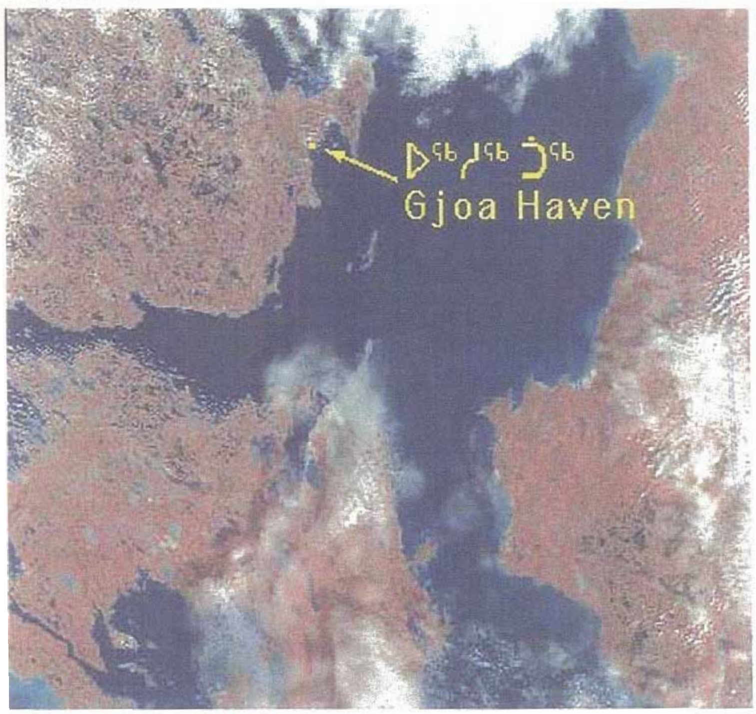
Final Report

New Water Works / Water Supply for Gjoa Haven, Nunavut

Prepared for
Community Government and Transportation
Government of Nunavut
Cambridge Bay, NU



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FSC Project No. 2000-1080

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Gjoa Haven New Water Source
Phase 2

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1. PROJECT OUTLINE

1.1 BACKGROUND

Gjoa Haven's water supply system required upgrading to address several concerns including storage, degraded water quality and an infestation of bloodworms (midge fly larvae).

FSC undertook a preliminary project to:

- Perform field surveys and preliminary engineering studies leading to the selection of the most cost-effective development that provides an ample and dependable supply of water; and

- Finished water is to be free of health hazards, meet or exceed the Nunavut Public Health Act and the Guidelines for Canadian Drinking Water Quality, and meet all specific requirements of the community's Nunavut Water Board licence to operate. The water must be aesthetically acceptable and of sufficient quality and quantity for domestic, commercial and industrial use, and for Fire Protection.

Three options have been identified from FSC's March 19, 2001 final report for further study. These are:

1. A pipeline from Swan Lake;

2. A pipeline from Lake B; and

3. Desalination.

This project, Phase 2, is to undertake a bench desalination test and perform further cost analysis on the three identified options, while meeting the goals of the original project.

2. WATER DEMAND FORECAST

A water demand forecast based on the present and future population predictions were compared to the actual consumption records provided by the community has been prepared.

As noted in the "GN – CG&T Water & Sewage Facilities Capital Program: Standards and Criteria", the design total community water use is calculated as follows:

Table 2.1 Design Total Community Water Use Estimates

Total Community Population	Total Water Use per Capita
0 to 2,000	RWU x (1.0 + (0.00023 x Population))

Where:

RWU = Residential Water Use (lcpd)

Ln = Natural Logorithm

The average water production in 1999 was 28,459,281 L. The population of the community in 1999 has been estimated at 964. This works out to a per capita water use of 80 lcpd. The current GNWT – CG&T accepted RWU factor for trucked system users is 90 lcpd. We suggest that this latter rate be used for all options studied in this planning document.

Based upon the design equation (for a population less than 2000), at the present population of 984 people, the theoretical per capita daily water consumption for the community is calculated at 110.4 lpcd, or approximately 108,600 litres per day for the total population.

At the 20-year design horizon (year 2020), the population projection is for 1,435 residents. Using the same equation the theoretical per capita daily water consumption for the community is calculated at 119.7 lpcd, or approximately 171,770 litres per day for the total population. We will be using this latter per capita consumption rate in our system analysis for this project.

2.1 SEVEN DAY WATER PRODUCTION PROGRAM

The following calculates the estimated daily production rate based upon the following assumptions:

- Operation in 2020 to be 24 hours per day;

- Seven day water production;
- Capable of meeting Peak Day Demand (PDD);
- Average Daily Demand in 2020 = 171,770 L (ADD);
- Allow additional 10% for in-plant and facility use.

PDD_{2020} = PDF x ADD_{2020}

= 257,655 litres/day

Where:

PDD_{2020} = Peak Day Demand in Year 2020

PDF = Peak Day Factor = 1.5

In following:

Total Production Rate2020 = 257,655 x 110%

= 283,342 L/day

= 3.28 L/second

3. GN/CG&T REQUIREMENTS FOR TREATED WATER STORAGE

When calculating the treated water storage requirements for the community, the specific volumes for the reservoirs need to consider the following:

- Storage for Fire Protection;
- Dead Storage (inaccessible storage)
- Storage for Emergency Purposes (loss of supply); and
- Equalization Storage.

Some of the options use the natural storage capacity of an existing lake. The water bodies recommended have the required volumes. This exercise will provide a double check on the suitability of using the various lakes.

3.1 STORAGE FOR FIRE PROTECTION

3.1.1 LAKE OPTIONS

Following consultation with the Fire Marshal, on January 10, 2001, FSC was directed to provide for 170,000 litres of firewater storage. The GN has requested that Water Lake be retained for this purpose.

3.1.2 DESALINATION

The GN has requested Firewater not be drawn directly from the ocean as discussed in earlier reports. It has been determined that 170,000L of dedicated firewater storage will be required.

3.2 DEAD STORAGE

3.2.1 LAKE OPTIONS

Dead Storage is water that is not accessible to the distribution system. Generally, for engineered reservoirs dead storage volume is 5% of the overall storage capacity of the system. For the two lakes under consideration, dead storage is not an issue.

3.2.2 Desalination

For the desalination plant, vertical steel tankage will be used for storage. Dead storage, therefore, should be cost-effectively minimized. In estimating the storage requirements, we have allowed for a dead storage volume of 25,000 L.

3.3 Emergency Storage

3.3.1 Lake Options

Emergency water storage within a community may be required where the water source is remote from the community (over 3.2 km) and interruption of the supply is likely. Although some of the options considered are further than 3.2 km away extended supply interruption is not expected.

The GN – CG&T Capital Standards & Criteria for Emergency Storage volume states that the storage volume required under these conditions is equal to the projected average day at design horizon times the longest possible supply interruption.

For the purpose of this portion of the report, we will assume only a temporary disruption to the incoming water supply. That storage volume is recommended to be equivalent to 8 hours at average day demand for the design year.

ES_{2020} = 8 hrs x ADD / (24 hrs/day) = 57,260 L
Where:
ES_{2020} = Emergency Storage Requirement
ADD = Average Day Demand (171,770L)

Emergency storage will be provided for in the storage tanks.

3.3.2 Desalination

As the desalination system will be located within the community, emergency storage is not required. However, since there have been concerns raised by the GN. There will be a provision of emergency storage should the RO plant be rendered inoperable.

3.4 EQUALIZATION STORAGE

3.4.1 LAKE OPTIONS

As noted earlier, the equalization storage represents a component of the overall system storage that must be considered in sizing a storage reservoir.

Equalization storage is required where the water supply capacity is limited and cannot supply the peak demand. This is an issue with options that use the lakes and engineered reservoir storage. The GN – CG&T standard for this is based on an 8-hour system production schedule five days per week. Examples of limiting factors include treatment facilities, pipelines, etc. The estimated equalization storage volume is based on the following equation:

EV_{2020} = PDD - Average 8 hr system production = 226,085 L

Where:

EV_{2020} = Equalization Volume

PDD_{2020} = PDF x TDF x ADD

PDD_{2020} = Peak Day Demand in Year 2020 (283,342 L)

PDF = Peak Day Factor = 1.5

TDF = Truck Delivery Factor

= 7/5 based on water delivery 5 days per week.

ADD_{2020} = Average Day Demand in Year 2020 (171,770 L)

Note: This number assumes that the refill rate of the storage tank is equivalent to the average hourly draw down rate.

New storage tankage will be used to provide equalization storage.

3.4.2 DESALINATION

New storage tankage will be used to provide equalization storage.

FSC GROUP

3.5 Treated Water Storage Requirement Summaries

Table 3.1 – CG&T Water Storage Requirements for Lake Options 1 & 3

Requirement	Volume (litres)
Fire Storage	n/a
8 hour Emergency Storage	57,260
Equalization Storage	226,100
Dead Storage	25,000
Total	**308,360**

Table 3.2 – CG&T Water Storage Requirements for Lake Options 2 & 4

Requirement	Volume (litres)
Fire Storage	170,000
8 hour Emergency Storage	57,260
Equalization Storage	226,100
Dead Storage	25,000
Total	**478,360**

Table 3.3 – CG&T Water Storage Requirements for Desalination

Requirement	Volume (litres)
Fire Storage	170,000
8 hour Emergency Storage	57,260
Equalization Storage	226,100
Dead Storage	25,000
Total	**478,360**

3.6 ADDITIONAL STORAGE CONSIDERATIONS FOR THE DESALINATION OPTION

CG&T has expressed concern over the ability to respond in a timely manner to a failure of the desalination system. Water storage for the community is, therefore, a major consideration.

The year 2020 average daily 7-day production rate (ADP) requirement is 171,770 litres.

In plant water uses are estimated at 10% for backwash and clean up equals 17,180 litres.

Therefore the total average daily 7-day production rate is 188,950 litres. The table, which follows, summarizes potential storage scenarios.

Table 3.3 – Potential Water Storage Scenarios for the Desalination Option

Scenario	Volume (litres)
Minimum CG&T Requirement (from Table 3.2)	308,360
3 days storage @ ADP	515,310
3 days storage @ TADP	566,840
5 days storage @ ADP	858,850
5 days storage @ TADP	944,740

To be conservative, the water storage volume to determine the size of the water tank will be the 5-day storage at TADP and will also include the 170,000L for fire storage. This brings the volume of the storage tank to 1,114,740 L.

4. REVIEW OF WATER QUALITY ANALYSIS

Swan Lake water quality preliminary results have found the water to be of good chemical quality for domestic use. It is hard, well buffered, slightly alkaline, containing a moderate amount of dissolved solids and slightly undersaturated with respect to calcium carbonate. Such water is likely to cause dark tea. Comparison of the Swan Lake water sample to the Guidelines for Canadian Drinking Water Quality showed those parameters tested as being below the recommended maximum limits with the exception of turbidity.

Turbidity (1.9 NTU) exceeds the maximum acceptable concentration (1 NTU), however is less than the aesthetic objective of 5 NTU. The Kitikmeot Regional Health Board will accept such an exceedance as long as disinfection is not compromised.

TOC (5.2 mg/l) may result in taste and odour issues following chlorination.

Based on this sample, water from Swan Lake treatment should comprise filtration followed by granular activated carbon (GAC) and chlorination. All options developed include such a system. For comparison purposes the filtration system recommended for Kugluktuk is also recommended in this application.

A sample from Tasiqyuaq Lake was collected, however, an error in the laboratory caused some of the sample to be lost. The results are similar to Swan Lake, as they should be since Swan Lake is a headwater for Tasiqyuaq Lake. Some of the parameters are elevated above the Swan Lake results, however, it is difficult on a single sample to definitively compare and contrast the results.

Regardless, for Tasiqyuaq Lake, water treatment should also comprise filtration followed by GAC and chlorination.

5. WATER SUPPLY ALTERNATIVES

5.1 DO NOTHING

It is quite clear from discussions with the residents of Gjoa Haven that the current water supply system is considered not to be acceptable. A large majority uses the water from this lake only for showering and laundry purposes. Even if the pumphouse and treatment system were replaced, continued use of 'Water Lake' as the community's water source would be a difficult sell. As such, this option will not be discussed further.

5.2 ALL-WEATHER PIPELINE FROM SWAN LAKE

In this concept, a pipeline would be constructed from Swan Lake to a location near the community where a truckfill station would be constructed.

It is unlikely that a 4km line would be able to provide the minimum flows of 1000 L/min. This option would require the construction of a storage reservoir. The line would be insulated and buried within a granular berm.

The storage reservoir would be an insulated steel vertical tank. The tank would be sized to store the required volumes that were calculated in section 3. Location of the reservoir and pumpfill station is an issue that will require further planning. Routing of this line would require a minimum of one crossing over existing transportation routes.

5.3 ALL-WEATHER PIPELINE FROM LAKE B (TASIQYUAQ)

In this concept, a pipeline would be constructed from Tasiqyuaq Lake to a location near the community.

This option would require the same components as the all-weather line from Swan Lake. Lake B is further away from the community than Swan Lake. This would result in an additional expense. However, it could be possible to route the line to reduce the impact on the existing transportation routes.

This option would also require the construction of a storage reservoir. Again, the reservoir would be an insulated steel vertical tank.

5.4 DESALINATION PLANT

A desalination plant would draw water directly from the ocean. Storage would need to be provided for the volumes calculated in earlier in section 3. It may be possible to reduce the amount of equalization water required. This would depend on the production capabilities of the chosen desalination system. The plant could be located within the community. This would reduce the haul distance of the trucks from the other options under consideration. Recent improvements in Reverse Osmosis technology may allow this option to be implemented economically.

6. PROJECT OPTIONS

6.1 OPTION 1 – RECIRCULATING PIPELINE FROM SWAN LAKE, TREATMENT IN TOWN, WATER LAKE FIRE STORAGE

This option will involve constructing a four-kilometre all-weather pipeline from Swan Lake to a water treatment plant in the community. The water will be processed and transferred to an above ground storage tank. Water will be distributed from this tank with trucks. The routing of the line should run parallel to the existing road to Swan Lake. This will allow for easy access to the access vaults for routine maintenance.

Fire storage capacity will be provided by the existing water supply system at Water Lake. Replacement of the intake line that transfers water from the pump shack to the pump house should be considered. The intake pump is relatively new and should be able to provide the required flows with a new line.

A new permanent water intake would need to be constructed at Swan Lake. The pipeline system under consideration is an eight-inch HDPE pipe feed line with a six-inch return. Both of these pipes would have 2 inches of insulation. The water in the pipe would recirculate continuously along the 4km route to and from Swan Lake.

It is proposed that the pipeline be buried to at least one meter below the existing ground to provide additional protection from extreme ambient temperatures. One reason for burying the line is to avoid creating an obstruction on the landscape. As well, burying the pipe avoids a considerable cost in constructing a berm or a utilidor structure. Access vaults will be constructed every three hundred meters. It may be prudent to have a truck fill arm at the water intake building. This would allow access to water should the water line to the community break or freeze.

The water storage tank would have to be sized to hold 310m^3 of water. An insulated, vertical steel tank would likely be the best choice. This type of water storage structure has been used successfully in several communities throughout Nunavut.

A cartridge type water treatment system is under consideration. This type of treatment is simple to operate and efficient. Essentially, the feed water flows through a series of cartridge filters that remove solids without the use of chemicals. The quantity of wastewater produced is small enough that a standard sewage tank can be used to hold the filtrate until it is disposed of. Chlorine would be added to the water after passing through the filters and then stored in the vertical tank.

The cost estimate and sketch of this option can be viewed in the appendices.

Table 6.1 – Option 1: List of Major Pros and Cons

Pros	Cons
❑ No weather related issues impacting on the transportation of water; ❑ No requirements to maintain access road to Swan Lake to a high standard; and ❑ Reduced tank size results in lower capital costs.	❑ Swan Lake is a recreational area and there are cabins on the shoreline. ❑ Susceptible to freezing, pipe failure disruptive and expensive; ❑ If failed, truckfill at Swan Lake may be inaccessible due to weather; ❑ Community concern over loss of Swan Lake as a recreation area. ❑ Water Lake required for fire flows, existing infrastructure in poor condition, increased O&M expense.

6.2 Option 2 – Single Pipeline from Swan Lake, Treatment in Town, All Storage Tanked

This option will involve constructing a four-kilometre all-weather pipeline from Swan Lake to a water treatment plant in the community. The water will be processed and transferred to an above ground storage tank. Water will be distributed from this tank with trucks. The routing of the line should run parallel to the existing road to Swan Lake. This will allow for easy access for routine maintenance.

A new permanent water intake would need to be constructed at Swan Lake. The pipeline system under consideration is an eight-inch HDPE pipe with 2 inches of insulation. It is proposed that the pipeline be buried to at least one meter below the existing ground to provide additional protection from extreme ambient temperatures. One reason for burying the line is to avoid creating an obstruction on the landscape. As well, burying the pipe avoids a considerable cost in constructing a berm or a utilidor structure. Access vaults will be constructed every three hundred meters. It may be prudent to have a truck fill arm at the water intake building. This would allow access to water should the water line to the community break or freeze.

Only one pipe would be utilized for this option. The water would run continuously. When the storage tank fills to the maximum level supply water would be diverted to the water lake. This will minimize the complexity of the system. Careful analysis should be put into determining the required flow rate through the pipe. The rate should closely match the draw down rate of the storage tank due to community use. This will minimize overflow and wastage of water. However, the flow rate needs to be high enough to avoid the formation of ice crystals in the supply water.

The water storage tank would have to be sized to hold 480m^3 of water. An insulated, vertical steel tank would likely be the best choice. This type of water storage structure has been used successfully in several communities throughout Nunavut.

A cartridge type water treatment system is under consideration. This type of treatment is simple to operate but efficient. Essentially, the feed water flows through a series of cartridge filters that remove solids without the use of chemicals. The quantity of wastewater produced is small enough that a standard sewage tank can be used to hold the filtrate until it is disposed of. Chlorine would be added to the water after passing through the filters and then stored in the vertical tank.

The cost estimate and sketch of this option can be viewed in the appendices.

Table 6.2 – Option 2: List of Major Pros and Cons

Pros	Cons
❑ No weather related issues impacting on the transportation of water; ❑ No requirements to maintain access road to a high standard; and ❑ Lowest operating costs of any option. ❑ Simple system, no complex valving or pumping.	❑ Swan Lake is a recreational area and there are cabins on the shoreline. ❑ Susceptible to freezing, pipe failure disruptive and expensive; ❑ If pipeline fails, truckfill at Swan Lake may be inaccessible due to inclement weather; ❑ Community concern over loss of Swan Lake as a recreation area.

6.3 Option 3 - Recirculating Pipeline from Tasiqyuaq Lake, Treatment in Town, Water Lake Fire Storage

This option will involve constructing a 5.5 - kilometre all-weather pipeline from Tasiqyuaq Lake to a water treatment plant in the community. The water will be processed and transferred to an above ground storage tank. Water will be distributed from this tank with trucks. The routing of the line should run parallel to the existing road to swan lake. This will allow for easy access to the access vaults for routine maintenance.

Fire storage capacity will be provided by the existing water supply system at Water Lake. Replacement of the intake line that transfers water from the pump shack to the pump house should be considered. The intake pump is relatively new and should be able to provide the required flows with a new line.

A new permanent water intake would need to be constructed at Swan Lake. The pipeline system under consideration is an eight-inch HDPE pipe feed line with a six-inch return. Both of these pipes would have 2 inches of insulation. The water in the pipe would recirculate continuously along the 4km route to and from Swan Lake.

It is proposed that the pipeline be buried to at least one meter below the existing ground to provide additional protection from extreme ambient temperatures. One reason for burying the line is to avoid creating an obstruction on the landscape. As well, burying the pipe avoids a considerable cost in constructing a berm or a utilidor structure. Access vaults will be constructed every three hundred meters. It may be prudent to have a truck fill arm at the water intake building. This would allow access to water should the water line to the community break or freeze.

The water storage tank would be sized to hold 310m^3 of water. An insulated, vertical steel tank would likely be the best choice. This type of water storage structure has been used successfully in several communities throughout Nunavut.

A cartridge type water treatment system is under consideration. This type of treatment is simple to operate but efficient. Essentially, the feed water flows through a series of cartridge filters that remove solids without the use of chemicals. The quantity of wastewater produced is small enough that a standard sewage tank can be used to hold the filtrate until it is disposed of. Chlorine would be added to the water after passing through the filters and then stored in the vertical tank.

The cost estimate and sketch of this option can be viewed in the appendices.

Table 6.3 – Option 3: List of Major Pros and Cons

Pros	Cons
❑ No weather related issues impacting on the transportation of water; ❑ No requirements to maintain access road to a high standard; and ❑ Reduced tank size results in lower capital costs.	❑ Swan Lake is a recreational area and there are cabins on the shoreline. ❑ Susceptible to freezing, pipe failure disruptive and expensive; ❑ If failed, truckfill at Swan Lake may be inaccessible; and ❑ Existing Water Lake infrastructure in poor condition.

6.4 OPTION 4 - SINGLE PIPELINE FROM TASIQYUAQ LAKE, TREATMENT IN TOWN, ALL STORAGE TANKED

This option will involve constructing a 5.5 - kilometre all-weather pipeline from Tasiqyuaq Lake to a water treatment plant in the community. The water will be processed through the water treatment system and transferred to an above ground storage tank. Water will be distributed from this tank with trucks. The routing of the line should run parallel to the existing road to Swan Lake with the intent of minimizing the number of road crossings. This will also allow for easy access to the access vaults for routine maintenance.

A new permanent water intake would need to be constructed at Swan Lake. The pipeline system under consideration is an eight-inch HDPE pipe with 2 inches of insulation. It is proposed that the pipeline be buried to at least one meter below the existing ground to provide additional protection from extreme ambient temperatures. One reason for burying the line is to avoid creating an obstruction on the landscape. As well, burying the pipe avoids a considerable cost in constructing a berm or a utilidor structure. Access vaults will be constructed every three hundred meters. It may be prudent to have a truck fill arm at the water intake building. This would allow access to water should the water line to the community break or freeze.

Only one pipe would be utilized for this option. The water would run continuously. When the storage tank fills to the maximum level supply water from the pipeline would be diverted to the water lake. This will minimize the complexity of the system. Careful analysis should be put into determining the required flow rate through the pipe. The rate should closely match the draw down rate of the storage tank due to community use. This will minimize overflow and wastage of water. However, the flow rate needs to be high enough to avoid the formation of ice crystals in the supply water.

The water storage tank would have to be sized to hold 480m^3 of water. An insulated, vertical steel tank would likely be the best choice. This type of water storage structure has been used successfully in several communities throughout Nunavut.

A cartridge type water treatment system is under consideration. This type of treatment is simple to operate but efficient. Essentially, the feed water flows through a series of cartridge filters that remove solids without the use of chemicals. The quantity of wastewater produced is small enough that a standard sewage tank can be used to hold the filtrate until it is disposed of. After passing through the cartridge filters the water would be chlorinated. The water would then be stored in the vertical tank until delivery.

The cost estimate and sketch of this option can be viewed in the appendices.

Table 6.4 – Option 4: List of Major Pros and Cons

Pros	Cons
❑ No weather related issues impacting on the transportation of water; ❑ No requirements to maintain access road to a high standard; and ❑ Lower operating costs. ❑ Simple system.	❑ Swan Lake is a recreational area and there are cabins on the shoreline. ❑ Susceptible to freezing, pipe failure disruptive and expensive; ❑ If failed, truckfill at Swan Lake may be inaccessible; and ❑ Water Lake required for fire flows.

6.5 Option 5 - Desalination Plant, Treated Water Fire Storage

This option will also involve obtaining water directly from the ocean. The intake and plant will be located within the community. The feed water will be treated to remove the salt and any other impurities in the water. After the water has been treated, it will be transferred to a water storage reservoir. The water will then be distributed throughout the community by trucks.

A water intake line will need to be constructed. This structure will have to be designed to withstand any forces that the sea ice could impose on it. Tidal regimes are not significant in this area of the North. In the neighbouring community of Taloyoak the high tide is 1.3m and the low tide is 0.7m.

Information on the desalination plant under consideration can be viewed in the appendices of this report. The cost estimate and sketch of this option can also be viewed in the appendices.

A new potable water storage tank would be needed. This tank would need to be sized to hold approximately 950m^3 of water. An insulated, vertical steel tank would likely be the best choice. This type of water storage structure has been used successfully in several communities throughout Nunavut. A new truck fill will be required to transfer water from the holding tank to the water trucks.

When originally discussed the intent of the desalination system was to use seawater as the source for fire storage. Typically, water would be drawn directly from the ocean and be channelled through the treatment system. Additionally, a treatment plant bypass line will be installed. In the event of a fire flow situation water would have been redirected from going through the treatment system and been delivered directly to the receiving truck through the truck fill arm.

However, concerns were raised by the Fire Marshal over the effect of seawater on the water trucks and instruments. It has been decided that all fire storage will be provided within the constructed storage tank.

A water recovery efficiency rate of 55% is achievable. A water disposal line would have to be constructed to dispose of this 'waste' water. It is estimated that this water could be discharged back into the ocean. The outlet would need to be a minimum of 90 meters away from the water intake. Preliminary discussions with Environmental Regulators have been initiated to determine what reviews would be necessary to grant this option approval.

Table 6.5 – Option 5 - Lists of Major Pros and Cons

Pros	Cons
❑ Community Concerns over Swan Lake and adjoining recreational lakes will be relieved; ❑ Least capital cost option; and ❑ Desalination produces an exceptionally high quality water, very low in microbial activity.	❑ While not difficult to operate, the desalination plant would require specialized and continuing training for operators; ❑ Procurement of spare parts for RO unit could be time consuming; ❑ Investigation of effect of releasing brine into the ocean shall be required; ❑ Higher operating costs; and ❑ Water Lake may have to be retained as a backup potable water supply in the event of a failure.

6.6 OPTIONS DISCUSSION SUMMARY

Pipeline construction is capital intensive. The recirculating pipeline options are relatively complex systems. Heat will need to be added to the water to prevent ice build up along the pipeline. The dual pipeline allows for redundancy in the system. If one line freezes it is possible to deliver water down the other pipeline. However, without recirculation, it is likely that the second pipe would follow suit in freezing. If the lake intake is constructed with the infrastructure to fill trucks this would prevent a complete disruption of water delivery upon exhaustion of the emergency reserves storage. This triple redundancy may not be justified due to the higher capital cost associated with it.

The single pipeline does not allow the redundancy of going to a backup line in the event of a pipe freeze. It would be prudent to construct the intake building with a truckfill arm. The capital costs for materials required are reduced. The quantity of pipe is halved. There is less trenching required if the pipe is buried. Less granular material would be needed if the pipe is enclosed in a berm. The system is less complex. Less equipment (i.e. pumps, valves, etc.) is required to keep the water moving through the system. This reduction in complexity and cost may justify the additional risk associated with a pipe freeze up. Operators in the community are familiar with the equipment required to operate, maintain and repair a pipeline.

Desalination appears to be very attractive from a capital cost and NPV point of view. However, operation costs for the facility rank among the highest of the options. As well, RO technology is unproven in the extreme climate of the Canadian north. Cost of repairs and downtime would be extensive in the event of a failure to the RO process. As well, since this is a new process it is likely that the potential effects of the by-products of the RO process on the environment will be required by the various regulating authorities before approval to proceed is granted.

7. OPTIONS EVALUATION

In order to evaluate potential remediation options objectively, we have used a decision making tool called a weighted factor analysis. This tool/method is a modification of the Kepner-Tregoe analysis. It involves two distinct steps, which are outlined as follows:

7.1 INITIAL SCREENING

The initial screening process involves the creation of constraints, which each option/alternative **must** meet. Only options/alternatives that meet each constraint will be included in the final analysis.

- **Must** meet Drinking Water Regulations; and
- **Must** meet Nunavut Water Board Acts and Regulations; and
- **Must** meet 20-year storage/supply need.

The results are shown in Table 7.1.

Description	Option 1	Option 2	Option 3	Option 4	Option 5
Water Must Meet Drinking Water Regulations	pass	pass	pass	pass	pass
Facility Must Meet Nunavut Water Board Requirements	pass	pass	pass	pass	pass
System Must Meet 20 Year Requirement	pass	pass	pass	pass	pass
System Must Be Approved By Regulating Authorities	pass	pass	pass	pass	unknown

Option 1	Swan Lake Pipeline, Treatment in town, Water Lake Fire Storage
Option 2	Swan Lake Pipeline, Treatment in Town, Tanked Fire Storage
Option 3	Tasiqyuaq Lake Pipeline, Treatment in Town, Water Lake Fire Storage
Option 4	Tasiqyuaq Lake Pipeline, Treatment at Swan Lake, Tanked Fire Storage
Option 5	Desalination, Tanked Water Storage

7.2 OPTIONS ANALYSIS

If an option passes our initial screening process it will be included in our final evaluation process. The final process consists of evaluating each option on a set of objectives that has been deemed the 'want' criteria.

The want criteria are a list of objectives that are weighted according to their importance to the decision to be made. Each option is then objectively ranked against these criteria and scores assigned based on the ranking multiplied by the weight of the criteria. The weighted scores for the various options are added to provide a total score for each option.

The total score for different options can be compared to provide an indication of which option best meets the stated objectives for a new solid waste disposal system.

The following "want" objectives have been established for this project:

1. Lowest Capital Cost;
2. Lowest O&M Costs;
3. Lowest Net Present Value (NPV);
4. Use familiar technology;
5. Eliminate the use of Water Lake; and
6. No potable water outages for greater than 2 days;

7.2.1 SELECTING WEIGHTS

A binary choice decision model was used to generate preliminary weighting for each objective. In this model, only two objectives are considered at a time, the more important objective receiving a "1" and the other a "0". When all objectives are considered the scores are summed and the results placed in descending order. The highest-ranking objective is then assigned a "10". Others receive a lesser weight.

The following table shows the decision process.

Table 7.2 - Binary Decision Model to Assign Weights to Objectives

Objective	Capital Cost	O&M Cost	NPV	Familiar Technology	No Outages	No Water Lake	Employ	Total	Weight
O&M Cost	1	-	1		1	1	1	5	10
Capital Cost	-	0	1		1	1	1	4	9
NPV	0	0	-		1	1	1	3	8
Familiar Technology	0	0	0	-	1	1	1	3	7
No Outages	0	0	0	0	-	1	1	2	6
No Water Lake	0	0	0		0	-	1	1	5

7.2.2 SCORING

1. **Lowest O&M Costs**

The lowest O&M cost will be scored "10". Others will be scored based on percentage. The cost estimates can be viewed in the appendices.

2. **Lowest Capital Cost**

The lowest capital cost will be scored "10". Others will be scored on percentage. The cost estimates can be viewed in the appendices.

3. **Lowest Net Present Value**

The lowest Net Present Value will be scored "10". Others will be scored on percentage. The cost estimates can be viewed in the appendices.

4. **Use of Familiar Technology**

Technology that has been used predominantly throughout the Canadian North will be scored "10".

Options that have certain attributes that have been utilized in the Canadian North will be scored "5".

Technology that has not been used will be scored "0".

5. No Outages Greater Than Two Days

Except for failure or freezing (assumed to be preventable to some extent) none will occur - 10

Some outages may occur (for example the treatment plant requires attention) - 8

Some outages are foreseen due to weather - 5

Outages are inevitable - 0

6. Get Rid of Water Lake

Water Lake is no longer required for any purpose – 10

Water Lake is required for fire flows - 5

Water Lake could be retained as a contingency – 2

Water Lake is required for potable water- 0

7.3 RESULTS

Table 11.3 shows the results of the modified K-T Analysis.

		Option 1		Option 2		Option 3		Option 4		Option 5	
K-T Item	Weight	Score	W*S	Score	W*S	Score	W*S	Score	W*S	Score	W*S
Lowest O&M Cost	10	8.2	82.0	10.0	100.0	7.1	71.0	8.5	84.9	6.5	65.2
Lowest Capital Cost	9	6.4	57.8	8.0	72.3	5.2	47.2	6.8	61.1	10.0	90.0
Lowest NPV	8	8.1	64.5	10.0	80.0	6.7	53.8	8.5	67.7	9.2	74.0
Familiar Technology	7	10.0	70.0	10.0	70.0	10.0	70.0	10.0	70.0	5.0	35.0
No Potable Water Outage > 2 days	6	8	48.0	8	48.0	8	48.0	8	48.0	8	48.0
Get Rid of Water Lake	5	5	25.0	10	50.0	5	25.0	10	50.0	10	50.0
Total			265.3		320.3		244.0		296.8		297.0
Rank		4		1		5		3		2	

	Capital	Annual O&M	NPV	
Option 1	$7,478,856	$421,571	$11,949,028	Swan Lake Recirc. Pipeline, Treatment in town, Water Lake Fire Storage
Option 2	$5,973,260	$345,776	$9,639,734	Swan Lake Single Pipeline, Treatment in Town, Tanked Fire Storage
Option 3	$9,160,606	$487,155	$14,326,199	Tasiqyuaq Lake Recirc. Pipeline, Treatment in Town, Water Lake Fire Storage
Option 4	$7,067,500	$407,317	$11,386,530	Tasiqyuaq Lake Single Pipeline, Treatment in Town, Tanked Fire Storage
Option 5	$4,799,795	$530,242	$10,422,269	Desalination, Tanked Fire Storage

8. DISCUSSION

Option 2, which is a single pipeline from Swan Lake is the highest scoring option. Option 2 scored 320.3 in the KT analysis.

Option 5, Desalination had the next highest score at 297.0.

Option 4, a single pipeline from Tasiqyuaq Lake, had the third highest score at 296.8.

The lowest capital cost of $4,799,795 belonged to Option 5, Desalination. The next lowest was the single pipeline from Swan Lake, which was totalled at $5,973,260. The third lowest option at $7,067,500 was the single Tasiqyuaq Lake pipeline. The main reason for the higher capital costs of the pipeline option is the amount of piping material and the labour required to install it.

The lowest operating and maintenance cost was the single Swan Lake pipeline. Its O&M cost was $345,776. The highest O&M cost was for the desalination option. Its O&M cost was $530,242. The reason for the higher O&M cost is the fuel oil required to heat the raw ocean water to a temperature of 5 degrees Celsius prior to processing through the RO plant.

The lowest NPV was for the single Swan Lake pipeline option. Option 5, desalination, was the next lowest option.

Based on the analysis presented it appears as though the single pipeline from Swan Lake (Option 2) is the best suited solution to Gjoa Haven's drinking water problem. It received the highest score in the KT analysis. Although it requires a higher initial capital investment than the desalination option, this money is easily recouped over time through its lower O&M costs. As well, operators in the community are familiar with the equipment that is necessary to run a pipeline and associated truckfill station. The water treatment plant for Option 2 requires little operator input outside of what is currently practiced in Gjoa Haven's water distribution facility.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS & GEOPHYSICISTS OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
003
FERGUSON SIMEK CLARK

REGISTERED PROFESSIONAL ENGINEER
R. J. KENT
N.W.T.

FSC GROUP

Appendix A

Desalination Information

Desalination

Background

Desalination is the process of removing salt, mineral or chemical compounds from impure water. The need for desalination occurs when oceananic or contaminated water is the only water supply available to coastal and island communities whose ground and/or surface water supplies have been reduced or eliminated. The desalination of seawater has been successfully implemented in various climates, including the Middle East and California.

Desalination facilities use one of two basic technologies to extract potable water from seawater. Reverse osmosis, which works by forcing seawater through a semipermeable membrane, which restricts salt and other minerals, but allows water molecules to pass through. The second method is distillation, where seawater is heated to produce steam, which is then condensed to produce water with a low salt concentration and few of the other impurities contained in the original water. The desalination system proposed for Gjoa Haven is a reverse osmosis system.

Seawater Testing

There were concerns that the seawater near Gjoa Haven could be contaminated and even once desalinated would not be suitable for consumption. FSC faxed a sampling procedure for the Hamlet staff on October 22, 2001 to sample the seawater and prepare the samples to be sent to both BCA and Enviro-Test Laboratory. Sampling instructions are appended.

The BCA Jerry Can samples were sent to their laboratory in California for analysis and the Enviro-Test samples were sent to the Edmonton Enviro-Test office for analysis.

Enviro-Test Laboratories are accredited by the Standard Council of Canada / Canadian Association for Environmental Analytical Laboratories (SCC/CAEAL), American Industrial Hygiene Association (AIHA), and SCC/Health Canada, and certified by the National Environmental Laboratory Accreditation Program (NELAP).

Seawater Laboratory Results

	Unit	Enviro-test	BCA Lab
Temperature	°C	- - -	5.0
Iron	mg/L	<0.05	0.0
Manganese	mg/L	<0.01	- - -
Silver	mg/L	<0.002	- - -
Aluminum	mg/L	0.1	- - -
Arsenic	mg/L	0.091	- - -
Boron	mg/L	2.4	- - -
Barium	mg/L	0.009	0.0
Beryllium	mg/L	<0.005	- - -
Cadmium	mg/L	<0.01	- - -
Cobalt	mg/L	<0.01	- - -
Chromium	mg/L	0.033	- - -
Copper	mg/L	0.078	- - -
Mercury	mg/L	0.004	- - -
Molybdenum	mg/L	0.007	- - -
Nickel	mg/L	0.003	- - -
Lead	mg/L	0.009	- - -
Antimony	mg/L	<0.008	- - -
Selenium	mg/L	0.061	- - -
Uranium	mg/L	0.002	- - -
Vanadium	mg/L	0.17	- - -
Zinc	mg/L	0.09	- - -
Chloride	mg/L	11300	11300.0
Fluoride	mg/L	0.66	0.7
Nitrate+Nitrate-N	mg/L	<0.1	0.0
PH	pH	7.7	7.7
Conductivity	uS/cm	30300	32571.0
Bicarbonate	mg/L	93	93.0
Carbonate	mg/L	<5	0.1
Hydroxide	mg/L	<5	- - -
Alkalinity, Total	mg/L	76	- - -
Ion Balance	%	97.2	- - -
TDS (calculated)	mg/L	20200	- - -
Hardness	mg/L	3630	- - -
Calcium	mg/L	239	239.0
Potassium	mg/L	226	228.0
Magnesium	mg/L	736	738.0
Sodium	mg/L	6080	6080.0
Sulfate	mg/L	1560	1560.0
Turbidity	NTU	<0.1	0.0
SAR	SAR	43.9	- - -
Carbon Dioxide	mg/L	- - -	4.6
Hydrogen Sulfide	mg/L	- - -	0.0

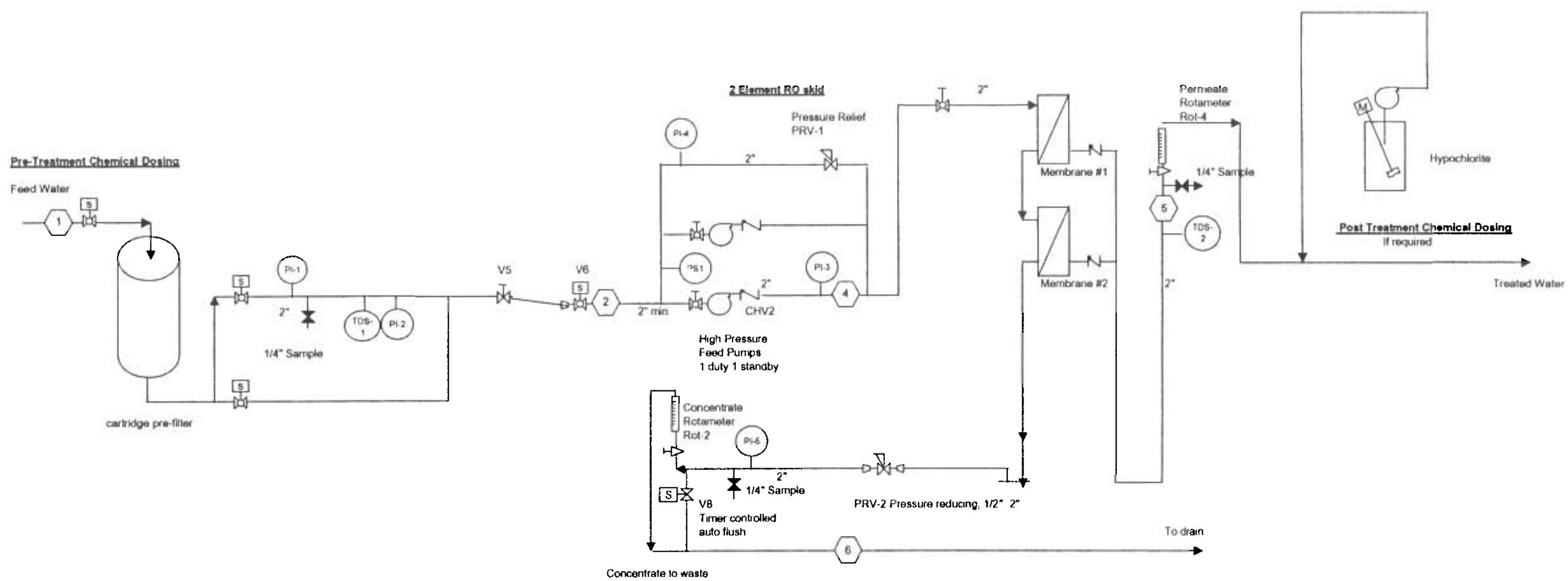
BCA

BCA Industrial Controls was chosen by FSC to provide initial cost estimates for a reverse osmosis desalination system. After review of the conditions and requirements in Gjoa Haven a BCA RO-3 Reverse Osmosis WTP was selected. A flow schematic and an outline layout of the system follow in Figures 1 and 2.

As mentioned in the previous section, seawater samples were taken from Gjoa Haven and tested by BCA. BCA determined that the seawater in Gjoa Haven has a lower salt content then standard seawater, 20 000 ppm compared to 32 100 ppm. This resulted in a higher then expected recovery rate and expected finished water quality of 200 ppm salt content. The finished water meets the CCME Guidelines for finished water of ≤ 200 ppm of sodium. The higher recovery rate also allows for the raw water supply and the high-pressure membrane pumps to be much smaller – 100 USGPM vs. 150 USGPM.

The system proposed by BCA will consist of three, 5-membrane modules, mounted on a pre-fabricated skid approximately 6.1 m x 1.8 m x 1.5 m. This dimension will include the main pump, the control panel, piping, valves and pre- filters.

Figure 1
BCA Reverse Osmosis WTP Gjoa Haven - Flow Schematic



TDS Probes require 3/4" NPT Tee

	1	2	4	5	6
	Raw Feed	LP Feed	HP Feed	Permeate	Reject
Max Flow (gpm)	100	100	100	55	45
Min pressure (psi)	50	50	1000	20	20
Max Pressure (psi)	75	75	1100	50	50
Line dia (in)	4	4	min. 2	2	2

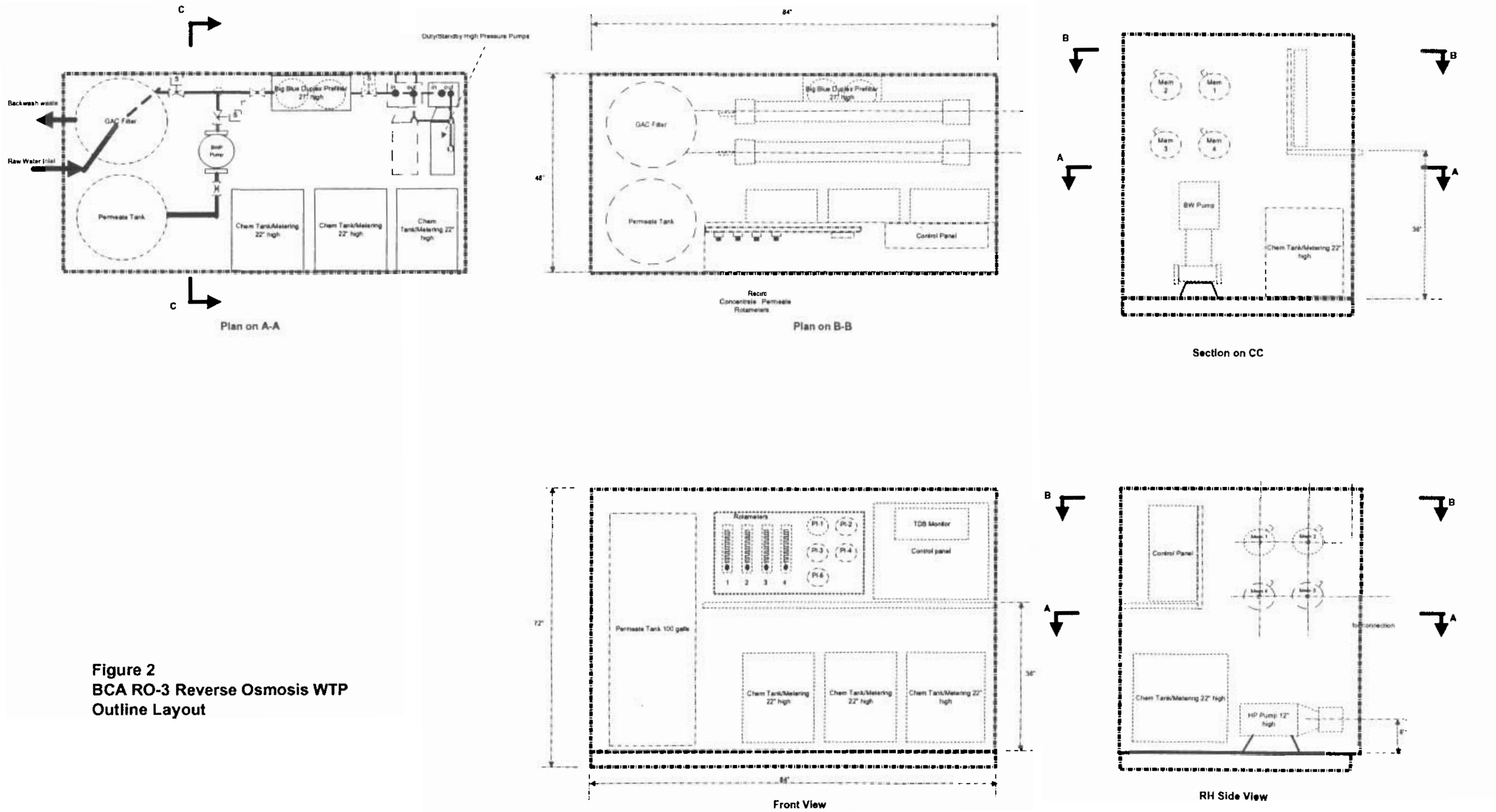


Figure 2
BCA RO-3 Reverse Osmosis WTP
Outline Layout

FERGUSON SIMEK CLARK
ENGINEERS AND ARCHITECTS

Our File: 2000-1080-051 **Sent by fax: 867-360-6309**
October 22, 2001

Raymond Kamookak
Senior Administrative Officer
Hamlet of Gjoa Haven

Re: Gjoa Haven New Water Supply Phase 2
Project Outline
Sea Water Sampling Protocol

Dear Raymond:

Thank you for our telephone conversation the other morning and your agreement to take seawater samples as part of this study.

Project Outline

Three options have been identified from FSC's March 19, 2001 final report for further study. These are:

1. A pipeline from Swan Lake;
2. A pipeline from Lake B; and
3. Desalination.

Our project now is to undertake a detailed pre-design study of the three options to provide a Class "C" cost estimate

For the desalination portion of the project 230 litres (10 Jerry Cans) of sea water is to be taken from a site approximating the location of a sea water intake. Water samples would then be shipped to BCA in Vancouver for bench testing for treatment, and to EnviroTest Laboratories in Edmonton for chemical analysis. FSC would provide properly prepared sample containers.

The results of the taste test will provide input to the decision making process.

Water Sampling

Following is the test protocol for collecting seawater samples.

First, samples should be taken on either a Sunday or a Monday so that the samples will arrive in the laboratories at a time when they can deal with them.

You will have received 10 Jerry Cans and one small cooler with sample bottles.

- **YELLOWKNIFE** 4910 53 Street, P.O.Box 1777, Yellowknife, NT Canada X1A 2P4 Tel: (867) 920-2882, Fax: (867) 920-4319, email: fscnorth@fsc.ca
- **IQALUIT** building 1052, P.O.Box 1779, Iqaluit, NT Canada X0A 0H0 Tel: (867) 979-0555, Fax: (867) 979-5711, email: fscnunavut@fsc.ca
- **WHITEHORSE** Suite 202, 107 Main Street, Whitehorse, Yukon, Y1A 2A7 Tel: (867) 633-2400 Fax (867) 633-2481, email: fscyukon@fsc.ca

An ideal site for the water intake would be located away from the petroleum manifolds for fuel re-supply, away from the discharge of the garbage dump, in an area where sea currents keep the water fresh, and out of the sea lanes where barges and ships may drag their anchors. It should also be close to the community to reduce trucking costs. Certainly, it will be difficult to sample from such a location.

Instead, please sample from within the area circled on the attached map.

Samples are to be taken from a boat away from shore 30 to 50 metres and outside the influence of the tide and currents on the shoreline.

It would be preferable if samples can be obtained from a depth of about 5 metres (15 feet). If you can take samples from that depth it would be best. Perhaps you have a small portable pump that could be used. If not then you can take a sample from the surface.

For safety's sake there should be two people in the boat. Both must wear life jackets. People should wear new lined rubber gloves when sampling. Wearing old gloves may contaminate the water samples.

The sampling site should be approached into the current to minimize the risk of fuel contamination. The boat should be maintained stationary at the sampling site. However, this should be done with an anchor (a rock tied to a rope will do just fine) rather than with the motor. The motor should be shut off and staff should wait 5 or 10 minutes to ensure that there is no fuel in the water.

Each Jerry Can should first be filled with about 2 or 3 litres of water. The cap should then be closed with the spout inside, and the can shaken to rinse the entire inside.

Samples should be taken from one side of the boat. The rinse water should be dumped on the other side of the boat.

This is to be done three (3) times for each Jerry Can before they are filled. Some space should be left inside the Jerry Can because if they freeze, they could split the can.

The cooler has sample bottles that will be used for laboratory analysis. Please rinse each bottle 3 times

The bottles that are labeled "METALS" require a preservative be put into the bottle. These bottles are also marked with a blue dot on the top. The preservative is in vials provided. These vials also have blue tops. The preservative is 20% nitric acid, however, there is only 5 millilitres in each vial. Put the contents of one vial in each bottle marked with a blue dot.

Yes, it's an acid but it's not as strong as the battery acid in the garage.

That said, I strongly recommend that you wait until everyone is ashore before putting the preservative in the bottle. Especially if the sea is not calm. You should add the preservative when you are near a sink the has running water. If you are careful, there should be no concern.

If an accident happens and acid gets on your skin, IMMEDIATELY wash the affected area with lots and lots of running water. Afterwards, you should see the nurse.

Once everyone is safely ashore, please attach the labels that have been provided and ship the samples pre-paid, priority and delivered using the shipping form provided. Advise the shipper that everything contains seawater.

We put the labels and completed shipping forms in the cooler in a plastic bag. There will be no cost to the Hamlet for shipping.

For reference, all the Jerry Cans go to BCA in Langley, BC.

The cooler goes to Envirotest Laboratory. Please ensure that the provided sample custody form goes in a plastic bag, then into the cooler prior to shipping. Envirotest cannot do any analysis without this form.

Please advise me at 867-920-2882 or ron@fsc.ca when you have shipped the samples so that I may advise BCA and the laboratory.

If there are any costs for boat rental, fuel, or new gloves, please invoice me at FSC. Please quote our project number 2000-1080-051

Thank you for your assistance.

Please contact me with your questions and comments.

Yours truly,
Ferguson Simek Clark

Ron Kent, P. Eng.
Head, Environment Department

CC
Sharif El-Attar **Fax 867-983-4003**
Municipal Planning Engineer
Community Government and Transportation
Government of Nunavut
Cambridge Bay, Nu

- **YELLOWKNIFE** 4910 53 Street, P.O.Box 1777, Yellowknife, NT Canada X1A 2P4 Tel: (867) 920-2882, Fax: (867) 920-4319, email: fscnorth@fsc.ca
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Enviro-Test Laboratories
A Division of ETL Chemspec Analytical Limited
Toll Free 1-800-668-9878
9936 -67 Avenue, Edmonton,Alberta,T6E 0P5
Customer service - (780) 413-5220
Main Number - (780) 413-5227

FAX'S: DIOXIN/ENVIRONMENTAL DEPT - (780) 437-2311
AGR. CHEM. DIV./PESTICIDE - (780) 434-9178
INORGANICS/QAQC - (780) 435-7044

ENVIRO-TEST FAST FAXED ANALYSIS REPORT

PROJECT INFORMATION:

COMPANY:	FERGUSON SIMEK CLARK
ATTENTION:	RON KENT
LAB WORK ORDER #:	L52170
PROJECT REFERENCE:	2000-1080
PROJECT P.O.#:	
SAMPLED BY:	CLIENT
DATE RECEIVED:	26-NOV-01
FAX NUMBER:	867-920-4319
TECHNICAL QUESTIONS:	RICK ZOLKIEWSKI
# of PAGES:	4

MESSAGE: Preliminary Results

If you require results couriered immediately, check ____ and return by fax.
All results will be mailed unless otherwise notified.
All couriered results will be billed directly at cost.

If you did not receive all pages, Please notify 1-800-668-9878 as soon as possible

08-FEB-02 04:02 PM

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

PRELIMINARY RESULTS

Lab ID	Sample ID	Test Description	Result	D.L.	Units	Extracted	Analyzed	By
L52170-1	GHSW01							
Sample Date:	19-NOV-01 00:00:00							
Matrix:	WATER							
		Drinking Water Metals						
		Iron (Fe)-Extractable	<0.05	0.05	mg/L		27-NOV-01	EC
		Manganese (Mn)-Extractable	<0.01	0.01	mg/L		27-NOV-01	EC
		Extractable Trace Metals						
		Silver (Ag)	<0.002	0.002	mg/L		27-NOV-01	ZG
		Aluminum (Al)	0.1	0.1	mg/L		27-NOV-01	ZG
		Arsenic (As)	0.091	0.004	mg/L		27-NOV-01	ZG
		Boron (B)	2.40	0.02	mg/L		27-NOV-01	ZG
		Barium (Ba)	0.009	0.001	mg/L		27-NOV-01	ZG
		Beryllium (Be)	<0.005	0.005	mg/L		27-NOV-01	ZG
		Cadmium (Cd)	<0.001	0.001	mg/L		27-NOV-01	ZG
		Cobalt (Co)	<0.001	0.001	mg/L		27-NOV-01	ZG
		Chromium (Cr)	0.033	0.004	mg/L		27-NOV-01	ZG
		Copper (Cu)	0.078	0.006	mg/L		27-NOV-01	ZG
		Mercury (Hg)	0.004	0.001	mg/L		27-NOV-01	ZG
		Molybdenum (Mo)	0.007	0.001	mg/L		27-NOV-01	ZG
		Nickel (Ni)	0.003	0.001	mg/L		27-NOV-01	ZG
		Lead (Pb)	0.009	0.001	mg/L		27-NOV-01	ZG
		Antimony (Sb)	<0.008	0.008	mg/L		27-NOV-01	ZG
		Selenium (Se)	0.061	0.004	mg/L		27-NOV-01	ZG
		Uranium (U)	0.002	0.001	mg/L		27-NOV-01	ZG
		Vanadium (V)	0.170	0.001	mg/L		27-NOV-01	ZG
		Zinc (Zn)	0.09	0.02	mg/L		27-NOV-01	ZG
		Routine Water: Major Ions & Fluoride						
		Chloride (Cl)	11300	1	mg/L		27-NOV-01	CNP
		Fluoride (F)	0.66	0.05	mg/L		26-NOV-01	PTT
		Nitrate+Nitrite-N	<0.1	0.1	mg/L		28-NOV-01	CNP
		pH, Conductivity and Total Alkalinity						
		pH	7.7	0.1	pH		27-NOV-01	PTT
		Conductivity (EC)	30300	0.2	uS/cm		27-NOV-01	PTT
		Bicarbonate (HCO3)	93	5	mg/L		27-NOV-01	PTT
		Carbonate (CO3)	<5	5	mg/L		27-NOV-01	PTT
		Hydroxide	<5	5	mg/L		27-NOV-01	PTT
		Alkalinity, Total	76	5	mg/L		27-NOV-01	PTT
		Ion Balance Calculation						
		Ion Balance	97.2		%		28-NOV-01	
		TDS (Calculated)	20200		mg/L		28-NOV-01	
		Hardness	3630		mg/L		28-NOV-01	
		ICP metals and SO4 for routine water						
		Calcium (Ca)	239	0.5	mg/L		27-NOV-01	MOR
		Potassium (K)	226	0.1	mg/L		27-NOV-01	MOR
		Magnesium (Mg)	736	0.1	mg/L		27-NOV-01	MOR
		Sodium (Na)	6080	1	mg/L		27-NOV-01	MOR
		Sulfate (SO4)	1560	0.5	mg/L		27-NOV-01	MOR
		Turbidity	<0.1	0.1	NTU		27-NOV-01	JTV
		SAR						
		Calcium (Ca)	239	0.5	mg/L		27-NOV-01	MOR
		Potassium (K)	226	0.1	mg/L		27-NOV-01	MOR
		Magnesium (Mg)	736	0.1	mg/L		27-NOV-01	MOR

ENVIRO-TEST CHEMICAL ANALYSIS REPORT

PRELIMINARY RESULTS

Lab ID	Sample ID	Test Description	Result	D.L	Units	Extracted	Analyzed	By
L52170-1	GHSW01							
Sample Date:	19-NOV-01 00:00:00							
Matrix:	WATER							
	SAR							
	Sodium (Na)		6080	1	mg/L		27-NOV-01	MOR
	SAR		43.9		SAR		27-NOV-01	MOR

Methodology Reference

ETL Test Code	Test Description	Methodology Reference (In-House Standard Operating Procedures which Generally Follow:)
CL-ED	Chloride (Cl)	APHA 4500 Cl E-Colorimetry
ETL-ROUTINE-ICP-ED	ICP metals and SO4 for routine water	APHA 3120 B-ICP-OES
F-ED	Fluoride (F)	APHA 4500 F-C-Electrode
FE-EXT-ED	Iron (Fe)-Extractable	APHA 3120 B-ICP-OES
IONBALANCE-ED	Ion Balance Calculation	APHA 1030E
MET1-EXT-DW-ED	Extractable Trace Metals	APHA 3125-ICP-MS
MN-EXT-ED	Manganese (Mn)-Extractable	APHA 3120 B-ICP-OES
N2N3-ED	Nitrate+Nitrite-N	APHA 4500 NO3H-Colorimetry
PH/EC/ALK-ED	pH, Conductivity and Total Alkalinity	APHA 4500-H, 2510, 2320
SAR-CALC-ED	SAR	CSSS 18.4-Calculation
TURBIDITY-ED	Turbidity	APHA 2130 B-Nephelometer

The Clearwater Group™

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Calgary Office:
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Calgary, AB, Canada T2E 8K5
Tel. (403) 280-0004
Fax (403) 280-7711

US Office:
Pacific Keystone Technologies Incorporated
PO Box 360, Black Diamond, WA. 98010-0491
Tel. (360) 886-1396
Fax (360) 886-2480
E-MAIL: keystone@clearwaterworld.com

WEBSITE: www.clearwaterworld.com

FAX

DATE:	January 31, 2002	TIME:	11:10:12 AM
FROM:	Rick Johnson BCA Industrial Controls (1995) Limited	PHONE: FAX:	(604) 539-9399 (604) 539-9309
COPIES:	Poul Wesch (BCA-Cgy)		
TO:	Ferguson Simek Clark Ron Kent, P.Eng.	PHONE: FAX:	867-920-2882 867-920-4319

Number of copies including this cover page: 5

Ron,

Further to my E-mail and our telcon earlier this morning, here is some information regarding an R.O. unit to make potable water from the Gjoa Haven seawater.

Hydranautics tested the sample water that we sent them and compared it to "standard" seawater. The Gjoa Haven water is less salty, 20,000 ppm vs. 32,100 ppm for standard seawater, which resulted in an improved flux rate approximately 50% higher. They ran these tests at 23.9° C and 13.9° C for the Arctic water and at 23.4° C and 11.8° C for the standard water.

The end result is that due to the lower salt content, the recovery rate is much higher that originally expected. The recovery rate for the Gjoa Haven water will be approx. 55%, as compared to the expected 30% and we're expecting to make water with a quality of 200 ppm. The higher recovery rate means that the raw water supply pump and the high-pressure membrane pumps can be much smaller – 100 USGPM vs. 150 USGPM.

We also determined that the temperature had less effect on the membrane selection than first expected. For instance, at 5° C raw water, we expect that a 100 HP pump will be required; heating the water to 20° C only decreased the HP required to about 80 HP.

We expect that the cost to heat the water will out-weigh the additional HP cost.

The package we're recommending will consist of three, 5-membrane modules, mounted on a pre-fabricated skid approx. 20-ft L x 6-ft W x 5-ft H (6.1 m x 1.8 m x 1.5 m). This dimension will include the main pump, the control panel, piping, valves and pre-filters.

Separate from this skid would be the membrane cleaning chemical package (if desired). We expect these membranes will operate from 3-5 years without cleaning. The chem feed package would take up an additional 6-ft x 4 ft of floor area. Additional space requirements are 4-ft clear space at each end to allow membrane installation and

BCA
The Clearwater Group™

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Fax (604) 539-9309
E-MAIL: bca@clearwaterworld.com

Calgary Office:
PO Box 56052 Airways,
Calgary, AB, Canada T2E 8K5
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Pacific Keystone Technologies Incorporated
PO Box 360, Black Diamond, WA. 98010-0491
Tel. (360) 886-1396
Fax (360) 886-2480
E-MAIL: keystone@clearwaterworld.com

WEBSITE: www.clearwaterworld.com

FAX

DATE:	January 31, 2002	**TIME:**	1:55:45 PM
FROM:	Rick Johnson BCA Industrial Controls (1995) Limited	**PHONE:** **FAX:**	(604) 539-9399 (604) 539-9309
COPIES:			
TO:	FERGUSON SIMEK CLARK Ron Kent, P.Eng.	**PHONE:** **FAX:**	867-920-2882 867-920-4319

Number of copies including this cover page:

Ron,

Further to the information I sent you this morning, here's some supporting information.

The sizing programme was run at 5°, 10° and 20°, please call if you have any questions.

Rick

file-enq-wtp-01-01-0578-corr-0131'02

Hydranautics RO System Design Software, v. 7.00 (c) 2000 1/31/02

BASIC DESIGN

5°C

RO program licensed to:
Calculation created by: PW

Project name: Gjoa Haven		Permeate flow:	52.0 gpm
HP Pump flow:	94.5 gpm	Raw water flow:	94.5 gpm
Recommended pump press.:	1053.7 psi		
Feed pressure:	984.0 psi	Permeate recovery ratio:	55.0 %
Feedwater Temperature:	5.0 C(41F)		
Raw water pH:	7.70	Element age:	2.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	4.6	Salt passage increase, %/yr:	10.0
Average flux rate:	15.8 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	psi	Element Type	Elem. No.	Array
1-1	38.5	47.3	28.0	17.6	1.11	962.6	0.0	SWC2	10	2x5
1-2	13.5	56.0	42.5	12.3	1.05	928.2	0.0	SWC2	5	1x5

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	239.0	596.0	239.0	596.0	0.5	1.4	530.4	1322.8
Mg	738.0	3037.0	738.0	3037.0	1.7	6.9	1637.9	6740.5
Na	6080.0	13217.4	6080.0	13217.4	66.4	144.4	13429.9	29195.5
K	228.0	292.3	228.0	292.3	3.1	4.0	502.9	644.7
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.009	0.0	0.009	0.0	0.000	0.0	0.020	0.0
Sr	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
CO3	0.1	0.2	0.1	0.2	0.0	0.0	0.3	0.5
HCO3	93.0	76.2	93.0	76.2	1.6	1.3	204.8	167.8
SO4	1560.0	1625.0	1560.0	1625.0	3.7	3.8	3462.2	3606.5
Cl	11300.0	15937.9	11300.0	15937.9	105.5	148.9	24982.1	35235.7
F	0.7	1.8	0.7	1.8	0.0	0.0	1.5	4.1
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	0.0		0.0		0.0		0.0	
TDS	20238.8		20238.8		182.5		44752.1	
pH	7.7		7.7		5.9		8.2	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	14%	14%	37%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	86%	86%	227%
SiO2 saturation:	0%	0%	0%
Langelier Saturation Index	-0.09	-0.09	1.07
Stiff & Davis Saturation Index	-0.73	-0.73	0.20
Ionic strength	0.40	0.40	0.89
Osmotic pressure	199.3 psi	199.3 psi	440.6 psi

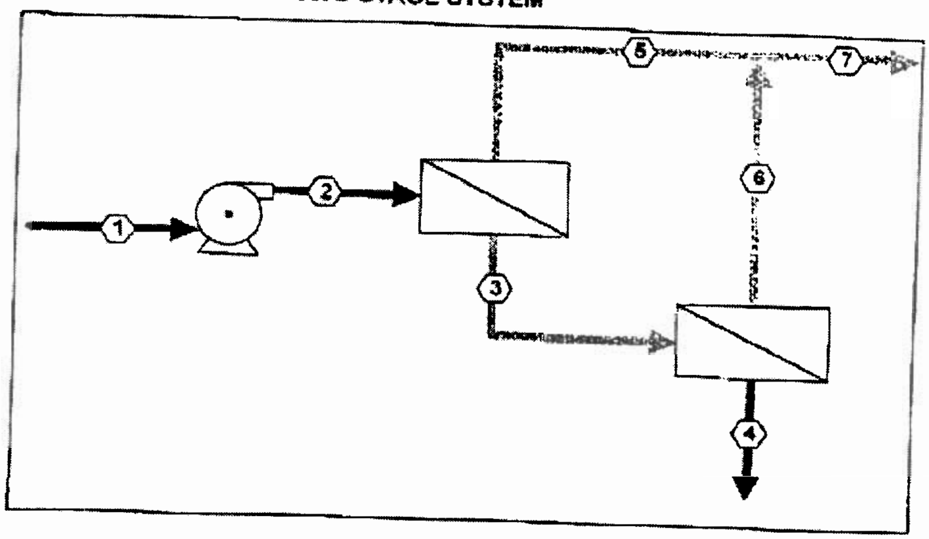
These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

Hydranautics (USA) Ph:(760)901-2500 Fax:(760)901-2578 info@hydranautics.com
Hydranautics (Europe) Ph: 31 5465 88355 Fax: 31 5465 73288 (63)

Gjoa Haven

1/31/02

TWO STAGE SYSTEM



		1	2	3	4	5	6	7
Flow	gpm	94.5	94.5	56.0	42.5	38.5	13.5	52.0
Pressure	psi	0.0	984.0	962.6	928.2	0.0	0.0	0.0
TDS (ppm)		20238.8	20238.8	34040.3	44752.1	144.4	291.4	182.5

5°C

Hydranautics RO System Design Software, v. 7.00 (c) 2000 1/31/02

BASIC DESIGN

10°C

RO program licensed to:
Calculation created by: PW

Project name: Gjoa Haven		Permeate flow:	52.0 gpm
HP Pump flow:	94.5 gpm	Raw water flow:	94.5 gpm
Recommended pump press.:	955.2 psi		
Feed pressure:	894.9 psi	Permeate recovery ratio:	55.0 %
Feedwater Temperature:	10.0 C(50F)		
Raw water pH:	7.70	Element age:	2.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	4.1	Salt passage increase, %/yr:	10.0
Average flux rate:	15.8 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	psi	Element Type	Elem. No.	Array
1-1	39.0	47.3	27.8	17.8	1.10	873.7	0.0	SWC2	10	2x5
1-2	13.0	55.5	42.5	11.9	1.05	839.6	0.0	SWC2	5	1x5

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	239.0	596.0	239.0	596.0	0.7	1.6	530.3	1322.5
Mg	738.0	3037.0	738.0	3037.0	2.0	8.3	1637.5	6738.9
Na	6080.0	13217.4	6080.0	13217.4	79.3	172.4	13414.2	29161.3
K	228.0	292.3	228.0	292.3	3.7	4.8	502.1	643.8
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.009	0.0	0.009	0.0	0.000	0.0	0.020	0.0
Sr	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
CO3	0.1	0.2	0.1	0.2	0.0	0.0	0.3	0.5
HCO3	93.0	76.2	93.0	76.2	1.9	1.5	204.4	167.5
SO4	1560.0	1625.0	1560.0	1625.0	4.4	4.5	3461.3	3605.6
Cl	11300.0	15937.9	11300.0	15937.9	126.0	177.7	24957.1	35200.5
F	0.7	1.8	0.7	1.8	0.0	0.0	1.5	4.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	0.0		0.0		0.0		0.0	
TDS	20238.8		20238.8		217.9		44708.9	
pH	7.7		7.7		6.0		8.2	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	12%	12%	33%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	56%	56%	147%
SiO2 saturation:	0%	0%	0%
Langelier Saturation Index	0.02	0.02	1.18
Stiff & Davis Saturation Index	-0.66	-0.66	0.28
Ionic strength	0.40	0.40	0.89
Osmotic pressure	202.9 psi	202.9 psi	448.1 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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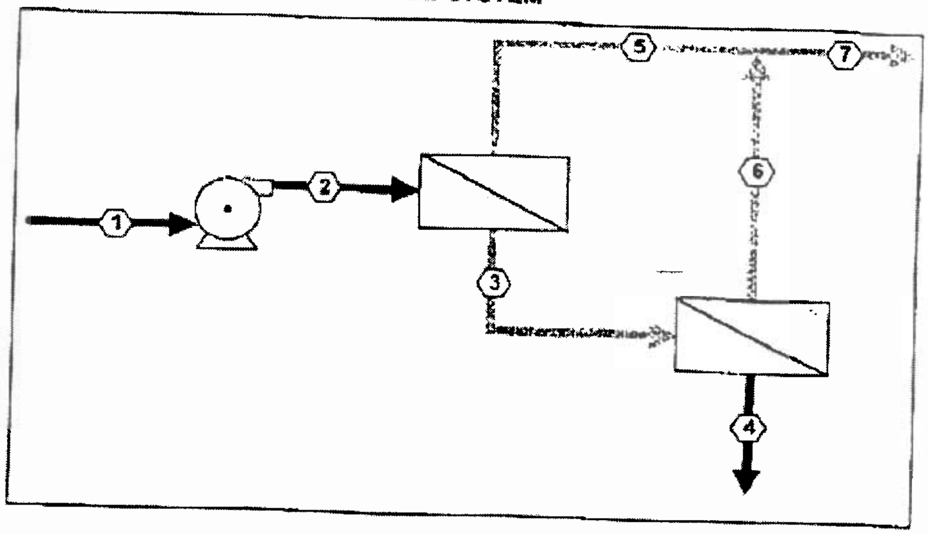
Gjoa Haven

1/31/02

TWO STAGE SYSTEM



		1	2	3	4	5	6	7
Flow	gpm	94.5	94.5	55.5	42.5	39.0	13.0	52.0
Pressure	psi	0.0	894.9	873.7	839.6	0.0	0.0	0.0
TDS (ppm)		20238.8	20238.8	34345.5	44708.9	170.2	361.2	217.9

10°C

Hydranautics RO System Design Software, v. 7.00 (c) 2000 1/31/02

BASIC DESIGN

20°C

RO program licensed to:
Calculation created by: PW
Project name: Gjoa Haven

HP Pump flow:	94.5 gpm	Permeate flow:	52.0 gpm
Recommended pump press.:	813.0 psi	Raw water flow:	94.5 gpm
Feed pressure:	766.4 psi	Permeate recovery ratio:	55.0 %
Feedwater Temperature:	20.0 C(68F)		
Raw water pH:	7.70	Element age:	2.0 years
Acid dosage, ppm (100%):	0.0 H2SO4	Flux decline % per year:	7.0
Acidified feed CO2:	3.4	Salt passage increase, %/yr:	10.0
Average flux rate:	15.8 gfd	Feed type:	Well water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	psi	Element Type	Elem. No.	Array
1-1	40.2	47.3	27.2	18.4	1.10	745.7	0.0	SWC2	10	2x5
1-2	11.8	54.3	42.5	10.8	1.04	712.2	0.0	SWC2	5	1x5

Ion	Raw water mg/l	Raw water CaCO3	Feed water mg/l	Feed water CaCO3	Permeate mg/l	Permeate CaCO3	Concentrate mg/l	Concentrate CaCO3
Ca	239.0	596.0	239.0	596.0	0.9	2.3	530.0	1321.7
Mg	738.0	3037.0	738.0	3037.0	2.8	11.6	1636.5	6734.7
Na	6080.0	13217.4	6080.0	13217.4	111.4	242.1	13375.0	29076.1
K	228.0	292.3	228.0	292.3	5.2	6.7	500.3	641.4
NH4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ba	0.009	0.0	0.009	0.0	0.000	0.0	0.020	0.0
Sr	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0
CO3	0.1	0.2	0.1	0.2	0.0	0.0	0.4	0.7
HCO3	93.0	76.2	93.0	76.2	2.6	2.1	203.5	166.8
SO4	1560.0	1625.0	1560.0	1625.0	6.1	6.4	3459.2	3603.3
Cl	11300.0	15937.9	11300.0	15937.9	177.0	249.7	24894.8	35112.5
F	0.7	1.8	0.7	1.8	0.0	0.1	1.5	4.0
NO3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SiO2	0.0		0.0		0.0		0.0	
TDS	20238.8		20238.8		306.1		44601.2	
pH	7.7		7.7		6.2		8.2	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	11%	11%	30%
SrSO4 / Ksp * 100:	0%	0%	0%
BaSO4 / Ksp * 100:	36%	36%	96%
SiO2 saturation:	0%	0%	0%
Langelier Saturation Index	0.23	0.23	1.39
Stiff & Davis Saturation Index	-0.50	-0.50	0.43
Ionic strength	0.40	0.40	0.88
Osmotic pressure	210.1 psi	210.1 psi	462.8 psi

These calculations are based on nominal element performance when operated on a feed water of acceptable quality. No guarantee of system performance is expressed or implied unless provided in writing by Hydranautics.

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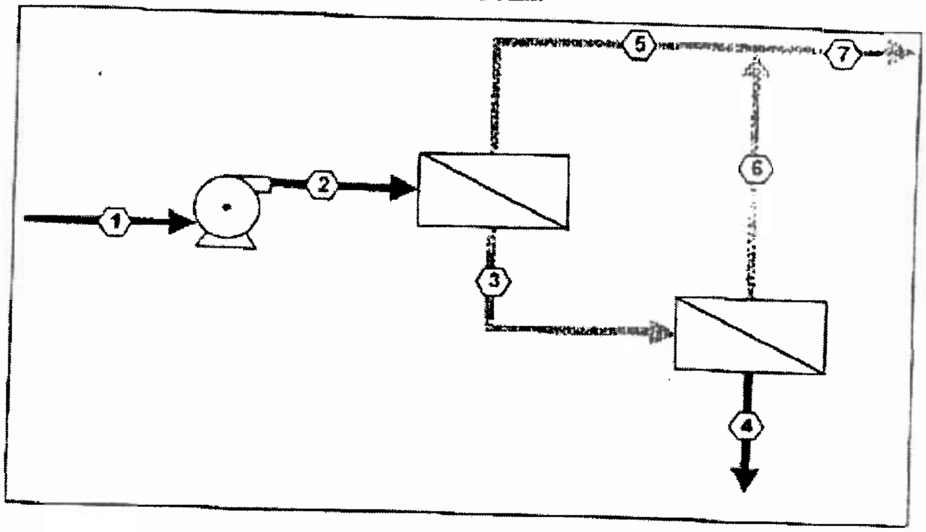
Gjoa Haven

1/31/02

TWO STAGE SYSTEM



		1	2	3	4	5	6	7
Flow	gpm	94.5	94.5	64.3	42.8	40.2	11.8	52.0
Pressure	psi	0.0	766.4	745.7	712.2	0.0	0.0	0.0
TDS (ppm)		20238.8	20238.8	35056.6	44601.2	233.2	655.3	306.1

20°C

Hydranautics RO System Design Software, v. 7.00 (c) 2000

Project name: Gjoa Haven
Water source: Well water

1/31/02

WATER ANALYSIS

pH	7.70	Turb	0.0	E. cond	32571	CO2	4.6	H2S	0.0
Temp	5.0 C	SDI	0.0	TDS	20239	Fe	0.0		

Ca	239.0 mg/l	11.9 meq/l	CO3	0.1 mg/l	0.0 meq/l
Mg	738.0 mg/l	60.7 meq/l	HCO3	93.0 mg/l	1.5 meq/l
Na	6080.0 mg/l	264.4 meq/l	SO4	1560.0 mg/l	32.5 meq/l
K	228.0 mg/l	5.9 meq/l	Cl	11300.0 mg/l	318.8 meq/l
NH4	0.0 mg/l	0.0 meq/l	F	0.7 mg/l	0.0 meq/l
Ba	0.0 mg/l	0.0 meq/l	NO3	0.0 mg/l	0.0 meq/l
Sr	0.0 mg/l	0.0 meq/l	SiO2	0.0 mg/l	0.0 meq/l

CaSO4 saturation	14 %
SrSO4 saturation	0 %
BaSO4 saturation	86 %
SiO2 saturation	0 %
LSI	-0.1
SDI	-0.7
Ionic strength	0.400
Osmotic pressure	199.3

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removal.

Also separate from this package is the raw water supply pump; the skid needs to be supplied with 100 USGPM of seawater at 50 psi to serve the pre-filters.

The estimated cost of this package is $250,000, plus freight and start-up.

We're also looking at a turn-key package that will include the R.O. skid, the raw water pump and two gen-sets all installed in a pre-engineered building with heat, lights, etc.

Once we have this pricing, we'll pass it on, as well.

We're assuming that the raw water can be used as the cooling source for the gen sets and will investigate that potential.

I apologize for the delay getting any information to you, we trust this will help you generating your report to your client. Please call if you have any questions or require any additional information; the detailed calculations will be sent to you shortly (probably later today).

Thanks again for your patience,

Rick Johnson

file-enq-wtp-01-01-0578-budget-0131'02

HYDRANAUTICS
High Performance Membrane Products
A NITTO DENKO CORPORATION

401 Jones Road
Oceanside, CA 92054
Phone: 760-901-2565
Fax: 760-901-2578
E-Mail: jkutilek@hydranautics.com
Web site: www.membranes.com

JANUARY 21, 2002

BCA PACIFIC KEYSTONE
ATTN: RICK JOHNSON
FAX : 604-539-9309.

RE: GJOA HAVEN CANADIAN HIGH ARCTIC

ATTACHED PLEASE FIND THE HYDRANAUTICS LAB RESULTS ON THE SWC 3 FLAT SH
(SPECIFICATION ATTACHED)

ALSO RAN TEST ON "BENCHMARK" SEAWATER OF

1) 32,100 ppm NaCl lab feed water

2) 20,000 ppm GJOA HAVEN sample

FLUX ON 13.9°C sample = 21.86 GFD ; 99.75% R

NOT TOO BAD!

REGARDS,
JOHN KUTILEK

Analytical & Testing – Membrane Cell Test Data

Log #:		[illegible]	[illegible]	[illegible]
Originator:	JOHN KUTILEK	Feed conductivity (μmho):	[illegible] 20,000 ppm	[illegible] 2000[illegible]
Membrane type:	SWC3	Feed Concentration (ppm):		
Sample arrival date:	DEC 2001	Feed temperature (°C):	23.9	13.9
Test loop:	1	pH:	7.51	7.5
Operator:	TT	[illegible]	800 [illegible]	80[illegible]

TEST #1 Start Date: 01-21-02 Start Time: 6:45 Duration: 1 hrs ____ min Continuing: [X] Yes [ ]
Read Date: 01- Read Time: 7:45.

Sample ID	Cell #	ml	min	Flux Factor	Flux GFD	Perm. Cond.	Conduct. Conv. Factor	% Rej.	Io[illegible] S[illegible]
	1	6.8	6.0	21.90	24.82	34.9	0.4687	99.92	
	2	6.9	↓		25.19	39.8		99.91	
	3	6.25			22.81	33.5		99.92	
	4	6.4			23.36	44.2		99.90	
	5	6.0			21.90	43.5		99.90	
	6	6.0	↓		21.90	59.1		99.86	
				Average ± SD →	23.33	1.42	Average ± SD →	99.90	0

Further tests (treatments) on these coupons:

TEST #2 Start Date: 01-21-02 Start Time: 11 30 Duration: ____ hrs 15 min Continuing: [ ] Yes [ ]
Read Date: 01-21-02 Read Time: 11 45.

Sample ID	Cell #	ml	min	Flux Factor	Flux GFD	Perm. Cond.	Conduct. Conv. Factor	% Rej.	Ion Su[illegible]
	1	5.7	7.0	28.47	23.18	45.7	0.4687	99.89	
	2	5.8	↓		23.58	66.5	↓	99.84	
	3	5.25			21.35	37.4	↓	99.91	
	4	5.4			21.96	235	0.4721	99.45	
	5	5.05			20.54	95.2	↓	99.78	
	6	5.05	↓		20.54	150	↓	99.65	
				Average ± SD →	21.86	1.30	Average ± SD →	99.75	0.1[illegible]

Notes:

Analytical & Testing – Membrane Cell Test Data

Log #:		[illegible]	[illegible]	[illegible]
Originator:	R# 020114-A-STA 5	Feed conductivity (µmho):	32,100 ppm NaCl	32,10
Membrane type:	SWC3	Feed Concentration (ppm):		
Sample arrival date:		Feed temperature (°C):	23.4	11.8
Test loop:	1	pH:	6.93	6.9
[illegible]:	TT	[illegible]	[illegible]	[illegible]

TEST #1	Start Date: 01-18-02	Start Time: 10:30	Duration: 1 hrs ____ min	Continuing: [X] Yes [ ]
	Read Date: 01-18-02	Read Time: 11:30		

Sample ID	Cell #	ml	min	Flux Factor	Flux GFD	Perm. Cond.	Conduct. Conv. Factor	% Rej.	Io S
	1	5.5	7.0	22.23	17.47	123	0.4721	99.82	
	2	5.5	↓		17.47	133		99.80	
	3	5.0			15.88	105		99.85	
	4	5.05			16.04	147		99.78	
	5	4.8			15.24	150		99.78	
	6	4.7	↓		14.93	204		99.70	
				Average ± SD →	16.17	1.08	Average ± SD →	99.79	0.

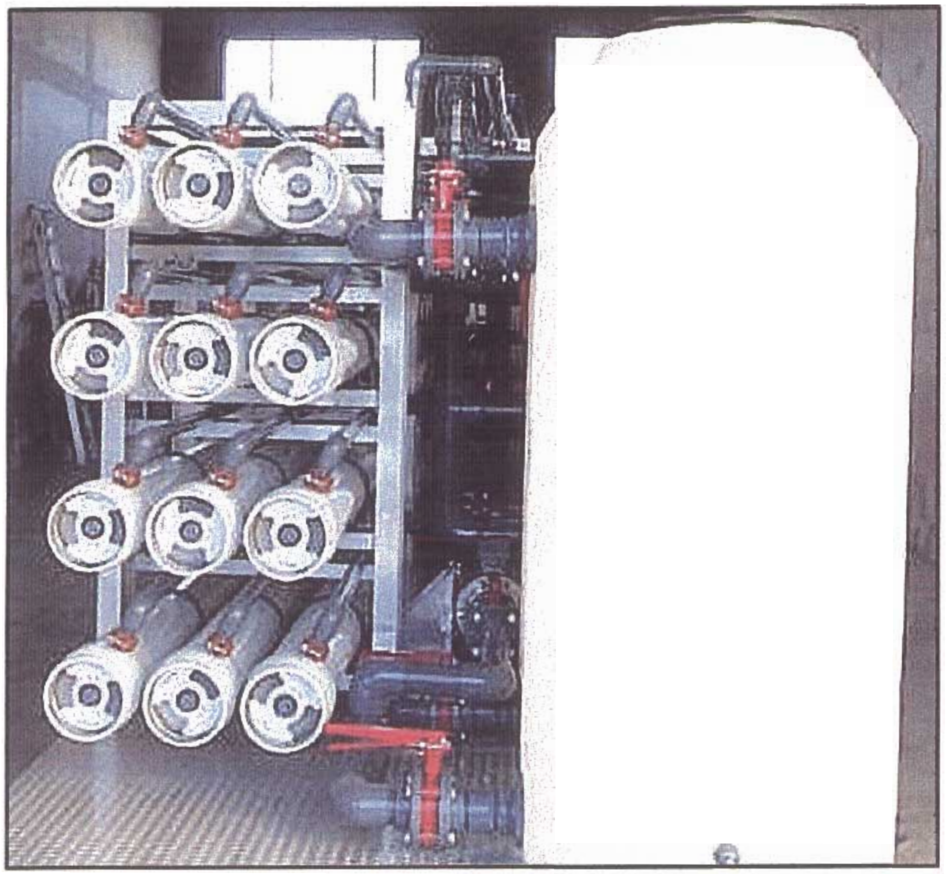
Further tests (treatments) on these coupons:

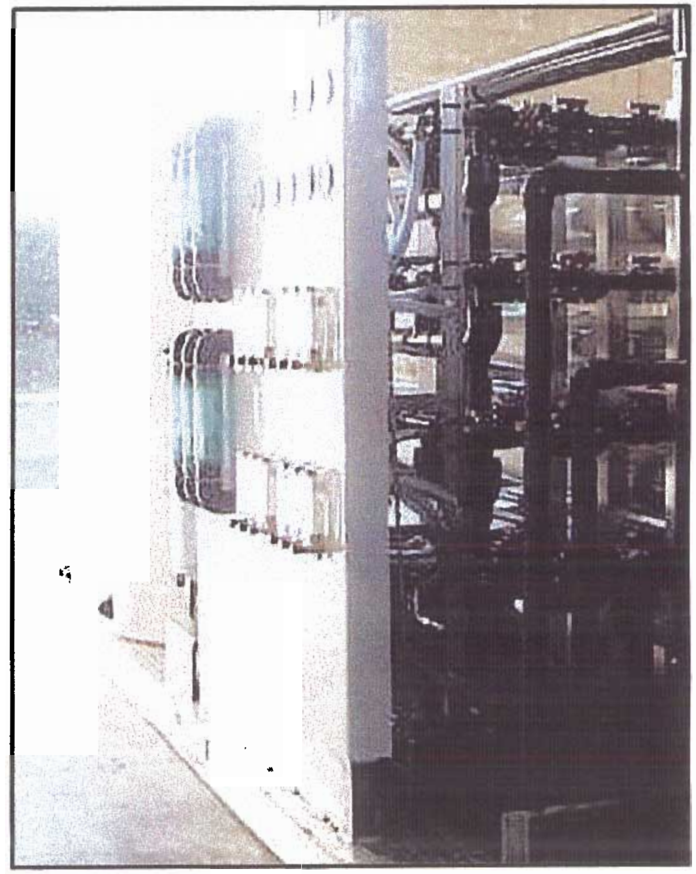
TEST #2	Start Date: 01-18-02	Start Time: 14:15	Duration: ____ hrs 20 min	Continuing: [X] Yes [ ]
	Read Date: 01-18-02	Read Time: 14:35		

Sample ID	Cell #	ml	min	Flux Factor	Flux GFD	Perm. Cond.	Conduct. Conv. Factor	% Rej.	Ions Su
	1	4.8	9.0	29.85	15.92	135	0.4721	99.80	
	2	4.8	↓		15.92	186		99.73	
	3	4.35			14.43	119		99.82	
	4	4.45			14.76	229		99.66	
	5	4.2			13.93	211		99.69	
	6	4.2	↓		13.93	279		99.59	
				Average ± SD →	14.82	0.91	Average ± SD →	99.72	0.0

Notes:

Reverse Osmosis Desalination System





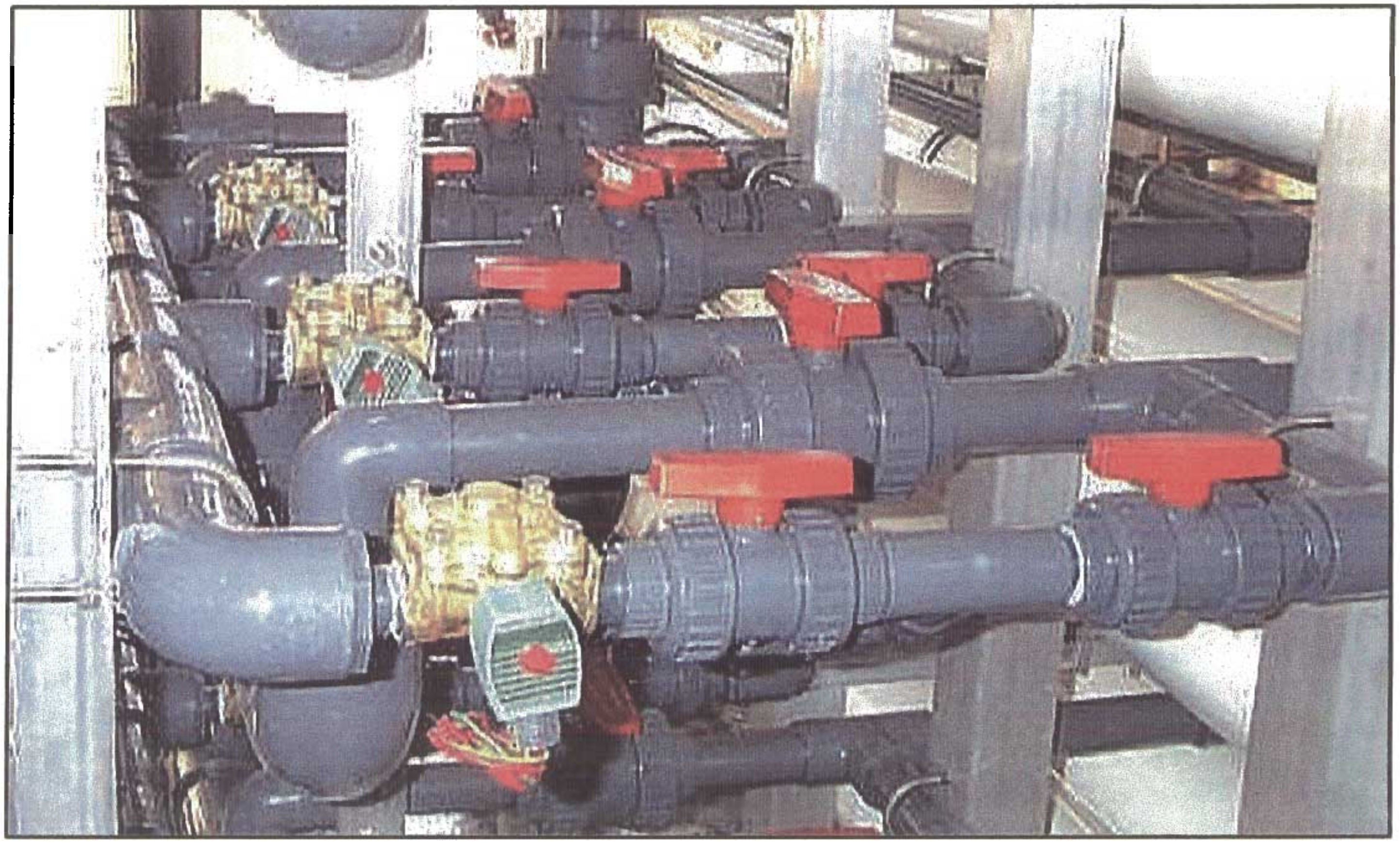
Reverse Osmosis Desalination System

Reverse Osmosis Desalination System

Reverse Osmosis Desalination System

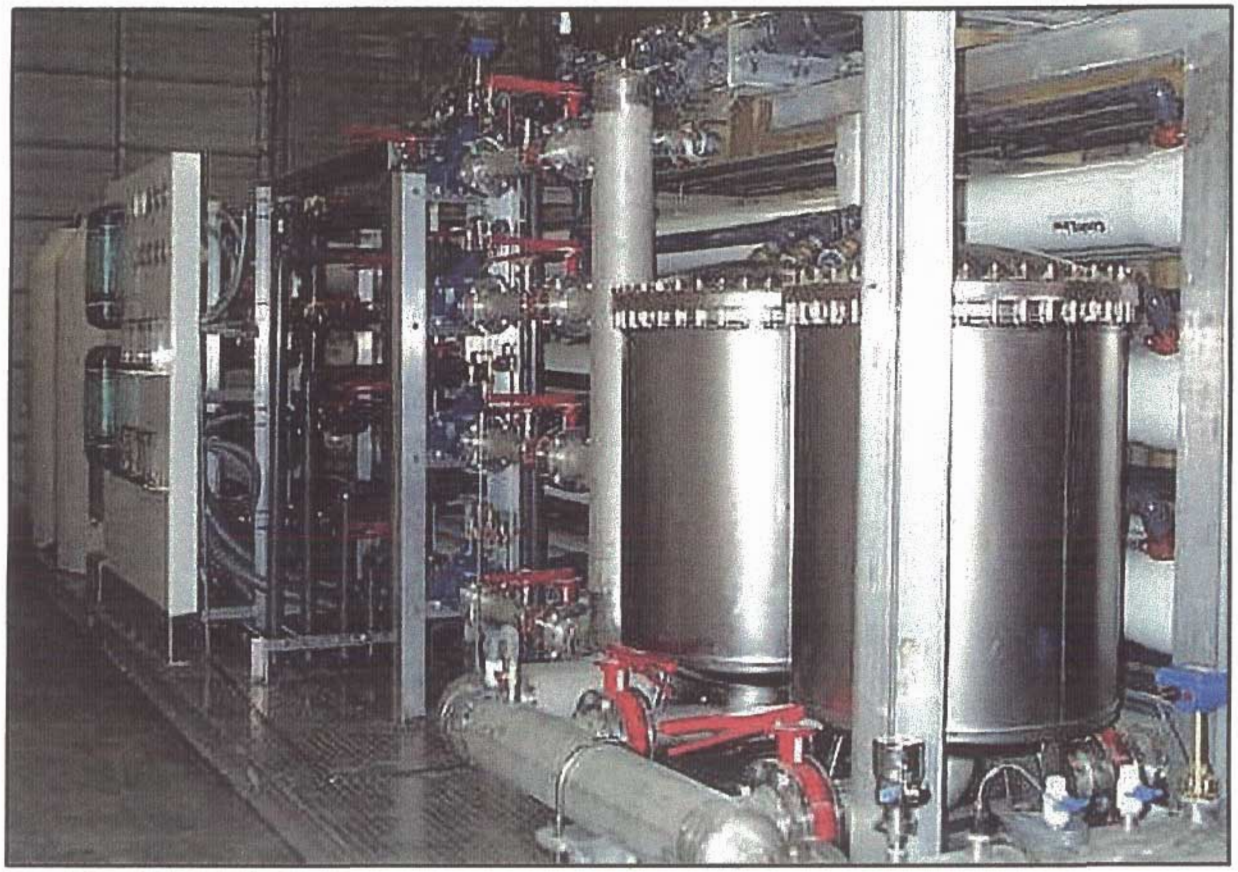
Reverse Osmosis Desalination System

Reverse Osmosis Desalination System



FSC GROUP

Reverse Osmosis Desalination System



Appendix B

Cost Estimates

Option 1

Swan Lake Recirc. Pipeline, Treatment in town, Water Lake Fire Storage

Capital Component	Unit Cost	Unit	Quantity	Extension
Lake Intake Facility	$750,000	ea.	1	$750,000
200mm Insulated HDPE Pipe	$300	lin.m.	3,240	$972,000
150mm Insulated HDPE Pipe	$250	lin.m.	3,240	$810,000
Excavate and Backfill (0.75m cover)	$200	lin.m.	3,240	$648,000
Access Vaults	$15,000	ea.	11	$165,000
Treatment Process Equipment Process Controls & Building Envelope	$1,200,000	lump	1	$1,200,000
Potable Storage Tank (310 m3)**	$854	m2	260	$222,040
Truckfill Facility In Town	$500,000	ea.	1	$500,000
Upgrades to existing pumphouse	$75,000	lump	1	$75,000
Subtotal				$5,342,040
Engineering & Contingency @ 40%				$2,136,816
Total				$7,478,856

O&M Component	Unit Cost	Unit	Quantity	Extension
Truckfill	5%		$500,000	$25,000
Intake	5%		$750,000	$37,500
Water Storage Tank	3%		$222,040	$6,661
Pipeline	3%		$1,947,000	$58,410
Treatment System	12%		$1,200,000	$144,000
Existing Intake Building O&M	$50,000	L.S.	1	$50,000
Heat Intake Water to 4 degC	$100,000		1	$100,000
Total				$421,571

* ROH2O Cartridge Filter System from Kugluktuk Analysis (530 lpm)

** Grise Fiord & Hay River Cost Analysis, 32 ft high tanks

*** Truckfill & Treatment Building area = 56m2. Intake Building area = 28m2

Building Area = 15m x 5m = 75

Storage = Emergency + Dead + Equalization

Water Storage Tank 32 feet high.

Year	i = 8%	
1	1	$421,571
2	0.9259259	$390,344
3	0.8573388	$361,429
4	0.7938322	$334,657
5	0.7350299	$309,867
6	0.6805832	$286,914
7	0.6301696	$265,661
8	0.5834904	$245,983
9	0.5402689	$227,762
10	0.500249	$210,891
11	0.4631935	$195,269
12	0.4288829	$180,805
13	0.3971138	$167,412
14	0.3676979	$155,011
15	0.340461	$143,529
16	0.3152417	$132,897
17	0.2918905	$123,053
18	0.270269	$113,938
19	0.250249	$105,498
20	0.2317121	$97,683
Sum Annual Costs		$4,470,172
Capital Cost		$7,478,856
Net Present Value		$11,949,028

Option 2

Swan Lake Pipeline, Treatment in town, All Storage Tanked

Capital Component	Unit Cost	Unit	Quantity	Extension
Lake Intake Facility	$750,000	ea.	1	$750,000
Truckfill Facility In Town	$500,000	ea.	1	$500,000
200mm Insulated HDPE Pipe	$300	lin.m.	3,240	$972,000
150mm Insulated HDPE Bleed Pipe	$250	lin.m.	184	$46,000
Excavate and Backfill (0.75m cover)	$100	lin.m.	3,424	$342,400
Access Vaults	$15,000	ea.	11	$165,000
Treatment Process Equipment Process Controls & Building Envelope	$1,200,000	lump	1	$1,200,000
Water Storage Tank (480 m3)**	$854	m2	341	$291,214
Subtotal				$4,266,614
Engineering & Contingency @ 40%				$1,706,646
Total				$5,973,260

O&M Component	Unit Cost	Unit	Quantity	Extension
Truckfill	5%		$500,000	$25,000
Intake	5%		$750,000	$37,500
Water Storage Tank	3%		291,214 L	$8,736
Pipeline	3%		$1,018,000	$30,540
Treatment System	12%		$1,200,000	$144,000
Heat Intake Water to 4 degC	$100,000		1	$100,000
Total				$345,776

* ROH2O Cartridge Filter System from Kugluktuk Analysis (530 lpm)

** Grise Fiord & Hay River Cost Analysis, 32 ft high tanks

*** Truckfill & Treatment Building area = 56m2. Intake Building area = 28m2

Building Area = 15m x 5m = 75

Storage = Emergency + Fire + Dead + Equalization

Water Storage Tank 32 feet high.

Year	i = 8%	
1	1	$345,776
2	0.9259259	$320,163
3	0.8573388	$296,448
4	0.7938322	$274,488
5	0.7350299	$254,156
6	0.6805832	$235,330
7	0.6301696	$217,898
8	0.5834904	$201,757
9	0.5402689	$186,812
10	0.500249	$172,974
11	0.4631935	$160,161
12	0.4288829	$148,298
13	0.3971138	$137,313
14	0.3676979	$127,141
15	0.340461	$117,723
16	0.3152417	$109,003
17	0.2918905	$100,929
18	0.270269	$93,453
19	0.250249	$86,530
20	0.2317121	$80,121
Sum Annual Costs		$3,666,475
Capital Cost		$5,973,260
Net Present Value		$9,639,734

Option 3

Tasiqyuaq Recirc. Pipeline, Treatment in town, Water Lake Fire Storage

Capital Component	Unit Cost	Unit	Quantity	Extension
Lake Intake Facility	$750,000	ea.	1	$750,000
200mm Insulated HDPE Pipe	$300	lin.m.	4,439	$1,331,700
150mm Insulated HDPE Pipe	$250	lin.m.	4,439	$1,109,750
Excavate and Backfill (0.75m cover)	$200	lin.m.	4,439	$887,800
Access Vaults	$15,000	ea.	15	$225,000
New Access Road to Intake	$275	lin.m.	880	$242,000
Treatment Process Equipment Process Controls & Building Envelope	$1,200,000	lump	1	$1,200,000
Potable Storage Tank (310)**	$854	m2	260	$222,040
Upgrades to existing pumphouse	$75,000	lump	1	$75,000
Truckfill Facility In Town	$500,000	ea.	1	$500,000
Subtotal				$6,543,290
Engineering & Contingency @ 40%				$2,617,316
Total				$9,160,606

O&M Component	Unit Cost	Unit	Quantity	Extension
Heat Intake Water to 4 degC	$100,000		1	$100,000
Truckfill O&M	5%		$500,000	$25,000
Intake O&M	5%		$750,000	$37,500
Water Storage Tank	3%		$222,040	$6,661
Pipeline Maintenance	3%		$2,666,450	$79,994
Treatment System O & M	12%		$1,200,000	$144,000
Existing Intake Building O&M	$50,000	L.S.	1	$50,000
Access Road	$50	lin.m.	880	$44,000
Total				$487,155

* ROH2O Cartridge Filter System from Kugluktuk Analysis (530 lpm)

** Grise Fiord & Hay River Cost Analysis, 32 ft high tanks

*** Truckfill & Treatment Building area = 56m2. Intake Building area = 28m2

Building Area = 15m x 5m = 75

Storage = Emergency + Dead + Equalization

Water Storage Tank 32 feet high.

Year	i = 8%	
1	1	$487,155
2	0.9259259	$451,069
3	0.8573388	$417,657
4	0.7938322	$386,719
5	0.7350299	$358,073
6	0.6805832	$331,549
7	0.6301696	$306,990
8	0.5834904	$284,250
9	0.5402689	$263,195
10	0.500249	$243,699
11	0.4631935	$225,647
12	0.4288829	$208,932
13	0.3971138	$193,456
14	0.3676979	$179,126
15	0.340461	$165,857
16	0.3152417	$153,571
17	0.2918905	$142,196
18	0.270269	$131,663
19	0.250249	$121,910
20	0.2317121	$112,880
Sum Annual Costs		$5,165,593
Capital Cost		$9,160,606
Net Present Value		$14,326,199

Option 4

Tasiqyuaq Pipeline, Treatment in town, All Storage Tanked

Capital Component	Unit Cost	Unit	Quantity	Extension
Lake Intake Facility	$750,000	ea.	1	$750,000
200mm Insulated HDPE Pipe	$300	lin.m.	4,439	$1,331,700
150mm Insulated HDPE Bleed Pipe	$250	lin.m.	184	$46,000
Excavate and Backfill (0.75m cover)	$100	lin.m.	4,623	$462,300
Access Vaults	$15,000	ea.	15	$225,000
New Access Road to Intake	$275	lin.m.	880	$242,000
Treatment Process Equipment Process Controls & Building Envelope	$1,200,000	lump	1	$1,200,000
Water Storage Tank (480 m3)**	$854	m2	341	$291,214
Truckfill Facility In Town	$500,000	ea.	1	$500,000
Subtotal				$5,048,214
Engineering & Contingency @ 40%				$2,019,286
Total				$7,067,500

O&M Component	Unit Cost	Unit	Quantity	Extension
Heat Intake Water to 4 degC	$100,000		1	$100,000
Truckfill	5%		$500,000	$25,000
Intake O&M	5%		$750,000	$37,500
Water Storage Tank	3%		$291,214	$8,736
Pipeline O&M	3%		$1,602,700	$48,081
Treatment System O & M	12%		$1,200,000	$144,000
Access Road	$50	lin.m.	880	$44,000
Total				$407,317

Year	i = 8%	
1	1	$407,317
2	0.9259259	$377,146
3	0.8573388	$349,209
4	0.7938322	$323,342
5	0.7350299	$299,390
6	0.6805832	$277,213
7	0.6301696	$256,679
8	0.5834904	$237,666
9	0.5402689	$220,061
10	0.500249	$203,760
11	0.4631935	$188,667
12	0.4288829	$174,691
13	0.3971138	$161,751
14	0.3676979	$149,770
15	0.340461	$138,676
16	0.3152417	$128,403
17	0.2918905	$118,892
18	0.270269	$110,085
19	0.250249	$101,931
20	0.2317121	$94,380
Sum Annual Costs		$4,319,031
Capital Cost		$7,067,500
Net Present Value		$11,386,530

* ROH2O Cartridge Filter System from Kugluktuk Analysis (530 lpm)

** Grise Fiord & Hay River Cost Analysis, 32 ft high tanks

Intake Building area = 28m2

Treatment Building Area = 15m x 5m = 75

Storage = Emergency + Fire + Dead + Equalization

Water Storage Tank 32 feet high.

Option 5
Desalination Plant, Fire Flow from Ocean

Capital Component	Unit Cost	Unit	Quantity	Extension
Treatment Process	$250,000	ea.	1	$250,000
Desalination Plant Building	$2,700	m2	75	$202,500
Electrical	$267	m2	75	$20,025
Mechanical	$850,000	lump	1	$850,000
Potable Storage Tank (1115 m3)	$854	m3	600	$512,400
Wastewater Outfall	$935	lin.m.	100	$93,500
Truckfill Facility In Town	$500,000	ea.	1	$500,000
Ocean Intake	$1,000,000	ea.	1	$1,000,000
Subtotal				$3,428,425
Engineering & Contingency @ 40%				$1,371,370
Total				$4,799,795

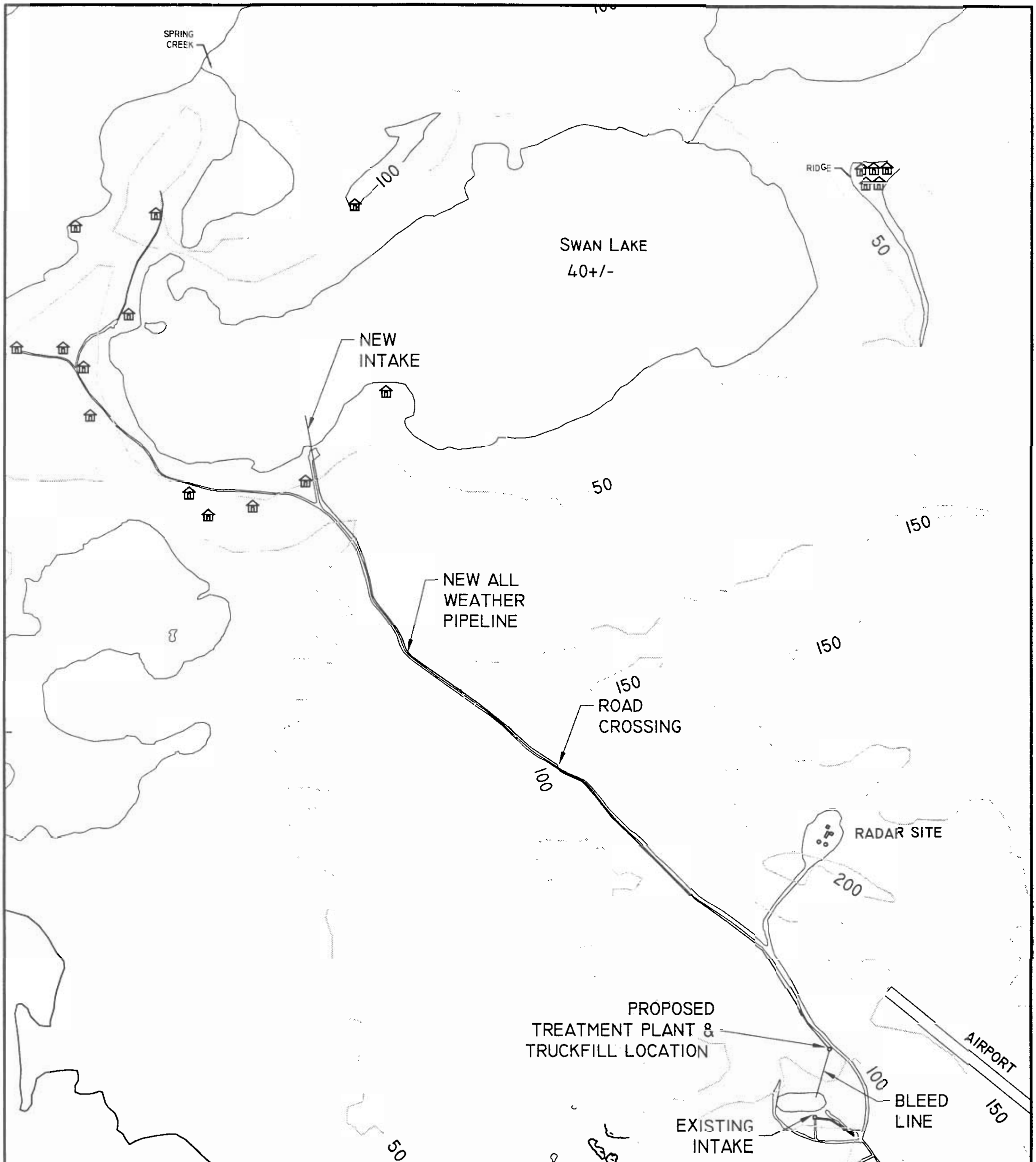
O&M Component	Unit Cost	Unit	Quantity	Extension
System Operator	$75,000	ea.	1	$75,000
Technical Support	$10,000	ea.	2	$20,000
Heat Intake Water to 5 degC	$211,000		1	$211,000
Storage Tank O&M	3%		$512,400	$15,372
Mechanical O&M	12%		$1,100,000	$132,000
Intake Maintenance	5%		$1,000,000	$50,000
Truckfill	5%		$500,000	$25,000
Outfall	2%		$93,500	$1,870
Total				$530,242

Year	i = 8%	
1	1	$530,242
2	0.9259	$490,965
3	0.8573	$454,597
4	0.7938	$420,923
5	0.735	$389,744
6	0.6806	$360,874
7	0.6302	$334,142
8	0.5835	$309,391
9	0.5403	$286,473
10	0.5002	$265,253
11	0.4632	$245,605
12	0.4289	$227,412
13	0.3971	$210,566
14	0.3677	$194,969
15	0.3405	$180,527
16	0.3152	$167,154
17	0.2919	$154,773
18	0.2703	$143,308
19	0.2502	$132,693
20	0.2317	$122,863
Sum Annual Costs		$5,622,474
Capital Cost		$4,799,795
Net Present Value		$10,422,269

Storage = Emergency + Dead + Equalization + 5 Day TADP
** Grise Fiord & Hay River Cost Analysis, 32 ft high tanks
Water Storage = 5 day storage at Total Average Daily Production (TADP) + Fire Storage = 1115 cu.m.
Water Storage Tank 32 feet high.

Appendix C

Drawings



FSC GROUP FERGUSON SIMEK CLARK ENGINEERS AND ARCHITECTS	JOB TITLE WATER SUPPLY IMPROVEMENTS GJOA HAVEN, NUNAVUT	DRAWING TITLE ALL WEATHER LINE SWAN LAKE TO TRUCKFILL/RESERVOIR OPTION 1 AND 2	DESIGNED BY	SCALE NTS
			DRAWN BY	DATE FEB.2002
			CHECKED BY	CLIENT JOB NO.
			FSC FILE NO. phase2.DWG	FSC PROJECT NO. 2000-1080
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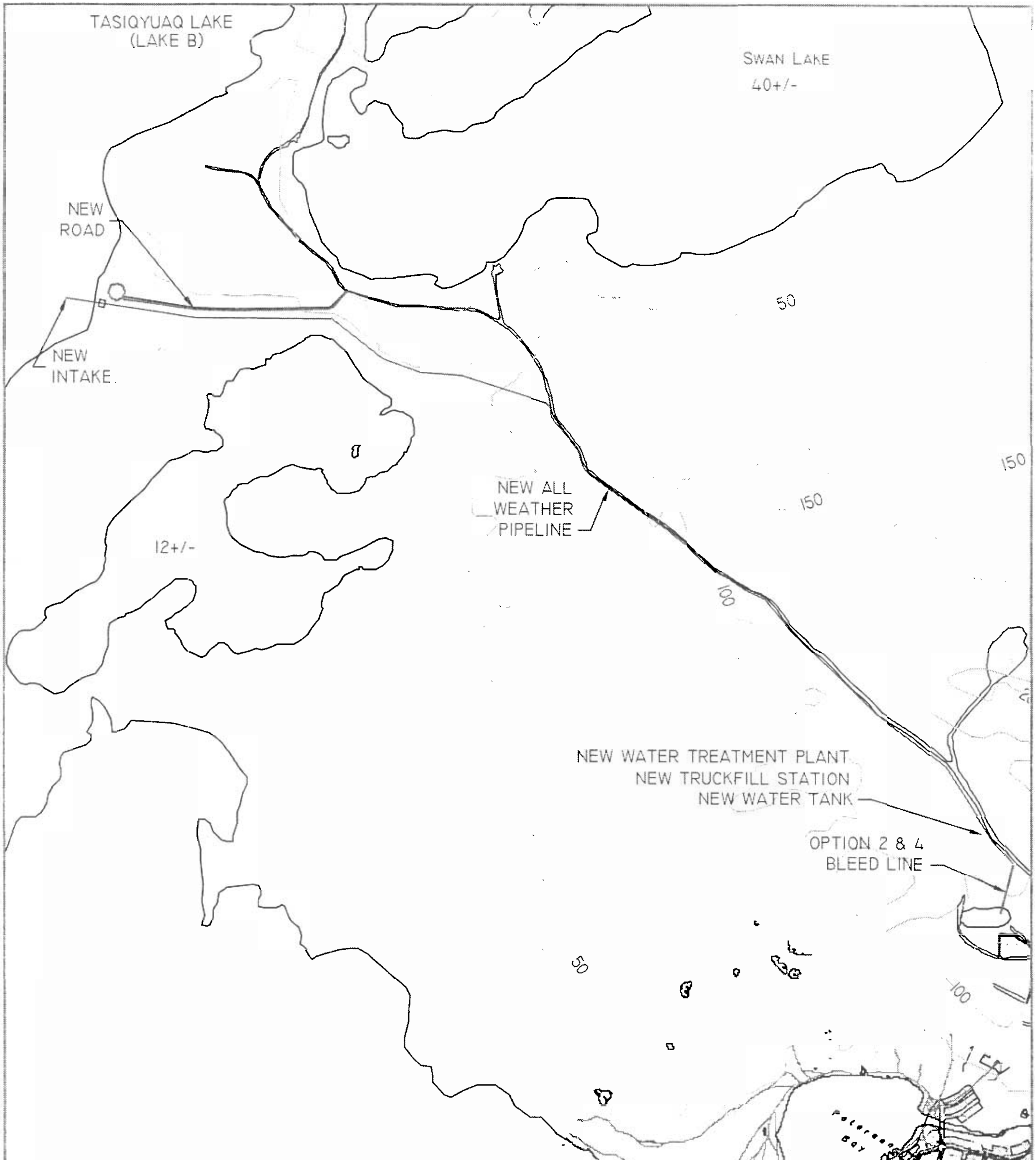

FSC GROUP

JOB TITLE

WATER SUPPLY IMPROVEMENTS

GJOA HAVEN, NUNAVUT

DRAWING TITLE

ALL WEATHER LINE LAKE B (TASIQYUAQ) TO TRUCKFILL/RESERVOIR OPTION 3 AND 4

DESIGNED BY	SCALE
DRAWN BY	DATE
CHECKED BY	CLIENT JOB NO.
FSC FILE NO.	FSC PROJECT NO.
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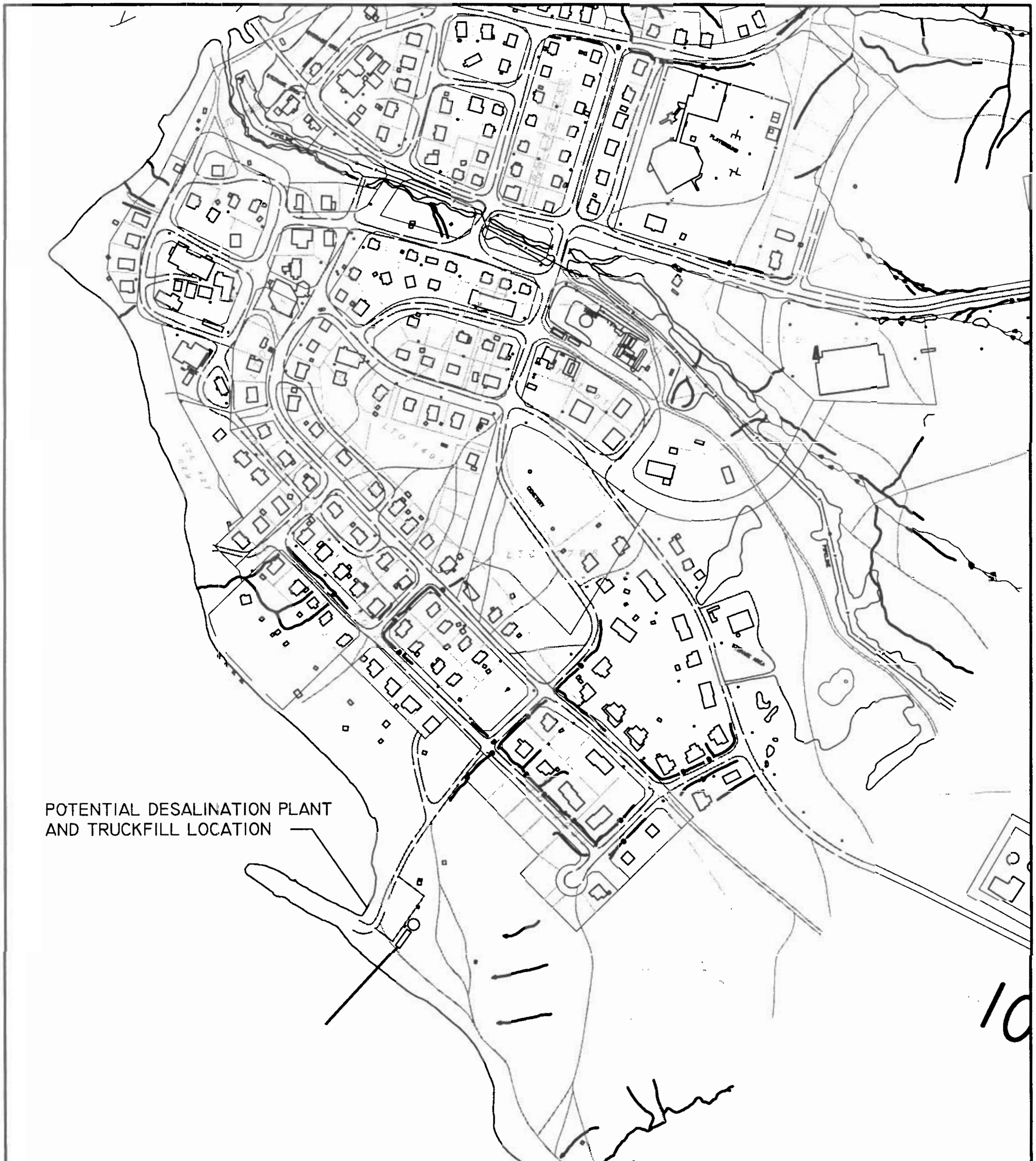

FSC GROUP
FERGUSON SIMEK CLARK
ENGINEERS AND ARCHITECTS

JOB TITLE
WATER SUPPLY IMPROVEMENTS

GJOA HAVEN, NUNAVUT

DRAWING TITLE
DESALINATION PLANT AND TRUCKFILL OPTION 5

DESIGNED BY	SCALE NTS
DRAWN BY WM	DATE DEC.2000
CHECKED BY	CLIENT JOB NO.
FSC FILE NO. BASEMAP.DWG	FSC PROJECT NO. 2000-1080
SHEET OF	DRAWING NO