WATERBORNE GIARDIASIS - TREATMENT PROCESS SELECTION

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WATERBORNE GIARDIASIS-TREATMENT PROCESS SELECTION

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ABSTRACT: In the fall of 1981 about sixty cases of waterborne Giardiasis were confirmed at the Village of 100 Mile House, British Columbia. At the time of the incident the addition of chlorine solution to the surface water source with minimal contact time was the only water treatment practised. It was recommended that a water filtration plant be constructed. In 1983 a pilot water treatment program involving four types of filtration was undertaken. The pilot program monitored the effort required to operate four general filters, including slow sand filtration, diatomaceous earth filtration, gravity rapid rate multi-media filtration and pressurized rapid rate multi-media filtration, in a manner identified by the United States Environmental Protection Agency that would be required to ensure removal of the Giardia cyst. From this program an estimate of the annual capital and operation and maintenance costs of the four filtration processes was made. The slow sand filtration process was chosen by the Village for incorporation in a new water treatment plant substantially complete December 1984 at a construction cost of $780,000 (Cdn). The plant began operation in November 1985.

INTRODUCTION

In the fall of 1981 at least sixty cases of Giardiasis associated with the pathogen Giardia lamblia were confirmed at 100 Mile House, British Columbia, Canada. The service area population was about 2,000 persons. The outbreak affected people living in a wide geographical area around 100 Mile House and no other source explained the findings as well as waterborne contamination of the municipal water system. The source was suspected to be beavers and muskrats subsequently confirmed positive for Giardia cysts and located upstream of the Village's surface water intake. At the time of the incident water supply was surface water from Bridge Creek, located within the uncontrolled Horse Lake watershed, and to a minor extent from a groundwater well. The addition of chlorine solution, with minimal contact time provided in the distribution system was the only treatment practised. The surface water quality at the time of the incident is not known. However, subsequent testing over a calendar year determined that water quality generally exceeded the recommended objective levels set by the British Columbia Ministry of Health. This included turbidity which was less than 2 NTU over a calendar year and was generally less than 1 NTU over several months.

The circumstances that allowed the passage of the cyst from the water source to the Village's distribution system were not unique. Outbreaks in other communities have occurred where the source was surface water, where disinfection of the water source was either absent or poorly practised or where water treatment did not include filtration or if filtration was present there were structural or operational defects including the absence of coagulation. (1)(2)

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The further development of the Bridge Creek surface water source, including a treatment plant, was chosen by Village council as the preferred method of meeting the Village's domestic water demand. The construction of additional wells and the abandonment of the surface water source was rejected due to the uncertainty of yield, uncertainty of water quality and projected high pumping costs. The existing wells are low yield located to a depth of 183 m (600 ft.) in fractured bedrock.

The major concern with design of the treatment plant for a small community such as 100 Mile House was to choose a filtration process that reliably ensure protection against the passage of the cyst from the low temperature low turbidity water source to the distribution system and yet minimize the yearly operation and maintenance cost. The fact that even without filtration the water source met the current drinking water objectives, except for the implied presence of the Giardia cyst, allowed a number of filtration processes to be considered.

For several years the Drinking Water Research Division of the United States Environment Protection Agency (USEPA) has been conducting and sponsoring research on the appropriate water treatment technology for small systems to ensure removal of the Giardia cyst. (3)(4)(5)(6)(7)(8) The research programs have identified the most important operating variables for each filtration process to ensure removal of the cyst. A pilot water treatment program for 100 Mile House was undertaken that monitored the effort required to operate each filter in a manner identified by the USEPA to remove the giardia cyst. Four types of filters were used in the program including gravity rapid rate multi-media filtration, pressurized rapid rate multi-media filtration, slow sand filtration and diatomaceous earth filtration. Based on the pilot plant results capital and operation and maintenance costs were estimated for full scale plants and an evaluation was made of each treatment method.

The slow sand filtration treatment process to be incorporated in a new water treatment centre was chosen by the Village. The new water treatment centre substantially completed in December 1984 includes a surface water intake, raw and treated water pumping stations, chlorine disinfection equipment and contact tank, clear well, operations building and connection to the existing distribution system. The water treatment plant began operation in October 1985. The delay between plant completion and startup was contractual problems with the supply of media.

PAST STUDIES

Slow Sand Filtration - An evaluation of the effectiveness of slow sand filtration and the role of operating conditions on the removal of the Giardia cyst were tested at Colorado State University under a cooperative agreement with the USEPA.(3) (4). The research looked at the effect on cyst removal of hydraulic loading rate, temperature, cyst concentration, age of schmutzdecke, and age of filter bed (biological maturity). The hydraulic loading rates included 0.04 $m^3/m^2/hr$ (1,000,000 vs. USgals per ac. per day (gapd)), 0.12 $m^3/m^2m/hr$ (3,000,000 gapd) and 0.40 $m^3/m^2/hr$ (10,000,000 gapd), the raw water cyst concentrations ranged from 50 to 5,075 cysts/litre, and the raw water temperatures were 15°C and 5°C. (Note: The measurement of gallons is a British measure unless noted.) Conclusions were that the cyst removal can be expected to be greater than 98 percent when the filter is establishing the biopopulation and is virtually complete once established. Within the limitations of the research, temperature, cyst concentration and hydraulic loading rate did not affect cyst removal. The most important variable in the performance of the filter media was established to be the biopopulation. Logsdon (5) reported coliform removal of 99% for the months of March to November and 94 percent to 97 percent for the months of November to January at a full scale slow sand filter. The applied cyst removal was 99.9 percent at a variety of operating conditions but the author noted that at low temperatures the Giardia cyst removal efficiency may decrease. The United States Public Health Service reported virus removals of 22 to 96 percent and the Metropolitan Board of Health in London, England, found reduction of 99.9 percent in viruses through a laboratory size slow sand filter at a temperature of 11-12°C and 99.8 percent with a temperature at 6°C. (6)

Diatomaceous Earth Filtration - Logsdon (7) reported that diatomaceous earth (DE) is an effective method for treating cyst contaminated waters. With a precoat of 1.0 kg/m^2 (0.2 lb/ft^2) and a clean filter, the DE can remove more than 99 percent of the cysts applied to the filter. The removal of coliform bacteria was reported to be 90 percent with a coarse DE grade while it was 99.86 percent with the finest grade tested. It was concluded that as the particle size decreased from plankton to coliform to virus, the straining mechanism becomes less effective. The use of polymers can enhance the removal of the very small particles so that DE filtration can be a barrier against passage of bacteria and viruses. Lange (8) found that the Giardia cyst removal was virtually 100 percent for all grades of DE over a wide range of conditions. The DE grade was the most important factor in the removal of bacteria and turbidity. The turbidity removal increased from 17 to 98 percent and coliform bacteria from 28 to 99.9 percent when comparing the use of coarse and fine DE grades. The effectiveness of DE filtration was not influenced by temperature over the range 3.5°C to 15°C. Hydraulic loading rate showed no effect on removal efficiency of Giardia cyst and a decreased removal efficiency for bacteria, particles and turbidity with an increased hydraulic loading rate.

Rapid Rate Multi Media Filtration - Al-Ani (9) reported on Giardia cyst removal with gravity rapid rate filtration for low temperature, low turbidity raw waters. With the use of both a polymer and alum, greater than 99 percent of the cysts in the raw water with turbidity of less than 1 NTU were removed through a gravity rapid rate multi media filter. The removals were greater than 90 percent for turbidity and 99 percent for total coliforms when effective chemical dosages were used with low turbidity waters, even at temperatures of 3°C. In this work the major concern was the use of an effective water quality parameter for process control as the measurement of Giardia cysts cannot be done as a routine task. Based on an examination of a number of relationships it was concluded that when turbidity removals exceeded 80 percent, the Giardia cyst removal exceeded 99 percent.

Logsdon (6) stated that research by the USEPA has shown that Giardia cysts may pass through filters when doses of coagulant are inadequate or when raw water is not coagulated. Also, cysts break through occurred during a filter run when coagulant feed was interrupted, when the rate of filtration was increased or when a break through of turbidity occurred at the end of a run. The cyst reduction was 99 percent when the raw water was properly coagulated. This work has noted that research at the University of Washington determined a cyst removal of only 15 percent for filter runs with uncoagulated water. It was also noted that the removal of coliform bacteria ranged from 80 percent to 99 percent at 3 filtration plants. Under pilot plant work, a virus removal rate of 1 to 50 percent was determined for uncoagulated water and 90 to 99 percent with properly coagulated water without sedimentation, and 99 percent with water that had been coagulated, flocculated and settled prior to filtration.

BACKGROUND

The Village of 100 Mile House, (51° 39' north and 121° 18' west), is at an elevation of 1000 m (3200 ft.) above sea level. The present population within the Village boundaries is about 2075 persons. The Village's 1984 budget for the supply and distribution of water is $195,000 (Cdn.) including administration, wages, power, telephone, chemicals, repairs and planned capital works projects. Table 1 presents a summary of the average historical monthly temperature and precipitation. The total annual precipitation is about 386.0 mm (15.2 in.). The temperature of the surface water source is near 0°C for extended periods of the year.

	Daily Maximum Temperature (°C)	Daily Minimum Temperature (°C)	Daily Temperature (°C)	Rainfall (mm)	Snowfall (mm)	Total Precipitation (mm)
JAN	-4.7	-14.6	-9.4	2.5	44.3	40.6
FEB	1.4	-10.5	-4.5	1.6	18.7	22.0
MAR	5.2	-7.3	-1.4	0.9	16.1	16.1
APR	11.2	-2.2	4.3	7.8	2.1	15.0
MAY	16.7	2.1	9.2	32.4	1.2	33.3
JUN	19.8	5.7	12.8	52.9	0.0	52.9
JUL	23.0	7.6	15.4	42.3	0.0	42.3
AUG	22.2	6.9	14.7	39.2	0.0	39.2
SEP	17.9	3.4	10.8	27.8	0.6	28.3
OCT	11.0	-0.9	5.0	20.6	1.5	25.8
NOV	2.1	-6.8	-2.3	2.9	26.4	30.7
DEC	-2.4	-11.1	-6.5	1.1	38.0	39.8
YEAR	10.3	-2.3	4.0	232.0	148.9	386.0

TABLE 1 - Historical Temperature and Precipitation
100 Mile House

Water Demand. The Village's projected population and water demand is summarized in Table 2. There are presently about 675 water connections.

		1984	1987	1992	1997	2002
Population Served		2,075	2,300	2,800	3,400	4,200
Peak Day Demand	ML/d	3.30	3.66	4.45	5.41	6.68
	(gpd)	725,000	805,000	980,000	1,190,000	1,470,000
Yearly Total Demand	ML	565	636	773	932	1,136
	(Mg)	(125)	(140)	(170)	(205)	(250)
Average Day	ML/d	1.55	1.75	2.11	2.55	3.11
	(gpd)	(342,000)	(385,000)	(465,000)	(560,000)	(685,000)

TABLE 2 - Projected Water Demand

Water Supply. The peak day water demand will be met with treated Bridge Creek water supplemented from the existing Well No. 2. The water treatment plant will be sized to provide the peak day flows as outlined in Table 3.

		1984	1987	1992	1997	2002
Peak Day Demand	ML/d (gpd)	3.30 (725,000)	3.66 (805,000)	4.45 (980,000)	5.41 (1,190,000)	6.68 (1,470,000)
Peak Day Supply by Well No. 2	ML/d (gpd)	0.91 (200,000)	0.91 (200,000)	0.91 (200,000)	0.91 (200,000)	0.91 (200,000)
Peak Day Supply by Water Treatment	ML/d (gpd)	2.39 (525,000)	2.75 (605,000)	3.54 (780,000)	4.50 (990,000)	5.77 (1,270,000)

TABLE 3 - Projected Water Supply

Water Quality. Bridge Creek water originates in Horse Lake some 10 km (6 mi.) upstream of 100 Mile House. A control structure on Bridge Creek near Horse Lake allows the storage of water in Horse Lake in the spring and a controlled release through the dry summer months. The creek meanders through fields, pasture and bush from Horse Lake to the proposed intake. The watershed is not controlled and residential and agricultural land uses occur around Horse Lake and along Bridge Creek. Bridge Creek is also used to water cattle.

A summary of Bridge Creek water quality parameters is included in Table 4. Also included is the recommended maximum and objective water quality levels for water used in domestic consumption as outlined in the Environment Canada - Water Quality Source Book, 1979 and the B.C. Ministry of Health - Drinking Water Quality Standards, 1982.

The following are noted in a comparison of the measured Bridge Creek water quality parameters summarized in Table 4 to the maximum and objective levels:

1) The water is classified as hard. The water hardness is about 130 to 140 mg/L as $CaCO_3$ while the objective level is less than 120 mg/L. The total alkalinity is about 160 mg/L as $CaCO_3$.

2) Iron and manganese levels are less than the maximum acceptable levels but greater than objective levels. These parameters are aesthetic considerations.

3) Nitrite, nitrate plus nitrite and phosphate levels are less than the maximum acceptable levels but greater than objective levels. These parameters are health considerations.

4) Potential trihalomethanes are less than maximum acceptable levels but greater than objective levels. This parameter is a health consideration.

5) The remainder of the parameters analyzed are less than the objective levels.

6) Total solids are about 200 mg/L. About 0.5% to 3% of the total solids are suspended and the remainder are dissolved and colloidal.

7) Turbidity is less than 2 NTU year round.

8) The pH ranges from 8.0 to 8.4.

PILOT TESTING PROGRAM

The pilot plant water treatment program was undertaken between July and October, 1983 within the fenced area of the old Village intake site. This location provided protection for the equipment and made available electricity and water supply to the units. No attempt was made to modify the natural water quality or temperature of the Bridge Creek raw water supplied to the pilot units.

The water supply to the units was from the Village's water distribution system immediately upstream of the pumps at the Bridge Creek intake. The line pressure at a point where the lateral to the pilot units was located was about 480 - 500 kPa (70-73 psi) when the pumps were off and 655 kPa (95 psi) when the pumps were operating.

Equipment. The pilot water treatment program used four units. Three units were supplied by manufacturers while the slow sand filter unit was constructed by the Village. The manufacturer supplied pilot units included:

Manufacturer	Filtration Description
Filtronics, Incorporated (Anaheim, California)	Pressurized Rapid Rate Multi-Media Filtration
Industrial Filter and Pump Mfg. Co. (Cicero, Illinois)	Diatomaceous Earth Filtration
Neptune Microfloc (Corvallis, Oregon)	Gravity Rapid Rate Multi-Media Filtration

The manufacturer's supplied pilot units were chosen from a number available on rental price. It is assumed that results from each pilot unit would be typical of similar pilot units supplied by other manufacturers.

Water Analysis. The presence of Giardia lamblia was not tested for in the pilot plant program. Rather the raw and treated water to and from each of the pilot units was analyzed for turbidity at selected intervals by Village staff using a Fisher Model DRT-15 Turbidimeter. The unit, sensitive to change of 0.02 NTU, measured turbidity over four switch-selectable ranges: 0 to 1.0, 10, 100 and 200 NTU.

In addition, on September 8, 1983, a total of seven water samples, each a total of 6 L in volume were collected at the various locations and analyzed for the following parameters:

(a) Particle size distribution in range 1-100 microns
(b) pH
(c) Alkalinity
(d) Hardness
(e) Turbidity
(f) Total, dissolved and suspended solids with 0.45 and 5 micron filters
(g) Aluminum

The particle distribution was analyzed with an Electrozone Cellescope (manufactured by Particle Data Inc.) at the Faculty of Applied Science, Department of Mineral Engineering, University of British Columbia, and the remaining parameters were analyzed at the laboratories of Can-Test Ltd., Vancouver, B.C.

SLOW SAND FILTRATION

For the slow sand filter process the goal was to determine the filter cycle length for the accepted maximum filter rate of 0.40 $m^3/m^2/hr$ (10,000,000 gapd) and for the intermediate rate of 0.20 $m^3/m^2/hr$ (5,000,000 gapd).

Equipment. The unit was constructed using 1050 mm (42 in.) diameter concrete manhole barrels placed to a height of 3.45m (11.31 ft.) as measured from the invert of the 100 mm (4 in.) PVC underdrain pipe to the top of the filter. The barrels were located on a cast-in-place concrete base.

The filter media, from stock piled material of a local aggregate supplier had an effective size (d_{10}) of 0.15 mm and a uniformity coefficient (d_{60}/d_{10}) of 7.3. The filter media was placed 1050 mm (42 in.) deep and was located on top of 450 mm (18 in.) of gravel placed in three distinct layers. At filter start-up, the distance from the top of the filter media to the top of the filter was 1.9 m (6.2 ft.).

The raw water was fed to the top of the filter while the treated water drained from the bottom of the filter through a 100 mm (4 in.) PVC perforated underdrain located in the gravel layer. The perforated pipe was connected to 100 mm diameter PVC drain pipe located through the filter wall. On the outside of the filter the drain pipe was in a vertical upwards direction until it reached the level of the filter media where it then was vertical and downwards to discharge. The intention was to establish control for a declining rate filter, prevent dewatering of the filter media and prevent a negative head in the filter in the event of temporary loss of raw water flow.

Operation. The pilot plant operated continuously in the declining rate mode for a total of 89 days through three operating cycles starting July 18, 1983. An operating cycle was defined as the time between start of pilot operation after filter cleaning and the time at which the water level reached the top of the filter. At the end of a cycle, the raw water supply was turned off, the water level drained to about 200 mm (8 in.) below the top of the filter surface and about 50-100 mm (2 to 4 in.) of filter media was removed and disposed. At that point the unit was put back into operation. The cleaning operation took less than one-half hour.

The filter was operated continuously at 0.40 $m^3/m^2/hr$ (10,000,000 gapd) for cycles 1 and 2 and at 0.20 $m^3/m^2/hr$ (5,000,000 gapd) for cycle 3. The water temperature was between 7 and 15°C.

Results. The water surface profile and the raw and treated water turbidity profiles for the three operating cycles are summarized on Figure 1. The parts of the water surface profile identified by an interpolated line are for those time periods when no data were collected due to staff annual vacations.

<u>Cycle 1 (July 18, 1983 - August 18, 1983)</u>. The water surface at the start of Cycle 1 was 0.43 m (1.40 ft.) above the top surface of the filter media. By the end of the twenty nineth day of operation the water surface had risen to 1.89 m (6.20 ft.) above the filter surface. The increase in water depth in thirty-one days of operation was 1.46 m (4.80 ft.).

The turbidity in the raw water varied between 0.9 to 2 NTU with two measurements out of 80 being 3.2 and 4.2 NTU. The turbidity in the treated water was typically less than 0.4 NTU.

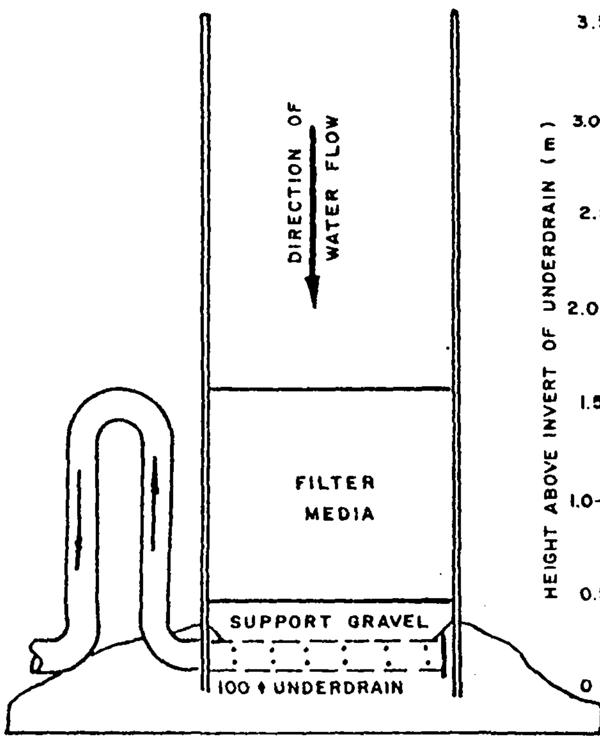
<u>Cycle 2 (August 18, 1983 - September 3, 1983)</u>. The water surface at the start of Cycle 2 was assumed to be 0.43 m (1.40 ft.) above the top surface of the filter media. By the end of the sixteenth day of operation, the water surface had risen to 1.74 m (5.72 ft.) above the filter surface. The increase in water depth in sixteen days of operation was 1.31 m (4.32 ft.).

The turbidity in the raw water varied between 0.52 NTU and 0.76 NTU with the treated water turbidity being between 0.21 NTU and 0.43 NTU.

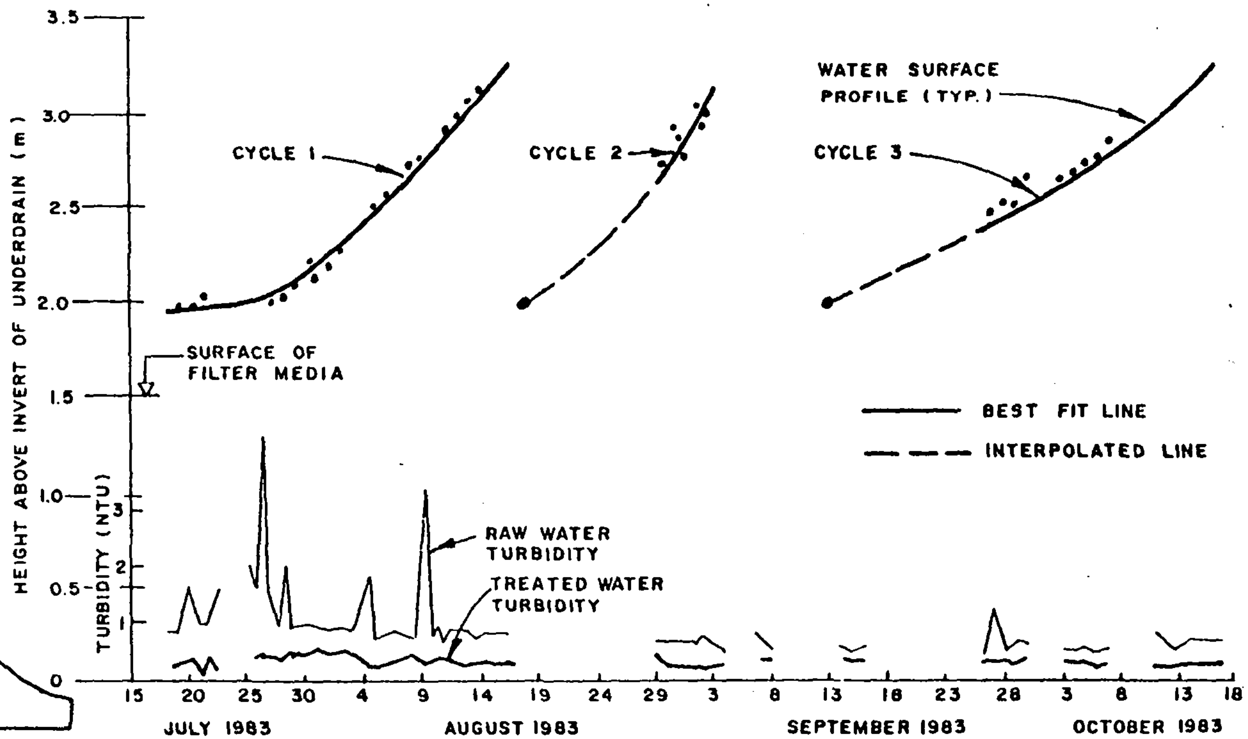
<u>Cycle 3 (September 12, 1983 to October 17, 1983)</u>. The water surface at the start of Cycle 3 was assumed to be 0.43 m (1.40 ft.) above the top surface of the filter media. By the end of the thirty-seventh day of operation, the water surface had risen to 1.92 m (6.31 ft.) above the filter surface. The water depth increase in thirty-seven days was 1.49 m (4.91 ft.).

The turbidity in the raw water varied between 0.50 NTU and 1.31 NTU and the treated water turbidity ranged between 0.28 NTU and 0.43 NTU.

A summary of the distribution by number of particles greater than 1 micron for the raw and treated water is presented on Table 5.



CROSS SECTION
SLOW SAND FILTER



SLOW SAND FILTER
WATER SURFACE AND TURBIDITY PROFILE

FIGURE 1 - Slow Sand Filter - Water Surface and Turbidity Profile

Diameter (microns)	Raw Water	Treated Water Sept. 8, 1983	Treated Water Oct. 4/83
1-5	34.4%	88.9%	83.0%
5-10	32.5%	10.6%	15.4%
10-15	14.2%	0.3%	1.9%
greater than 15	19.2%	0.2%	0.6%

TABLE 5 - Particle Size Distribution Greater Than 1 Micron-Slow Sand Filter

In the treated water samples, 88.9 percent and 83.0 percent of the particles greater than 1 micron were less than 5 microns. By comparison 34.4 percent of the particles in the raw water were less than 5 microns. The turbidity in the raw and treated water samples taken for the particle size distribution analysis were 0.65 NTU and 0.35 NTU, respectively. Based on the sample taken, the removal efficiency in the 7.5 - 15 micron range through the slow sand filter was 93 percent. The Giardia cyst measures from 10 - 15 microns in length and 7 - 12 microns in width. However, the treated water sample was taken about 30 minutes after the raw water sample. The raw water would have entered the unit approximately 7-8 hours earlier. The effect of this time difference was not assessed.

Filter Design. The filter cycle length for continuous operation was about 35 to 45 days at a filtration rate of 0.20 $m^3/m^2/hr$ (5,000,000 gapd) and about 20 to 30 days at a filtration rate of 0.40 $m^3/m^2/hr$ (10,000,000 gapd).

The slow sand filter would be designed to supply the peak day flow summarized in Table 3. The filter areas required for the 1992 and 2002 peak day flows at the chosen filtration rate of 0.20 $m^3/m^2/hr$ (5,000,000 gapd) are summarized as follows:

	Peak Flow by Treatment Plant		Total Filter Area Required	
	ML/d	(gpd)	m^2	(ft^2)
1992	3.54	(780,000)	760	(8,200)
2002	5.77	(1,270,000)	1235	(13,300)

For the year 2002 peak day flow the total filter area would be provided by a filter bed with a total dimension of 30 m x 43 m (100 ft x 140 ft). To provide operating versatility, 5 modules each 43 m x 6 m (140 ft x 20 ft) were considered. For the 1992 design horizon, 3 modules with these dimensions would provide 780 m^2 (8,400 ft^2) of filter area. The beds would be covered to moderate the winter conditions and minimize the potential for algae growth within the filters.

DIATOMACEOUS EARTH FILTRATION

For the diatomaceous earth process, the goal was to establish a filter cycle length and the associated diatomaceous earth requirements for a number of body feed concentrations, a precoat rate of 976.5 gm DE/m^2 (0.2 lbs. DE/ft^2) and a filter rate of 2.4 m^3/m^2/hr (1 USgpm/ft^2).

Equipment. The pilot unit consisted of the filter located on one skid, and the body feed and pre-coat tanks, including pumps, on the second skid. The Type 122 Industrial filter unit consisted of a horizontal pressure vessel with four vertical stainless filter leaves which had a total filter surface area of 0.93 m^2 (10 $ft.^2$). The filters were covered with textile socks.

The volume of the body feed and pre-coat tank was 0.21 m^3 (46 gals). A mixer operating at 1800 rpm was included with each tank. The body feed pump included a variable speed electric motor. An air diaphram pump was included to operate the filter. The diatomaceous earth used in the program was Manville Hyflo Super-Cel.

Operation. A total of three runs of varying body feed concentration were carried out with Hyflo Super-Cel.

A run of the DE pilot unit was as follows:

1) The filter vessel was filled with raw water to about 345 Kpa (50 psi) pressure.

2) In the pre-coat tank 0.91 kg (2 lbs) of DE was added to about 37.8 L (8.3 gals) of water.

3) The filter leaves were pre-coated with DE by circulating the water from the pre-coat tank through the filters and back to the pre-coat tank until the pre-coat water visually became clear. This indicated the DE had coated the filter textile cloth. The total time was usually less than 5 minutes.

4) The calculated amount of DE and water were added to the body feed tank to achieve the design concentration for the specified body feed pump rate.

5) While the pressure was maintained in the filter unit, the body feed pump was started and water treatment commenced at a constant rate of 37.8 L/min (10 USgpm).

6) When the pressure drop across the filters was about 276 kPa (40 psi), the water treatment was stopped and a dry cake on the filter faces was obtained by using the air compressor. The air compressor maintained the pressure while the water in the pressure vessel was drained.

Results. The pressure difference across the filters with elapsed operating time for Hyflo Super-Cel DE body feed concentrations of 5, 10 and 20 mg/L is presented on Figure 2. A line of best fit is drawn through the measured points for each run.

At a body feed rate of 5 mg/L, the pressure drop across the filter was 138 kPa (20 psi) and 276 kPa (40 psi) after elapsed operating times of 18 hours and 36 hours, respectively. A pressure drop of about 138 kPa (20 psi) and 276 kPa (40 psi) was reached after about 45 hours and 90 hours, respectively, with a body feed of 10 mg/L. The pressure drop of about 138 kPa (20 psi) and 276 kPa (40 psi) was reached after about 80 hours and 100 hours, respectively, with a body feed rate of 20 mg/L.

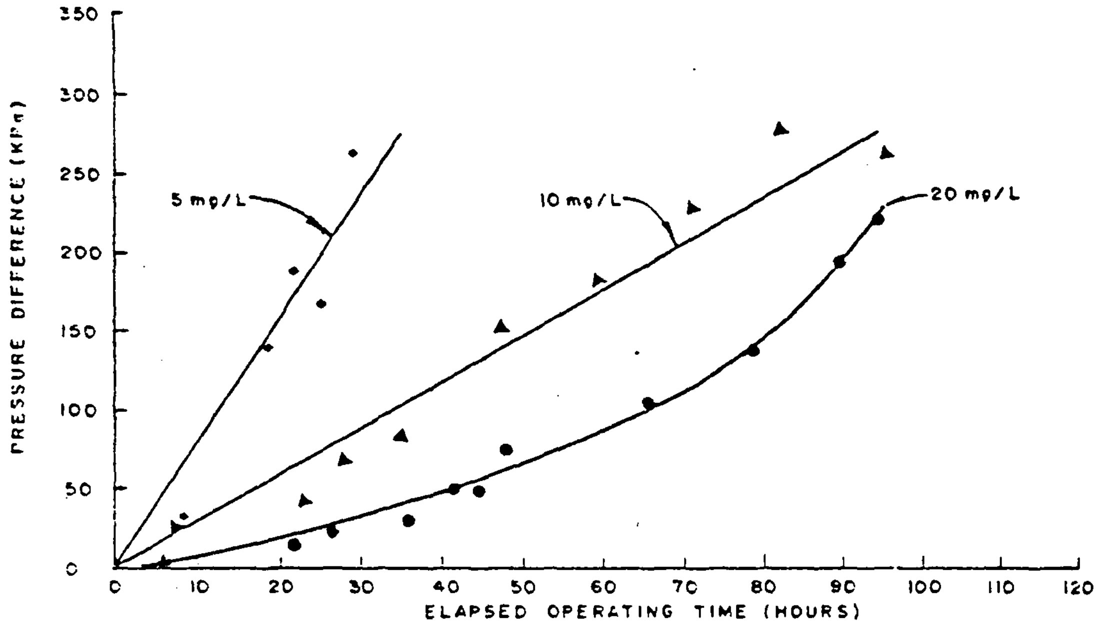


FIG. 2 - Diatomaceous Earth Filter - Pressure Difference With Elapsed Operating Time

A summary of the amount of water treated to pressure drops of 20 psi (138 kPa) and 40 psi (276 kPa) for varying body feed concentrations is presented on Table 6. By doubling the body feed concentration from 5 mg/L to 10 mg/L, the operating time and amount of water treated went up by a factor of 2.5. By doubling the body feed concentration from 10 mg/L to 20 mg/L, the operating time and amount of water treated went up by a factor of 1.8 times.

DE Body Feed Concentration	Filter Pressure Loss = 138 kPa		Filter Pressure Loss = 276 kPa	
	Operating Time (hrs)	Amount of Water Treated (L)	Operating Time (hrs)	Amount of Water Treated (L)
5 mg/L	18	40,880	36	81,765
10 mg/L	45	102,205	90	204,410
20 mg/L	80	181,700	100	227,125

TABLE 6 - Diatomaceous Earth Filter - Summary of Amount of Water Treated

A summary of the turbidity measured in the raw and treated waters for each run is presented in Table 7.

Elapsed Operating Time (hrs)	Raw Water Turbidity (NTU)	Treated Water Turbidity (NTU)
	5 mg/L	
0	.74	.28
2	.74	.26
8	.67	.25
18	.94	.25
21.5	.88	.26
25	.68	.24
29	.92	.24
	10 mg/L	
0	.76	.55
1.5	.78	.28
5	.52	.25
7.5	.78	.24
28	.66	.24
29	.74	.23
35	.62	.22
47	.86	.22
49	.72	.23
59	.64	.24
71	.80	.25
82	.65	.22
95	.46	.20
	20 mg/L	
2.25	.62	.28
5	.50	.24
18	.84	.25
22.5	.66	.24
26.25	1.18	.23
36	.64	.26
41.5	.50	.21
44.5	.84	.24
65.5	.46	.20
78.5	.48	.20
89.5	.49	.19
94	.48	.20

TABLE 7 - Diatomaceous Earth Filter
Summary of Turbidity Measurements

The treated water turbidity for all runs of Hyflo Super-Cel ranged from 0.20 to 0.25 NTU. This compares with the range of raw water turbidities of 0.46 NTU to 1.18 NTU.

A summary of the distribution by number of particles greater than 1 micron for the raw and treated water is presented in Table 8.

Diameter (Microns)	Raw Water	Treated Water
1-5	34.4%	91.5%
5-10	32.5%	8.4%
10-15	14.2%	.1%
greater than 15	19.2%	0

TABLE 8 - Summary of Particle Size Distribution Greater Than 1 Micron - Diatomaceous Earth Filter

Over 91.5 percent of the particles greater than 1 micron in the DE pilot unit treated water were less than 5 microns. By comparison, in the raw water sample 34.4 percent of the particles were less than 5 microns in size. The turbidity in the raw and treated water samples for the particle size distribution were 0.65 NTU and 0.26 NTU, respectively. Based on the sample taken, the removal efficiency in the 7.5-15 micron range through the DE pilot unit was 98.8 percent.

Filter Design. The diatomaceous earth filter would be designed to supply the peak day flow summarized in Table 3. For a flow rate of 2.4 $m^3/m^2/hr$ (1 $USgpm/ft^2$), a pre-coat rate of 976.5 gm/m^2 and a body feed rate of 20 mg/L, the filter cycle length for continuous operation was estimated to be 70 to 80 hours. The following criteria were established for the design of a diatomaceous earth water filtration plant for the Village:

Minimum Day Flow	0.91 ML/d	(200,000 gpd)
Filtration Rate	2.4 $m^3/m^2/hr$.	(1 $USgpm/ft^2$)
Precoat	976.5 gm/m^2	(.2 lb/ft^2)
Body Feed Concentration	20 mg/L	

The filter areas required for the 1992 and 2002 peak day flows are summarized as follows:

	Peak Flow by Treatment Plant		Total Required Filter Area	
	ML/d	(gpd)	m^2	(ft^2)
1992	3.54	(780,000)	60.4	(650)
2002	5.77	(1,270,000)	98.3	(1060)

To keep the body feed on the filter face in suspension during minimum day flows as well as provide standby capacity for maintenance purposes, three filters rather than 1 large filter were costed.

GRAVITY RAPID RATE MULTI-MEDIA FILTRATION

For the gravity rapid rate multi-media process, the goal was to determine the chemical requirements, including alum and polymer, to achieve an 80 percent reduction in raw water turbidity.

Equipment. The gravity rapid rate multi-media filter was a modified direct filtration unit consisting of a 2.44 m (8 ft.) high, 0.19 m^2 (2 ft^2) down flow multi-media filter and a 2.44 m (8 ft.) high, 0.19 m^2 (2 ft^2) combined flocculation and floc trapping upflow unit filled with floatable small plastic media. The filter media was to a depth of 750 mm (30 in.) in three layers. The top layer of 420 mm (16.5 in.) thickness was anthracite coal, the middle layer of 229 mm (9 in.) thickness was silica sand, while the bottom layer of 114 mm (4.5 in.) thickness was high density sand. The unit included polymer and alum feed pumps.

Two microprocessors monitored the influent and effluent turbidity and adjusted the alum dosage to maintain the effluent turbidity at a predetermined set point. The microprocessor adjustment of the alum dosage occurred at preset time intervals.

Operation. The pilot unit was operated by a Neptune Microfloc technician between September 6, 1983 and September 11, 1983, for a total of eight separate runs each distinguished by a change in chemical feed strategy. The chemical addition included Alum, Bentonite, cationic polymer (NALCO 8103) and non-ionic polymer (American Cyanimid 985N). The filter was operated at 12.2 $m^3/m^2/hr$ (5 $USgpm/ft^2$) while the upflow combined flocculation and floc trapping unit operated at 24.4 $m^3/m^2/hr$ (10 $USgpm/ft^2$). One half of the flow from the flocculation and floc trapping unit was wasted.

Results. The water temperature was between 12 and 15^oC. The mean turbidity for the raw water ranged between 0.62 NTU to 0.76 NTU. The mean treated water turbidity over the eight runs ranged between 0.15 NTU to 0.30 NTU. To maintain an effluent turbidity of between 0.10 NTU and 0.15 NTU, an Alum feed concentration of about 30 - 35 mg/L and non-ionic polymer concentration of about 0.35 -0.40 mg/L was required. The filter run was about 8.5 hours to a terminal head loss of 2.4 m (8 ft.). The filter run was less than 2 hours when a Bentonite feed concentration of 8.2 mg/L, an Alum feed concentration of 8.2 mg/L and the non-ionic polymer concentration of 0.35 mg/L was used. The effluent turbidity was between 0.15 to 0.20 NTU.

The report prepared by Neptune Microfloc concluded that to achieve a treated water turbidity of 0.25 NTU, the alum and the non-ionic polymer dosages would have to be 8-10 mg/L and 0.35 mg/L, respectively. Similarly to achieve a treated water turbidity of 0.14 to 0.16 NTU, the alum dosage would have to be 20-23 mg/L and the non-ionic polymer dosage would have to be 0.32 mg/L and to achieve a treated water turbidity of 0.10 to 0.12 NTU, the alum dosage would have to be 30-32 mg/L and the non-ionic polymer dosage would have to be 0.32 mg/L. The effect of low water temperature on the required alum or polymer concentration was not addressed in the report.

A summary of the distribution by number of particles greater than 1 micron in the raw and treated water is presented in Table 9.

Diameter (micron)	Raw Water	Treated Water 1.	Treated Water 2.
1-5	34.4%	86.0%	81.6%
5-10	32.5%	13.4%	17.2%
10-15	14.2%	0.6%	1.2%
greater than 15	19.2%	0	0

TABLE 9 - Summary of Particle Size Distribution Greater than 1 Micron - Gravity Rapid Rate Multi-Media Filter

In the treated water between 81.6 and 86.0 percent of the particles greater than 1 micron were less than 5 microns. In the raw water, 34.4 percent of the particles were between 1 and 5 microns in size. The turbidity in the raw and treated water samples for the particle size distribution were 0.65 NTU and 0.17 NTU, respectively. The removal efficiency in the 7.5-15 micron range through the pilot plant was 96 percent to 98 percent.

Filter Design. The rapid rate multi-media filter would be designed to supply the peak day flow as summarized in Table 3. An alum feed rate of 35 mg/L and a polymer feed rate of 0.35 mg/L were considered necessary to obtain an eighty percent reduction in the raw water turbidity. A filtration surface loading rate of 12.5 m/hr (5 USgpm/ft^2) was established as the basis of evaluation of a gravity rapid rate multi-media filter.

For the estimated peak day in 1992 and 2002, the following total filter areas would be required:

	Peak Day Supply by Treatment Plant		Filter Area Required	
	ML/d	(gpd)	m^2	(ft^2)
1992	3.54	(780,000)	12	(130)
2002	5.77	(1,270,000)	20	(215)

PRESSURIZED RAPID RATE MULTI-MEDIA FILTRATION

For the pressurized rapid rate multi-media process, the goal was to determine an eighty percent reduction in raw water turbidity was possible with no chemical addition prior to filtration.

Equipment. The pressurized rapid rate multi-media filter pilot included a pressure filter vessel and a motor control center.

The pressure vessel, 450 mm (18 in.) diameter and 1.2 m (4 ft.) in height, contained filter media to a depth of approximately 750 mm (30 in.) in four layers. The top 150 mm (6 in.) was anthracite coal while the remaining 600 mm (24 in.) was a proprietary media in three separate layers of differing grain size distribution. No information was provided for the proprietary media except "it is a granular free flowing material similar to sand but does not contain any silica products. The material is composed of natural material, not synthetic". The normal operating flow, from the top of the filter to the bottom of the filter, was 24.4 $m^3/m^2/hr$ (10 gpm/ft^2).

Operation. The pilot plant commenced operation July 14, 1983 and ran almost continuously until the program was stopped September 10, 1983. Timers controlled the treatment and the backwash cycles. The unit operated on a cycle of 18 hours treating water and 4 minutes for filter backwash. No chemical addition or pre-treatment was used in the pilot program.

Results. The raw and treated water turbidities and the pressure loss across the filter were measured approximately every six to twenty-four hours of filter operation. Approximately 90 sets of measurements were made for the 45 days of operation.

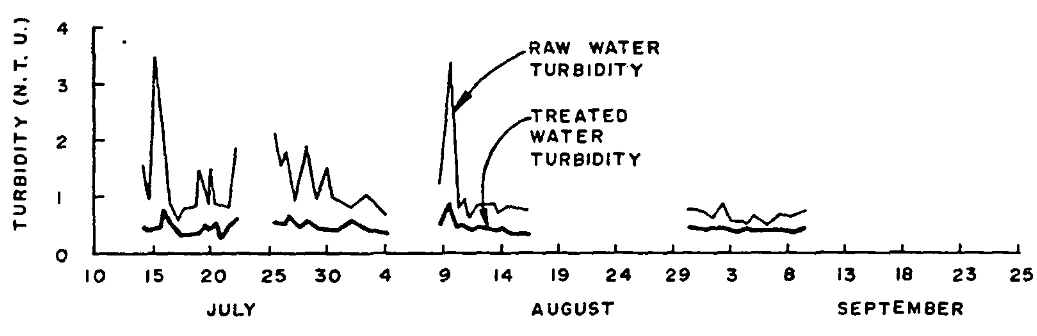


FIG. 3 - Pressurized Rapid Rate Filter - Turbidity Profile

A plot of treated and raw water turbidity with operating time is presented on Figure 3. The raw water turbidity varied from 0.5 NTU to 3.5 NTU and was typically about 0.9 NTU. The treated water turbidity varied between 0.20 NTU to 0.94 NTU and was typically 0.50 NTU. The trend in turbidity increase and decrease with time was similar for the raw water and treated water turbidities. The parts of the turbidity profile with no data are those time periods when no data was collected due to staff annual vacations.

The pressure loss was typically 100 kPa (15 psi) across the filter at the end of an 18 hour treatment cycle under an inlet pressure of 490 kPa (71 psi) and an outlet pressure of 385 kPa (56 psi).

A summary of the distribution by number of particles greater than 1 micron for the raw and treated water is presented in Table 10.

Diameter (micron)	Raw Water	Treated Water
1-5	34.1%	88.3%
5-10	32.5%	10.9%
10-15	14.2%	0.8%
greater than 15	19.2%	0%

TABLE 10 - Summary of Particle Size Distribution Greater Than 1 Micron Pressurized Rapid Rate Multi-Media Filter

In the treated water over 88.3 percent of the particles greater than 1 micron were less than 5 microns while in the treated water sample 34.1 percent of the particles were between 1 and 5 microns. The turbidity in the raw and treated water samples for the particle size distribution were 0.65 NTU and 0.39 NTU, respectively. The removal efficiency in the 7.5-15 micron range through the pressurized rapid rate pilot plant was 88.3 percent.

Filter Design. The pressurized rapid rate multi-media filter would be designed to supply the peak day as summarized on Table 3. However, the unit without chemical addition was not capable of meeting the goal of reducing the raw water turbidity by eighty percent.

For evaluation of a full scale plant, the peak operating rate was chosen to be 24.4 $m^3/m^2/hr$ (10 USgpm/ft^2), the same unit rate as the pilot plant was operated. The areas of filter required for the 1992 and 2002 peak day flows are summarized as follows:

	Peak Flow by Treatment Plant		Total Filter Area Required	
	ML/d	(gpd)	m^2	(ft^2)
1992	3.54	780,000	6.0	65
2002	5.77	1,270,000	9.8	105

EVALUATION

The efforts required to operate the four pilot water treatment filters in a manner identified by the USEPA to ensure removal of the Giardia cyst were evaluated in terms of both capital and operation and maintenance costs. Also, a review of current treatment standards in other jurisdictions for prevention of waterborne Giardiasis was made. The goal was to identify the appropriate filtration process to prevent the waterborne distribution of Giardiasis in the Village's distribution system and yet have simplicity and reliability of operation in a low temperature, low turbidity water source.

Financial Impact. The Village's estimated annual water treatment cost of the four treatment processes is summarized in Table 11. The annual cost includes capital cost repayment and operation and maintenance costs. This will be in addition to the Village's 1984 budget of $195,000 (Cdn.) for all aspects of water supply and distribution.

The debt retirement of the capital cost is based on a sinking fund with twenty-year amortization period at 12 percent interest rate. The Village's share to the retirement of the 1984 capital cost is 25 percent but based on current Provincial Government legislation, it is assumed to be 75 percent for the expansion in 1992. The capital cost includes a surface water intake, raw and treated water pumping stations, chlorine disinfection tanks and equipment, clear well, connection to the existing distribution system and filtration equipment.

The estimated operation and maintenance costs include chemicals such as chlorine, diatomaceous earth, sand, Alum and polymer, for power to operate all equipment, for heating, for labour to operate the plant and for replacement parts. Operation and maintenance costs receive no grants and must be paid entirely by the Village.

The estimated total annual cost to the Village in 1984 for a water treatment plant, including the pressurized rapid rate multi-media filtration, is $54,200 made up of $32,000 for debt repayment and $22,200 for operation and maintenance costs. Similarly, the estimated total annual cost to the Village for a water treatment plant including the slow sand filtration is $62,800 made up of $38,700 for debt repayment and $24,100 for operation and maintenance costs. The estimated total annual cost to the Village for the gravity rapid rate multi-media filtration is $72,100 including $37,400 for debt repayment and $34,700 for operation and maintenance costs while for the diatomaceous earth filtration, the total annual cost to the Village is $87,300 including $45,200 for debt repayment and $42,100 for operation and maintenance costs. The water treatment plant including the pressurized rapid rate filtration has the lowest annual cost to the Village.

By 1992, when expansion is necessary, the annual costs increase to (expressed in 1984 dollars) $80,200 for a water treatment plant based on pressurized rapid rate multi-media filtration, $101,300 for gravity rapid rate multi-media filtration, $108,400 for slow sand filtration, and $123,500 for diatomaceous earth filtration. Pressurized rapid rate remains the lowest cost option with gravity rapid rate replacing slow sand filtration as the second least cost option. This is because the higher capital cost for expansion and the lower Provincial grant combine to outweigh the lower operation cost associated with slow sand filtration as compared with gravity rapid rate filtration.

The operation and maintenance portion of annual costs are compared as follows:

	1984	1992
pressurized rapid rate	$22,200	$25,700
slow sand	$24,100	$30,400
gravity rapid rate	$34,700	$41,300
diatomaceous earth	$42,100	$51,500

Regulatory. The British Columbia Ministry of Health has no treatment plant requirements. The Ministry recommends that water meet the British Columbia Drinking Water Quality Standards, 1983. For parameters tested, the Bridge Creek water met or exceeded the maximum and generally met or exceeded the objective values of these standards, with the exception of the inferred presence of Giardia lamblia.

The regulatory authorities in the Province of Alberta and the States of Colorado, Oregon and Washington were contacted about the treatment standards if the presence of the Giardia cyst was suspected or confirmed in a watershed.

The Alberta Environmental Protection Services, Standards and Approvals Division, Municipal Engineering Branch requires that minimum treatment for all drinking water derived from surface water sources be disinfection and filtration. This minimum treatment is not considered adequate to ensure removal/destruction of the Giardia lamblia cyst. Full treatment is required including coagulation, sedimentation, filtration and disinfection. Sedimentation may be omitted in a low turbidity raw water source. Other processes are considered if they can be proven to remove particles greater than a set value and the manufacturer is prepared to guarantee the results.

The standards of the Colorado Department of Health were amended in November, 1967 to require disinfection. These standards were again amended in 1977 to require all surface water sources to be filtered and disinfected. The requirement for this minimum treatment was based on the increasing number of reported outbreaks of waterborne Giardiasis. While the cyst is resistant to commonly practised methods of chlorination, proper filtration will remove the cyst and proper chlorination will destroy other pathogens. Filtration, according to the Colorado Primary Drinking Water Regulations of October 30, 1981 means the "physical and chemical process for separating suspended and colloidal impurities from water by addition of chemicals, sedimentation and passage through a porous media".

The Washington State Department of Social and Health Services, Olympia, Washington, requires treatment unless water utilities draw from controlled watersheds that have approved watershed management plans and a turbidity level less than 5 NTU. For those utilities drawing water from an uncontrolled watershed the turbidity level must be less than 1 NTU or treatment is required. The requirements are being reviewed in light of the problems with waterborne distribution of Giardia lamblia. The State does not have regulations governing water treatment processes but coagulation, flocculation, sedimentation and filtration are normal processes. In low turbidity waters coagulation, flocculation and filtration have been accepted. Rapid rate filtration, either pressurized or gravity, without coagulation and flocculation would not be an accepted filtration process.

In Oregon, full water treatment including coagulation, flocculation, sedimentation and filtration is required where there is a possibility of "fecal contamination". The regulations do not specify the type of filtration.

Discussion. Properly operated, all four treatment options are capable of removing most Giardia cyst size particles.

The diatomaceous earth filtration treatment process had the highest estimated annual cost to the Village. On the basis of cost it was not considered.

The use of rapid rate multi-media filtration, either in a pressurized or gravity vessel, without coagulation and flocculation is generally not accepted in other jurisdictions where the removal of Giardia lamblia is required. If the coagulation and flocculation steps were included prior to pressurized rapid rate filtration, then the process and chemical needs would be similar to gravity rapid rate filtration. On the basis of lack of acceptance of direct filtration without chemical pre-treatment in other jurisdictions, and on the lowest removal efficiency of Giardia sized particles in the pilot water treatment program, the pressurized rapid rate filtration option was not considered.

Of the remaining two processes, gravity rapid rate multi-media filtration has a higher annual cost to the Village in 1984 while it has a lower annual cost to the Village in 1992. However, the operation and maintenance cost of the slow sand filter is lower than that for gravity rapid rate in both 1984 and 1992. The lower annual cost in 1992 is due to the fact that the higher capital cost for expansion combined with the assumed lower Provincial grant of twenty-five percent outweigh the lower operation cost of the slow sand filter.

In terms of only operation and maintenance costs, the slow sand filter has lower costs and was favoured. For small communities, such as 100 Mile House, it is essential to provide a water treatment plant that is reliable and easy to operate and maintain. It is desirable that power and chemical requirements be minimized as these items are susceptible to increased costs in the future. It is also desirable to avoid the need for skilled operation because staffing becomes difficult and expensive. Slow sand filtration is a passive process, requiring little operator attention or understanding except to clean the filter surface at terminal head loss. Rapid rate filtration in low temperature, low turbidity waters depends on the proper use of chemicals for coagulation, relies on automated control of the filter units and requires an operator with skill and understanding of the process. The slow sand filtration process was chosen for installation in the water treatment plant.

TREATMENT PLANT DESCRIPTION

The construction of the water treatment plant, designed for a peak day flow of 3.36 ML/d and an average day flow of 1.75 ML/d, was completed December, 1984. The plant includes a surface water intake (infiltration gallery), raw and treated water pumping stations, chlorination equipment and contact tank, a clear well, connection to an existing Village water storage reservoir, three slow sand filters, pipe gallery and control room.

Slow Sand Filters. The total slow sand filter area is 774 m^2 (8330 ft^2), with the dimensions of each filter being 43.0 m (141.1 ft.) by 6 m (19.7 ft.). The design flow rate through each filter is 1.2 ML/d. The filter walls and slab are constructed of cast-in-place reinforced concrete while the filters are covered with precast concrete panels. The distance from the floor slab to the top of the filter wall varies from 3.85 m (12.6 ft.) to 4.05 m (13.3 ft.). Soil backfill was placed around the outside of the filters to the elevation of the filter roof for insulation against cold temperature.

A filter comprises a 1150 mm (42 in.) thick layer of filter sand underlain by 3 layers of supporting filter gravel (support gravel 1, 2 and 3) of total thickness varying between 800 mm (32 in.) and 600 mm (24 in.). The filter sand and support gravel were produced by washing, drying and sieving of natural material at one site located in the vicinity of 100 Mile House. Method of production of the filter sand was modified several times in an attempt to produce material that would meet the specifications.

The effective size of the filter sand (D10) based on samples taken after placement of the material ranges between 0.20 mm and 0.30 mm with an average value of 0.25 mm. The specified value was 0.22 mm to 0.32 mm. The uniformity coefficient ranges between 3.30 and 3.80 with an average value of 3.50. The specified value was 2.0 to 2.5. For the support gravel 3 the D10 was 20.0 (specified 16.65 to 48.00) while the D90 was 63.0 (specified 23.5 to 67.7). For the support gravel 2 the D10 was 8.8 (specified 4.15 to 12.00) while the D90 was 14.0 (specified 5.9 to 17.0). For the support gravel 1 the D10 was 3.0 (specified 1.05 to 3.00) while the D90 was 6.0 (specified 1.50 to 4.25). The filter support gravel and media were dumped through a hole in the filter roof panels. A small tired tractor with a bucket was used to place the material.

There are three underdrains the length of each filter and located in filter gravel 3 with one run located along the centerline axis of the filter and the remaining two runs parallel and located 2.0 m (6.6 ft.) on either side. The underdrains are 150 mm (6 in.) diameter, 40 slot (40 slots per row per foot of pipe) SDR 26 PVC pipe. The slots in three rows, are 1 mm (0.039 in.) wide and 25 mm (1 in.) long with 6 mm (.25 in.) spacing between each slot. The three underdrains are combined as one at point of exit from each filter with a butterfly valve and water meter located on this pipe inside the control building. To avoid either dewatering of the filter or a negative head in the filter sand, the filtered water passes over a weir with the elevation of the weir equal to the top elevation of the filter sand.

The cleaning of a slow sand filter at a terminal head loss involves drawing the headwater level down to below the filter surface and mechanically removing the top 6 mm to 25 mm of the filters. The use of a small tractor and trailer to aid in the removal of the material is anticipated. To allow ease of access a 2 m x 2 m, watertight door was installed in each filter wall common with the control building. The bottom elevation of the door was equal to the elevation of the top surface of the sand media and was equal to the elevation of the control room floor. Double wide doors on the control building allow direct access from the outside of the building to the watertight doors.

The filters include several features to aid in operation. A drain is located at the elevation of the filter sand. During cleaning the drain allows the water level to be lowered at a much quicker rate. A second drain at the bottom of the filters allows the lowering of the water level in the filter bed so that the top layer is dry and easy to clean. The ability to divert filtered water to waste during the ripening period of a new or newly cleaned filter is incorporated into the design of the piping. The piping allows the ability to introduce water from the filter underdrains to drive out air bubbles from the filter sand as the water level inside the sand rises. An overflow to Bridge Creek set 0.3 m (1.0 ft.) below the underside of the pre-stressed concrete panels has also been provided in each filter. A set of piezometers of 35 mm clear rigid polyethylene plastic tubing to indicate the hydraulic gradeline upstream and downstream of each filter have also been installed.

Water from each filter discharges to a header pipe where chlorine solution is injected. The water passes through a chlorine contact tank designed for a twenty minutes of contact at the peak day flow. From the chlorine contact tank the water flows to a clear well for pumping directly to the Village's Low Zone Reservoir 570 m^3 (150,000 gal.) storage reservoir and to the Village distribution system.

Raw and Treated Water Pump Stations. An intake screen (5 m long, 300 mm diameter slotted PVC pipe) forms an infiltration gallery under Bridge Creek. The screen is connected to a wet well raw water pump station with three submersible pumps, each 5 Hp. The three treated water pumps are vertical turbine pumps located above the clearwell. Each pump is 10 Hp.

Control Building. The heated control area housing the chlorination equipment, the motor control centre, treated water pumps, office, pipe gallery and provisions for standby power generation is 8 m x 20 m. The area has a common wall with the three filters and is located on top of the chlorine contact and clearwell tanks.

TREATMENT PLANT CONSTRUCTION COSTS

The construction cost was $780,000 (Cdn.) with the cost breakdown as follows:

	Description	Cost	Percent of Total Construction Cost
1)	Concrete Work (temporary formwork, reinforcing, supply, delivery & placement of concrete, remove forms)	$335,000	43 %
2)	PIPING (supply & installation of all pipe, supports, fittings, valves)	90,000	12 %
3)	MECHANICAL EQUIPMENT (supply, installation & testing of all mechanical equipment)	70,000	9 %
4)	EARTHWORK	65,000	8 %
5)	ARCHITECTURAL	60,000	8 %
6)	ELECTRICAL	55,000	7 %
7)	MISCELLANEOUS METAL	33,000	4 %
8)	CORROSION PROTECTION AND PAINTING	32,000	4 %
9)	SUPPLY & DELIVERY OF MEDIA Support Filter Sand - 1,000 m^3 Support Gravel 1 - 120 m^3 Support Gravel 2 - 120 m^3 Support Gravel 3 - 320 m^3	35,000	4 %
10)	PLACEMENT OF MEDIA	5,000	1 %
	Total Construction Costs	$780,000	

The total construction cost was about $0.23 per litre of installed peak day capacity ($1.05 per gallon of installed peak day capacity).

TREATMENT PLANT OPERATION

The Bridge Creek raw water pumps are automatically controlled by water level in the filters. The treated water pumps are automatically controlled by water level in the Village's storage reservoir. Low water level in the clearwell will shut down the treated water pumps. The operator must manually adjust each filter butterfly valve to supply enough water to keep the clearwell full. An overflow from the clearwell to the raw water pumping station is provided. An automatic control of each butterfly valve will be added when funds are available.

TESTING PROGRAM

A study funded by Health and Welfare Canada that began with plant startup and which will continue to February 1987 will detail the operation and maintenance of the plant as well as document the treatment achieved by slow sand filtration.

SUMMARY

In the fall of 1981 about sixty cases of waterborne Giardiasis were confirmed at the Village of 100 Mile House, British Columbia. The source of the cysts was suspected to be beavers and muskrats subsequently confirmed positive for Giardia cyst and located upstream of the Village's surface water intake. At the time of incidence the surface water treatment included only chlorination with minimal contact time. It was recommended that a water filtration plant be constructed to treat the surface water. A number of filtration processes were considered including slow sand filtration, diatomaceous earth filtration, pressurized rapid rate multi-media filtration and gravity rapid rate multi-media filtration. Research either by or for the United States Environmental Protection Agency has identified the most important operating variables for each filtration process to ensure removal of the cyst. To provide a basis for evaluating each process under the conditions common to the water source, a pilot water treatment program was undertaken. The goal of the pilot program was to monitor the effort required to operate each filter in a manner identified by the USEPA that would remove the Giardia cyst. The data collected from the pilot water treatment program provided criteria to estimate the capital and operation and maintenance costs for full scale treatment. The treatment requirements in other judisdictions for protection against waterborne Giardiasis were evaluated. The slow sand filtration process was chosen. The tenders for construction of the water treatment plant were received on May 29, 1984 and construction of the water treatment plant was substantially completed by December 15, 1984. The total construction cost was about $780,000 (Cdn).

ACKNOWLEDGEMENTS

The support of the Council of the Village of 100 Mile House is gratefully acknowledged as is the advice of Dr. G. Logsdon, P.E. of the Drinking Water Research Division of the USEPA and Dr. D. Hendricks, Professor of Civil Engineering, Colorado State University. The advice of regulatory authorities, plant operators and consulting engineers contacted in Alberta, Ontario, Colorado, Washington, Oregon and New York was most helpful, especially Mr. G. Lloyd, P.E. of Parsons Brinckerhoff, New York. The suppliers of equipment and materials used in the pilot program are offered a special thanks.

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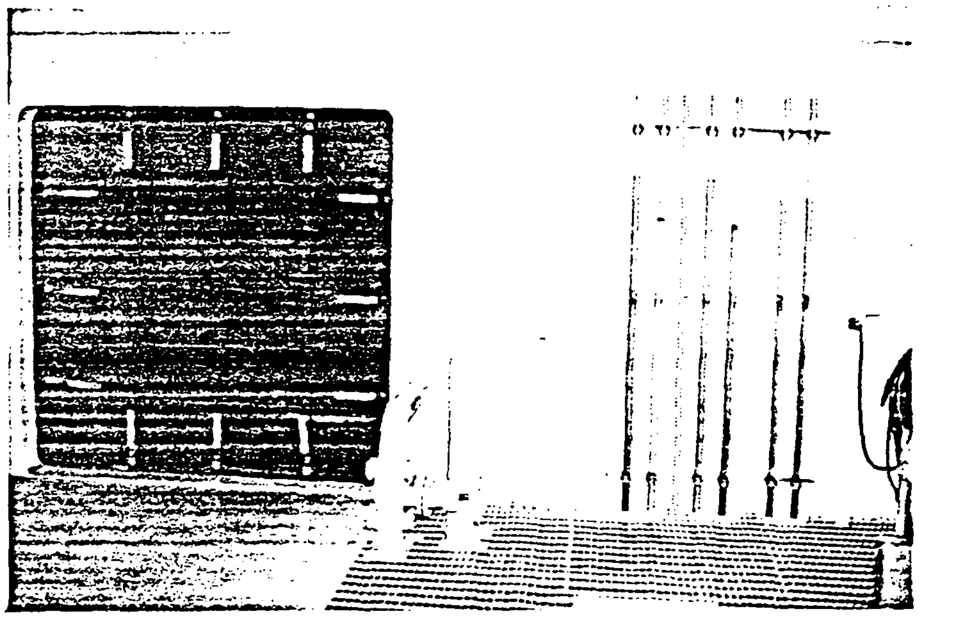
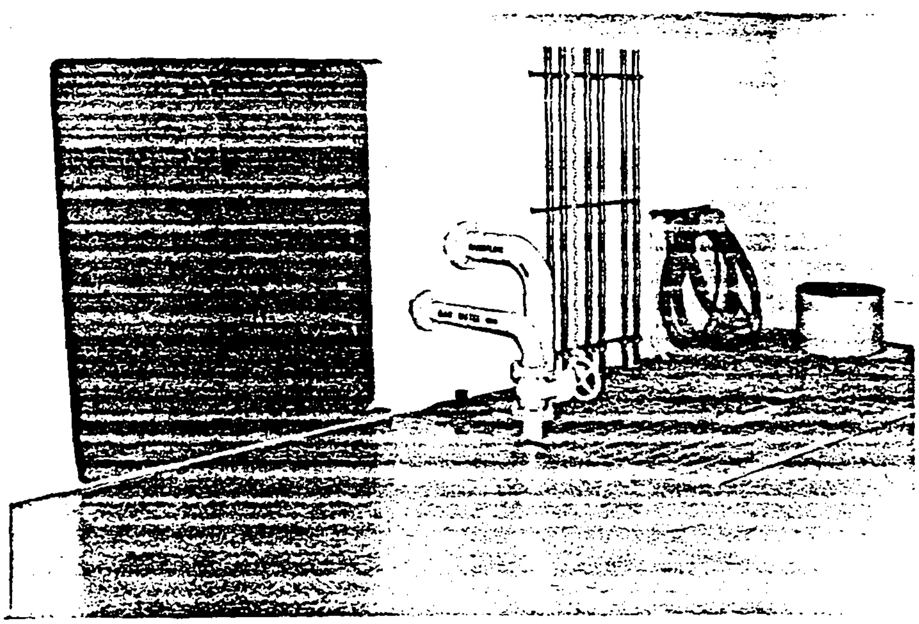
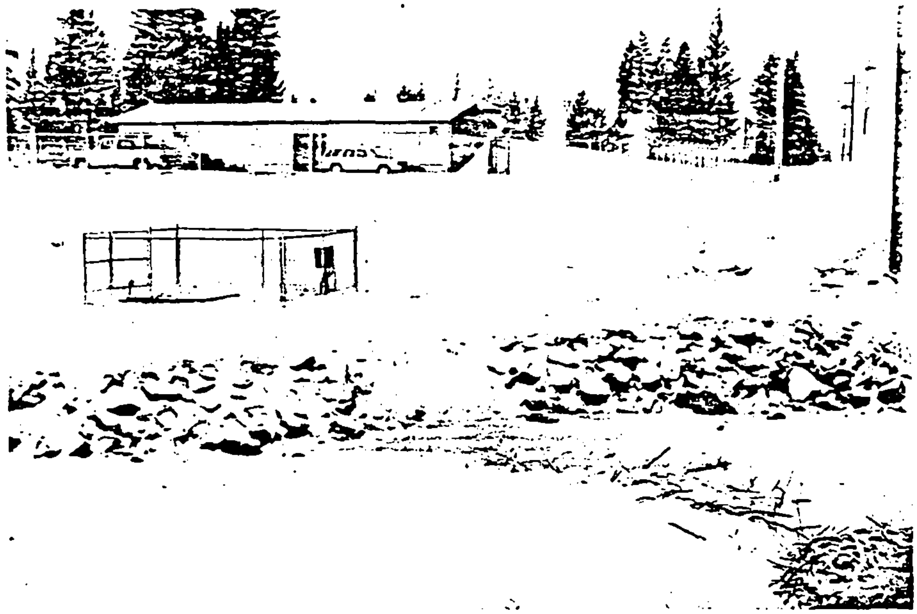


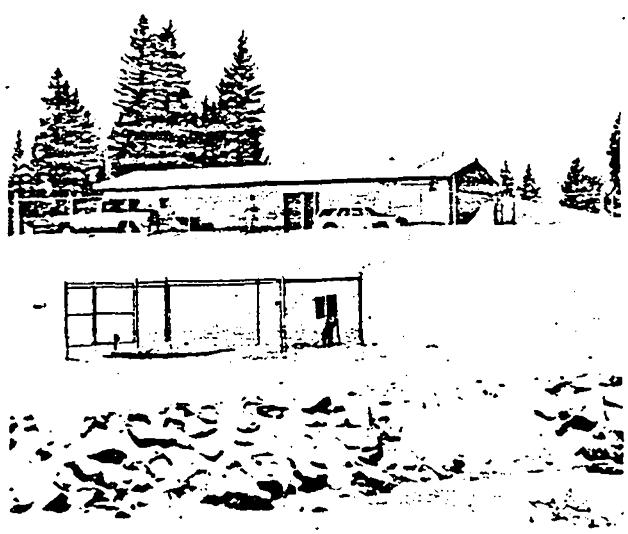
VILLAGE OF 100 MILE HOUSE, B.C. WATER TREATMENT PLANT. Watertight access door to slow sand filter and piezometers for three filters. Grating over pipe chase.



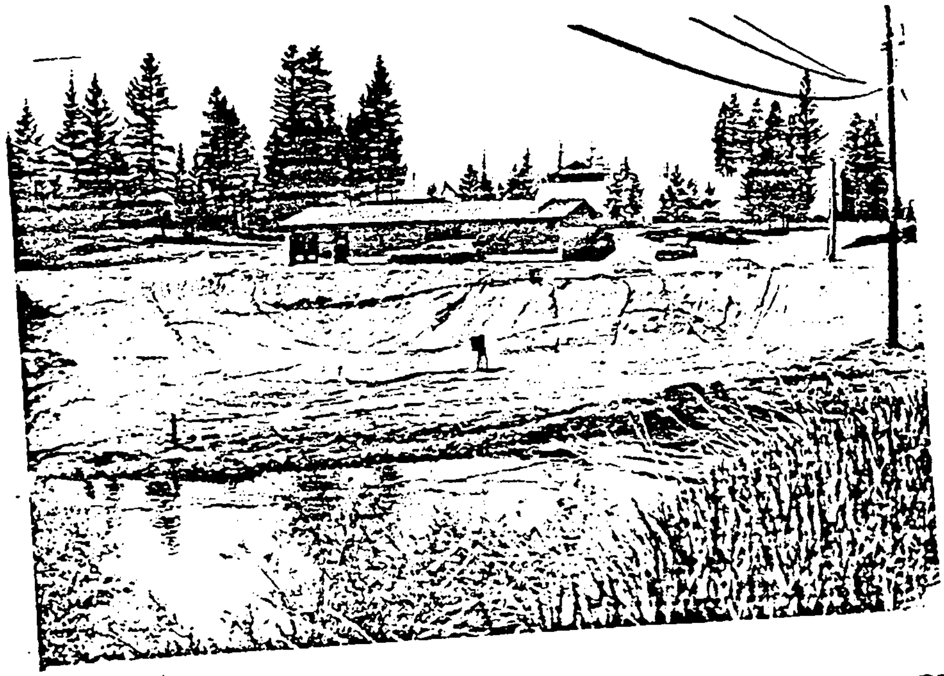
VILLAGE OF 100 MILE HOUSE, B.C. WATER TREATMENT PLANT. Watertight access door to slow sand filter. Treated water overflow is inside cylinder to far right of picture. Bottom of door is at same elevation as top of media.



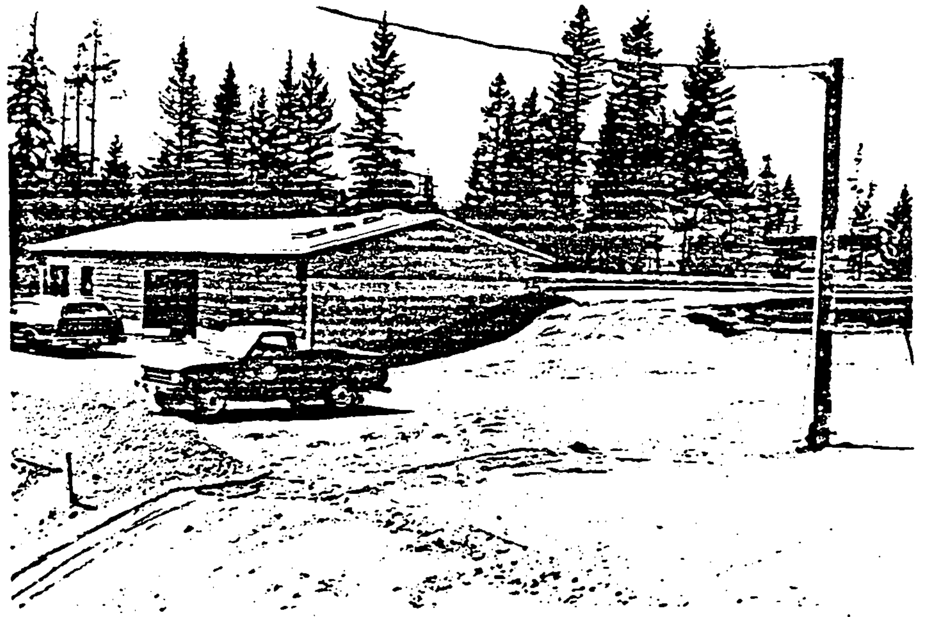
VILLAGE OF 100 MILE HOUSE, B.C. WATER TREATMENT PLANT. Picture taken November 1985 with air temperature at -35°C. Bridge Creek surface water supply, raw water wet well submersible pump station (small fenced area) and control building (by vehicles). Note beaver dam lower right of picture.



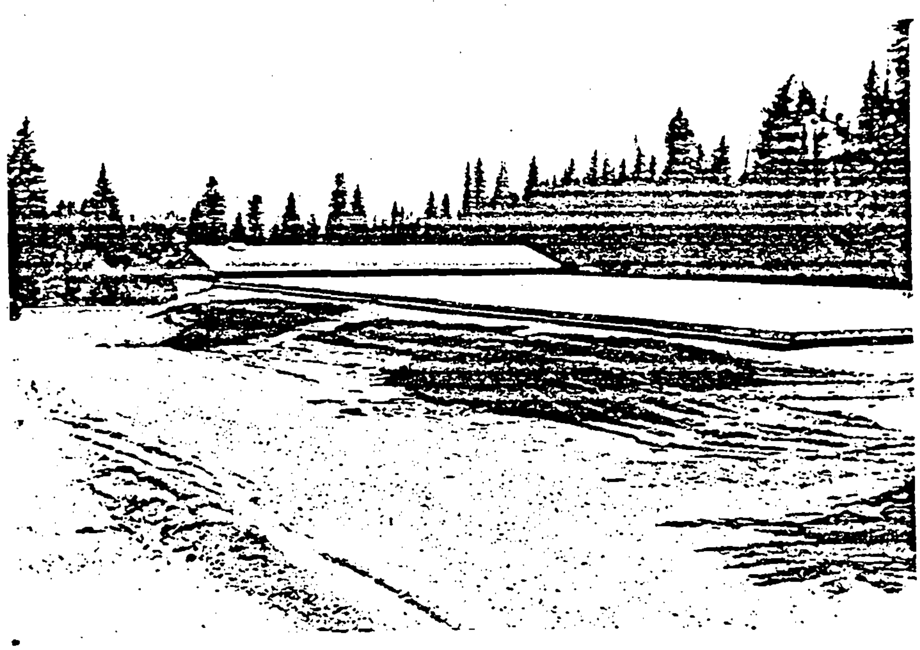
VILLAGE OF 100 MILE HOUSE, B.C. Water Treatment Plant. Picture taken November 1985 with air temperature at -35°C. Bridge Creek surface water supply, raw water wet well submersible pump station (small fenced area) and control building (by vehicles).



VILLAGE OF 100 MILE HOUSE, B.C. WATER TREATMENT PLANT. Bridge Creek surface water supply, wet well submersible raw water pump station (centre of picture), control building and Village's storage reservoir (conical roof top of picture).



VILLAGE OF 100 MILE HOUSE, B.C. WATER TREATMENT PLANT. Control area and precast concrete panel covering slow sand filters.



VILLAGE OF 100 MILE HOUSE, B.C. Water Treatment Plant precast concrete panels covering slow sand filters and control area (sloped roof).