
7.3.11	Upgrade laboratory		15,000
7.4.1	Upgrade Pouce Coupe chamber		40,000
		Subtotal	$789,000
		E & C (30%)	237,000
		Admin (10%)	79,000
		GST (7%)	72,000
		Total	**$1,177,000**

YEAR 3

7.2.2	Construct pond near Arras	$850,000
7.2.3	Construct high lift pumphouse	120,000
7.3.6	Install UV disinfection	90,000
7.4.2	Upsize Parkhill reservoir feed line	200,000
	Subtotal	$1,260,000
	E & C (30%)	378,000
	Admin (10%)	126,000
	GST (7%)	115,000
	Total	**$1,879,000**

YEAR 4

7.2.5	Replace pipeline: Hart to Trail	1,400,000
	E & C (30%)	420,000
	Admin (10%)	140,000
	GST (7%)	127,000
	Total	**$2,087,000**

TOTAL PROGRAM VALUE: $7,279,000

8.0 CONCLUSIONS & RECOMMENDATIONS

8.1 Conclusions

The overall water system assessment reveals a functional but ageing set of major components. For long-term planning, investments must be made to ensure safe water quality for the consumers and a sufficient reliable supply on dry years.

8.1.1 Source Water

The Kiskatinaw is currently the City's only viable source of water. While other sources may be accessed, these sources are extremely remote and would incur excessive capital costs to develop. Groundwater may be found, but not likely in sufficient quantity to become the primary supply.

It is therefore important that the City make every effort to:

a) Protect the Kiskatinaw from further deterioration in water quality.
b) Provide sufficient storage mechanisms to get through the dry years. This includes increased storage of raw water (at Bear Hole Lake) and increased storage of pumped water (at Arras).

8.1.2 Delivery System

The delivery system has been upgraded over recent years with upgrades at the Arras pumphouse and the transmission main to the Hart Reservoir. However, other components date back to the 1950's and are nearing the end of their useful life.

The transmission main from Hart to Trail is one such element. Cathodic protection has kept this steel pipe functional and rigorous monitoring and upkeep may extend its life for several more years.

However, it should be anticipated that increasing maintenance and repair costs will warrant the cost of replacement and it will be prudent to budget for the replacement costs well in advance.

8.1.3 Water Treatment Components

The plant is in need of component upgrading in order to:

a) Ensure that it can process enough water to meet the demand at an acceptable level of quality.

b) Provide sufficient protection for the consumer and produce safe water on a consistent basis.

c) Reduce the risk of re-contamination by elimination of open finished water storage and by filtration of sludge return.

Since the plant has been meticulously maintained, all the existing components are in excellent working order, and the upgrades suggested are primarily to ensure adequate processing capacity and to provide adequate barriers to contaminant or microbiological breakthrough. Microbes such as Cryptosporidium and by-products such as Trihalomethanes were not a concern 10 years ago, but Health authorities are becoming increasingly vigilant over these risks. Cryptosporidium outbreaks such as Milwaukee have killed hundreds of people. At the same time, there are serious concerns of long-term ingestion of high levels of Trihalomethanes.

The proposed improvements attempt to achieve a balanced reduction of both microbiological risks and chemical risks, while retaining all existing elements to minimize the financial investment.

8.1.4 Water Conservation

The City has historically encouraged water conservation and has used sprinkling restrictions in the past during dry summer periods. It is suggested that more pro-active initiatives be considered including:

a) Programmable timer systems for City-operated parks and green areas.
b) Rigorous monitoring of leaks.
c) Development of a by-law requiring all new developments to use low water-use fixtures.
d) Initiating a program for retrofit low-flow showerheads in conjunction with BC Hydro.
e) Obtain and distribute the CHMC “Household Guide to Water Efficiency”.
f) Hold and sponsor a public open house to increase with water-use efficiency awareness.
g) Develop “billing stuffers” with water efficiency tips.
h) Publish weekly water consumption data in local newspaper.

8.2 Recommendation

It is recommended that this report be submitted to the Regional Public Health Authority for review and approval.

It is also recommended that the report be submitted to the Ministry of Municipal Affairs together with a request for funding assistance under the Canada-BC Infrastructure Funding Program.

Further review and discussion may result in priority and schedule adjustments in order to dovetail with available funding.

APPENDIX I

Peace Liard Health Report