Technical Evaluation Of An Arctic Char Production Facility Near The Town Of Hay River

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resource and pollution management

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Renewable Resources,
Economic Development and Tourism,
GOVERNMENT OF THE NORTHWEST TERRITORIES,
P.O. Box 1366,
Hay River, Northwest Territories,
XOE ORO

Dear Mr. Hachey:

Please find enclosed copies of our final report entitled:

“Technical Evaluation of an Arctic Char
Production Facility Near the Town of Hay River, N.W.T.”.

Our findings indicate that the fingerling-only production option offers better potential for further development than production of market-size fish. Production of market-size fish might be possible at 400 to 700 tonnes, but capital costs would be high ($6. O-$8.O million) and substantial support funding would be required. Annul operating costs would be approximately $4.0 to $5.0 million. Without support funding, a break-even facility size is greater than 800 tonnes, requiring a capital investment of at least $10 million.

The ~~viable~~ size of a fingerling facility will depend greatly on the price that government or other users are willing to pay. If prices are similar to the costs of bringing fingerlings from southern facilities, a viable facility is estimated to have a capital cost of $0.9 to $1.0 million and annual operating costs of $0.45 to $0.5 million.

We recommend that a pilot facility be operated for at least one full production cycle before full-scale development is undertaken to test site and technological uncertainties. A pilot facility is estimated to have a capital cost of $0.35 to $0.45 million and annual operating costs of $0.25 to $0.3 million.

We have found the present study to be challenging and thank you for the opportunity to undertake it.

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If you have questions regarding the enclosed study, please do not hesitate to contact us.

Yours truly,

MALCOLM W&BY,
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MW/HFM/5640C

TABLE OF CON-

TABLE OF CONTENTS
(CONTINUED)

Page

TABLE OF CONTENTS
(CONTINUED)

Page

6.0 OPTION 1: FINGERLING PRODUCTION (CONT'D.)

6.2 OPERATING COSTS (Cont'd.)

TABLE OF CONTENTS
(CONTINUED)

Page

BLE OF

LIST OF TABLES

LIST OF FIGURES

APPENDIX

SUMMARY

This study evaluates the technical potential for establishing a landbased Ar'ctic char production facility near the Town of Hay River, Northwest Territories. The study includes a brief review of siting conditions near the Town of Hay River, an assessment of a facility capable of producing fingerlings, and an assessment of a facility capable of growing fish to market size.

Initially, the study called for examining the potential utilization of surplus heat from a planned waste oil heating unit, located near the Town of Hay River water supply pumphouse. Plans to install the waste **oil** heating unit were subsequently reconsidered and placement put in question. Accordingly, the client requested that the study analysis be kept flexible in the event that other potential heat sources are identified. The present study has used the water supply pumphouse location for initial costing purposes, but indicates cost extremes that might apply to alternate sites in the Northwest Territories.

No sites providing large quantities of good quality surface or groundwater are evident near the Town of Hay River. A possible exception is near+urface water infiltration along the shoreline of Great Slave Lake near the pumphouse. Studies of water infiltration rates and soil suitability for such a concept must be undertaken to verify its practicability.

A **fingerling-only** production facility, capable of producing 250,000 fingerlings, is estimated to have a minimum capital cost of $0.8 million and an annual operating cost of approximately $0.3 million. Such a facility would have very high unit production costs (i.e., greater than $l.45/fingerling) and likely would not be viable unless purchasers accepted very high prices ($1.60-$1 .80/fingerling). At approximately $1.20 per fingerling, a break-even production size is estimated to be approximately 400,000 fingerlings. Fingerlings produced at a facility producing market-size fish could be offered at

much lower prices because most capital and operating costs for fingerling production would be offset by the larger commercial facility. The break-even production size for a fingerling facility is estimated to have a capital investment cost of $0.9 to $1.0 million and annual operating costs of $0.45 to $0.5 million.

Capital costs were estimated for two facility sizes of commercial growout to market size. These were a facility having a design biomass limit of 50 tonnes capable of harvesting up to 80-100 tonnes and a facility having a design biomass of 200 tonnes capable of harvesting up to 320 tonnes. Cost estimates for facilities maintaining high winter water temperatures (12°C) are $2.4-$ 4.7 million (for the 50 tonne biomass facility) and $7.9-$14.6 million (for the 200 tonne biomass facility). Capital costs for a 200 tonne biomass facility maintaining cool winter temperatures (4-6°C), are estimated to be $5.5-$6.0 million. A 200 tonne facility (capable of producing 320 tonnes by harvesting over most of the year) does not appear to be commercially viable. A break-even harvest size assuming normal financing is estimated to be 800-1,000 tonnes (maximum biomass size 500-700 tonnes), and would require a capital investment of at least $10 million. A break-even harvest size assuming substantial support financing in the form of grants or interest-free loans is estimated to be 400-500 tonnes (maximum biomass size 250-300 tonnes) and would require a capital investment of $6-$8 million. Annual operating costs would be $4-$5 million.

The results of the study indicate that a fingerling facility including broodstock has better potential for further development than a facility producing fish to market size. However, in both cases important siting, technical and pricing uncertainties are identified. A pilot facility should first be developed to test both biological performance of Northwest Territories' strains of Arctic char and equipment operating under northern conditions A pilot facility of 4 tonnes (100,000 fingerlings) is estimated to have a capital construction cost of $0.35 to $0.45 million and annual operating costs of $0.25 to $0.3 million. Turn-key landbased salmon production facilities should not be considered for direct application.

A strategy for further development of the project is presented.

1.0 INTRODUCTION

Arctic char culture has been shown to be technically viable both in Canada and northern Europe. At present, the species receives good market prices compared to salmon and trout and commercial culture to pan-size is underway at a growing number of locations, primarily in freshwater. Commercial growout to larger harvest sizes and growout in saltwater is also being investigated.

The Town of Hay River, Northwest Territories, has been considering installation of a waste oil heating system to heat the municipal water supplies. The system under consideration was felt to have a surplus heat potential that might be utilized in a fish culture facility. Consequently, the Government of the Northwest Territories commissioned a study to examine the potential for utilizing surplus heat from the proposed heating system in a landbased Arctic char production facility.

The following report presents the results of this study.

2.0 TERMS OF REFERENCE, APPROACH AND METHODS

2.1 OBJECTIVES AND SCOPE

This study is based on objectives and tasks outlined in a Terms of Reference for Development of an Aquiculture Production System for Arctic char issued July 1988 by the Government of the Northwest Territories Economic Development and Tourism Department (Hay River). Specifically the objectives are:

- to undertake a technical evaluation of a tank production system for Arctic char near Hay River, Northwest Territories (Figure 2.1).
- to examine two production options:
  - raising of fingerlings; and
  - growing out fingerlings for market.

Initially, the study was to be based on expected surplus heat available from a waste oil heating system to be used for heating the Town of Hay River's water supply. The Town of Hay River subsequently reconsidered installing a waste oil heating system. Accordingly, the client for this project requested that the geographical location for the facility concept be kept flexible so that the study could be used to identify other potential sites in the Northwest Territories, especially with respect to possible sources of waste heat.

2.2 APPROACH AND METHODS

The study is comprised of the following components:

- a preliminary appraisal of the site originally proposed;
- a review of the culture requirements for Arctic char including conceptual facility designs and operating strategies;
- definition of capital and operating costs for different production options;

- assessment of the viability of different production options, the potential for using waste heat, and use of ‘turn-key” landbased salmon systems; and
- development of recommendations for project implementation.

The review of culture requirements included an examination of literature, discussions with researchers at the Department of Fisheries and Oceans, Rockwood Experimental Fish Hatchery in Winnipeg, Manitoba and at the Huntsman Marine Laboratory in St. Andrews, New Brunswick; and discussions with operators of private facilities in Winnipeg, Manitoba (Elders Aqua Farms Ltd.), and in Whitehorse, the Yukon (polar Sea Fisheries).

Capital and operating costs are based on information provided by suppliers of specialized equipment (e.g., fish rearing units, pumps and heat exchangers, etc.), construction contractors in the Northwest Territories and experience of the report authors during assessment of salmonid production facilities elsewhere (e.g., British Columbia, Alaska and eastern Canada).

3.0 POTENTIAL SITING NEAR THE TOWN OF HAY RIVER

3.1 WATER SUPPLY PUMPHOUSE

The original project concept called for utilizing waste heat from the proposed waste oil heating unit at the town water supply pump station. The pump station is located approximately 5 km north of the Town of Hay River on the edge of Great Slave Lake (Figure 3.1). The station is situated slightly landward of the ice scour limit.

Two options for supplying water to a culture facility adjacent to the pumphouse were discussed with municipal engineering staff. One option is to utilize lake water drawn from the town water supply line; the second is to use lake infiltration water from a dugout constructed near the shoreline.

3.1.1 Lake Water from the Town Water Supply

The water supply intake point is located approximately 5 km from the lake shore at a depth of 20 m. The water supply system is currently running at 25% capacity. It was designed for a town size of 12,000 people, but is currently servicing 3,000 (Bruin, personal communication). Two water supply pumps are housed in the water treatment/pumphouse (one working pump; one standby pump). Each has a maximum motor speed of 3,600 rpm and a pump design point of approximately 63.0 LPS. —

The incoming water is heated, then chlorine is added and the water passes through suspended solids settling units. The water heating units are in operation only during the winter, to ensure the water in the supply lines have temperatures high enough so that freezing will not occur. The temperature of the heated water varies over a 24 hour period depending on water usage (Bruin, personal communication). During the day, winter water temperatures at the pumphouse are normally between 5. O-10.O”C. At night temperatures can reach 20. O-30.O”C.

Use of the town water supply might involve:

1. tying into the main supply line before heating (in which case the culture facility would construct and manage its own heat source);

2. tying into the water supply after water is heated (in which case the culture facility would have to negotiate their portion of the heating costs and develop a system to reduce the high temperatures at night); and

3. tying into the main supply line, but use heat exchangers to obtain heat from the town water after it is heated (in which case a large, insulated storage tank might be required to try to store the abundant excess heat available at night, and utilize the heat over part of the daytime).

Two problems exist for using the water drawn from the town water supply directly as the water supply to the hatchery (points 1 and 2 above). One is the assurance of sustainable water volume when the culture facility requirements are at their peak; the second is the need for a settling basin or other system to reduce seasonally high turbidity (particularly during high flows over spring and early summer from the Hay River).

3.1.1.1 Water Volume Assurance

Clearly, use of the town water supply places the needs of the culture facility in conflict with the needs of the town. As indicated above, the water supply is being utilized at 25% of capacity. As the town grows, this utilization will increase. The production size at which a culture facility will be profitable is analyzed in subsequent sections of this report. However, rough calculations assuming a production size of 50 tonnes (which is a very large fingerling production facility or a small, probably unprofitable commercial growout facility) indicate a water requirement of approximately 46 LPS using recirculation of 95% (which is technically possible, but is not conservative for planning purposes). The 46 LPS represents close to 75% of the water supply capacity. A commitment by the town to assure such water volumes over a 10 to 20 year period (or longer) is unlikely. A commitment to provide a lesser amount, such as 20% of capacity, would limit the production capacity accordingly (for example, in this case, to a maximum production size of approximately 10-15 tonnes).

3.1.1.2 Water Quality

The Hay River has high runoff over spring (400-800 m^3/s) and this is usually accompanied by high turbidity. A summary of water quality features of the Hay River near the Town of Hay River are shown in Table 3.1. These data indicate that water quality isgenerally acceptable for salmonid culture except for high turbidity levels. The water intakeis located5 km away from the mouth of the Hay River toreduce the effect of suspended solids coming from Hay River, but high levels occur periodically at the intake. Other water quality features are acceptable for fish culture, however, high pesticide levels have recently been detected (B. Olding, personal communication).

3.1.2 Useof Lake Infiltration Water from a Shoreline Dugout

During discussions with municipal personnel about potential difficulties utilizing the town water supply system and the poor local groundwater potential as an alternate source, the possibility of using a lake shore dugout near the pump station was presented asan option.

Apparently hardpan (shale) near the lake is approximately 13 m deep and above that alluvial clay is reached at 4 m. In concept, a reservoir could be dug to the 4 m depth with interceptor ditches running out from it. Excavated material could be used for fill and berming. Water from the reservoir could be pumped to or near the existing town water supply pumphouse to extract heat (by means of heat exchangers) from the proposed separate waste oil heating unit. A standby pipe connection could be made to the water supply system to be used if the reservoir pumps failed.

Uncertainties with this concept are:

- the exact soil condition (for both excavation and water infiltration rates in the area where a reservoir might be constructed); and
- the cost of preparing the water intake structure (i.e., the reservoir, interception ditches, pumps in the reservoir and piping between the reservoir and the heating unit and/or pumphouse).

Estimated water volume requirements are outlined in Sections 6.0 (Fingerling Production) and 7.0 (Commercial Growout Production) based on assumed water infiltration rates. Clearly, site tests will be required before project development can proceed.

3.1.3 Terrain and Site Preparation

Land in the vicinity of the town water supply pumphouse/water treatment plant is very flat. Soil maps for the area indicate general surface soils are comprised of sand and loam, possibly mixed with gravels, over silty loams mixed with sands and gravels. Permafrost occurs in the area, but its distribution is patchy and detailed studies would be required for developing site plans. Some form of bed preparation (piles or insulating material) to prevent problems with permafrost melting will likely be required.

Plood risk maps indicate the site is above the flood line from the Hay River. However, municipal personnel noted that high lake levels can back water up the roadside drainage ditches at the pump station. This means that the fish production rearing units would have to be elevated slightly above local ground level to allow proper tank drainage during periods of high water. Earth fill from the reservoir could be used for this.

The fish rearing area would be constructed above the ice scour line along the lake shore. However, the reservoir might be better constructed closer to the lake edge to increase water infiltration (from the lake). In this case, a berm would be required (from excavated material) to prevent ice scour and inundation during high lake water levels.

3.1.4 Site Acceas and Logistics

Site access and logistics are excellent. The site is approximately 5 km from the Town of Hay River and 4 km from the Hay River Airport. An existing dirt road runs from the town along the south shore of Great Slave Lake. A short road connects the pumphouse to the lake road.

3.2 ALTERNATE WATER SUPPLIES

Alternate water supply sources were discussed briefly with the client and municipal personnel.

3.2.1 Near the Town of Hay River

The Town of Hay River is situated near the mouth of the Hay River. To draw water directly from the Hay River problems would be experienced with:

- the fluctuating and seasonally high water discharge levels;
- periodically high levels of suspended solids; and
- winter ice conditions, particularly moving ice (in relation to construction of water intake facilities).

Alternatively, high level groundwater exists around the town given a layer of sandy soils that extends to approximately 3 m depths. However, water in this zone periodically dries up and is not appropriate for the water volumes required in the fish production facility. Larger sources of deeper-level groundwater are not expected to be present. However, if suitable groundwater is found in the vicinity of the town, one possible heat source is the sewage line. During a brief examination of the sewage line in early February, the sewage outfall temperature was 10.0°C when the ambient air temperature was approximately -25.0°C. At the same time, storm drains in the town had a temperature of 1.5°C.

3.2.2 Near the Town of Enterprise

Near surface groundwater, including artesian springs, have been found near the Town of Enterprise, approximately 25 km south of Hay River. However, both water quality and water volume (to meet the needs of a fish production facility) do not appear adequate (Thurber Consultants Ltd. 1979). High levels of iron, iron bacteria, hydrogen sulphide and hydrocarbons have been recorded at test locations within the settlement of

Enterprise (Tilden 1982). It does not appear that a suitable water source exists in that area for a fish production facility.

3.2.3 Other Sources

The client has indicated that waste heat is available in the Town of Fort Simpson, but that development of a fish production site would likely be constrained by difficulties in finding a suitable land area for construction.

Other waste heat sources are felt to be likely in the southern Northwest Territories (E. Hachey, personal communication). If suitable sources are identified, other siting criteria will have to be assessed: the volume and quality of water to be used directly within the fish culture facility, and terrain conditions and site logistics (including the size and proximity of nearby communities and airports).

4.0 PRODUCTION OPTIONS AND ASSUMPTIONS

4.1 PRODUCTION OPTIONS

Two options are considered during this study:

- fingerling production; and
- growout to market-size.

A facility might in fact be capable of producing both fingerling for outplanting and fish grown to market-size. It is assumed that in both cases the facility will eventually develop and maintain its own broodstock, though in concept, the facility might rely on eggs purchased elsewhere.

4.1.1 Option 1: Fingerling-Only Production

Fingerlings produced at a char culture facility might be used for stocking selected public lakes, to be recaptured in the recreational fishery, or for growout in private "fee-fishing" lakes or other commercial facilities. The demand for both is relatively low at present and not well defined. One hundred thousand fingerlings is likely sufficient to meet annual government stocking needs over the near term. For facility costing purposes (Section 6.0), a larger production size (250,000 fingerlings) was used; this production size should be sufficient to meet foreseeable government and/or commercial needs.

4.1.2 Option 2: Commercial Growout Production

Arctic char are currently being commercially produced in freshwater to a 250-400 gram size ("pan-size") elsewhere in Canada and in northern Europe. Commercial growout to larger sizes is technically possible and market prices are likely as good as or better than those for pan-size fish (see Section 7.0), but the operating experience with such fish is very limited. At present, fish are grown to a larger size primarily as broodstock. The facility costs and analyses in Section 7.0 concentrate on pan-size production.

The commercial break-even point for landbased salmon farms is generally between 200 tonnes and 500 tonnes (Babtie, Shaw, Morton 1988). These facilities normally do not consider a form of supplemental heat to optimize growth and reduce the production time. Therefore, to identify the minimum size for commercial viability for this study, detailed cost estimates were made for facilities having a maximum biomass of 50 tonnes and 200 tonnes. Total annual harvest tonnage would range from 50-100 tonnes at the 50 tonne facility and 200-350 tonnes at the 200 tonne facility depending on the harvest scheduling. Harvesting normally takes place over several months, however, actual harvest schedules usually vary depending on market and production condition% Therefore, harvest is assumed to occur during one month for design purposes and the financial effects of harvesting over a one to eight month period is assessed.

4.2 FACILITY DESIGN CONCEPTS

4.2.1 Siting Uncertainties

The original project concept called for examining the potential use of excess heat produced by a waste oil heating unit to be installed at the Town of Hay River water supply pumphouse. The Town of Hay River subsequently postponed installation of the waste oil heating unit. Consequently, the placement of an Arctic char culture facility became uncertain and the client requested that the analysis remain flexible so that siting might be considered either at the Town of Hay River pumphouse location or elsewhere, given a suitable source of waste heat.

Local construction contractors indicated a high variability in site preparation and construction costs for the Northwest Territories, depending on site conditions, even within the Town of Hay River area. These costs appear particularly sensitive to local permafrost and soil conditions which vary greatly over very small areas, and affect, in particular, site excavation and preparation costs. Also, building construction costs can vary according to geographic location and relative quality desired. Therefore, based on these uncertainties, two costing structures were used for capital costing purposes: pessimistic costs, which reflect worst case conditions; and optimistic costs, which reflect improved cost conditions.

Other factors can affect the suitability of a particular site. Apart from sufficient water volume and the presence of warm water or a waste heat source, water quality is a primary concern for biological viability of the operation. Also, the facility must be within a reasonable location of a community capable of supplying support services (manpower, supplies and suitable land and air transportation to southern equipment suppliers and markets).

4.2.2 Assumed Water Source

The water supply for the facility is based on construction of a lakeshore reservoir with infiltration ditches (discussed in Section 3.0). Approximate dimensions and location are assumed for initial costing purposes. Prior to developing the site, studies of soil conditions, water infiltration rates, and water quality are required to assess the suitability of the location and identify actual excavation requirements.

4.2.3 Biological Production Components

Biological requirements and assumptions are described in Section 5.0. For design purposes, three general biological components are included in the facilities considered during the present study:

1. egg incubation;
2. fish rearing to target production size; and
3. broodstock rearing to spawning size.

Egg incubation requirements are based on the numbers of eggs needed to grow sufficient fish to the target production size plus broodstock for providing an on-going self-sufficient egg supply. For the initial years of operation, eggs must be obtained from outside sources. Eventually surplus eggs might be produced from broodstock for sale to outside parties.

The fish rearing requirements are generally greater than the other biological components and vary considerably between the fingerling production option and the commercial growout option. Within each option, the rearing requirements obviously depend also on the chosen production levels.

Broodstock requirements are similar to those for production fish. However, the broodstock fish must be maintained over a much longer period involving overlapping year-classes which are kept separate. Also, Arctic char broodstock require lower temperatures as they approach spawning (discussed in Section 5.0).

4.2.4 Physical Components

For both production options (i.e., fingerling and commercial growout), the facilities will be comprised of:

- a water supply and distribution system (water intake structure, distribution plumbing amongst incubation and rearing units, possibly using water recirculation, and discharge);
- separate containment facilities for egg incubation, fry to fingerling rearing, rearing to commercial harvest-size (for Option 2), and broodstock rearing;
- an assumed water heating component including heat exchangers and
- additional facility building requirements (manager's house, laboratory/ office/shop, feed storage).

Additional facility requirements identified for costing purposes include vehicles, electrical and instrumentation requirements and miscellaneous equipment (e.g., laboratory, office and fish handling supplies).

4.2.4.1 Water Supply System

As outlined above, the water source is assumed to be a lakeshore reservoir adjacent to the Town of Hay River water supply pumphouse. The water supply system would be comprised of a water intake component, water distribution system to the incubation and fish rearing units, and a water discharge component.

Water Intake Structures

Water intake development would include:

- an earthen dug-out with water interception ditches;
- a protective berm around the reservoir;
- one main and two standby pumps in the reservoir;
- one or two storage tanks (depending on the facility size); and
- one main and one standby water line from the reservoir to the water storage tanks.

Water from the intake area is brought to a storage tank where the water is held before being heated or entering the egg incubation or fish rearing area. Water recirculation is assumed for some facility concept% In these cases, several capacities for intake facilities are considered: 30% intake capability (which assumes a minimum recirculation of 70% during peak demand) and 10% intake capability (which assumes a – minimum recirculation of 90% during peak water demand).

Internal Water Distribution Plumbing

The internal plumbing feeds water from the head tank and water heating area to the separate production facilities (hatchery and early fry rearing area, rearing tanks and broodstock tanks). These components have different temperature and flow requirements so that independent flow and temperature control would be required.

Water Recirculation

Ideally, the water supply to a facility would require neither initial pumping (i.e., flowing to the facility by gravity) nor reuse, so that the risks of mechanical failure are reduced. However, water in a culture facility can be reused before discharge if limited initial quantities are available or if the water is subjected to expensive treatment such as heating.

Technology exists to allow recirculation of 90-95% of the water needs at a culture facility, though experience operating at commercial production levels is limited. Design features must include alarm and backup pumping systems and large water treatment facilities to remove suspended solids and dissolved nitrogen compounds. Electrical wiring and instrumentation should include wiring of alarms to a number of locations including an on-site house for the manager or assistant manager and automatic switch-on of backup systems. Water treatment is essential because increased suspended solids from feed and fecal material can increase turbidity, creating both unsatisfactory rearing conditions for the fish and interference with the function of heat exchangers. Dissolved nitrogen compounds must be removed since they can be toxic to the fish.

As indicated for the intake structures, the design concepts considered for this study allow for construction of water intakes providing 30% and 10% of the facility water needs and water recirculation of 70% and 90%. A conservative facility design would have a water intake capability of 30% and capability to recirculate 90% of the water. This would allow a reduction of the recirculation capacity to 70%, if necessary.

Oxygenation

Water flow in fish rearing units is important to provide the fish with oxygen and for removing metabolic wastes. Oxygen can be used to reduce water flow requirements to levels where toxic nitrogen compounds and not oxygen become limiting to fish health. Therefore, oxygen supplementation is also considered. Flow requirements can be reduced by 15-30% through addition of pure oxygen. Greater reductions in flow are possible, but as flows decrease, the metabolic waste products become more concentrated. These begin to limit biological performance even in well-oxygenated water.

Water Treatment

As indicated above, suspended and dissolved material must be removed from water before reuse. Technological approaches for treating recirculated water in culture facilities vary:

- removal of suspended solids includes settling basins and particle filters; and
- removal of metabolic waste includes filter media containing nitrogen-bacteria, that are constructed in large central beds or are contained separately within or near each rearing unit so the units are treated independently.

The treatment of recirculating water has been demonstrated to be technically viable at hatcheries and small-scale commercial facilities. Treatment should also be technically viable at larger facilities, but the financial and technical suitability of different treatment systems has not been well tested. Therefore, a conservative approach has been used for estimating the water treatment requirements and associated costs used for the present study. Central water settling facilities and bacterial filter beds, both having multiple chambers (for maintenance shut-down and emergency backup), have been assumed.

Water Discharge

Exact discharge locations are not identified. For costing purposes, discharge pipe lengths of approximately 200 meters are assumed.

4.2.4.2 Egg and Fish Containment Units

Egg Incubation

The design assumes use of vertical-stack incubation units, small rearing units (for early fry), internal piping requirements and building construction. Combined incubation-rearing units have been developed in Norway and are now being used at salmonid facilities in Canada. The use of these could reduce costs. The more conservative conventional separate units are assumed for this study. Egg loading densities in the vertical-stack incubators are assumed to be 40,000 eggs per eight tray stack.

Fish Rearing Tanks

Small 1 m by 1 m tanks (1 m depth) are assumed for initial fry rearing. As indicated above, tanks of similar size have been combined with egg incubation units. In these systems eggs, hatched-fry, and first feeding fry are contained within the same unit.

Fingerling units are assumed to be 4 m by 4 m by 1.5 m height. Commercial production fish are assumed grown-out in larger tanks (10 m diameter by 2 m height). The smaller fingerling tanks (4 m by 4 m by 1.5 m height) are also assumed to be used for holding broodstock once separated from production fish.

4.2.4.3 Water Heating and Cooling Systems

Heated water is assumed to be available from outside sources for accelerating the growth of production fish. Cooled water is assumed necessary for broodstock fish during the last summer before spawning (discussed in Section 5.0).

At the present time, the type and quantity of waste heat that might be used is not certain. Nonetheless, cost effective means of using the available heat and for reducing heat loss within the facility will be required. In some cases, heated water can be used directly after use, in which case heat exchangers are not required. Normally, this is not the case given water additives and cleaning procedures in the water heaters. Therefore, suitable heat exchange or heat pump facilities are necessary and these are assumed to be required in the facility design for this study.

Reducing heat loss within the facility means that water containing units (including both fish containing facilities and water treatment facilities) must be insulated directly or be enclosed within buildings. Given the potentially very low winter temperatures that can occur in the Hay River area, these costs can be very high. Heat loss is important during normal operation, where it affects operating efficiency and financial gains, but also during periods of emergency shutdown. Fish can be stressed or killed if temperatures drop rapidly.

A fish production facility near Hay River operating at temperatures of 12-13°C during winter would be exposed to ambient water temperatures near O°C and air temperatures of approximately -20°C to -40°C if heating systems failed. A rapid drop from 12°C to O°C would likely be fatal.

The largest fish biomass occurs during winter for the commercial growout facility. Therefore, two winter temperature scenarios were considered (Section 7.0):

- one at optimum temperature (12°C); and
- one at minimum temperature (4-6°C).

The water flow and summer cooling requirement for broodstock fish is not large relative to the flow and heating requirements for commercial production fish, but is relatively high for fingerling-only production. An allowance is made for capital and operating costs for a small water refrigeration unit to prevent summer rearing temperatures from exceeding 8°C.

4.2.4.4 Additional Facility Requirements

Building Construction

The culture facilities normally require building space to house an office and staff rest area, laboratory, workshop, mechanical equipment, intake aeration towers, and feed storage. In addition, on-site housing is usually needed for a manager or assistant manager to provide site security both from intruders and in case of equipment failure. Given the risks of potentially low ambient temperatures during winter (discussed in the preceding subsection), an allowance is also made for housing and/or insulating fish containment units and the water treatment facilities to minimize heat loss during winter.

Electrical and Instrumentation

The facilities require automatic sensors and activation of backup equipment, alarm systems, water control valves, control panelling, equipment wiring, and general site wiring and lighting. These costs can vary greatly according to the type and amount of automation chosen. Therefore, high and low capital estimates are made for the facility designs. In addition, a backup electrical generator is necessary.

Miscellaneous

An allowance is made for miscellaneous site and equipment requirements including potable water supplies, telephone connections, domestic sewage, vehicles, fish feeders, nets and fish handling/grading equipment, water quality monitoring equipment, disease diagnostic equipment, and office equipment.

4.2.5 Other Considerations

4.2.5.1 Site Preparation

Site preparation includes clearing, grading and placement of support media for the buildings and rearing facilities. These costs can vary greatly from site to site, particularly in relation to permafrost conditions. As indicated previously, local contractors indicated conditions and costs can vary greatly even at different locations within a general site area. Therefore, conservative costs are based on worst case conditions suggested by contractors, and the optimistic costs are based on more favorable conditions.

4.2.5.2 Site Hydrogeological Studies and Engineering Design

Apart from actual site preparation, the surface and permafrost variability amongst sites indicates a need for more intensive pre-engineering site evaluations than would be undertaken in more southern areas.

Uncertainties about the soil and permafrost conditions and, in the case of the water supply reservoir, water infiltration rates place a large importance on undertaking preliminary hydrogeological studies. The cost of these studies will depend on whether substantial information is already available and on specific site conditions. Pessimistic cost estimates assume a relatively high cost for initial hydrogeological studies and engineering design. More optimistic estimates assume the hydrogeological study requirements are minimal and incorporated within a standard engineering design costing.

4.2.5.3 Contingency

A standard 10% contingency is added to all facility capital costs.

5.0 BIOLOGICAL REQUIREMENTS AND OPERATING ASSUMPTIONS

The biological requirements and assumptions underlying operating procedures and facility designs are described in this section.

5.1 GENERAL TEMPERATURE REQUIREMENTS

Each facility option is assumed to have an egg incubation, fish rearing (for production) and broodstock component. The temperature, flow and other requirements differ for each of these life history stages. The preferred culture temperatures and approximate timing of each life history stage are:

	TEMPERATURE	TIMING
Egg Incubation	7°C	October - January.
Rearing to Fingerling Size	12°c	February to June/July of the same year.
Rearing to Commercial Size	12°c	February to following winter-spring.
Broodstock	6°C	Young fish can be maintained at 12°C until the final year before spawning at which time they should be held at less than 8*C.

The expected ambient temperatures, preferred temperatures and temperature differences are summarized in Table 5.1.

5.2 EGG SOURCES AND INCUBATION REQUIREMENTS

The facility will initially require eggs from outside sources; eventually eggs will be supplied by broodstock maintained within the facility. Initial egg sources and regulations governing the movement of fish eggs and fish within Canada are discussed in Appendix L

Results at the Freshwater Institute facilities in Winnipeg, Manitoba, indicate that broodstock spawning first occurs mainly in the fourth year of life, but some can occur in the third year. **Therefore,** the assumed egg requirements for the initial year of operation are:

- start-up year : 100% from outside **sources;**
- second year : 100% from outside sources;
- third year : 100% from outside **sources;**
- fourth year : 70% from outside sources,
  30% from facility broodstock; and
- fifth year and onwards : 100% from facility broodstock.

BroodStock requirements and assumptions are discussed further in Section 5.4.

5.2.1 Water Flow Requirements

Incubation of Arctic char eggs in Canada has normally been undertaken in vertical-flow stacks. However, incubation has been undertaken in Norway in incubation systems that are combined with early rearing units and consequently can reduce total incubation/early fry rearing costs. **These** systems are now marketed in Canada, however, for initial planning purposes, vertical flow stacks are assumed since their operational performance is better known and they provide a conservative cost estimate.

Arctic char appear to do well in vertical-flow incubation stacks with the same water flow requirements of other **salmonids.** Therefore, a maximum water flow requirement of 20 LPM per eight tray stack is assumed.

Eggs are variable in size; an average size of 4.0-5.0 mm is assumed. A stocking density in each vertical stack tray is assumed to be 5,000. This might increase as optimum egg tray stocking densities are investigated.

5.2.2 Egg survivals

Early studies on egg fertilization and viability for eggs obtained from cultured broodstock produced poor results. Fertilization and survival rates have increased in recent years and are expected to increase further especially as broodstock diets ‘are improved (J. Tabachek, personal communication). Based on recent results at the Freshwater Institute, the following egg survivals are assumed:

- green egg to eyed stage : 60%;
- eyed stage to hatch : 80%; and
- hatch to swimup : 80%.

These are conservative and likely will be exceeded as operating experience increases.

5.2.3 Egg Development Timing

Egg development rates, and consequently the timing of first-fry, are dependent on ambient temperatures. Given egg incubation timing for Northwest Territories Arctic char strains at the Freshwater Institute facilities in Manitoba, the following approximate egg development times are assumed:

- green eggs available (spawning) - end of September or early October (October 1);
- eyed eggs - early November (November 10);
- eggs hatch - mid-December (December 15); and
- fry swimup - early February (February 5).

These are based on egg incubation temperatures of approximately 6.5-7 .O”C. During the final one to two weeks, temperatures are assumed to increase slowly to approximately 9.0-10.0°C to coincide with the higher temperature requirement at first feeding.

5.3 FISH REARING CONDITIONS AND GROWTH RATES

5.3.1 First Feeding

Swimup fry are assumed to be relatively small (0.3 g). Temperatures at this time are increased to 9.0-10 .0°C. A relatively good semi-moist swimup fry diet is also assumed. When the fry appear to be feeding well (within several weeks), rearing temperatures will be gradually increased to 12.0°C.

5.3.2 Growth Ratea

In general, Arctic char growth rates appear to be better than those for rainbow trout at temperatures below approximately 1O.O°C, but similar at temperatures between 1O.O°C and 15.0°C. Arctic char growth rates in the higher temperature range could surpass those of rainbow trout as stocks are domesticated and culture experience improves, however, this study will assume that the Arctic char growth rates are the same as those for rainbow trout. Growth projections are based on the growth model developed by Papst et al. (1982) using a conservative growth factor assumption.

Fish size can vary considerably in a culture population, with some fish (10-20 %) failing to grow well beyond a small size. Conservative survival rates (discussed in Subsection 5.3.6) are used to reflect an economic loss from these fish.

5.3.3 Temperatures

Optimum temperatures appear to lie between 1O.O°C and 13.0°C. Serious disease problems can develop above **18.0°C;** this temperature should not be exceeded and, preferably, temperatures should be kept below 16.O”C (M. Papst, personal communication). Below 1O.O°C, growth rates will decrease and, ideally, temperatures should be kept above this leveL However, important differences in temperature optima might exist amongst strains of Arctic char, so that some strains might grow well at low temperatures. For facility design purposes, the lower acceptable temperature is assumed to be 4.O”C, the temperature at which growth normally ceases for other salmonids. This is likely conservative for Arctic char.

5.3.4 Water Flow Requirements

Maximum water flow requirements will occur when production biomass has reached a maximum just before harvest and possibly during the harvest period depending on the harvest scheduling. Generally, the water supply needs of Arctic char appear similar to those required by other salmonids (Papst and Hopky 1983, 1984; and M. Papst, personal communication). Therefore, a conservative flow loading rate of 0.9 kg/LPM is assumed when flow requirements are at a maximum. The oxygen content of the water is assumed to be close to saturated and supplemental oxygen is not added.

5.3.5 Stocking Densities

Char appear to tolerate much higher stocking densities than other salmonids, up to and possibly higher than 100 kg/m^3. A maximum density of 70 kg/m^3 will be assumed when biomass reaches a maximum before harvest. In general, densities should not drop below 40 kg/m^3.

5.3.6 survivals

Culture experience indicates that a proportion of a given population does not grow beyond a small size. This proportion is approximately 10-20%. Commercial production experience is limited, therefore, survivals at commercial-scale production levels are not well known. Conservative survival estimates are:

- swimup to fingerling : 70% ;
- fingerling to pan-size (350 g) : 80%; and
- pan-size to adults (2.0-3.0 kg) : 80%.

The survivals used in this study allow for 20% mortality between swimup and first commercial size (pan-size) and 20% economic loss for fish that fail to reach a commercial size. These values will likely improve as the species becomes domesticated and culture experience is obtained.

5.3.7 Feed Consumption

Feed conversion usually decreases as fish increase in size. Dry diet feed utilization by Arctic char appears similar to trout and, for this study, is assumed to be a gross feed to fish wet weight conversion of 1.5:1 for fish to a large fingerling size (40 g), and 1.8: 1 for fish above this size.

5.3.8 Fish Production Timing

5.3.8.1 Fingerling Production

Fry are expected to grow to a large fingerling size (e.g., 30-40 g) within four to five months after swimup at temperatures of 10.0-13 .0°C. Fingerling removal from the facility will be based on the stocking objectives and conditions within the receiving waterbodies. In general, fingerling transport might occur over the May-July period.

5.3.8.2 Pan-Size Production

Fingerlings are expected to growout to pan-size within one year from swimup. As indicated in Section 7.0, the harvest might occur during a single month depending on production or marketing constraints; or, more likely, the harvest will occur over a longer period (e.g., six to twelve months). Lengthening the harvest period can increase the total annual tonnage.

5.3.8.3 Production of Larger-Size Fish

The commercial production of larger-size fish is more difficult to define since there is limited experience in producing larger Arctic char to harvest size. However, fish of this size (2-3 kg) are expected to be available during the spring and summer in the second year following swimup.

5.4 BROODSTOCK

To supply the needs of the facility, eggs can be purchased from outside sources (if adequate supplies of disease-free eggs are available) or broodstock can be developed and maintained on-site. For broodstock held at the site, the first spawning is expected to occur three to four years after eggs are first brought to the facility. Arctic char will repeat-spawn in subsequent years, but in some populations individual fish might spawn every second year (J. Tabachek, personal communication). For estimating the numbers of eggs available from the broodstock, 30% of the broodstock are assumed to spawn in year three and thereafter 100 % of the eggs are assumed to be available from multiple year-class spawning stock by the fourth year of operation.

Arctic char broodstock, especially males, appear to require cold water conditions (i.e., 6.0-8 .0°C) for some period before spawning (J. Tabachek, personal communication). Therefore, after their second summer, broodstock are assumed to be maintained at maximum temperatures of 6.0-8 .0°C. Based on the current understanding of Arctic char, this is expected to require water refrigeration over the succeeding summers, since ambient temperatures will be higher than 8.O”C (Table 5.1).

The broodstock sex ratio is assumed to be 50:50. The female fecundity is assumed to be 3,000 eggs/spawning female at a spawning size of 1,500-2,000 g.

6.0 OPTION 1: Fingerling PRODUCTION

A production design size of 250,000 fingerlings (maximum size 40 g) is examined. Approximately 100,000 fingerlings are currently brought from southern commercial facilities for stocking (G. Lowe, personal communication). Consequently; the 250,000 fingerling production size allows for production several times greater than the current government requirement% The design assumptions allow juveniles to be grown to a relatively large size (40 g), and for eggs to be produced by broodstock maintained within the facility.

Estimates of capital costs are described in Section 6.1 and operating costs are described in Section 6.2. The financial viability is assessed in Section 6.3. Conceptual layouts of a fingerling production facility adjacent to the Town of Hay River are shown in Figure 6.1 (no water recirculation), Figure 6.2 (with water recirculation), and Figure 6.3 (plan view of internal building features).

6.1 CAPITAL COSTS

Capital cost estimates are summarized in Table 6.1. A range of possible costs are shown. Pessimistic costs are conservative and reflect worst case assumptions about site development and construction costs. Some of these costs likely would not apply for a culture facility located close to the Town of Hay River, but could for a facility located elsewhere.

6.1.1 Site Preparation

As indicated in Section 4.0, local contractors indicated soil and permafrost conditions and, consequently, costs can vary greatly even at different locations within a general site area. Therefore, conservative costs are based on worst case conditions indicated by contractors, and the optimistic costs are approximately 50% of the worst case costs.

6.1.2 Water Intake Facilities

Water intake costs allow for excavation of a reservoir and water interception ditches, three pumps (one main and two backup), two water lines (one main **and** one backup) and one head tank for storage prior to entering the fish production area. Conservative costs are for water intake facilities providing 30% of the peak water demand (70 % recirculation). The optimistic costs are for intake facilities providing 10% of the peak water demand (90% recirculation) and a further reduction in reservoir, pump and pipe costs by 15 % to reflect use of an oxygenation system (described in subsection 4.4.4).

Intake flow requirements (LPM) at maximum biomass are:

. 30% Total Flow	Without Oxygen	4,100
	With Oxygen	3,500
. 10% Total Flow	Without Oxygen	1,300
	With Oxygen	1,100

Reservoir excavation volumes allow for a one hour retention time. Construction of a lakeside reservoir likely would not be required at other locations, consequently, the reservoir construction portion of this cost component would be eliminated.

6.1.3 Water Distribution, Treatment and Discharge

The costs are based on a maximum 90% recirculation capability and include: internal piping amongst tanks, collection **sumps,** recirculation pumps (one main and one backup), treatment facilities for removal of solid and nitrogen wastes, aeration towers and oxygen backup systems, discharge piping, and building and insulation costs. Recirculation flow requirements (LPM) at maximum biomass are:

- Without Oxygen 12,000
- With Oxygen 10,200

The water treatment facilities represent a large cost especially if they are adequately covered or insulated to minimize heat loss. The optimistic costs are the same as the conservative costs except that the cost of covering and insulating the water treatment facilities is reduced by 50%. Also, an oxygen injection system is assumed to be part of the facility design and the total costs are therefore further reduced by 15%. The cost of the oxygen injection system is added.

6.1.4 Hatchery and Early Fry Rearing

The design costs include vertical-stack incubation units, small rearing units (for early fry), internal piping requirements and building construction. Requirements for approximately 930,000 fertilized eggs are assumed and allowance is made for six small rearing tanks for early fry. Separate costs for incubation and rearing facilities are used for the conservative estimate. As discussed in Section 4.0, combined incubation-rearing units are available and use of these could reduce overall costs. Therefore, the conservative cost estimate includes the conventional separate units and the optimistic cost estimate assumes lower cost units are used and the total costs are approximately 60% of the conservative costs.

6.1.5 Rearing Tanks

These costs include installation of fourteen 4 m by 4 m (1.5 m height) growout tanks both for fingerling production and broodstock production ($4,500.00 per tank). Eight fingerling rearing tanks and six broodstock tanks are assumed. A small number of broodstock fish must be separated from production fish each year to provide an annual supply of approximately 600 spawning fish. Apart from installation costs, a substantial cost is allowed for insulating and covering the commercial rearing tanks. For the optimistic estimate, insulating and building costs are reduced by 50%.

6.1.6 Water Heating and Cooling System

The conservative cost estimate also assumes that the facility bears the cost of installing its own backup diesel boilers. Heat exchangers, with connecting pipes, and small refrigeration units to reduce summer water temperatures for broodstock are included in the estimate. Heat pumps might be a suitable alternative to heat exchangers once the heat characteristics of the waste water heating source are identified. Heat pumps have a higher capital cost, but lower operating cost. The optimistic estimate is 60% of the conservative estimate to reflect the absence of backup boilers, use of lower cost heat exchangers, and use of an oxygen injection system (which reduces overall flow requirements). The maintenance requirements of heat exchangers can vary so that an assumed use of lower cost exchangers would likely mean increased maintenance cost if water quality is poor.

6.1.7 Building Construction

Building space is required for office, laboratory, workshop, mechanical equipment, intake aeration towers, feed storage, staff rest space and on-site housing for a manager or assistant manager. These costs can vary considerably given the site location and conditions. Therefore, very conservative construction costs are assumed for the pessimistic estimate and the optimistic costs assume that costs are 50% of the conservative estimates.

6.1.8 Electrical and Instrumentation

The facilities require automatic sensors and activation of backup equipment, alarm systems, water control valves, control panelling, equipment wiring, and general site wiring and lighting. These costs can vary greatly according to the type and amount of automation chosen. An allowance of 25% of capital costs (not including site preparation costs, miscellaneous costs, and costs of preliminary hydrogeological studies and engineering design) has been used for the conservative estimate and 10% of the capital costs has been used for the optimistic cost. The cost of a backup electrical generator is added and is the same for both the conservative and optimistic estimates.

6.1.9 Miscellaneous

An allowance is made for miscellaneous site and equipment requirements including potable water supplies, telephone connections, domestic sewage, vehicles, fish feeders, nets and fish handling/grading equipment, water quality monitoring equipment, disease diagnostic equipment, and office equipment. These costs are assumed to be the same for the conservative and optimistic estimates.

6.1.10 Site Hydrogeological Studies and Engineering Design

Uncertainties about the soil and permafrost conditions place a large importance on undertaking preliminary hydrogeological studies. The cost of these studies will depend on whether substantial information is already available and on the specific site conditions. The pessimistic costs for hydrogeological studies and engineering design is estimated to be 15% of the other site development costs; the optimistic cost is estimated to be 10%. In the latter case, the hydrogeological study requirements are minimal and incorporated within a standard engineering design costing.

6.1.11 Contingency

A 10% contingency is calculated for both the conservative and optimistic estimates.

6.2 OPERATING COSTS

Fixed costs are assumed to include: wages, salaries and benefits for personnel; vehicle fuel costs; repair and maintenance; veterinary and diagnostics costs; fixed insurance; miscellaneous supply costs; general and administration costs; and depreciation. Variable costs include: egg purchases, feed costs, water pumping and heating costs, and stock insurance. Most variable costs are influenced by fish growth during a production cycle. Based on the assumed growth rates described in Section 5.0, the fingerling growth is summarized in Table 6.2. Monthly operating costs are shown in Table 6.3 for a normal operating year. These costs assume the eggs are produced by broodstock within the facility and heating costs do not occur because waste heat is used. Annual operating costs before financing costs (discussed in Section 6.3, Financial Analysis) are estimated to be approximately $300,000.

6.2.1 Fixed Costs

6.2.1.1 Personnel

Permanent staff include a facility manager, an assistant manager and one full-time worker and part-time or seasonal staff. Assumed annual salaries are:

Manager	$40,000
Assistant Manager	$30,000
Full-Time Worker	$20,000 (1)
Seasonal Worker	$6,000 (1)
Part-Time Administrative Support	$9,000 (1)

A benefits cost is also assumed for full-time employees.

6.2.1.2 Vehicle Fuel Costs

A fuel allowance of $150.00/month is provided. Vehicle maintenance costs are included in the Maintenance Services and Supplies category below (Section 6.2.1.3).

6.2.1.3 Maintenance Services and Supplies

An annual allowance of 2 % of capital costs has been provided for maintaining and servicing equipment and physical facilities on site.

6.2.1.4 Veterinary and Diagnostic Services

Costs for disease management can include collection and preparation of samples for preliminary diagnosis on-site or for shipping off-site; visits to the site by fish health specialists; and purchase and administration of medicines. An allowance of $500.00/month is provided for health management costs. These are high and assume private laboratory analyses at southern laboratories and periodic site visits by private fish health specialists from southern locations.

6.2.1.5 Fixed Insurance

An allowance of 1.5% is provided for insuring site equipment and facilities. Feed and stock insurance is included as a variable cost.

6.2.1.6 Depreciation

Fixed assets are depreciated on a straight-line basis over a ten year period.

6.2.1.7 Miscellaneous Supplies

An allowance of $l,OOO.OO/month is provided for miscellaneous supply items. These include: ongoing requirements for water quality monitoring, fish handling supplies, and unforeseen supply costs.

6.2.1.8 General and Administration

An allowance is made for additional travel, legal and accounting costs, communication costs and general office supplies.

6.2.1.9 Financing of Capital Costs

Capital costs are assumed to be financed by 50% equity and 50% long-term debt at an interest rate of 12%, repayable over ten years.

6.2.2 Variable Costs

6.2.2.1 Egg Purchase Costs

Eggs will be required from outside sources for the initial three to five years of operation. These might come from wild sources within the Northwest Territories, from the federal Department of Fisheries and Oceans Rockwood hatchery in Winnipeg, or from private sources. The cost of egg input from the Northwest Territories or the Rockwood hatchery likely would be subsidized; however, for the purpose of this analysis, a commercial egg cost of $0.20/egg (certified disease-free) is assumed.

6.2.2.2 Feed Costs

Feed costs (delivered to the culture facility) are assumed to be higher than southern areas: $2.50/kg for starter feeds (used for the first month after first feeding); $2.00/kg for juvenile feed (used for four months after using the starter feeds); and $1.50/kg for growout and broodstock feed. Feed conversion is assumed to be 1.5:1 fOr — smaller fish (to 40 g) and 1.8:1 for larger fish (up to 2-3 kg for broodstock).

6.2.2.3 Pumping and Heating Costs

Pumping costs are based on $0.14 /kw/hr. at usage up to 1,000 kw/hr. and 0.10 kw/hr. above 1,000 kw hr.; heating costs are based on diesel costs of $0.038 kw/hr. Electrical costs could be lower than $0.14 /kw/hr. and $0.10 kw/hr. in the Hay River area, because lower rates can be negotiated for high volume usage with the local utilities company.

6.2.2.4 Stock Insurance

An insurance allowance is provided for 4 % of the feed and fish stock on-hand each month.

6.2.2.5 Interest on Working Capital

Interest on working capital is based on 12%, payable over ten years.

6.3 FINANCIAL ANALYSIS

6.3.1 Assumed Prices and Demand

The potential revenues from a fingerling production facility are difficult to define given the absence of an established commercial market near the proposed culture facility. The costs for the facility assumed in this study are based on a production size greater than the current amount of fingerlings brought from southern commercial facilities for stocking (100,000; G. Lowe, personal communication) The culture facility in the present study allows for a production of approximately 250,000 fingerlings. This production size would meet the current government needs and allows additional production for expansion of the government requirements and to supply local commercial growers. The government presently obtains fingerlings from southern facilities for approximately $0.50 per fingerling or $1.20 including transportation to the Northwest Territories (G. Lowe, personal communication).

6.3.2 Base Case Analysis

The base case facility produces 253,000 fingerling per year and the capital cost is estimated to be approximately $0.8 million, under favorable site development conditions.

6.3.2.1 Unit Production Costs

Unit production costs for the $0.8 million facility are shown in Table 6.4. Three operating scenarios (Cases A, B and C) are shown in the table. Case A indicates the highest expected operating costs and assumes the facility purchases new eggs each year and pays its own heating costs. Case B and C assume the facility produces eggs from its own broodstock. Case C assumes heating costs are not paid because waste heat is utilized. If waste heat is available, the unit production costs are estimated to be approximately $1.70 during the first three to four years of operation (Case B) and afterwards $1.40-$1.50 (Case C). These data indicate production costs for a facility producing approximately 250,000 fingerlings per year would be approximately $0.20 to $0.30 per fingerling greater than the $1.20 currently paid. If waste heat is not available and the facility paid for its heating costs to meet production objectives, the unit cost would increase by $0.11 to $0.20 per fingerling (8% - 14%). After heating costs, labour is the largest cost, followed by depreciation.

Approximate break-even production sizes for the facility are also shown in Table 6.4. These have been estimated using the formula:

$$\text{Break-Even Point} = \frac{\text{Fixed Cost Total}}{\text{Contribution Margin}}$$

(i.e. Unit Selling Price Minus Unit Variable Cost)

Under expected typical operating conditions (Case C), the facility would need to produce greater than 330,000 fingerlings to break-even at a fingerling price of $1.20. Capital costs will also increase if production volume increases substantially. Consequently, an actual break-even size is likely closer to 400,000 fingerlings. The capital cost for such a facility would be approximately $0.9-$1.0 milliion and annual operating costs would be $450,000-$500,000.

The future demand for Arctic char juveniles produced by a facility in the Northwest Territories is not clear. Potential sources of demand are government stocking of natural waterbodies, private stocking of lakes and ponds for fee-fishing and/or commercial growout, and commercial growout in nearby lake netpens. Government stocking appears to be the most probable over the near-term and an assessment of lake stocking potential is currently underway. Shipment of juveniles to growers in other areas (i.e., southern Canada) is technically possible but unlikely given the fact that char culture is now taking place in most jurisdictions in Canada.

6.3.2.2 Initial Cash Flow

A cash flow for the initial years of operation is shown in Table 6.5. Two prices are assumed: the price currently paid ($1.20) and a price 50 % greater ($1.80). The annual debt continues to accumulate at the $1.20 price but shows a decline after year 4 at the $1.80 price. The annual deficit at the $1.80 price is eliminated by year 8. The accumulated operating cash outflow requirement before sales is approximately $0.45 million and start-up costs, including initial capital investment, to first harvest are about $1.2 million.

6.3.3 Opportunities for Reducing Costs

If fingerlings are produced for sale by a facility normally growing out larger size market fish (Section 7.0), fingerling production costs would be largely absorbed by operation of the larger commercial growout facility. A small capital cost would be required for additional egg incubation and broodstock facilities but would be negligible given the generally high capital costs associated with the commercial facility. However, the analysis in Section 7.0 indicates the viability of a large commercial growout facility is questionable.

The use of pumps to draw water from a lake and water recirculation have been assumed for costing purposes, but might not be required at sites other than the Town of Hay River pumphouse. Ideally, a facility would receive sufficient water volumes by gravity, eliminating the need for initial pumping or recirculation. Water intake pipes, an intake control structure or storage reservoir would still be necessary. Nonetheless, a gravity water supply might reduce capital costs by approximately $100,000-$150,000, if sufficient flow is available for single flow-through. This would mean capital costs of $620,000-$670,000 for the 250,000 fingerling facility under otherwise good site development conditions. In addition to capital costs, pumping costs during operation would eliminated. These combined cost reductions would reduce production costs by $0.05 to$O.10 per fingerling. Clearly, other costs would also have to be reduced to assure the facility is viable at the 250,000 fingerlings production level unless higher prices were paid.

As discussed in Section 8.0 (Technical and Financial Viability Assessment), other capital costs and operating costs might be reduced under certain site development conditions, but not in the same magnitude as removal of water intake costs. Commercial financing costs have been assumed for the present study (described in Section 6.2). A reduction in these costs, through provision of grants or interest-free loans, would correspondingly reduce the production costs shown in Tables 6.4 and 6.5.

7.0 OPTION 2: COMMERCIAL GROWOUT PRODUCTION

Capital costs have been estimated for two production design sizes:

- a small facility having a maximum biomass capability of 50 tonnes which can produce a commercial harvest of up to approximately 80-100 tonnes depending on harvest scheduling; and

- a large facility having a maximum biomass capability of 200 tonnes which can produce a commercial harvest up to 320-350 tonnes, again depending on harvest scheduling.

Pessimistic and optimistic capital costs were estimated given uncertainties regarding site conditions (discussed in Section 2.0). The pessimistic costs are very conservative and reflect worst case assumptions about site development, building construction and equipment installation costs. Some of these costs likely would not apply to a culture facility located close to the Town of Hay River, but might for a facility located elsewhere.

Capital costs were first estimated assuming that the facility would maintain high temperatures (i.e., optimum growing temperatures of 12-13°C) during winter (Table 7.1). Costs were then estimated for the 200 tonne design size assuming that temperatures during the second winter of fish growth would be allowed to drop to 4-6°C (Table 7.2). ‘The capital costs were lower for this facility concept and were used as the basis for further analysis in Section 7.3 (Financial Analysis). The 50 tonne design size was not examined further because the examination of the 200 tonne size indicates that a financial breakeven size will occur at a much larger production size (i.e., greater than 400 tonnes). Conceptual layouts for a 200-300 tonne commercial production facility are shown in Figure 7.1 (without recirculation) and Figure 7.2 (with recirculation), and Figure 6.3 (plan view of internal building features).

7.1 CAPITAL COSTS

Capital costs for the 50 tonne biomass and 200 tonne biomass facilities are summarized in Table 7.1. Costs for a 200 tonne facility maintaining minimum winter water temperatures of 4-6°C are summarized in Table 7.2.

7.1.1 Site Preparation

As indicated in Section 4.0, local contractors indicated soil and permafrost conditions and, consequently, costs can vary greatly even at different locations within a general site area. Therefore, pessimistic costs (Table 7.1) are based on worst case conditions indicated by contractors, and the optimistic costs are approximately 30% of the worst case costs.

7.1.2 Water Intake Facilities

Water intake costs allow for excavation of a reservoir and feeder ditches, three pumps (one main and two backup), two water lines (one main and one backup) and head tanks for storage prior to entering the fish production area (one head tank for the 50 tonne facility and two head tanks for the 200 tonne facility). In Table 7.1, the pessimistic –· for water intake facilities providing 30% of the peak water demand — recirculation). The optimistic costs are for intake facilities providing 10% of the peak water demand (90 % recirculation) and a further reduction in reservoir, pump and pipe costs by 15% to reflect use of an oxygenation system (described in subsection 4.2.4). In Table 7.2, the facility is assumed in one case to recirculate water and in the second case not to recirculate water. If water is not recirculated, water intake costs increase by almost $1 million dollars. Water distribution costs which include water recirculation systems decrease by almost the same amount.

Intake flow requirements (LPM) at maximum biomass are:

		50 TONNES	200 TONNES
100 %	Without Oxygen	59,000	232,000
	With Oxygen	50,000	200,000,
30%	Without Oxygen	18,000	70,000
	With Oxygen	14,300	59,500
100	Without Oxygen	5,900	23,200
	With Oxygen	5,000	20,000

The size of the intake reservoir is based on a one hour water retention time. Construction of a lakeside reservoir likely would not be required at other site locations, consequently the reservoir construction portion of this cost component would be eliminated.

7.1.3 Water Distribution, Treatment and Discharge

In Table 7.1, the costs are based on a maximum 90% recirculation capability and include: internal piping amongst tanks, collection sumps, recirculation pumps (one main and one backup), treatment facilities for removal of solid and nitrogen wastes, aeration towers and oxygen backup systems, discharge piping, and building and insulation costs. Recirculation flow requirements (LPM) at maximum biomass are:

	50 TONNES	200 TONNES
Without Oxygen	**52,000**	**206,000**
With Oxygen	44,200	175,100

The water treatment facilities represent a large cost especially if they are adequately covered or insulated to minimize heat loss. The optimistic costs outlined in Table 7.1 are the same as the conservative costs except that the cost of covering and insulating the water treatment facilities is reduced by 50%. Also, an oxygen injection system is added to the facility design and the total costs are, therefore, further reduced by 15%. The cost of the oxygen injection system is added. The water treatment costs can be further reduced if low temperatures (i.e., are assumed over winter and largely eliminated if the facility does not recirculate water (Table 7.2).

7.1.4 Hatchery and Early Fry Rearing

The conservative design costs include vertical-stack incubation units, small rearing units (for early fry), internal piping requirements and building construction. Approximately 610,000 newly fertilized eggs are assumed for the 50 tonne facility and 2,430,000 are assumed for the 200 tonne facility. Allowance is made for small early fry rearing tanks and separate costs for incubation and rearing facilities are used for the conservative estimate. Combined incubation/rearing units are available and use of these could reduce overall . [illegible] The optimistic cost estimates are approximately 60% of the conservative costs to allow for use of combination equipment and possible reductions in construction and installation [illegible]

7.1.5 Rearing Tanks

These costs include installation of commercial growout tanks (10 m diameter by 2 m height at $35,000 per tank) and smaller tanks for holding fingerlings and broodstock (4 m by 4 m by 1.5 m depth at $4,500 per tank). Six growout tanks are assumed for the 50 tonne facility and 23 growout tanks are assumed for the 200 tonne facility. A small number of broodstock fish must be separated from production fish each year; approximately 400 fish for the 50 tonne facility and 1,600 fish for the 200 tonne facility. A substantial cost is indicated for insulating and covering the commercial rearing tanks. For the optimistic estimate, this cost is reduced by [illegible] In Table 7.2, this factor is further reduced and allows several thousand dollars per tank for coverings.

[illegible] Water Heating cooling Syatem

In both Tables 7.1 and 7.2, heat exchangers, with connecting pipes and small refrigeration units to reduce summer water temperatures for broodstock, are included. The conservative cost estimate (Table 7.1) also assumes that the facility installs backup diesel boilers. Heat pumps might be a suitable alternative to heat exchangers once the heat characteristics of the waste water heating source are identified. Heat pumps generally have a higher capital cost but lower operating cost. The optimistic estimate assumes that backup diesel boilers are not included, use of lower cost heat exchangers, and an oxygen injection system is in use (which reduces overall flow requirements). A variety of heat exchange systems are available and both costs and operating performance can vary. Lower cost units can be installed if water quality conditions are very good but use of lower cost systems can often result in higher maintenance and operating costs.

701.7 Building Construction

Building space is required for office, laboratory, workshop, mechanical equipment, intake aeration towers, feed storage, staff rest space and housing for a manager or assistant manager. These costs can vary depending on the site location and conditions. The optimistic costs assume that costs are 50% of the conservative estimates.

7.1.8 Electrical and Instrumentation

The facilities require automatic sensors and activation of backup equipment, alarm systems, water control valves, control panelling, equipment wiring, and general site wiring and lighting. These costs can vary greatly according to the type and amount of automation chosen. An allowance of 25 of capital costs (minus site preparation costs, miscellaneous equipment and site costs, and preliminary hydrogeological studies and engineering design) has been used for the conservative estimate and 10% for the optimistic cost. The cost of a backup electrical generator is added and is the same for both the conservative and optimistic estimates.

7.1.9 Miacdlaneous

An allowance is made for miscellaneous site and equipment requirements including potable water supplies, telephone connections, domestic sewage, vehicles, fish feeders, nets and fish handling/grading equipment, water quality monitoring equipment, disease diagnostic equipment, and office equipment. costs are assumed to be the same for the conservative and optimistic estimates.

7.1.10 Site HyIIAL CASH FL Studies and Engineering Design

Uncertainties about the soil and permafrost conditions place a large importance on undertaking preliminary hydrogeological studies. The cost of these studies will depend on whether substantial information is already available and on specific site conditions. The pessimistic cost for hydrogeological studies and engineering design is estimated to be 15% of the other site development costs. The optimistic cost is estimated to be 10%. In the latter case, the hydrogeological study requirements are minimal and incorporated within a standard engineering design costing.

7.1.11 Contingency

A 10% contingency is calculated for both the conservative and optimistic estimates

7.2 OPERATING COSTS

Fixed costs are assumed to include: wages, salaries and benefits for personnel; vehicle fuel costs; repair and maintenance; veterinary and diagnostic costs; fixed insurance; miscellaneous supply costs; general and administration costs; and depreciation. Variable costs include: egg purchases, feed costs, water pumping and heating costs, stock insurance, processing and selling Most variable costs are influenced by fish growth during a production cycle. Based on the assumed growth rates described in Section 5.0, the expected fish growth at minimum water temperatures of 12°C and minimum winter temperatures of 4-6°C are shown in Table 7.3.

Monthly operating costs are shown in Table 7.4 for a normal operating year. These costs assume eggs are produced by broodstock within the facility and heating costs do not occur because waste heat is used. Annual operating costs before financing costs (discussed in Section 7.3, Financial Analyses) for the 200 tonne biomass operating at low winter temperatures (4 - 6°C) are estimated to be between $3.3 million and $3.5 million.

7.2.1 Fixed Costs

7.2.1.1 Personnel

Permanent staff include a facility manager, an assistant manager and one or more full-time workers. Assumed annual salaries are:

	50 TONNE	200 TONNE
Manager	$40,000	$45,000
Assistant Manager	$30,000	$30,000
Full-Time Workers	$40,000 [illegible]	$60,000 (3)
Seasonal Workers	(2)	$24,000 (4)
Administrative Support:		
- Full-Time		$18,000 (1)
- Part-Time	$9,000 (1)	

A benefits cost is also assumed for full-time employee%

7.2.1.2 Vehicle Fuel Costs

A fuel allowance of $200.00/month is provided for the 50 tonne facility and $350.00/month is provided for the 200 tonne facility. Vehicle maintenance costs are included in the Maintenance Services and Supplies category (Section 7.2.1.3).

7.2.1.3 Maintenance Services and Supplies

An annual allowance of 2% of capital costs has been provided for maintaining and equipment and physical facilities on site.

7.2.1.4 Veterinary and Diagnostic Services

Costs for disease management can include collection and preparation of samples for preliminary diagnosis on site or for shipping [illegible] visits to the site by fish health specialists; and purchase and administration of medicines. An allowance of $l,OOO.OO/month is provided for the 50 tonne facility and $2,000.00/month is provided for the 200 tonne facility. These are high and assume private laboratory analyses at southern laboratories and periodic site visits by private fish health specialists from southern locations.

7.2.1.5 Fixed Insurance

An allowance of 1.5% is provided for insuring site equipment and facilities. Feed and stock insurance is included as a variable cost.

7.2.1.6 [illegible]

Fixed assets are depreciated on a straight line basis over a ten year period.

7.2.1.7 Miscellaneous Supplies

An allowance of $2,000.00/month is provided for the 50 tonne facility and $3,000.00/month for the 200 tonne facility is provided for miscellaneous items. include: ongoing requirements for water quality monitoring, fish handling supplies and unforeseen supply costs.

7.2.1.8 General and Administration

An allowance is made for additional travel, legal, accounting, communication and general office

7.2.1.9 Financing of Capital Costs

Capital costs are assumed to be financed by 50% equity and 50% long-term debt at an interest rate of 12% repayable over ten years.

7.2.2 Variable Costs

7.2.2.1 Egg Purchase Costs

Eggs will be required from outside sources for the initial three to five years of operation. These might come from wild sources within the Northwest Territories, from the federal Department of Fisheries and Oceans Rockwood hatchery in Winnipeg or private sources. The cost of egg input from the Northwest Territories or the Rockwood hatchery likely would be subsidized. However, for the purpose of this analysis, a commercial egg cost of $0.20/egg (certified disease-free) is assumed.

7.2.2.2 Feed Costs

Feed costs (delivered to the culture facility) are assumed to be higher than southern areas: $2.50/kg for starter feeds (used for the first month after first feeding); $2.00/kg for Juvenile feed (used for four months after using the starter feeds); $1.50/kg for-growout feed. Feed conversion is assumed to be 1.5:1 for smaller fish (to 40 gm) and for larger fish.

7.2.2.3 Pumping and Heating Costs

Pumping costs are based on $0.14 /kw/hr up to 1,000 /kw/hr and $0.10 kw/hr above 1,000 /kw/hr; heating costs are based on diesel costs of $0.038 /kw/hr. Electrical costs for a site developed near the Town of Hay River could be less than $0.10 NOVEMBER subject to negotiations with the local utilities company.

7.2.2.4 Stock Insurance

An insurance allowance is provided for 4 % of the feed and fish stock on hand each month.

7.2.2.5 Processing

A processing cost of $0.95/kg and a transport cost to Toronto is included so that production costs are estimated to be dressed fish F. O.B., Toronto.

7.2.2.6

Harvests are assumed to be marketed through a seafood broker. Brokerage fees of 8 of the selling price are assumed.

7.2.2.7 Interest on Working Capital

Interest on working capital is based on 100% financing at an interest rate of **12%,** repayable over 10 years.

7.3 PINANCIAL ANALYSIS

7.3.1 Aasumed Prices

7.3.1.1 Market Conditions

Production

Commercial landings of Arctic char in Canada and worldwide have historically been minor but may increase over time due to aquiculture production. Landings in Canada originate from the Northwest Territories and Labrador and range between 150 and 300 tonnes. Limited production also occurs in Norway.

Cultured Arctic char production in 1988 is estimated to be 400 tonnes from Scandinavia and 60 tonnes from Canada (Papst & Hopky, 1989). The first commercial aquiculture production in Canada was in 1987 in Manitoba. Production was about 10 tonnes in that year.

Virtually all of the commercial production of wild Arctic char in Canada is sold frozen due to the long distances to markets. The frozen product in turn is almost all smoked. All of the cultured char was sold fresh.

The Arctic char produced in Canada is consumed within the country. The markets are large urban centres, particularly Montreal and Toronto.

Recent Prices

As with many seafood products, the quality and size of Arctic char are important price determinants. The N.W.T. char generally sells for more than the Atlantic landings because of a redder and more consistent flesh colour and larger size (3-5 kg.). Atlantic landings are typically in smaller 2-3 kg. sizes.

Marketing of N.W.T. char would also appear to be better coordinated and face somewhat fewer distribution problems. All N.W.T. char is sold through the Freshwater Fish Marketing Corporation. Unit values for char for the period 1983-87 are shown in Table 7.5.

The aquiculture char has been sold in pan sizes (200-300 grams) to restaurants at prices at around $10 per kilogram, which is close to the price of fresh farmed salmon. As a result, there is a considerable premium for cultured char over farmed raised rainbow trout in the same size category, which sells for about half the price.

7.3.1.2 Trends

No increases in wild char landings are forecast on a worldwide basis. In contrast, the long-term production potential for culturing char in Canada and elsewhere appears to be quite promising since broodstock have been successfully developed under culture condition%

Market studies conducted to date (Western Management Consultants 1989) suggest that cultured char in a fresh form should continue to earn a premium over rainbow trout and prices should be similar to those of farmed salmon. It is not clear, however, what price impacts the forecasted increased supplies of farmed salmon may have on cultured char.

The volume of pan-size Arctic char product entering the market is very low. However, market conditions at present are not fully understood, and consequently, it is not clear what market niche cultured Arctic char may occupy. Demand is not likely to be satisfied in the near term and prices will likely stay high for the next several years. Likely prices (F. O.B., Toronto) estimated for this study are:

High	$10.50/kg.
Medium	$7.85/kg.
Low	**BASE**

The selling price reflects relatively high prices that have been obtained for farmed salmon prior to 1989 and the prices reflect trout prices. The high prices ($10. SO/kg are similar to those obtained by an Arctic char producer in Manitoba. Higher prices can currently be expected for n char. However, prices in light of world market conditions for cultured salmonids, are unstable. **0.4** medium price is considered more realistic for business planning purposes.

7.3.2 Base Case Analysis

The base case facility is assumed to have a design biomass maximum of 200 **ABOUR** but having harvest occur over a protracted period so that actual annual harvest tonnage is approximately 320 tonnes. The facility is assumed to maintain low winter water temperatures as indicated in Table 7.2.

7.3.2.1 Unit Production Costs

Unit production costs ($/kg.) under five different financial and operating conditions are summarized in Table 7.6. Heating costs are very high (Case A), representing approximately 30-35 % of the production costs, and for this study are assumed to be provided by an outside source.

Case B assumes eggs are purchased from outside sources and Case C assumes eggs are produced from broodstock within the facility. Case B represents the situation for the first two to three years of operation and Case C represents typical years afterwards. For both cases, the total production costs are higher than the highest expected price for Arctic char ($10.50/kg). Apart from heating, the highest operating cost is feed, which is based on dry feed purchased and transported from southern locations. This might be reduced if a local feed plant is able to produce a high quality char diet.

Interest on working capital and financing of fixed capital represents a large cost and assumes substantial borrowing. This might not be the case if initial grants or interest-free loans are provided (Case D and Case E). Eliminating all financing costs (Case D) would mean unit production costs are approximately equal to the highest assumed selling price. However, this assumption is unlikely and in general production does not appear to be viable for this size of facility.

Approximate break-even production sizes are also shown in Table 7.6. These have been estimated using the formula:

$$\text{Break-Even Point} = \frac{\text{Fixed Cost Total}}{\text{Contribution Margin}}$$

(i.e., price per unit - variable cost per unit)

Assuming conservative growth rates and that eggs will eventually be produced by the facility (Case C), the facility tonnage would have to reach an annual production greater than 630 tonnes to break-even (assuming relatively high prices $10.50/kg.); breakeven production would have to be higher if prices drop. A facility harvesting 630 tonnes would have a biomass design size of approximately 400 tonnes. Further capital investment would be required so that the likely break-even size would be greater, with a biomass size of possibly 500-700 tonnes (or harvest production of 800-1,000 tonnes). The break-even size would be yet higher if lower selling prices are assumed. Assuming a small economy-of-scale reduction for capital costs as indicated by the 50 tonne and 200 tonne facility costs, a 400 tonne biomass facility would require approximately $11-$12 million and a 700 tonne facility would require approximately $15-$20 million.

Assuming further that the financing costs are defrayed by 50% (Case E), a break-even production size is estimated to be 450 tonnes annually (or a biomass design size of approximately 360 tonnes). Elimination of all financing costs would reduce the break-even point to 320 tonnes (Case D).

These data suggest that with a large amount of assistance in the form, of grants or interest-free loans and with good selling prices the probable minimum commercial break-even harvest production lies between approximately 400 and 500 The initial capital required for a facility harvesting 400 tonnes would be approximately $6-$8 million and annual operating costs would be approximately $4-$5 million. To be commercially profitable as an investment, production would have to be greater (e.g., a biomass design size of 500 to 700 tonnes, or harvest of 800-1,000 tonnes).

7.3.2.2 Initial Cash Flow

A cash flow for the initial years of operation of a facility harvesting 320 tonnes annually is shown in Table 7.7.

The working capital requirements for the project are substantial. The accumulated operating cash out flow requirements before [illegible] would be in the neighborhood of $3.5 million. Total start-up costs including initial capital investment and the working capital necessary to bring the first harvest to market would be about $9.5 million. Revenues are assumed to come only from sales of market-size fish. However, additional revenues could be generated through sales of fingerlings and/or Including eggs and fingerlings for production would require a minor increase in costs for additional broodstock and egg incubation facilities.

7.3.3 Oppo[illegible] for Reducing Costs

A water component of the capital costs for the facility are the water supply costs (with or without recirculation). For this study, the use of pumped lake water near the Town of Hay River has been assumed as the water supply source. [illegible] described for the [illegible]ulating the w[illegible] production facility (Section 6.0), the associated water intake costs would be largely eliminated if the water supply was by gravity. However, water volume requirements for the commercial growout facility are substantially larger and suitable sources are difficult to locate. Suitable volumes of warm, gravity-flow water likely would only be available from a large hydroelectric facility or industrial plant.

Other capital costs might be reduced if site construction conditions are good or if innovative approaches are used by facility owners/operators during construction and equipment installation (discussed in Section 8.0, Technical and Financial Viability Assessment). Possible cost reductions such as these are not certain and should not be assumed for initial financial assessment. Also, they likely would not represent the same magnitude of reduction as elimination of a major capital cost component such as the water intake pumps.

As discussed in Section 8.0, an alternative for commercial production is to grow juvenile fish at elevated temperatures during the first winter and early spring (i.e., fingerling production only), then grow the fish to market size in nearby lake pens to avoid the pumping requirements for large volumes of water as the fish reach larger sizes. With normal lake temperatures the fish would likely not reach market pan-size by the end of the first summer and would require growout well into the first autumn and winter normally under conditions of ice cover. This is technically possible and is being undertaken in areas of central Canada, but the likelihood of finding suitable sites is very limited in the southern Northwest Territories. Preferably, pen sites would have elevated temperatures during the fall and winter resulting from groundwater. Abandoned mine pits filled with groundwater have been found to have relatively high temperatures and are being used for aquiculture elsewhere. However, the water quality at mine sites must be monitored for potential problems such as low pH and high levels of heavy metals.

The financial viability of lake pen culture and fee-fishing has not been assessed as part of this study. The possible use of lake pens is discussed further in Section 8.0 (Technical and Financial Viability Assessment). The costs of lake pen operations would depend on the site location and type, and on production targets and methods.

8.0 VIABILITY OF AN ARCTIC CHAR PRODUCTION FACILITY NEAR THE TOWN OF HAY RIVER

8.1 GENERAL ASSESSMENT: FINGERLING ONLY PRODUCTION VERSUS COMMERCIAL GROWOUT

The results of this study indicate both fingerling production and commercial growout production appear to be technically possible at the Town of Hay River water supply pumphouse, subject to the uncertainties outlined in the following subsection. The technical feasibility and water quality conditions in one lake in the Yellowknife area has also been examined for possible Arctic char farm development. Development was concluded to be technically possible, subject to hatchery design measures to avoid water quality problems (Olding 1988).

At the Town of Hay River water supply pumphouse, commercial growout production appears to be financially viable only at very large production levels (greater than 400 tonnes), even with the incorporation of waste heat and assuming relatively high prices are maintained. Initial capital investment costs of at least $6-$11 million would be required, depending on the type of initial financial support provided. Fingerling production does not appear to be financially viable at the production level examined (250,000 fingerlings per year) unless purchasers accept prices approximately 20%-50% higher than those obtained from southern sources. At prices currently paid to obtain fingerlings from southern sources, fingerling production appears to be viable at a production level of 400,000-450,000 fingerlings per year, two to three times greater than the facility size examined during this study. Demand for fingerlings is expected to increase as the recreational stocking program in the Northwest Territories is expanded. The initial capital investment costs for a 400,000 fingerling facility are expected to be $0.9-$1.0 million.

The results of the present study suggest that the fingerling-only option (including broodstock) offers greater potential for further development than commercial growout production.

8.2 CRITICAL RISKS

8.2.1 Technical Risks and Uncertainties

Technical uncertainties exist in relation to biological risks (especially the performance of Arctic char during large+cale culture), siting conditions, and facility and equipment tobeused (the appropriate culture technology for northern conditions).

8.2.1.1 Biological Risks

As discussed in previous sections, Arctic char culture is technically possible, though experience at large+cale production levels is limited. Biological uncertainties exist (e.g., strain differences, size variability at early ages, and diet needs), but are being examined at research and commercial locations. Apart from these, the biological performance of cultured fish will be determined by the choice of a specific site (and, among other factors, the type of water supply and waste heat that might exist at that location) and the choice of appropriate culture technology for northern conditions. In addition, the success of a culture facility will be subject to the same risks that generally affect salmonid culture facilities, such as disease outbreaks, failure of mechanical systems and severe environmental conditions.

8.2.1.2 Site Uncertainties

A location adjacent to the Town of Hay River water supply pumphouse was defined for the present study, since a heating unit capable of producing waste heat was under consideration. Therefore, a lakeside water reservoir was assumed because suitable volumes of surface water or groundwater does not appear to occur in this area (discussed in Section 3.0). Development of such a reservoir as an intake for culture facilities is not common, though in concept is possible if satisfactory infiltration rates occur. A positive feature of a reservoir is the potential filtration of fine inorganic sediments that periodically occur in the area. A critical requirement, however, is field examination of water infiltration rates, and recharge capability, and, based on these data, calculation of exact excavation requirements

If sites are considered elsewhere, the technical and financial suitability of other water supply sources must be assessed individually and not according to the design assumptions for a water supply near the Town of Hay River water supply pumphouse. Ideal water supplies are usually high volumes of clean water, preferably spring water, flowing to a facility by gravity.

8.2.1.3 Equipment Uncertainties

The simplest and lowest risk facility designs usually have **once-through** water flow. Again, ideally, there would be no need to recover heat, recirculate water and, consequently, treat water (remove solids or nitrogen compounds), or add oxygen. Heat recovery systems (heat exchangers and heat pumps) and oxygen injection systems are used at commercial salmon hatcheries and trout **farms,** however, water recirculation/reuse systems have not been used commonly at a large commercial scale. Heat exchangers can vary in terms of heat recovery efficiency and maintenance requirements. Some units are suitable only for very clean water and require frequent maintenance shut-down if turbidity increases. Newer units are **less** susceptible to these problems but are more expensive. Heat pumps—use refrigerator coils to remove and transfer heat. These have been developed for use in fish culture facilities in Norway and are now used in several locations in Canada. They appear to have very high heat recovery capabilities at relatively low water temperatures and have low operating costs. Capital costs are higher than heat exchange units and operating experience in Canada is limited, but results suggest possible use where low temperature heat recovery is needed. The choice of heat exchangers or heat pumps will depend on specific site conditions and the type and amount of heat available.

Water recirculation for salmonid facilities has not been widespread because both capital and operating costs are usually high compared to completely open systems, and the risks of mechanical failure are high. As indicated in the present study, the capital requirements for water treatment (solids and nitrogen removal) can be high, however, recirculation offers substantial potential for using limited or expensive (e.g., heated) water supplies and new or improved approaches are constantly developing. In particular, improvements have been made to the media and systems for maintaining bacteria, and has included development of modular units for use on individual fish tanks. if once-through flow is not possible at a particular site, water recirculation should not necessarily be considered a proven method to increase fish production. The site conditions and personnel training must allow for unexpected system shut-down and/or maintenance.

8.2.2 Financial [illegible]

Financial risks include changes in production costs and changes in revenues.

8.2.2.1 Production Costs

Production costs can be seriously affected by the supply and costs of critical including labour, feed, equipment maintenance and operating costs, egg purchase, power supply costs, veterinary costs, insurance, processing and financing. Risks associated with changes in these costs are common to all aquiculture operations. Power supply costs and equipment maintenance and operating costs are of large importance for **1.8:1 for lan** land-based facilities given their high power consumption requirements and changes in costs can be critical. Similarly, equipment maintenance and operating costs are high and can vary greatly amongst facilities depending on the equipment selected, operating conditions, the training of site personnel and availability of contracted support services. These costs could be higher for a facility in the southern Northwest Territories compared to a site in southern Canada.

8.2.2.2 Revenues

Reduced revenue can result from lowered production quantities, or quality and/or lowered selling prices. Reductions in the quantity or quality of fish can from the technical risks described above. Selling prices for market size Arctic char are difficult to predict at present given large uncertainties related to future market acceptance of Arctic char in relation to salmon and trout. Similarly, both the demand and acceptable selling price for Arctic char fingerlings in the Hay River area is unclear.

An added uncertainty for market size char produced in the Hay River area is the cost of transportation to southern Increases in transportation costs (especially air costs for fresh product) could seriously affect the competitiveness of fish produced in the North West Territories%

8.3 OPPORTUNITIES FOR REDUCING COSTS

803.1 Potential Economies *of Scale*

Economies of scale can be substantial with a landbased salmon farm (Babtie, Shaw and Morton 1988). That study shows costs of production were reduced by approximately $5.00/kilogram by increasing production tonnage from a 50 tonne farm to a 200 tonne farm. In the present study, the capital investment cost per biomass design size is $49/kg for the 50 tonne facility and for the 200 tonne facility, assuming similar site and operating conditions The cost is $77/kg for the 250,000 fingerling facility (10 tonne biomass), though operating assumptions are different.

8.3.2 D Features

The options for reducing costs are limited. A major cost component for landbased systems that is influenced by conditions at a particular site is the water intake costs. The water supply costs (reservoir construction, the installation and operation of water intake pumps, and possibly the installation and operation of water recirculation systems) at the Town of Hay River water supply pumphouse site are a high proportion of total costs (representing approximately 20% of capital costs for both the fingerling and commercial growout facility options). Consequently, as discussed below, a site that allows water to flow into the facility by gravity could greatly reduce this cost component.

Other capital costs might be reduced by design and construction modifications or innovations as development proceeds, especially if owners/operators are themselves from construction-trade backgrounds However, these assumptions should not be made during initial financial planning. A common difficulty experienced during the start-up period of aquiculture industries is under-estimations of both capital and operating costs, normally leading to large unexpected time demands for site staff and the need for renegotiating financing after one to two years of operation. Operating costs for this study are conservative and ways to reduce them might be identified through operation of a pilot-scale facility.

8.3.3 Choosing an Alternate Site

One alternative in concept therefore for reducing costs is to select sites that receive water from a groundwater or industrial waste heat source by gravity. The water volume requirement for a fingerling production facility is relatively low, compared to the requirements for a commercial growout facility, and the possibility of finding such a site is high; however, the commercial production facility requires much larger water volumes and consequently the possibility of finding adequate water supplies is low. Elimination of the pumping costs at the fingerling facility would reduce unit production costs, but fingerling prices might still be higher than fingerlings produced in southern facilities.

Use of sites elsewhere will depend on their general suitability for fish culture and on the presence of a suitable source of waste heat. The heat requirements at a culture facility are determined partly by the heat demand (target temperatures and water volume to be heated), and the amount of heat recapture within the facility.

In the present study, a break-even production size for fingerlings appears to be approximately 400,000. Maintaining optimum growing temperatures would require winter temperatures greater than to) esti during the winter and up to 250,000 BTU/minute.

The minimum commercially viable production size is estimated to have a design biomass between 500 and 700 ka. To maintain a temperature of 3-5°C above ambient during winter would require approximately 400,000 BTU/minute for a 500 tonne facility and 600,000 BTU/minute for a 700 tonne facility, assuming most (e.g., 90%) of the water heat is recirculated within the system. This allows the facility to maintain minimum water temperatures of 4-6°C over winter if maximum water heating demand occurs at that time. To maintain optimum growing temperatures (e.g., Manit over winter would require approximately 1.4 million BTU/minute for the 500 tonne facility and 2.2 million BTU/minute for the 700 tonne facility.

A heat source of 400,000-600,000 BTU/minute would allow accelerated growth of early life history stages (Le., egg incubation and early fry rearing) by providing optimum temperatures during the first winter of growth (as long as the waste heat temperatures are greater than since water volume demand is low. During the second winter of growth (and subsequent winters for fish grown to a large harvest size), when water demand would be high, some or all fish would be held at lower temperatures (e.g., ze is a

8.3.4 Alternate Production Concepta

An alternative, in the case of commercial growout production, is to reduce the facility total water requirement by using lake netpens for at least part of the growout period. The viability of lake pen culture has not been assessed during this study, but in general, the unit production costs for cage culture are lower than for landbased systems Lake pen culture of salmonids is being undertaken elsewhere in Canada, including in lakes having ice cover in winter. However, the conditions are generally more severe and the site potential more limited in the Northwest Territories. Lakes in the Hay River area were examined previously for possible extensive trout farming; the suitability of these lakes were generally concluded to be constrained by shallowness and low productivity. Nonetheless for development of an Arctic char culture industry to proceed, the regional potential for lake pen growout should be examined before investment in a landbased commercial growout facility is undertaken.

This examination should focus on a preliminary identification of deep lakes or abandoned mine pits (having water depths greater than 10 meters) that have relatively high fall and winter temperatures, If suitable lakes or pits are identified, other siting requirements (site logistics, water and ice physical conditions and water quality) can be examined and the potential production estimated for each site. Estimates of the potential lake pen production, potential fee-fishing production and future government stocking programs could be used to project fingerling production requirements, The viability of developing combined on-land and lake growout operations within a geographical region can also then be assessed.

Development of lake pen sites would require that:

- sites are in close proximity to logistic centers and transportation routes to reduce operating difficulties and costs; and
- suitable depths, temperature% oxygen levels and other water quality factors (i.e., ph, metal levels, nutrients) to allow good growth and survival.

The minimum financially viable size of netpen operations would vary according to site and operating conditions, but assuming similar financial conditions to salmon production, a minimum size would be between -even size wo 50-100 ater, The fingerling production analysis in Section 6.0 suggests that fingerlings for growout will be more cheaply purchased from suppliers in southern areas unless local demand exceeds 400,000-600,000 fingerlings for capit growout of 100-150 tonnes). This suggests at least two relatively large lake growout operations would be required, if government stocking requirements were limited to 100,000 to 200,000 fingerlings

A second alternative is to have the production facility concentrate only on broodstock development and egg supply. Conceptually, the facility would maintain separate strains of char from the Northwest Territories in order to monitor culture characteristics. The objective would be to supply the industry within and outside the Northwest Territories with high quality eggs from selected culture stock. This type of facility is needed for development of the Arctic char culture industry and form be technically possible.

An important uncertainty is the future demand and competition for these eggs given broodstock programs that are being developed or are planned at private and institutional facilities elsewhere, particularly with Labrador stock in eastern Canada. This will influence the production size and costs for developing a central egg production facility in the Northwest Territories. To be commercially viable, the facility would have to be capable of:

- supplying a consistent supply of eggs from high-performing stock; and
- supplying the eggs at a competitive price and in sufficient volume for an adequate financial return.

Assuming cultured Arctic char production in Canada were to reach 5,000 tonnes in ten years; the egg demand would be 10 million to 25 million depending on the mix of pan-size and large size fish. If a hatchery based in the Northwest Territories were able to supply 25% of these egg needs, the potential production would be 2.5 million to 6.5 million eggs. Disease screened, domesticated salmon egg prices vary from approximately $0.10 to $0.20 per egg. At a high price of $0.20 per egg, the potential revenues would be $500,000 to $1.3 million. At a lower price of $0.10 per egg, the potential revenues would be $250,000 to $650,000.

A facility capable of maintaining sufficient broodstock and producing this number of eggs would be several times larger than the fingerling facility described in Section 6.0. A broodstock/egg production facility might be financially viable, but an assessment of the financial viability of a broodstock/egg production facility depends greatly on the assumptions concerning expected demand and competitive selling price.

8.4 PRACTICABILITY OF USING SALMON LAND-BASED ‘TURN-KEY^{W} SYSTEMS

Commercial growout of salmonids in landbased systems has been attempted for over two decades and versions are in operation in Scotland, Iceland, eastern Canada and along the Pacific coast. The development of landbased systems has been limited compared to cage culture operations, largely because the initial capital costs are very high. The high capital costs (usually associated with water intake requirements and rearing tanks), combined with operating costs higher than predicted, have made the commercial viability questionable. In recent **ajor c** several Norwegian companies have offered complete systems and other companies, with commercial operating experience, have offered design and operational advisory services.

The engineering features of the **during th** facilities are usually sound, but the operating and biological assumptions are often optimistic. The viability of culture systems is usually determined by **e volumes o** constraints and the suitability of species or strains of fish used. **es t e fish w** systems offered by the offshore firms are based primarily on saltwater growout of Atlantic salmon and rainbow trout. Therefore, caution is needed for applying landbased technology in the relatively harsh northern environment and to Arctic char. operation assumptions must be adapted to both the specific site to be developed and the particular **west Te**

Given the high investment costs and uncertainties underlying costing assumptions identified in the present study, a full investment in a turn-key landbased system should not be undertaken. Pilot development is required to test site condition% and to allow design modifications based on both site conditions and biological performance.

8.5 **cal and Finan** DEVELOPMENT

The large uncertainties concerning the commercial viability of either a fingerling-only or market-size production facility outlined in the preceding subsections indicate that full-scale development should not proceed without initial small-scale testing. The purpose of the facility is primarily to test operating conditions and efficiencies at the site to identify ways to reduce both capital and operating costs. The facility can also be used to assess the biological performance of one or more strains of Artic char.

The minimum period of operation of the test facility should be one full production cycle. The intention would be to grow fish both to fingerling size and possibly to market size. The size of the test facility should be smaller than a production-scale facility but large enough to test operating assumptions. A suggested size is approximately 100,000 fingerlings (or 3-5 tonnes maximum biomass). This is half the biomass capability of the fingerling-only production facility described in Section 6.0, though the layout and components would be similar. The water flow requirements of the pilot facility would be approximately 92 LPS, or 18 LPS using 80 % recirculation.

Apart from lower capital cost requirements for rearing tanks and water intake and distribution components, temporary, low cost facilities and equipment could be used where possible (e.g., trailers for office staff and laboratory requirements). A preliminary capital cost estimate at the Town of Hay River water supply pumphouse is approximately $350,000-$450,000. This could be reduced to $275,000-$325,000 if a suitable site having gravity water supply is identified elsewhere. Annual operating costs are expected to be $250,000-$300,000.

9.0 PROJECT IMPLEMENTATION

The results of the study indicate that full-scale investment in a fingerling-only or commercial growout facility should not be undertaken unless site development and ,fish production uncertainties and costs are reduced. Also, the results suggest that further efforts should concentrate initially on a **fingerling-only** plus broodstock concept.

9.1 FURTHER STUDIES

Prior to making final decisions on pursuing development at the Town of Hay River water supply pumphouse location, further **pre-development** studies are recommended. The pre-development investigations should include:

1. Examination of alternate water supply sources in the southern Northwest Territories, preferably able to supply water by gravity.
2. Geotechnical studies of the site at the Town of Hay River pumphouse to assess water infiltration rates, soil and permafrost conditions

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3. Estimation of future. fingerling demand for stocking or alternative uses within the Northwest Territories.

The factors that should be examined during these investigations are outlined in the following subsections.

A further consideration is that viable production sizes and investment costs vary greatly according to assumptions concerning financial support and production objectives. Acceptable production sizes and associated investment costs depend on whether the development objectives are for commercial profit or regional/social benefit. The potential for socio-economic benefits should be examined for facility sizes that appear too low for commercial profit, to determine whether they might meet the proponents objectives.

9.1.1 Examination of Alternate Water Supply Sources

Siting evaluation should include assessment of:

1. Volume and temperature regime of geothermal or industrial heat available, quality (if considered for direct use) and possible supply interruptions. Preferably, temperatures would be above 15°C to allow selection of lower temperatures and maximum heat production would be greater than 300,000 BTU/minute to allow for losses to heat exchange efficiency.

2. Volume, temperature regime and quality of an independent water supply source for the culture facility (if the industrial waste water cannot be used directly).

   The water intake volume requirement for the pilot facility would be approximately 92 LPS (or 28 LPS at 70% recirculation). The intake water volume requirement of a larger production facility (400,000-450,000 fingerlings) would be approximately 222 LPS (or 67 LPS at 70% recirculation).

3. Suitable land area for facility construction.

4. Logistic constraints (size and infrastructure at nearby communities, nearest airport, site access).

9.1.2 Geotechnical Studies of the Site at the Town of Hay River Pumphouse, or Alternate Location

If siting near the Town of Hay River water supply pumphouse is considered further, test ditches must be dug at several locations near the lakeshore to assess water infiltration rates. The quality of the infiltrating water should be assessed at the same time and excavated material can be examined to determine its suitability as berm material around the intake reservoir and/or as fill for preparing the culture facility land area.

At the water supply pumphouse location or alternate location, the soil and permafrost conditions must be examined and worst case flood-height conditions estimated for determining foundation and fill requirements for culture facilities placed adjacent to the pumphouse area.

9.1.3 Estimation of Future Fingerling Demand

The demand for fingerlings in the Northwest Territories should be estimated over near-term (five year) and long-term (25 year) periods. The territorial government is currently examining the recreational lake stocking potential and these data, combined with expected use by private groups, can be used to develop demand forecasts The potential for private fingerling usage (i.e., fee-fishing using isolated lakes or pits, or lake pen growout) should be assessed.

9.2 PILOT-SCALE DEVELOPMENT

The size and objectives of a pilot-scale facility are outlined in Section 8.5. Pilot facility project development should be based on operation of a small (3-5 tonne biomass) test facility. The test facility should be operated for at least one year before scaling-up.

The objectives of the pilot facility are to test assumptions concerning larger scale site development and operating costs, the operating efficiency of equipment and the biological performance of one or more strains of Arctic char.

As indicated in Section 8.5, initial capital costs for support structures should be minimized by using temporary facilities (e.g., trailers) and equipment, where possible, in case site conditions or facility operations appear unsuitable and further development is not warranted. Nonetheless, the design layout and equipment installation should allow for scaling-up if the pilot facility proves successful

Results obtainedat the pilot facility might indicate that the facility should not redeveloped **further,** or that development should proceed but under certain design and operating conditions.

‘1’ hepilotfacili tyshould contain egg incubation and fingerling rearing facilities and facilities **for on-growing** fingerlings as broodstock.

Final site selection and evaluation studies (outlined in Subsections 9.1.1 and 9.1.2) must be undertaken. Based on the results of these studies, detailed engineering designs for a pilot facility and preliminary designs for a larger target size can be prepared. Several types of rearing units should be used so that operating performance can be compared.

903 PERSONNEL REQUIREMENTS

The facility manager should have five to ten years experience as manager or assistant manager with a salmonid production facility. The individual must have a strong background in salmonid biology, culture methods and, preferably, studies of stock performance under culture conditions. Initial activities will require testing both biological and equipment performance and developing new approaches and techniques.

The assistant manager or other personnel at the facility should have expeAence with mechanical and electrical system% In particular, this experience should include operation and maintenance of hy&aulic and heating systems under northern conditions.

9.4 PRODUCTION-SCALE DEVELOPMENT

The results obtained at the pilot facility will be used to determine whether capital and operating costs can be reduced, the types of production equipment and procedures that can be used most efficiently at a larger facility, and the target production of the larger facility.

If the results indicate that the project should proceed further, development planning will require preparation of:

- a market strategy;
- a technical production plan;
- administration requirements; and
- a financial plan.

These topics are outlined briefly below.

9.4.1 Market Strategy

At this stage, it appears that facility production could involve both fingerlings and high quality eggs A preliminary definition of the expected demand for fingerlings can be made (as described in Subsection 9.1.3). During operation of the pilot facility the expected size, quantity, timing and selling price of fingerlings can be defined for different market groups. Similarly, the market requirements for high quality eggs can also be assessed.

9.4.2 Technical Production Plan

The overall scale of production and operating requirements wiU be defined during the pilot phase. A technical production plan can be prepared based on the market targets that are developed and information obtained on operating performance of equipment and stocks. This will involve identification of the numbers and production timing of fingerling and egg groups and, in turn, necessary physical and support requirements The general expected facility features and operating components are outlined in Section 6.0 of this report; these would likely be modified during pilot-scale testing. Outstanding technical risks would also be identified.

9.4.3 Financial Plan

The present study indicates that a capital investment of $0.9-1.0 million and initial annual operating costs of $0.45-$ 0.5 million will be required to develop a break-even facility. These costs will be refined during operation of the pilot facility.

This information, together with sales **forecasts,** can be used to prepare financial forecasts for determining financing requirements.

9.4.4 Administration Requirements

General personnel requirements are outlined in Sections 6.2 and 9.2. The numbers of personnel and other administrative needs will be based on the technical and marketing needs outlined above. Two important components for managing the facility will be:

- well defined linkages with outside contract services for mechanical and electrical support and fish disease management; and
- on-going training of personnel.

The linkages with outside contractors are essential for early responses to emergency situations, Training is important both for upgrading the skills of senior personnel and for developing capability amongst junior staff for morale and job permanence.

9.5 DEVELOPMENT TIMING

A time frame for undertaking project activities is listed in Table 9.1. A realistic target for start-up of the pilot operation is September 1990 for receiving eggs. If planning and construction activities are accelerated so that rearing units are in place by early spring, fry could be placed in the facility at that time. However, this would require site preparation and construction activities during winter.

Operation of a **full-scale** facility is indicated to start in 1992. This will depend on the types of results obtained at the pilot facility. The results could indicate that the pilot facility should be operated for a further one or two years before a **full-scale** facility is developed.

10.0 CONCLUSIONS

1. Fingerling-only production appears to be a more viable option than production of **market-size fish.** Technical uncertainties exist in relation to the site development requirement% the biological performance of Arctic char, and the operating performance of a culture facility in the southern Northwest **Territories.** Based on these **uncertainties,** a facility should not be developed at full-scale until pilot testing has been undertaken.

2. Pessimistic capital costs for a 250,000 fingerling production facility are approximately $1.4 million and optimistic capital costs are approximately $0.8 million.

   Market conditions (selling price and quantity) for fingerling production in the vicinity of Hay River are **uncertain.** A **fingerling-only** production facility does not appear commercially viable at a size expected to meet or slightly exceed local demand (250,000 **fingerlings),** unless potential purchasers accept a relatively high price ($1.50+2.00/fingerling).

   A minimum break-even production size for a fingerling facility at $1.20 per fingerling is approximately 400,000 fingerlings. Capital investment costs are estimated to be $0.9-$ 1.0 million and annual operating costs are estimated to be $450,000-$500,000.

   Fingerlings produced by a commercial growout facility could be offered at much lower prices because most capital and operating costs for fingerling production would be absorbed.

3* Capital costs for a 50 tonne commercial growout facility (maximum biomass), maintaining a constant water temperature of 12°C through the year, are estimated to be $2.4 million (optimistic) and $4.7 million (pessimistic). Capital costs for a 200 tonne facility (maximum biomass) are $7.9 million (optimistic) $14.6 million (pessimistic).

Optimistic capital costs for a 200 tonne facility, maintaining a minimum temperature of 4-6°C, is approximately $5.5-6.0 million.

The selling price of Arctic char is presently good (approximately $10.00/kg), but future prices are not clear, especially if culture production increases substantially.

Even with the benefit of waste heat and assuming high selling prices and substantial financial support in the form of grants and interest-free loans, a minimum harvest production size of 400-500 tonnes per year is required to break-even. Capital costs for a 400 tonne facility would likely be at least $6-$8 million and have annual operating costs of approximately $4-$5 million. The commercial suitability, in terms of acceptable profit, will require a larger facility size. A lower break-even production size would nonetheless provide regional or social development benefits if these meet the proponent's objectives,

Without substantial financial support, a minimum harvest production size would be at least 650 tonnes and more likely in the order of 800-1,000 tonnes (or design biomass size of S00-700 tonnes) would be required and a capital investment of at least $10 million.

4. Capital costs for water intake systems, including pumps, represent approximately 20% of the total capital costs. These costs might be reduced by selecting a site having a gravity water supply.

5. A pilot facility (e.g., 3-5 tonnes) should be operated at the chosen development site for several years before larger-scale investment is made. Such a facility can be used to evaluate site operating condition% equipment usage (including heat exchange units and modular recirculation units) and the biological performance of selected Northwest Territories' strains of Arctic char.

A 3-5 tonne pilot facility would require a minimum capital cost of approximately $350,000-$450,000 at the Town of Hay River pumphouse and possibly lower ($275,000-$325,000) at a site having a gravity water supply. A pilot facility of this size would be capable of producing approximately 100,000 fingerlings. Annual operating costs would be approximately $250,000-$300,000.

6. Site development should not proceed at the Town of Hay River water supply pumphouse until detailed studies of soil, permafrost conditions at the culture site, and studies on water infiltration rates at the reservoir site are made. These studies are necessary to confirm the suitability of site conditions.

7. Costs to operate a water heating system would be prohibitive if the costs are borne by the culture facility. At break-even production sizes, approximately 300,000-350,000 BTU/minute of waste heat are required by a fingerling-nly facility and approximately 400,000-600,000 BTU/minute will be required by a commercial production facility. Although the waste oil heat facility proposed for the Town of Hay River water supply pumphouse might not be considered further for heating the town water supply, it might nonetheless be suitable solely for a fish production facility.

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11.0 RECOMMENDATIONS

1. Purther efforts should concentrate initially on a **fingerling-only** plus broodstock concept.

2. The results of the study **indicate** hat **full-scale** investment should notbe undertaken unless site development, fish production uncertainties and costs are reduced. If development is to proceed, further pre-development studies and operation of a pilot facility is recommended.

   Predevelopment investigations should include:

   a) Examination of alternate water supply sources in the southern Northwest **Territories,** preferably able to supply water by gravity.

   b) **Geotechnical** studies of the site at the Town **of** Hay River water supply pumphouse, or elsewhere if a suitable location is **found.**

   c) Estimation of future fingerling demand for stocking or other uses within the Northwest Territories.

3. The viable production size and capital investment requirements vary substantially depending on the type of financing assumed and whether government grants or interest-free loans are used. **Therefore,** the potential **socio-economic** benefits should be examined in terms of facility production sizes and financial requirements that are acceptable for regional/social development, but are too low for commercial profit.

4. Pilot facility project development should be based on operation of a **small** (3-s tonne biomass) test facility. The test facility should be operated for at least one year.

   The objectives of the pilot facility are to test assumptions concerning **larger-scale** site development and operating efficiency of equipment and the biological performance of one or more strains of Arctic char.

capital costs for support structures should be minimized by using temporary facilities (e.g., trailers) and equipment where possible.

5. A recommended time frame for project implementation is described in Section 9.0. Briefly, to begin operating a pilot facility by September 1990, pre-development studies (including final site selection) should be completed by December 1989, site engineering design should be completed by March 1990, and construction should be completed by July 1990.

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TABLE 3.1 : **SUMMARY** OF WATER **QUALITY** OF SAMPLES TAKEN **FROM** MATER INTAKE AT TOWN OF **HAY** RIVER **HATER SUPPLY PUMPHOUSE.**
Source: **L, Bruin,** personal **communication.**

PERIOD OF **SAMPLING**	**pH**	COLOUR **(TCU)**	**ALKALINITY**	TOTAL HARDNESS **(mg/L)**	TURBIDITY **(NTU)**	IRON (mg/L)
April 30-t4ay 25, 1982*	6.5-8.04	10-+50	96-112	124.0-164.0	8.5-97.1	0.02-0.83

* 22 samples taken.
\+ = Greater than.

TABLE 5.1 : EXPECTEO AMBIENT **TEMPERATURES,** PREFERREO TEMPERATURES ANO **TEMPERATURE DIFFERENCES FOR ARCTIC CHAR INCUBATION,** REARING AND **BROODSTOCK**

	J	**F**	**M**	**A**	**M**	**J**	J	A	S	O	N	&
EXPECTED AMBIENT	2	1	1	3	6	10	13	15	12	8	6	4
INCUBATION												
Preferred	7	-								**7**	7	7
Differences	5	-							-	**(-1)**	1	3
REARING												
Preferred	12	12	12	12	12	12	12	12	12	12	12	12
Differences	10	11	11	9	6	2	(-1)	(-3)	0	4	6	8
BROODSTOCK												
Preferred	6	6	6	6	6	6	6	6	**6**	**6**	**6**	**6**
Differences	4	5	5	3	0	(-4)	(-7)	(-9)	**(-6)**	**(-2)**	**0**	**2**

TABLE 6.1 : CAPITAL COSTS: FINGERLING PRODUCTION FACILITY

		CONSERVATIVE	OPTIMISTIC
1.	SITE PREPARATION	100,000	50,000
2.	WATER INTAKE FACILITIES	102,000	72,000
3.	WATER DISTRIBUTION, TREATMENT AND DISCHARGE	154,000	119,000
4.	HATCHERY AND EARLY FRY REARING FACILITIES	2(?,000	12,000
5.	REARING TANKS	146,000	97,000
6.	WATER HEATING SYSTEM	88,000	53,000
7.	BUILDING CONSTRUCTION	217,000	109,000
8.	ELECTRICAL AND INSTRUMENTATION	227,000	66,000
9.	MISCELLANEOUS	60,000	60,000
10.	SITE HYDROGEOLOGICAL STUDIES AND ENGINEERING DESIGN	167,000	64,000
	Sub-Total	$1,279,000	$702,000
11•	CONTINGENCY (10%)	123,000	70,000
	TOTAL	**$1,402,000**	**$772,000**

TABLE 6.2: ASSUMED GROWTH OF ARCTIC CHAR FINGERLINGS.

MONTH	TEMPERATURE (“c)	WEIGHT ((34) ‘ ON FIRST DAY OF MONTH
FEBRUARY	12	0.3
MARCH	12	2.1
APRIL	12	5.9
MAY	12	12.5
JUNE	12	12.5
JULY	13	37.1
AUGUST	15	57.1

TABLE 3: FINGERLING RODUCT ON MONTHL COST SCHEDULE (WITH BROODSTOC PRODUCTION).

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
VARIABLE COSTS													
Feed	2,450	3,466	5,624	8,107	13,850	1,503	1,371	813	852	1,014	475	1,062	40,587
Pumping	684	766	1,060	1,692	2,480	3,994	5,394	662	691	979	953	912	20,267
Stock Insurance	5,060	-	-	-	-	-	-	-	-	-	-	-	5,060
Sub-Total	8,194	4,232	6,684	9,799	16,330	5,497	6,765	,475	,543	1,993	428	1,974	65,914
FIXED COSTS													
Labour	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	105,000
Benefits	700	700	700	700	700	700	700	700	700	700	700	700	8,400
Fuel	150	150	150	150	150	150	150	150	150	150	150	150	1,800
Repair and Maintenance	1,250	,250	1,250	,250	,250	1,250	1,250	1,250	,250	1,250	1,250	1,250	5,000
Veterinary and Diagnostics	500	500	500	500	500	500	500	500	500	500	500	500	6,000
Fixed Insurance	965	965	965	965	965	965	965	965	965	965	965	965	11,580
Misc. Supplies	,000	,000	1,000	1,000	1,000	1,000	1,000	.00	1,000	1,000	1,000	1.000	12,000
General and Administration	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	25,296
Depreciation	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	50,604
Sub-Total	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	235,680
TOTAL	27,834	23,872	26,324	29,439	35,970	25,[illegible]37	26,405	21,115	21,183	21,633	21,068	21,614	301,594

TABLE 6.4: **UNIT PRODUCTION COSTS** ($/Fingerling) FOR A FACILITY PRODUCING 253,000 FINGERLINGS PER YEAR.

	CASE A PURCHASE EGGS	CASE B OWN BROODSTOCK EGGS	CASE C WITHOUT HEATING COSTS
VARIABLE COSTS:			
Eggs	$0.32		-
Feed	0.13	6.16	0.16
Heating	0:11	0.20	-
Pumping	0.05	0.08	0.08
Stock Insurance	0.02	0.02	0.02
Interest on Working Capital	0.16	0.14	0.12
Sub-Total	0.79	0.60	0.38
FIXED COSTS:			
Labour	0.45	0.45	0.45
Other Production Costs	0.18	0.18	0.18
General and Administration	0.10	0.10	0.10
Depreciation	0.20	0.20	0.20
Financing	0.14	0.14	0.14
Sub-Total	1.07	1.07	1.07
TOTAL	**$1.86**	**$1.67**	**$1.45**
BREAK-EVEN POINT (FINGERLINGS)*: Greater than	(660,000)	(450,000)	330,000

* Assuming a selling price of $1.20/fingerling.

TABLE 6.5: INITIAL CASH FLOW FOR A FINGERLING-ONLY PRODUCTION FACILITY (253,000 FINGERLINGS PER YEAR).

	YEAR					
	1	2	3	4	5	6
CASH **OUTFLOWS** ($'000'S):						
OPERATING COSTS	152	333	337	279	251	251
FINANCING COSTS:						
• Short-Term Interest on **Working** Capital	18	40	40	33	30	30
. Long-Term Interest	46	46	46	46	46	46
. Principal Repayment	0	39	39	39	39	39
TOTAL	216	458	462	397	366	366
CASH INFLOW AND NET CASH FLOW ($'000's):						
ASSUMED PRICE: $1 .20/FINGERLING:						
• Cash Inflow	0	304	304	304	304	304
. Debt	0	241	442	672	857	1,029
. Net Cash Flow	(216)	(395)	(600)	(765)	(919)	(1 ,091)
ASSUMED PRICE: S1 .80/FINGERLING:						
. Cash Inflow	0	455	455	455	455	455
. Debt	0	241	273		287	222
. Net Cash Flow	(216)	(244)	(280)	(%	(198)	(133)

TABLE 7.1 : CAPITAL COSTS: ESTIMATES **FOR COMMERCIAL GROWOUT PRODUCTION** ASWING OPTIMUM GROWTH TEMPERATURES (12-13°C) ARE MAINTAINED.

ITEM	200 TONNE		50 TONNE	
	PESSIMISTIC COST	**OPTIMISTIC COST**	**PESSIMISTIC COST**	**OPTIMISTIC COST**
1. SITE PREPARATION	1,000,000	300,000	315,000	95,000
2. WATER INTAKE FACILITIES	857,000	375,000	250,000	169,000
3. UATER DISTRIBUTION, TREATMENT AND DISCHARGE	2,905,000	2,500,000	718,000	634,000
4. HATCHERY AND EARLY FRY REARING FACILITIES	83,000	49,000	20,000	12,000
5. REARING TANKS	2,733,000	1,793,000	613,000	420,000
6. MATER HEATING SYSTEM	1,254,000	502,000	572,000	229,000
7. BUILDING CONSTRUCTION	458,000	229,000	395,000	198,000
8. ELECTRICAL AND INSTRUMENTATION	2,073,000	575,000	721,000	170,000
9. MISCELLMEOUS EQUIPMENT	200,000	200,000	100,000	100,0000
10. SITE HYDROGEOLOGICAL STUDIES AND ENGINEERING DESIGN	1,734,000	652,000	556,000	197,000
11• CONTINGENCY (10%)	1.330.000	718.000	426,000	216,000
TOTAL	$14.627.000	**$7,893,000**	**$4,686,000**	**$2,440,000**

TABLE 7.2: CAPITAL COSTS AT A 200 TONNE FACILITY: ESTIMATES FOR **COMMERCIAL GROUOUT PRODUCTION** ASSUMING 141 **NIMUM TEMPERATURES OF 4-6'C ARE MAINTAINED DURING THE** MINTER.

ITEM	UITH UATER RECIRCULATION	WITHOUT HATER RECIRCULATION
1. SITE PREPARATION	300,000	300,000
2. WATER INTAKE FACILITIES	375,000	1,321,000
3. MATER DISTRIBUTION, TREATMENT AND DISCHARGE	1,900,000	968,000
4. HATCHERY MD EARLY FRY REARING FACILITIES	49,000	49,000
5. **REARING TANKS**	893,000	893,000
6. WATER HEATING SYSTEM	502,000	502,000
7. BUILDING CONSTRUCTION	229,000	229,000
8. **ELECTRICAL** AND INSTRUMENTATION	425,000	426,000
9. **MISCELLANEOUS EQUIPMENT**	200,000	200,000
10. SITE HYDROGEOLOGICAL STUDIES - AND ENGINEERING DESIGN	467,000	489,000
11• CONTINGENCY (10%)	514,000	538,000
TOTAL	**$5,854,000**	**$5,91**5.000

TABLE 7.3: ASSUMED GROWTH TO COMMERCIAL SIZE.

MONTH	MINIMUM TEMPERATURE OF 12°C		MINIMUM TEMPERATURE OF 6*C	
	Temperature	Weight	Temperature	Weight
FEBRUARY	12	0.3	12	0.3
MARCH	12	2.2	12	2.2
APRIL	12	7.1	12	7.1
MAY	12	18.5	12	18.5
JUNE	12	31.4	12	31.4
JULY	13	53.1	13	53.1
AUGUST	15	83.8	15	83.8
SEPTEMBER	12	124.1	12	124.1
OCTOBER	12	172.4	8	172.4
NOVEMBER	12	230.8	6	211.6
DECEMBER	12	299.8	6	241.5
JANUARY	12	394.2	6	279.1
FEBRUARY	12	487.5	4	313.7
MARCH	12	592.3	4	334.6
APRIL	12	709.0	6	356.0
MAY	12	837.2	6	395.0
JUNE	12	977.3	10	435.9
JULY	13	1,129.0	13	520.5
AUGUST	15	1,299.2	15	633.6
SEPTEMBER	12	1,483.6	12	781.9
OCTOBER	12	1,671.1	8	893.7
NOVEMBER	12	1,867.3	6	995.5
DECEMBER	12	2,074.9	6	1,045.0

TABLE 7.4: COMMERCIAL PRODUCTION (200 TONNE MONTHLY COST SCHEDULE (WITH BROODSTOCK PRODUCTION).

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
VARIABLE COSTS													
Feed	68,557	81,039	80,927	83,502	88,553	146,385	153,470	174,960	150,980	72,646	71,140	82,787	,254,946
Pumping	12,057	13,219	14,520	13,873	13,166	12,512	13,231	14,592	7,184	9,202	8,245	11,294	143,095
Stock Insurance	-	-	-	68,491	-	158,401	-	-	-	-	-	-	226,892
Processing	53,941	56,830	101,389	58,021	61,397	53,504	64,649	69,203	-	-	33,942	34,045	586,921
Selling	18,312	19,291	34,417	19,696	20,842	18,162	21,945	23,491	-	-	11,522	11,557	199,235
	152,867	170,379	231,253	243,583	183,958	388 96	253,295	282,246	158,164	81.848	124,849	39,683	2,411,089
FIXED COSTS													
Labour	14,750	14,750	4,740	14,750	14,750	14,750	14,750	14,750	14,750	14,750	4,750	14,750	177,000
Benefits	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	1,032	12,834
Fuel	350	350	350	350	350	350	350	350	350	350	350	350	4,200
Repair and Maintenance	9,757	9,757	,757	9,757	9,756	9,757	9,757	9,757	9,757	9,757	9,757	9,757	1'7,084
Veterinary and Diagnostics	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	24,000
Fixed Insurance	7,318	7,318	7,318	7,318	7,318	7,318	7,[illegible]	[illegible]18	7,318	7,318	7,318	7,318	87,816
Misc. Supplies	3,000	3,000	3,000	3,000	3,000	3,000	3,000	[illegible]000	3,000	3,000	3,000	3,000	12,000
General and Administration	3,434	3,434	3,434	3,434	3,434	3,434	3,434	3,434	3,434	3,434	3,434	3,434	36,000
Depreciation	36,455	36,455	36,455	36,455	36,455	36,455	36,455	36,455	36,455	36,455	36,455	36,455	437,460
Sub-Total	78,096	78,096	78,096	78,096	78,096	78,096	78,096	78,096	78,096	78,096	78,096	78,096	937,152
TOTAL	230,963	248,475	309,349	321,679	262,054	467,060	331,391	360,342	236,260	159,944	202,945	217,779	3,348,241

TABLE 7.5: CANADIAN LANDINGS OF ARCTIC CHAR 1983-1987.

	ATLANTIC LANDINGS			N.W. T. LANDINGS		
YEAR	QUANTITY (tonnes)	VALUE ('$000)	UNIT PRICE ($/kg.)	~&N;:;; ('$000)	VALUE	UNIT PRICE ($/kg.)
1983	198	170	0.86	52	307	5.90
1984	152	151	0.99	62	380	6.13
1985	158	179	1.13	68	320	4.71
1986	130	165	1.27	67	411	6.13
1987	109	148	1.36	59	511	0.67

Source: Department of Fisheries and Oceans, Ottawa.

TABLE 7.6: UNIT PRODUCTION COSTS ($/kg) FOR A FACILITY PRODUCING 317 TONNES ANNUALLY.

	CASE A BASE CASE	ChSE B NO HEATING COSTS	CASE C OWN BROODSTOCK PRODUCTION	CASE D NO FINANCING COSTS	CASE 'E FINANCING COSTS REDUCED BY 50%
VARIABLE COSTS					
EGG	**0.92**	0.92			
FEED	**3.96**	3.96	3:;6	3:;6	3:;6
HEATING	**7.33**	**.0**	**.0**		
PUMPING	**0.45**	**0.45**	**0.45**	0::5	0::5
PROCESSING & TRANSPORT	**1.85**	1.85	1.85	1.85	1.85
STOCK INSURANCE	0.72	0.71	0.71	0.71	0.71
INTEREST ON UORKING CAPITAL	1.90	1.02	0.90	**.0**	0.45
SELLING	0.63	0.63	0.63	0 **.63**	0.63
Sub-Total	**17.76**	9.54	8.45	7.55	8.00
FIXED COSTS					
LABOUR	**0.60**	0.60	0.60	0.60	0.60
OTHER PRODUCTION COSTS	0.85	0.85	0.85	0.85	0.85
ADMINISTRATION	0.13	0.13	0.13	0.13	0.13
DEPRECIATION	1.38	1.38	1.38	1.38	1.38
FINANCING	**1.11**	1.11	1.11	.0	0.56
Sub-Total	4.07	**4.07**	4.07	**2.96**	**3.52**
TOTAL	21.83	**13.61**	**12.52**	**10.51**	**11.52**
BREAK-EVEN POINT **(TONNES)*** Greater than		**1340**	**630**	**320**	**450**

* **Assuming** a selling price of $10.50/kg.

TABLE 7.7: INITIAL CASH FLOW FOR A COMMERCIAL PRODUCTION FACILITY (317 TONNE ANNUAL HARVEST).

	YEAR					
	1	2	3	4	5	6
CASH OUTFLOWS ($'000's):						
OPERATING COSTS	459	3,177	3,185	2,998	2,911	2,911
FINANCING COSTS:						
Short-Term Interest on Working Capital	55	381	387	360	349	349
Long-Term Interest	351	351	351	351	351	351
Principal Repayment	0	293	293	293	293	293
TOTAL	865	4,202	4,211	4,002	3,904	3,904
CASH INFLOW ($'000'S) AT AN ASSUMED PRICE OF $10.50/KG:	0	0	3,360	3,360	3,360	3,360
DEBT:	0	967	5,791	7,439	9,051	10,746
NET CASH FLOW (DEFICIT):	(865)	(5,171)	(6,642)	(8,081)	(9,595)	(11,290)

			50 TONNES	200 TONNES
•	100 %	Without Oxygen	59,000	232,000
		With Oxygen	50,000	200,000
•	30%	Without Oxygen	18,000	70,000
		With Oxygen	14,300	59,500
.	10%	Without Oxygen	5,900	23,200
		With Oxygen	5,000	20,000

The size of the intake reservoir is based on a one hour water retention time. Construction of a lakeside reservoir likely would not be required at other site locations, consequently the reservoir construction portion of this cost component would be eliminated.

7.1.3 Water Distribution. Treatment and **Discharge**

In Table 7.1, the costs are based on a maximum 90% recirculation capability and include: internal piping amongst tanks, collection sumps, recirculation pumps (one main and one backup), treatment facilities for removal of solid and nitrogen wastes, aeration towers and oxygen backup systems, discharge piping, and building and insulation costs. Recirculation flow requirements (LPM) at maximum biomass are:

		50 TONNES	200 TONNES
•	Without Oxygen	52,000	206,000
•	With Oxygen	44,200	175,100

The water treatment facilities represent a large cost especially if they are adequately covered or insulated to minimize heat loss. The optimistic costs outlined in Table 7.1 are the same as the conservative costs except that the cost of covering and insulating the water treatment facilities is reduced by 50%. Also, an oxygen injection system is added to the facility design and the total costs are, therefore, further reduced by 15%. The cost of the oxygen injection system is added. The water treatment costs can be further reduced if low temperatures (i.e., 4-6°C) are assumed over winter and largely eliminated if the facility does not recirculate water (Table 7.2).

assumes that backup diesel boilers are not included, use of lower cost heat exchangers, and an oxygen injection system is in use (which reduces overall flow requirements). A variety of heat exchange systems are available and both costs and operating performance can vary. Lower cost units can be installed if water quality conditions are very good ,but use of lower cost systems can often result in higher maintenance and operating costs.

7.1.7 Building Construction

Building space is required for office, laboratory, workshop, mechanical equipment, intake aeration towers, feed storage, staff rest space and on-site housing for a manager or assistant manager. These costs can vary depending on the site location and conditions. The optimistic costs assume that costs are 50% of the conservative estimates.

7.1.8 Electrical and Instrumentation

The facilities require automatic sensors and activation of backup equipment, alarm systems, water control valves, control panelling, equipment wiring, and general site wiring and lighting. These costs can vary greatly according to the type and amount of automation chosen. An allowance of 25% of capital costs (minus site preparation costs, miscellaneous equipment and site costs, and preliminary hydrogeological studies and engineering design) has been used for the conservative estimate and 10% for the optimistic cost. The cost of a backup electrical generator is added and is the same for both the conservative and optimistic estimate%

7.1.9 Mhcellaneous

An allowance is made for miscellaneous site and equipment requirements including potable water supplies, telephone connections, domestic sewage, vehicles, fish feeders, nets and fish handling/grading equipment, water quality monitoring equipment, disease diagnostic equipment, and office equipment. These costs are assumed to be the same for the conservative and optimistic estimates.

7.1.10 Site Hydrogeological Studies and Engineering Design

Uncertainties about the soil and permafrost conditions place a large importance on undertaking preliminary hydrogeological studies. The cost of these studies will depend on whether substantial information is already available and on specific site conditions. The pessimistic cost for hydrogeological studies and engineering design is estimated to be 15% of the other site development costs. The optimistic cost is estimated to be 10%. In the latter case, the hydrogeological study requirements are minimal and incorporated within a standard engineering design costing.

7.1.11 Contingency

A 10% contingency is calculated for both the conservative and optimistic estimates

7.2 OPERATING COSTS

Fixed costs are assumed to include: wages, salaries and benefits for personnel; vehicle fuel costs; repair and maintenance; veterinary and diagnostic costs; fixed insurance; miscellaneous supply costs; general and administration costs; and depreciation. Variable costs include: egg purchases, feed costs, water pumping and heating costs, stock insurance, processing and selling costs. Most variable costs are influenced by fish growth during a production cycle. Based on the assumed growth rates described in Section 5.0, the expected fish growth at minimum water temperatures of 12°C and minimum winter temperatures of 4-6°C are shown in Table 7.3.

Monthly operating costs are shown in Table 7.4 for a normal operating year. These costs assume eggs are produced by broodstock within the facility and heating costs do not occur because waste heat is used. Annual operating costs before financing costs (discussed in Section 7.3, Financial Analyses) for the 200 tonne biomass operating at low winter temperatures (4 - 6°C) are estimated to be between $3.3 million and $3.5 million.

7.2.1 Fixed Cats

7.2.1.1 Personnel

Permanent staff include a facility manager, an assistant manager and one or more full-time workers. Assumed annual salaries are:

	50 TONNE	200 TONNE
Manager	$40,000	$45,000
Assistant Manager	$30,000	$30,000
Full-Time Workers	$40,000 (2)	$60,000 (3)
Seasonal Workers	$12,000 (2)	$24,000 (4)
Administrative Support:		
- Full-Time		$18,000 (1)
- Part-Time	$9,000 (1)	

A benefits cost is also assumed for full-time employees.

7.2.1.2 Vehicle Fuel Costs

A fuel allowance of $200.00/month is provided for the 50 tonne facility and $350.00/month is provided for the 200 tonne facility. Vehicle maintenance costs are included in the Maintenance Services and Supplies category (Section 7.2.1.3).

7.2.1.3 .Maintenance Services and Supplies

An annual allowance of 2% of capital costs has been provided for maintaining and servicing equipment and physical facilities on site.

7.2.1.4 Veterinary and Diagnostic Services

Costs for disease management can include collection and preparation of samples for preliminary diagnosis on site or for shipping off-site; visits to the site by fish health specialists; and purchase and administration of medicines An allowance of $1,000.00/month is provided for the 50 tonne facility and $2,000.00/month is provided for the 200 tonne facility. These are high and assume private laboratory analyses at southern laboratories and periodic site visits by private fish health specialists from southern locations.

7.2.1.5 Fixed Insurance

An allowance of 1.5% is provided for insuring site equipment and facilities. Feed and stock insurance is included as a variable cost.

7.2.1.6 Depreciation

Fixed assets are depreciated on a straight line basis over a ten year period.

7.2.1.7 Miscellaneous Supplies

An allowance of $2,000.00/month is provided for the 50 tonne facility and $3,000.00/month for the 200 tonne facility is provided for miscellaneous items. These include: ongoing requirements for water quality monitoring, fish handling supplies and unforeseen supply costs.

7.2.1.8 General and Administration

An allowance is made for additional travel, legal, accounting, communication and general office costs=

7.2.1.9 Financing of Capital Costs

Capital costs are assumed to be financed by 50% equity and 50% long-term debt at an interest rate of 12% repayable over ten years.

7.2.2 Variable Costs

7.2.2.1 Egg Purchase Costs

Eggs will be required from outside sources for the initial three to five years of operation. These might come from wild sources within the Northwest Territories, from the federal Department of Fisheries and Oceans Rockwood hatchery in Winnipeg or private sources. The cost of egg input from the Northwest Territories or the Rockwood hatchery likely would be subsidized. However, for the purpose of this analysis, a commercial egg cost of $0.20/egg (certified disease-free) is assumed.

7.2.2.2 Feed Costs

Feed costs (delivered to the culture facility) are assumed to be higher than southern areas: $2.50/kg for starter feeds (used for the first month after first feeding); $2.00/kg for juvenile feed (used for four months after using the starter feeds); $1.50/kg for growout feed. Feed conversion is assumed to be 1.5:1 for smaller fish (to 40 gm) and 1.8:1 for larger fish.

7.2.2.3 Pumping and Heating Costs

Pumping costs are based on $0.14 /kw/hr up to 1,000 /kw/hr and $0.10 kw/hr above 1,000 /kw/hr; heating costs are based on diesel costs of $0.038 /kw/hr. Electrical costs for a site developed near the Town of Hay River could be less than $0.10 /kw/hr-$0.14/kw/hr subject to negotiations with the local utilities company.

7.2.2.4 Stock Insurance

An insurance allowance is provided for 4% of the feed and fish stock on hand each month.

7.2.2.5 **Processing**

A processing cost of $0.95/kg and a transport cost to Toronto is included so that production costs are estimated to be dressed fish F.O.B., Toronto.

7.2.2.6 **Selling**

Harvests are assumed to be marketed through a seafood broker. Brokerage fees of 8 % of the selling price are assumed.

7.2.2.7 Interest on Working Capital

Interest on working capital is based on 100 % financing at an interest rate of 12%, repayable over 10 years.

7.3 PINANCIAL ANALYSIS

7.3.1 Assumed Prices

7.3.1.1 Market Conditions

Production

Commercial landings of Arctic char in Canada and worldwide have historically been minor but may increase over time due to aiquiculture production. Landings in Canada originate from the Northwest Territories and Labrador and range between 150 and 300 tonnes. Limited production also occurs in Norway.

Cultured Arctic char production in 1988 is estimated to be 400 tonnes from Scandinavia and 60 tonnes from Canada (Papst & Hopky, 1989). The first commercial aiquiculture production in Canada was in 1987 in Manitoba. Production was about 10 tonnes in that year.

Virtually all of the commercial production of wild Arctic char in Canada is sold frozen due to the long distances to markets. The frozen product in turn is almost all smoked. All of the cultured char was sold fresh.

The Arctic char produced in Canada is consumed within the country. The major markets are large urban centres, Particularly Montreal and Toronto.

Recent Prices

As with many seafood products, the quality and size of Arctic char are important price determinants. The N.W.T. char generally sells for more than the Atlantic landings because of a redder and more consistent flesh colour and larger size (3-5 kg.). The Atlantic landings are typically in smaller 2-3 kg. sizes.

Marketing of N.W.T. char would also appear to be better coordinated and face somewhat fewer distribution problems. All N.W.T. char is sold through the Freshwater Fish Marketing Corporation. Unit values for char for the period 1983-87 are shown in Table 7.5.

The aquiculture char has been sold in pan sizes (200-300 grams) to restaurants at prices at around $10 per kilogram, which is close to the price of fresh farmed salmon. As a result, there is a considerable premium for cultured char over farmed raised rainbow trout in the same size category, which sells for about half the price.

7.3.1.2 Trends

No increases in wild char landings are forecast on a worldwide basis. In contrast, the long-term production potential for culturing char in Canada and elsewhere appears to be quite promising since broodstock have been successfully developed under culture conditions.

Market studies conducted to date (Western Management Consultants 1989) suggest that cultured char in a fresh form should continue to earn a premium over rainbow trout and prices should be similar to those of farmed salmon. It is not clear, however, what price impacts the forecasted increased supplies of farmed salmon may have on cultured char.

The volume of pan-size Arctic char product entering the market is very low. However, market conditions at present are not fully understood, and consequently, it is not clear what market niche cultured Arctic char may occupy. Demand is not likely to be satisfied in the near term and prices will likely stay high for the next several years. Likely prices (F. O.B., Toronto) estimated for this study are:

High	$lo.50/kg.
Medium	$7.85/kg.
Low	$5.20/kg.

The "high" selling price reflects relatively high prices that have been obtained for farmed salmon prior to 1989 and the "low" prices reflect trout prices. The high prices ($10.50/kg are similar to those obtained by an Arctic char producer in Manitoba. Higher prices can currently be expected for larger-size char. However, prices in light of world market conditions for cultured salmonids, are unstable. The medium price is considered more realistic for business planning purposes.

7.3.2 Base Case Analysis

The base case facility is assumed to have a design biomass maximum of 200 tonnes, but having harvest occur over a protracted period so that actual annual harvest tonnage is approximately 320 tonnes. The facility is assumed to maintain low winter water temperatures (4-6°C) as indicated in Table 7.2.

7.3.2.1 Unit Production Costs

Unit production costs ($/kg.) under five different financial and operating conditions are summarized in Table 7.6. Heating costs are very high (Case A), representing approximately 30-35 % of the production costs, and for this study are assumed to be provided by an outside source.

Case B assumes eggs are purchased from outside sources and Case C assumes eggs are produced from broodstock within the facility. Case B represents the situation for the first two to three years of operation and Case C represents typical years afterwards. For both cases, the total production costs are higher than the highest expected price for Arctic char ($10.50/kg). Apart from heating, the highest operating cost is feed, which is based on dry feed purchased and transported from southern locations. This might be reduced if a local feed plant is able to produce a high quality char diet.

Interest on working capital and financing of fixed capital represents a large cost and assumes substantial borrowing. This might not be the case if initial grants or interest-free loans are provided (Case D and Case E). Eliminating all financing costs (Case D) would mean unit production costs are approximately equal to the highest assumed selling price. However, this assumption is unlikely and in general production does not appear to be viable for this size of facility.

Approximate break-even production sizes are also shown in Table 7.6. These have been estimated using the formula:

$$\text{Break-Even Point} = \frac{\text{Fixed Cost Total}}{\text{Contribution Margin}}$$

(i.e., price per unit - variable cost per unit)

Assuming conservative growth rates and that eggs will eventually be produced by the facility (Case C), the facility tonnage would have to reach an annual production greater than 630 tonnes to break-even (assuming relatively high prices $10.50/kg.); breakeven production would have to be higher if prices drop. A facility harvesting 630 tonnes would have a biomass design size of approximately 400 tonnes. Further capital investment would be required so that the likely break-even size would be greater, with a biomass size of possibly 500-700 tonnes (or harvest production of 800-1,000 tonnes). The break-even size would be yet higher if lower selling prices are assumed. Assuming a small economy-f-scale reduction for capital costs as indicated by the 50 tonne and 200 tonne facility costs, a 400 tonne biomass facility would require approximately $11-$12 million and a 700 tonne facility would require approximately $15-$20 million.

Assuming further that the financing costs are defrayed by 50% (Case E), a break-even production size is estimated to be 450 tonnes annually (or a biomass design size of approximately 360 tonnes). Elimination of all financing costs would reduce the break-even point to 320 tonnes (Case D).

These data suggest that with a large amount of assistance in the form of grants or interest-free loans and with good selling prices the probable minimum commercial break-even harvest production lies between approximately 400 and 500 tonnes. The initial capital required for a facility harvesting 400 tonnes would be approximately $6-$8 million. and annual operating costs would be approximately $4-$5 million. To be commercially profitable as an investment, production would have to be greater (e.g., a biomass design size of 500 to 700 tonnes, or harvest of 800-1,000 tonnes).

7.3.2.2 Initial Cash Flow

A cash flow for the initial years of operation of a facility harvesting 320 tonnes annually is shown in Table 7.7.

The working capital requirements for the project are substantial. The accumulated operating cash outflow requirements before sales would be in the neighborhood of $3.5 million. Total start-up costs including initial capital investment and the working capital necessary to bring the first harvest to market would be about $9.5 million. Revenues are assumed to come only from sales of market-size fish. However, additional revenues could be generated through sales of fingerlings and/or eggs. Including eggs and fingerlings for production would require a minor increase in capital costs for additional broodstock and egg incubation facilities.

7.3*3 Opportunities for Reducing Coats

A major component of the capital costs for the facility are the water supply costs (with or without recirculation). For this study, the use of pumped lake water near the Town of Hay River has been assumed as the water supply source. As described for the fingerling-only production facility (Section 6.0), the associated water intake costs would be largely eliminated if the water supply was by gravity. However, water volume requirements for the commercial growout facility are substantially larger and suitable sources are difficult to locate. Suitable volumes of warm, gravity-flow water likely would only be available from a large hydroelectric facility or industrial plant.

Other capital costs might be reduced if site construction conditions are good or if innovative approaches are used by facility owners/operators during construction and equipment installation (discussed in Section 8.0, Technical and Financial Viability Assessment). Possible cost reductions such as these are not certain and should not be assumed for initial financial assessment. Also, they likely would not represent the same magnitude of reduction as elimination of a major capital cost component such as the water intake pumps.

As discussed in Section 8.0, an alternative for commercial production is to grow juvenile fish at elevated temperatures during the first winter and early spring (i.e., fingerling production only), then grow the fish to market size in nearby lake pens to avoid the pumping requirements for large volumes of water as the fish reach larger sizes. With normal lake temperatures the fish would likely not reach market pan-size by the end of the first summer and would require growout well into the first autumn and winter normally under conditions of ice cover. This is technically possible and is being undertaken in areas of central Canada, but the likelihood of finding suitable sites is very limited in the southern Northwest Territories. Preferably, pen sites would have elevated temperatures during the fall and winter resulting from groundwater. Abandoned mine pits filled with groundwater have been found to have relatively high temperatures and are being used for aquiculture elsewhere. However, the water quality at mine sites must be monitored for potential problems such as low pH and high levels of heavy metals.

The financial viability of lake pen culture and fee-fishing has not been assessed as part of this study. The possible use of lake pens is discussed further in Section 8.0 (Technical and Financial Viability Assessment). The costs of lake pen operations would depend on the site location and type, and on production targets and methods.

8.0 VIABILITY OF AN ARCTIC CHAR PRODUCTION FACILITY NEAR THE TOWN OF HAY RIVER

8.1 GENERAL ASSESSMENT: FINGERLING ONLY PRODUCTION VERSUS COMMERCIAL GROWOUT

The results of this study indicate both fingerling production and commercial growout production appear to be technically possible at the Town of Hay River water supply pumphouse, subject to the uncertainties outlined in the following subsection. The technical feasibility and water quality conditions in one lake in the Yellowknife area has also been examined for possible Arctic char farm development. Development was concluded to be technically possible, subject to hatchery design measures to avoid water quality problems (Olding 1988).

At the Town of Hay River water supply pumphouse, commercial growout production appears to be financially viable only at very large production levels (greater than 400 tonnes), even with the incorporation of waste heat and assuming relatively high prices are maintained. Initial capital investment costs of at least $6-$11 million would be required, depending on the type of initial financial support provided. Fingerling production does not appear to be financially viable at the production level examined (250,000 fingerlings per year) unless purchasers accept prices approximately 20%-50$ higher than those obtained from southern sources. At prices currently paid to obtain fingerlings from southern sources, fingerling production appears to be viable at a – production level of 400,000-450,000 fingerlings per year, two to three times greater than the facility size examined during this study. Demand for fingerlings is expected to increase as the recreational stocking program in the Northwest Territories is expanded. The initial capital investment costs for a 400,000 fingerling facility are expected to be $0.9-$ 1.0 million.

The results of the present study suggest that the fingerling-only option (including broodstock) offers greater potential for further development than commercial growout production.

8.2 CRITICAL RISKS

8.2.1 Technical Risks end Uncertainties

Technical uncertainties exist in relation to biological risks (especially the performance of Arctic char during large-scale culture), siting condition% and facility and equipment to be used (the appropriate culture technology for northern conditions).

8.2.1.1 Biological Risks

As discussed in previous sections, Arctic char culture is technically possible, though experience at large-scale production levels is limited. Biological uncertainties exist (e.g., strain differences, size variability at early ages, and diet needs), but are being examined at research and commercial locations. Apart from these, the biological performance of cultured fish will be determined by the choice of a specific site (and, among other factors, the type of water supply and waste heat that might exist at that location) and the choice of appropriate culture technology for northern conditions. In addition, the success of a culture facility will be subject to the same risks that generally affect salmonid culture facilities, such as disease outbreaks, failure of mechanical systems and severe environmental conditions.

8.2.1.2 Site Uncertainties

A location adjacent to the Town of Hay River water supply pumphouse was defined for the present study, since a heating unit capable of producing waste heat was under consideration. Therefore, a lakeside water reservoir was assumed because suitable volumes of surface water or groundwater does not appear to occur in this area (discussed in Section 3.0). Development of such a reservoir as an intake for culture facilities is not common, though in concept is possible if satisfactory infiltration rates occur. A positive feature of a reservoir is the potential filtration of fine inorganic sediments that periodically occur in the area. A critical requirement, however, is field examination of water infiltration rates, and recharge capability, and, based on these data, calculation of exact excavation requirements

If sites are considered elsewhere, the technical and financial suitability of other water supply sources must be assessed individually and not according to the design assumptions for a water supply near the Town of Hay River water supply pumphouse. Ideal water supplies are usually high volumes of clean water, preferably spring water, flowing to a facility by gravity.

8.2.1.3 Equipment Uncertainties

The simplest and lowest risk facility designs usually have once-through water flow. Again, ideally, there would be no need to recover heat, recirculate water and, consequently, treat water (remove solids or nitrogen compounds), or add oxygen. Heat recovery systems (heat exchangers and heat pumps) and oxygen injection systems are used at commercial salmon hatcheries and trout farms, however, water recirculation/reuse systems have not been used commonly at a large commercial scale. Heat exchangers can vary in terms of heat recovery efficiency and maintenance requirements. Some units are suitable only for very clean water and require frequent. maintenance shut-down if turbidity increases. Newer units are less susceptible to these problems but are more expensive. Heat pumps use refrigerator coils to remove and transfer heat. These have been developed for use in fish culture facilities in Norway and are now used in several locations in Canada. They appear to have very high heat recovery capabilities at relatively low water temperatures and have low operating costs. Capital costs are higher than heat exchange units and operating experience in Canada is limited, but results suggest possible use where low temperature heat recovery is needed. The choice of heat exchangers or heat pumps will depend on specific site conditions and the type and amount of heat available.

Water recirculation for salmonid facilities has not been widespread because both capital and operating costs are usually high compared to completely open systems, and the risks of mechanical failure are high. As indicated in the present study, the capital requirements for water treatment (solids and nitrogen removal) can be high, however, recirculation offers substantial potential for using limited or expensive (e.g., heated) water supplies and new or improved approaches are constantly developing. In particular, improvements have been made to the media and systems for maintaining nitrogen-removal bacteria, and has included development of modular units for use on individual fish tanks. Nonetheless, if once-through flow is not possible at a particular site, water recirculation should not necessarily be considered a proven method to increase fish production. The site conditions and personnel training must allow for unexpected system shut-down and/or maintenance.

8.2.2 Financial Risks

Financial risks include changes in production costs and changes in revenues.

8.2.2.1 Production Costs

Production costs can be seriously affected by the supply and costs of critical inputs, including labour, feed, equipment maintenance and operating costs, egg purchase, power supply costs, veterinary costs, insurance, processing and financing. Risks associated with changes in these costs are common to all aquiculture operations Power supply costs and equipment maintenance and operating costs are of large importance for pump-ashore land-based facilities given their high power consumption requirements and changes in costs can be critical. Similarly, equipment maintenance and operating costs are high and can vary greatly amongst facilities depending on the equipment selected, operating conditions, the training of site personnel and availability of contracted support services. These costs could be higher for a facility in the southern Northwest Territories compared to a site in southern Canada.

8.2.2.2 Revenues

Reduced revenue can result from lowered production quantities, or quality and/or lowered selling prices. Reductions in the quantity or quality of fish can result from the technical risks described above. Selling prices for market size Arctic char are difficult to predict at present given large uncertainties related to future market acceptance of Arctic char in relation to salmon and trout. Similarly, both the demand and acceptable selling price for Arctic char fingerlings in the Hay River area is unclear.

An added uncertainty for market size char produced in the Hay River area is the cost of transportation to southern markets. Increases in transportation costs (especially air costs for fresh product) could seriously affect the competitiveness of fish produced in the North West Territories%

803 OPPORTUNITIES FOR REDUCING COSTS

8.3.1 Potential Economie8 of Scale

Economies of scale can be substantial with a landbased salmon farm (Babtie, Shaw and Morton 1988). That study shows costs of production were reduced by approximately $5.00/kilogram by increasing production tonnage from a 50 tonne farm to a 200 tonne farm. In the present study, the capital investment cost per biomass design size is $49/kg for the 50 tonne facility and $39/kg for the 200 tonne facility, assuming similar site and operating conditions The cost is $77/kg for the 250,000 fingerling facility (10 tonne biomass), though operating assumptions are different.

8.3.2 Design Features

The options for reducing costs are limited. A major cost component for landbased systems that is influenced by conditions at a particular site is the water intake costs. The water supply costs (reservoir construction, the installation and operation of water intake pumps, and possibly the installation and operation of water recirculation systems) at the Town of Hay River water supply pumphouse site are a high proportion of total costs (representing approximately 20% of capital costs for both the fingerling and commercial growout facility options). Consequently, as discussed below, a site that allows water to flow into the facility by gravity could greatly reduce this cost component.

Other capital costs might be reduced by design and construction modifications or innovations as development proceeds, especially if owners/operators are themselves from construction-trade backgrounds. However, these assumptions should not be made during initial financial planning. A common difficulty experienced during the start-up period of aquiculture industries is under-estimations of both capital and operating costs, normally leading to large unexpected time demands for site staff and the need for renegotiating financing after one to two years of operation. Operating costs for this study are conservative and ways to reduce them might be identified through operation of a pilot-scale facility.

8.3.3 Choosing an Alternate Site

One alternative in concept therefore for reducing costs is to select sites that receive water from a groundwater or industrial waste heat source by gravity. The water volume requirement for a fingerling production facility is relatively low, compared to the requirements for a commercial growout facility, and the possibility of finding such a site is high; however, the commercial production facility requires much larger water volumes and consequently the possibility of finding adequate water supplies is low. Elimination of the pumping costs at the fingerling facility would reduce unit production costs, but fingerling prices might still be higher than fingerlings produced in southern facilities.

Use of sites elsewhere will depend on their general suitability for fish culture and on the presence of a suitable source of waste heat. The heat requirements at a culture facility are determined partly by the heat demand (target temperatures and water volume to be heated), and the amount of heat recapture within the facility.

In the present study, a break-even production size for fingerlings appears to be approximately 400,000. Maintaining optimum growing temperatures would require winter temperatures greater than 12-13°C during the winter and up to 250,000 13TU/minute.

The minimum commercially viable production size is estimated to have a design biomass between 500 and 700 tonnes. To maintain a temperature of 3-5°C above ambient during winter would require approximately 400,000 BTU/minute for a 500 tonne facility and 600,000 BTU/minute for a 700 tonne facility, assuming most (e.g., 90%) of the water heat is recirculated within the system. This allows the facility to maintain minimum water temperatures of 4-6°C over winter if maximum water heating demand occurs at that time. To maintain optimum growing temperatures (e.g., 12°C) over winter would require approximately 1.4 million BTU/minute for the 500 tonne facility and 2.2 million BTU/minute for the 700 tonne facility.

A heat source of 400,000+00,000 BTU/minute would allow accelerated growth of early life history stages (Le., egg incubation and early fry rearing) by providing optimum temperatures during the first winter of growth (as long as the waste heat temperatures are greater than 12°C), since water volume demand is low. During the second winter of growth (and subsequent winters for fish grown to a large harvest size), when water demand would be high, some or all fish would be held at lower temperatures (e.g., 4-6°C).

8.3.4 Alternate Production Concepts

An alternative, in the case of commercial growout production, is to reduce the facility total water requirement by using lake netpens for at least part of the growout period. The viability of lake pen culture has not been assessed during this study, but in general, the unit production costs for cage culture are lower than for landbased system% Lake pen culture of salmonids is being undertaken elsewhere in Canada, including in lakes having ice cover in winter. However, the conditions are generally more severe and the site potential more limited in the Northwest Territories. Lakes in the Hay River area were examined previously for possible extensive trout farming; the suitability of these lakes were generally concluded to be constrained by shallowness and low productivity. Nonetheless, for development of an Arctic char culture industry to proceed, the regional potential for lake pen growout should be examined before investment In a landbased commercial growout facility is undertaken.

This examination should focus on a preliminary identification of deep lakes or abandoned mine pits (having water depths greater than 10 meters) that have relatively high fall and winter temperatures. If suitable lakes or pits are identified, other siting requirements (site logistics, water and ice physical conditions and water quality) can be examined and the potential production estimated for each site. Estimates of the potential lake pen production, potential fee-fishing production and future government stocking programs could be used to project fingerling production requirements The viability of developing combined on-land and lake growout operations within a geographical region can also then be assessed.

Development of lake pen sites would require that:

- sites are in close proximity to logistic centers and transportation routes to reduce operating difficulties and costs; and
- suitable depths, temperature% oxygen levels and other water quality factors (i.e., ph, metal levels, nutrients) to allow good growth and survival.

The minimum financially viable size of netpen operations would vary according to site and operating conditions, but assuming similar financial conditions to salmon production, a minimum size would be between approximately 50-100 tonnes. The fingerling production analysis in Section 6.0 suggests that fingerlings for growout will be more cheaply purchased from suppliers in southern areas unless local demand exceeds 400,000-600,000 fingerlings (pan-size growout of 100-150 tonnes). This suggests at least two relatively large lake growout operations would be required, if government stocking requirements were limited to 100,000 to 200,000 fingerlings

A second alternative is to have the production facility concentrate only on broodstock development and egg supply. Conceptually, the facility would maintain separate strains of char from the Northwest Territories in order to monitor culture characteristics. The objective would be to supply the industry within and outside the Northwest Territories with high quality eggs from selected culture stock. This type of facility is needed for development of the Arctic char culture industry and would be technically possible.

An important uncertainty is the future demand and competition for these eggs given broodstock programs that are being developed or are planned at private and institutional facilities elsewhere, particularly with Labrador stock in eastern Canada. This will influence the production size and costs for developing a central egg production facility in the Northwest Territories. To be commercially viable, the facility would have to be capable of:

- supplying a consistent supply of eggs from high-performing stock; and
- supplying the eggs at a competitive price and in sufficient volume for an adequate financial return.

Assuming cultured Arctic char production in Canada were to reach 5,000 tonnes in ten **years,** the egg demand would be 10 million to 25 million depending on the mix of **pan-size** and large size fish. If a hatchery based in the Northwest Territories were able to supply 25% of these egg needs, the potential production would be 2.5 million to 6.5 million eggs. Disease screened, domesticated salmon egg prices vary from approximately $O.1O to $0.20 per egg. At a high price of $0.20 per egg, the potential revenues would be $500,000 to $1.3 million. At a lower price of $0.10 per egg, the potential revenues would be $250,000 to $650,000.

A facility capable of maintaining sufficient broodstock and producing this number of eggs would be several times larger than the fingerling facility described in Section 6.0. A broodstock/egg production facility might be financially viable, but an assessment of the financial viability of a broodstock/egg production facility depends greatly on the assumptions concerning expected demand and competitive selling price.

8.4 PRACTICABILITY OF USING SALMON LAND-BASED "TURN-KEY" SYSTEMS

Commercial growout of salmonids in landbased systems has been attempted for over two decades and versions are in operation in Scotland, Iceland, eastern Canada and along the Pacific coast. The development of landbased systems has been limited compared to cage culture operations, largely because the initial capital costs are very high. The high capital costs (usually associated with water intake requirements and rearing tanks), combined with operating costs higher than predicted, have made the commercial viability questionable. In recent years, several Norwegian companies have offered complete systems and other companies, with commercial operating experience, have offered design and operational advisory services.

The engineering features of the "turn-key" facilities are usually sound, but the operating and biological assumptions are often optimistic. The viability of culture systems is usually determined by site-specific constraints and the suitability of species or strains of fish used. The turn-key systems offered by the offshore firms are based primarily on saltwater growout of Atlantic salmon and rainbow trout. Therefore, caution is needed for applying landbased technology in the relatively harsh northern environment and to Arctic char. Operation assumptions must be adapted to both the specific site to be developed and the particular species.

Given the high investment costs and uncertainties underlying costing assumptions identified in the present study, a full investment in a turn-key landbased system should not be undertaken. Pilot development is required to test site conditions, and to allow design modifications based on both site conditions and biological performance.

8.5 PILOT-SCALE DEVELOPMENT

The large uncertainties concerning the commercial viability of either a fingerling-only or market-size production facility outlined in the preceding subsections indicate that full-scale development should not proceed without initial small-scale testing. The purpose of the small-scale facility is primarily to test operating conditions and efficiencies at the site to identify ways to reduce both capital and operating costs. The facility can also be used to assess the biological performance of one or more strains of Artic char.

The minimum period of operation of the test facility should be one full production cycle. The intention would be to grow fish both to fingerling size and possibly to market size. The size of the test facility should be smaller than a production-scale facility but large enough to test operating assumptions. A suggested size is approximately 100,000 fingerlings (or 3-5 tonnes maximum biomass). This is half the biomass capability of the fingerling-only production facility described in Section 6.0, though the layout and components would be similar. The water flow requirements of the pilot facility would be approximately 92 LPS, or 18 LPS using 80% recirculation.

Apart from lower capital cost requirements for rearing tanks and water intake and distribution components, temporary, low cost facilities and equipment could be used where possible (e.g., trailers for office staff and laboratory requirements). A preliminary capital cost estimate at the Town of Hay River water supply pumphouse is approximately $350,000-$450,000. This could be reduced to $275,000-$325,000 if a suitable site having gravity water supply is identified elsewhere. Annual operating costs are expected to be $250,000-$300,000.

9.0 PROJECT IMPLEMENTATION

The results of the study indicate that full-scale investment in a fingerling-only or commercial growout facility should not be undertaken unless site development and fish production uncertainties and costs are reduced. Also, the results suggest that further efforts should concentrate initially on a fingerling-only plus broodstock concept.

9.1 FURTHER STUDIES

Prior to making final decisions on pursuing development at the Town of Hay River water supply pumphouse location, further pre-development studies are recommended. The pre-development investigations should include:

1. Examination of alternate water supply sources in the southern Northwest Territories, preferably able to supply water by gravity.
2. Geotechnical studies of the site at the Town of Hay River pumphouse to assess water infiltration rates, soil and permafrost conditions.
3. Estimation of future fingerling demand for stocking or alternative uses within the Northwest Territories.

Letter to Ren Res.

The factors that should be examined during these investigations are outlined in the following subsections.

A further consideration is that viable production sizes and investment costs vary greatly according to assumptions concerning financial support and production objectives. Acceptable production sizes and associated investment costs depend on whether the development objectives are for commercial profit or regional/social benefit. The potential for socio-economic benefits should be examined for facility sizes that appear too low for commercial profit, to determine whether they might meet the proponents objectives.

9.1.1 Examination of Alternate Water Supply Sources

Siting evaluation should include assessment of:

1. Volume and temperature regime of geothermal or industrial heat available, quality (if considered for direct use) and possible supply interruptions. Preferably, temperatures would be above 15°C to allow selection of lower temperatures and maximum heat production would be greater than 300,000 BTU/minute to allow for losses to heat exchange efficiency.

2. Volume, temperature regime and quality of an independent water supply source for the culture facility (if the industrial waste water cannot be used directly).

   The water intake volume requirement for the pilot facility would be approximately 92 LPS (or 28 LPS at 70% recirculation). The intake water volume requirement of a larger production facility (400,000-450,000 fingerlings) would be approximately 222 LPS (or 67 LPS at 70% recirculation).

3. Suitable land area for facility construction.

4* Logistic constraints (size and infrastructure at nearby communities, nearest airport, site access).

9.1.2 Geotechnical Studies *of the* Site at the Town of Hay River Pumphouse, or Alternate Location

If siting near the Town of Hay River water supply pumphouse is considered further, test ditches must be dug at several locations near the lakeshore to assess water infiltration rates. The quality of the infiltrating water should be assessed at the same time and excavated material can be examined to determine its suitability as berm material around the intake reservoir and/or as fill for preparing the culture facility land area.

At the water supply pumphouse location or alternate location, the soil and permafrost conditions must be examined and worst case flood-height conditions estimated for determining foundation and fffl requirements for culture facilities placed adjacent to the pumphouse area.

9.1.3 Estimation of Future Fingerling Demand

The demand for fingerlings in the Northwest Territories should be estimated over near-term (five year) and long-term (25 year) periods. The territorial government is currently examining the recreational lake stocking potential and these data, combined with expected use by private groups, can be used to develop demand forecast% The potential for private fingerling usage (i.e., fee-fishing using isolated lakes or pit& or lake pen growout) should be assessed.

9.2 PILOT-SCALE DEVELOPMENT

The size and objectives of a pilot-scale facility are outlined in Section 8.5. Pilot facility project development should be based on operation of a small (3-5 tonne biomass) test facility. The test facility should be operated for at least one year before scaling-up.

The objectives of the pilot facility are to test assumptions concerning larger scale site development and operating costs, the operating efficiency of equipment and the biological performance of one or more strains of Arctic char.

As indicated in Section 8.5, initial capital costs for support structures should be minimized by using temporary facilities (e.g., trailers) and equipment, where possible, in case site conditions or facility operations appear unsuitable and further development is not warranted. Nonetheless, the design layout and equipment installation should allow for scaling-up if the pilot facility proves successful

Results obtained at the pilot facility might indicate that the facility should not be developed further, or that development should proceed but under certain design and operating conditions.

The pilot facility should contain egg incubation and fingerling rearing facilities and facilities for **on-growing** fingerlings as broodstock.

Final site selection and evaluation studies (outlined **in** Subsections 9.1.1 and 9.1.2) must be undertaken. Based on the results of these studies, detailed engineering designs for a pilot facility and preliminary designs for a larger target size can be prepared. Several types of rearing units should be used so that operating performance can be compared.

902 PERSONNEL REQUIREMENTS

The facility manager should have five to ten years experience as manager or assistant manager with a salmonid production facility. The individual must have a strong background in salmonid biology, culture methods and, preferably, studies of stock performance under culture condition% **Initial** activities will require testing both biological and equipment performance and developing new approaches and techniques

The assistant manager or other personnel at the facility should have experience with mechanical and electrical **systems.** In particular, this experience should include operation and maintenance of hydraulic and heating systems under northern **conditions.**

9.4 **PRODUCTION-SCALE** DEVELOPMENT

The results obtained at the pilot facility will be used to determine whether capital and operating costs can be reduced, the types of production equipment and procedures that can be used most efficiently at a larger facility, and the target production of the larger facility.

If the **results** indicate that the project should proceed further, development planning will require preparation of:

- a market strategy;
- a technical production plan;
- administration requirements; and
- a financial plan.

These topics are outlined briefly below.

9.4.1 Market Strategy

At this stage, it appears that facility production could involve both fingerlings and high quality eggs. A preliminary definition of the expected demand for fingerlings can be made (as described in Subsection 9.1.3). During operation of the pilot facility the expected size, quantity, timing and selling price of fingerlings can be defined for different market groups. Similarly, the market requirements for high quality eggs can also be assessed.

9.4.2 Technical Production Plan

The overall scale of production and operating requirements will be defined during the pilot phase. A technical production plan can be prepared based on the market targets that are developed and information obtained on operating performance of equipment and stocks. This will involve identification of the numbers and production timing of fingerling and egg groupa and, in turn, necessary physical and support requirements, The general expected facility features and operating components are outlined in Section 6.0 of this report; these would likely be modified during pilot-scale testing. Outstanding technical risks would also be identified.

9.4.3 Financial Plan

The present study indicates that a capital investment of $0.9-1.0 million and Initial annual operating costs of $0.45+$ 0.5 million will be required to develop a break-even facility. These costs will be refined during operation of the pilot facility.

This information, together with sales **forecasts,** can be used to prepare financial forecasts for determining financing requirements

9.4.4 Administration RequIrements

General personnel requirements are outlined in Sections 6.2 and 9.2. The numbers of personnel and other administrative needs will be based on the technical and marketing needs outlined above. Two important components for managing the facility will be:

- well defined linkages with outside contract services for mechanical and electrical support and fish disease management; and
- on-going training of personneL

The linkages with outside contractors are essential for early responses to emergency situations. Training is important both for upgrading the skills of senior personnel and for developing capability amongst junior staff for morale and job permanence.

9.5 DEVELOPMENT TiMING

A time frame for undertaking project activities is listed in Table 9.1. A realistic target for start-up of the pilot operation is September 1990 for receiving **eggs.** If planning and construction activities **are** accelerated so that rearing units are in place by early spring, fry could be placed in the facility at that time. However, this would require site preparation and construction activities during winter.

Operation of a **full-scale** facility is indicated to start in 1992. This will depend on the types of results obtained at the pilot facility. The results could indicate that the pilot facility should be operated for a further one or two years before a **full-scale** facility is developed.

10.0 CONCLUSIONS

1. **Fingerling-only** production appears to be a more viable option than production of **market-size** fish. Technical uncertainties exist in relation to the site development requirement% the biological performance of Arctic char, and the operating performance of a culture facility in the southern Northwest **Territories.** Based on these uncertainties a facility should not be developed at **full-scale** until pilot testing has been undertaken.

2. Pessimistic capital costs for a 250,000 fingerling production facility are approximately $1.4 million and optimistic capital costs are approximately $0.8 million.

   Market conditions (selling price and quantity) for fingerling production in the vicinity of Hay River are uncertain. A fingerling-only production facility does not appear commercially viable at a size expected to meet or slightly exceed local demand (250,000 fingerlings), unless potential purchasers accept a relatively high price ($1.50-$2.00/fingerling).

   A minimum **break-even** production size for a fingerling facility at $1.20 per fingerling is approximately 400,000 fingerlings. Capital investment costs are estimated to be $0.9+ 1.0 million and annual operating costs are estimated to be **$450,000-$500,000.**

   Fingerlings produced by a commercial growout facility could be offered at much lower prices because most capital and operating costs for fingerling production would be absorbed.

3. Capital costs for **a** 50 tonne commercial growout facility (maximum biomass), maintaining a constant water temperature of **12°C** through the year, are estimated to be $2.4 million (optimistic) and $4.7 million (pessimistic). Capital costs for a 200 tonne facility (maximum biomass) are $7.9 million (optimistic) $14.6 million (pessimistic).

Optimistic capital costs for a 200 tonne facility, maintaining a minimum temperature of 4-6’C, is approximately $5.5-6.0 million.

The selling price of Arctic char is presently good (approximately $10.00/kg), but future prices are not clear, especially if culture production increases substantially.

Even with the benefit of waste heat and assuming high selling prices and substantial financial support in the form of grants and interest-free loans, a minimum harvest production size of 400-500 tonnes per year is required to break-even. Capital costs for a 400 tonne facility would likely be at least $6-$8 million and have annual operating costs of approximately $4-$5 million. The commercial suitability, in terms of acceptable profit, will require a larger facility size. A lower break-even production size would nonetheless provide regional or social development benefits if these meet the proponent% objectives,

Without substantial financial support, a minimum harvest production size would be at least 650 tonnes and more likely in the order of 800-1,000 tonnes (or design biomass size of 500-700 tonnes) would be required and a capital investment of at least $10 million.

4. Capital costs for water intake systems, including pumps, represent approximately 20% of the total capital costs. These costs might be reduced by selecting a site having a gravity water supply.

5. A pilot facility (e.g., 3-5 tonnes) should be operated at the chosen development site for several years before larger-scale investment is made. Such a facility can be used to evaluate site operating condition% equipment usage (including heat exchange units and modular recirculation units) and the biological performance of selected Northwest Territories's strains of Arctic char.

A 3-5 tonne pilot facility would require a minimum capital cost of approximately $350,000-$450,000 at the Town of Hay River pumphouse and possibly lower ($275,000-$325,000) at a site having a gravity water supply. A pilot facility of this size would be capable of producing approximately 100,000 fingerlings Annual operating costs would be approximately **$250,000-$300,000.**

6. Site development should not proceed at the Town of Hay River water supply pumphouse until detailed studies of soil, permafrost conditions at the culture site, and studies on water infiltration rates at the reservoir site are made. These studies are necessary to confirm the suitability of site conditions,

7. Costs to operate a water heating system would be prohibitive if the costs are borne by the culture facility. At break-even production **sizes,** approximately 300,000-350,000 BTU/minute of waste heat are required by a **fingerling-only** facility and approximately 400,000-600,000 BTU/minute will be required by a commercial production facility. Although the waste oil heat facility proposed for the Town of Hay River water supply pumphouse might not be considered further for heating the town water supply, it might nonetheless be **suitable solely for a fish** production facility.

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11.0 RECOMMENDATIONS

1. Further efforts should concentrate initially on a fingerling-only plus broodstock concept.

2. The results of the study indicate that full-scale investment should not be undertaken unless site development, fish production uncertainties and costs are reduced. If development is to proceed, further **pre-development** studies and operation of a pilot **facility** is recommended.

   Pre-development investigations should include:

   a) Examination of alternate water supply sources in the southern Northwest **Territories,** preferably able to supply water by gravity.

   b) Geotechnical studies of the site at the Town of Hay River water supply pumphouse, or elsewhere **if** a suitable location is **found.**

   c) Estimation of future fingerling demand for stocking or other uses within the Northwest Territories.

3. The viable production size and capital investment requirements vary substantially depending on the type of financing assumed and whether government grants or interest-free **loans** are used. Therefore, the potential **socio-economic** benefits should be examined in terms of facility production sizes and financial requirements that are acceptable for regional/social development, but are too low for commercial profit.

4. Pilot facility project development should be based on operation of a small (3-5 tonne biomass) test facility. The test facility should be operated for at least one year.

   The objectives of the pilot facility are to test assumptions concerning **larger-scale** site development and operating efficiency of equipment and the biological performance of one or more strains of Arctic char. Initial capital costs for support structures should be minimized by using temporary facilities (e.g., trailers) and equipment where possible.

5. A recommended time frame for project implementation is described in Section 9.0. Briefly, to begin operating a pilot facility by September 1990, pre-development studies (including final site selection) should be completed by December 1989, site engineering design should be completed by March 1990, and construction should be completed by July 1990.

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TABLE 3.1: **SUMMARY** OF WATER QUALITY OF SAMPLES TAKEN FROM WATER INTAKE AT TOWN OF HAY RIVER WATER SUPPLY PUMPHOUSE.
Source: L. Bruin, **personal communication.**

PERIOD OF SAMPLING	pH	COLOUR (TCU)	ALKALINITY	TOTAL HARDNESS (mg/L)	TURBIDITY (NTU)	IRON (mg/L)
April 30-May 25, 1982*	6.5-8.04	10-+50	96-112	124.0-164.0	8.5-97.1	0.02-0.83

* 22 samples taken.
\+ = Greater than.

TABLE 5.1 : EXPECTED AMBIENT TEMPERATURES, PREFERRED TEMPERATURES AND TEMPERATURE DIFFERENCES FOR ARCTIC CNAR INCUBATION, REARING AND BROODSTOCK

	J	F	M	A	M	J	J	A	S	O	N	D
EXPECTED AMBIENT	2	1	1	3	6	10	13	15	12	8	6	4
INCUBATION												
Preferred	7		-	-	-	-	-	-	-	**7**	7	7
Differences	5		-	-	-	-	-	-	-	**(-1)**	1	3
REARING												
Preferred	12	12	12	12	12	12	12	12	12	12	12	12
Differences	10	11	11	9	6	2	(-1)	(-3)	0	4	6	8
BROODSTOCK												
Preferred	6	6	.6	6	6		**6**	**6**	**6**		**6**	**6**
Differences	4	5	5	3	0	(-i)	**(-7)**	**(-9)**	**(-6)**	(-i	**0**	**2**

TABLE 6.1 : CAPITAL COSTS: FINGERLING PRODUCTION FACILITY

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		CONSERVATIVE	OPTIMISTIC
1.	SITE PREPARATION	100,000	50,000
2.	WATER INTAKE FACILITIES	102,000	72,000
3.	WATER DISTRIBUTION, TREATMENT AND DISCHARGE	154,000	119,000
4.	HATCHERY AND EARLY FRY REARING FACILITIES	20,000	12,000
5.	REARING TANKS	146,000	97,000
6.	WATER HEATING SYSTEM	88,000	53,000
7.	BUILDING CONSTRUCTION	217,000	109,000
8.	ELECTRICAL AND INSTRUMENTATION	227,000	66,000
9.	MISCELLANEOUS	60,000	60,000
10.	SITE HYDROGEOLOGICAL STUDIES AND ENGINEERING DESIGN	167,000	64,000
	Sub-Total	$1,279,000	$702,000
11.	CONTINGENCY (10%)	123,000	70,000
	TOTAL	**$1,402,000**	**$772,000**

TABLE 6.2: ASSUMED GROWTH OF ARCTIC CHAR FINGERLINGS.

MONTH	TEMPERATURE (cc)	WEIGHT (GM) ON FIRST DAY OF MONTH
FEBRUARY	12	0.3
MARCH	12	2.1
APRIL	12	5.9
MAY	12	12.5
JUNE	12	12.5
JULY	13	37.1
AUGUST	15	57.1

TABLE 6.3: FINGERLING PRODUCTION MONTHLY COST SCHEDULE (WITH BROODSTOCK PRODUCTION).

	JAN.	FEB.	MAR.	APR.	IMY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
VARIABLE COSTS													
Feed	2,450	3,466	5,624	8,107	13,850	1,503	1,371	813	852	1,014	475	1,062	40,587
Pumping	684	766	1,060	1,692	2,480	3,994	5,394	662	691	979	953	912	20,267
Stock Insurance	5,060	-	-	-	-	-	-	-	-	-			5,060
Sub-Total	8,194	4,232	6,684	9,799	16,330	5,497	6,765	1,475	1,543	1,993	1,428	1,974	65,914
FIXED COSTS													
Labour	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	105,000
Benefits	700	700	700	700	700	700	700	700	700	700	700	700	8,400
Fuel	150	150	150	150	150	150	150	150	150	150	150	150	1,800
Repair and Maintenance	1,250	,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	1,250	15,000
Veterinary and 01 agnostics	500	500	500	500	500	500	500	500	500	500	500	500	6,000
Fixed Insurance	965	965	965	965	965	965	965	965	965	965	965	965	11,580
Misc. Supplies	1,000	,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	12,000
General and AtMinistration	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	2,108	25,296
Depredation	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	4,217	50,604
Sub-Total	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	19,640	235,680
TOTAL	27,834	23,872	26,324	29,439	35,970	25,137	26,405	21,115	21,183	21,633	21,068	21,614	301,594

FIGURE 3.1:
Town of Hay River Water Supply Pumphouse

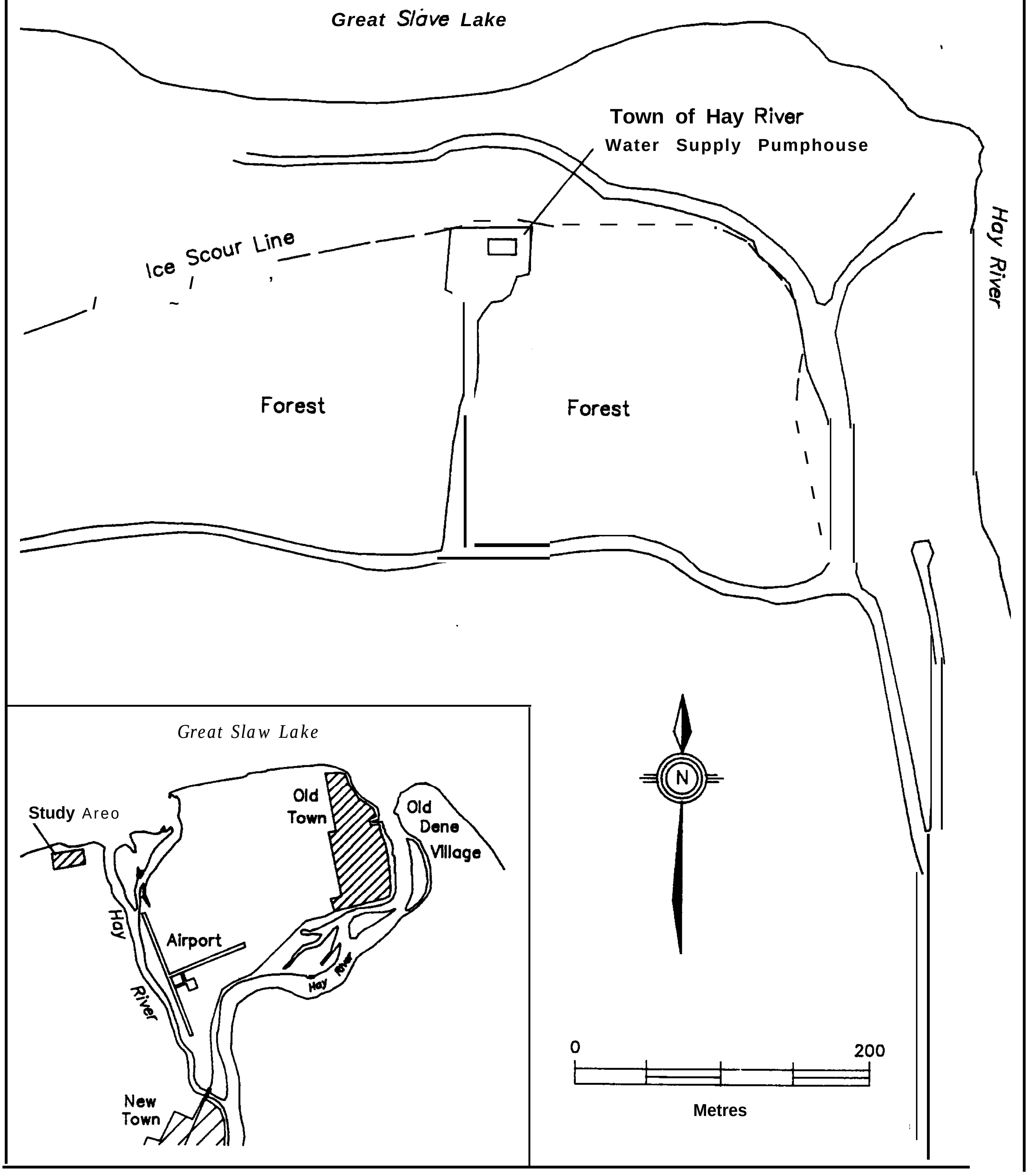


FIGURE 5.1:

Conceptual Layout of Arctic Char Fingerling Production Facility

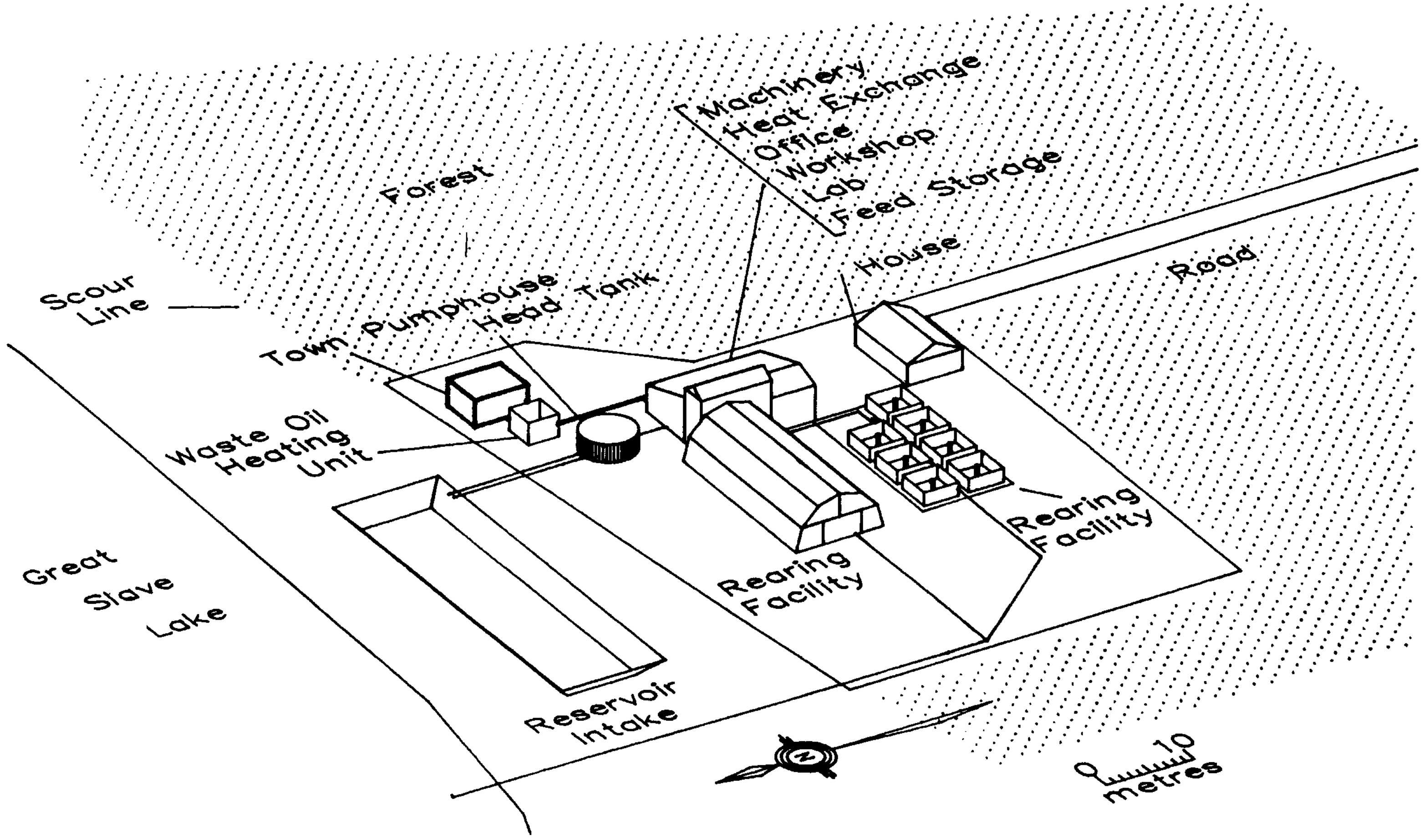


FIGURE 6.3: Conceptual Layout of Arctic Char Fingerling Production Facility – Plan View.

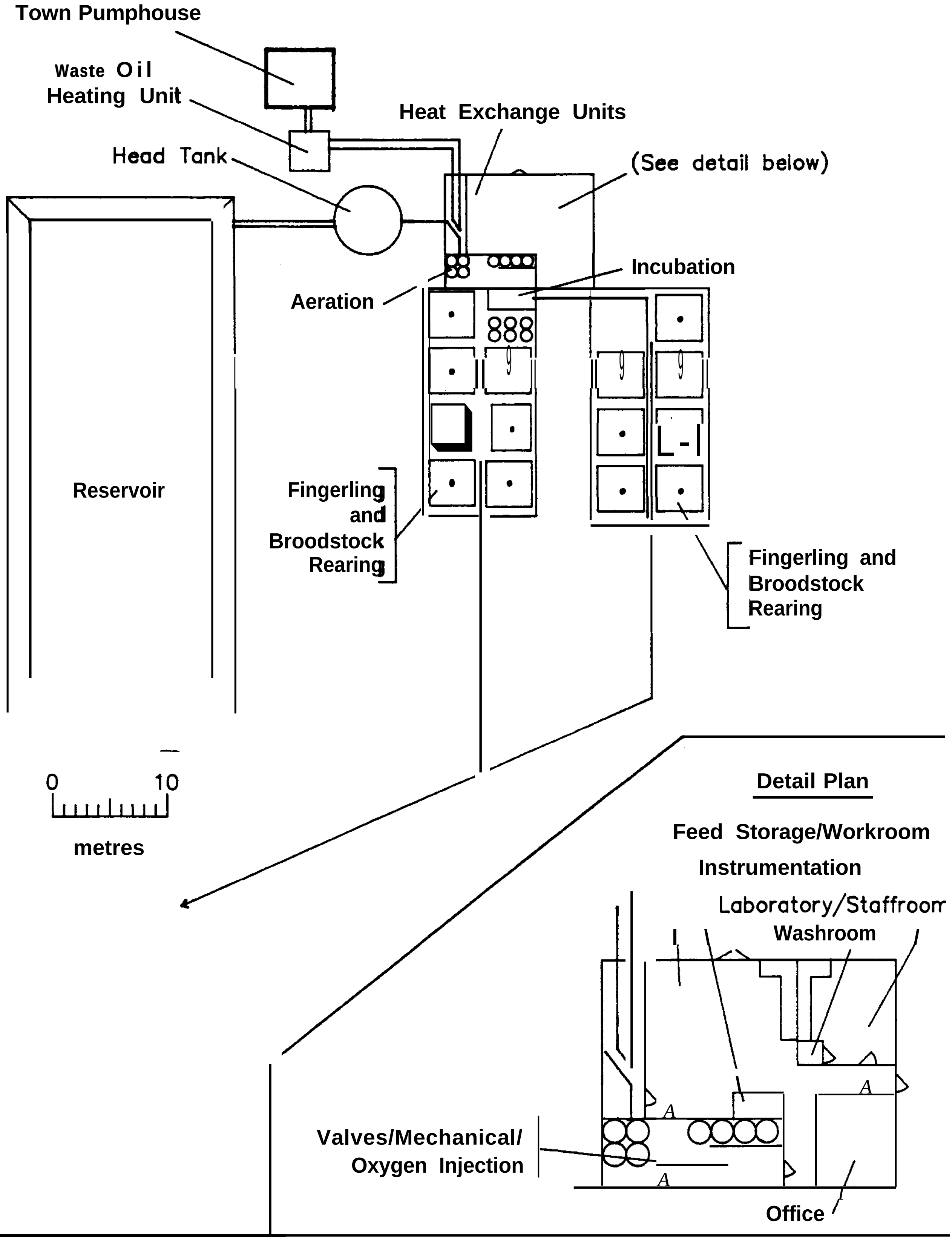


FIGURE 7.1:

Conceptual Layout of Arctic Char 200-350 Tonn Commercial Production Facility

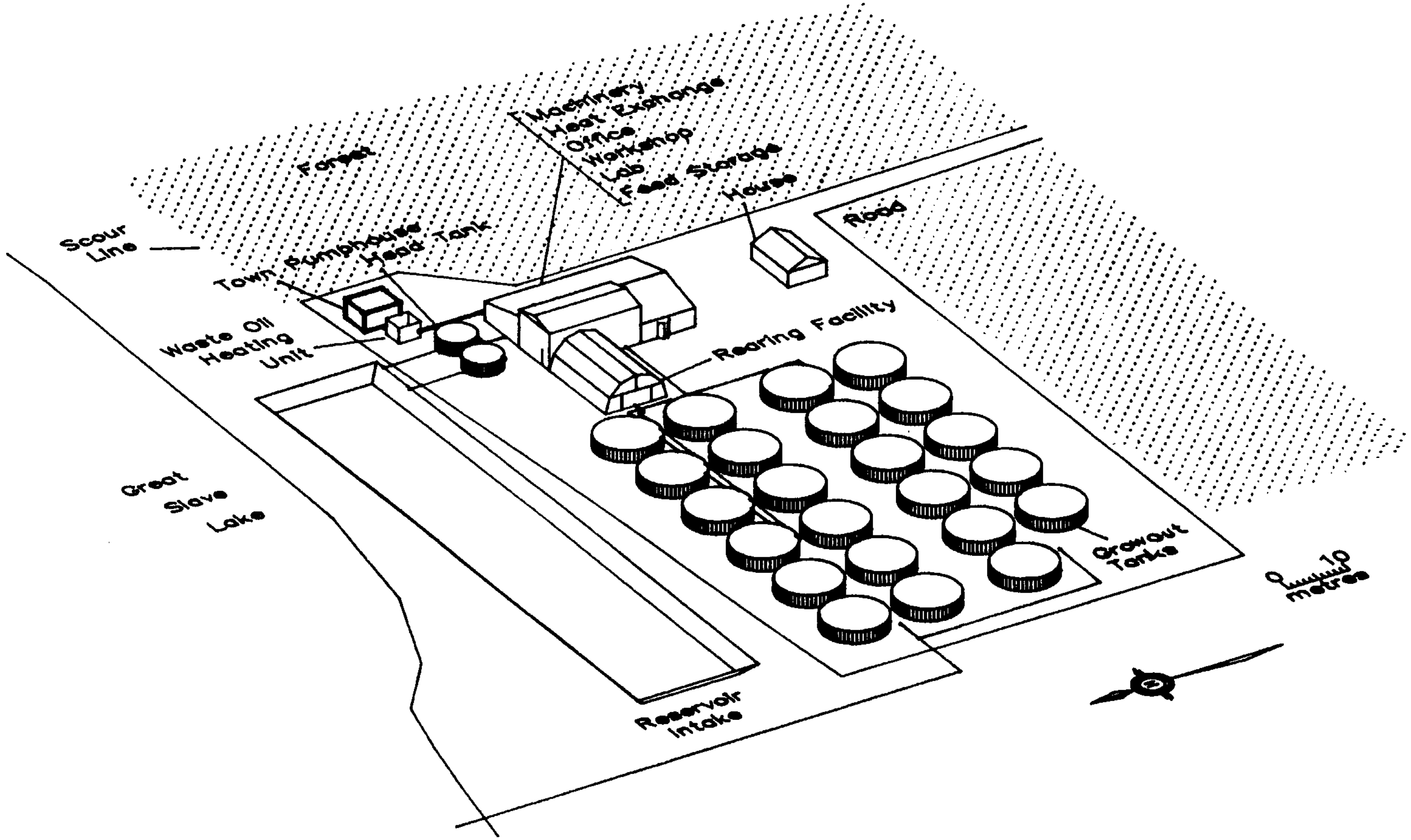


FIGURE 7.2:

Conceptual Layout of Arctic Char 200–350 Tonne Commercial Production Facility with Water Recirculation

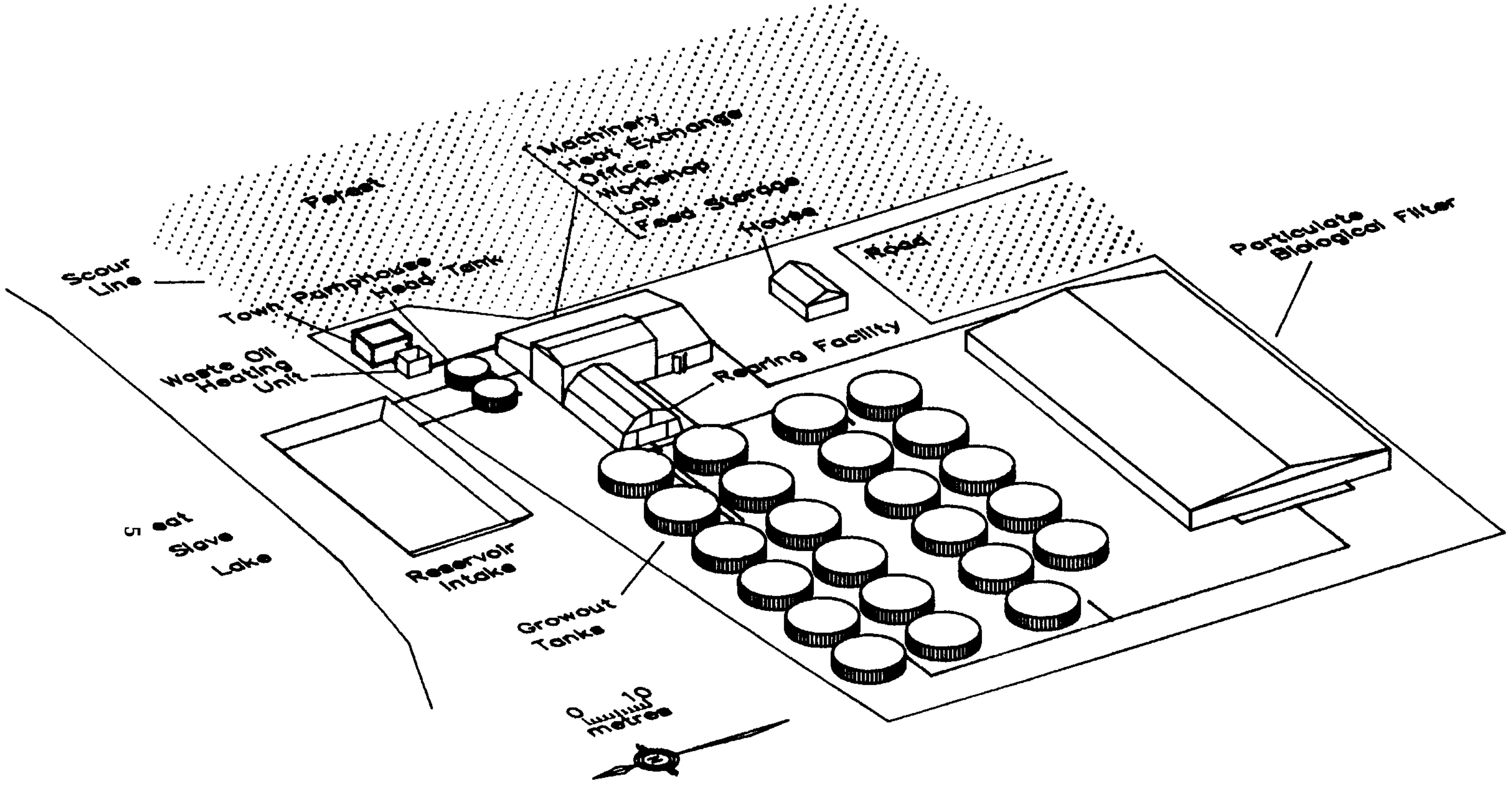
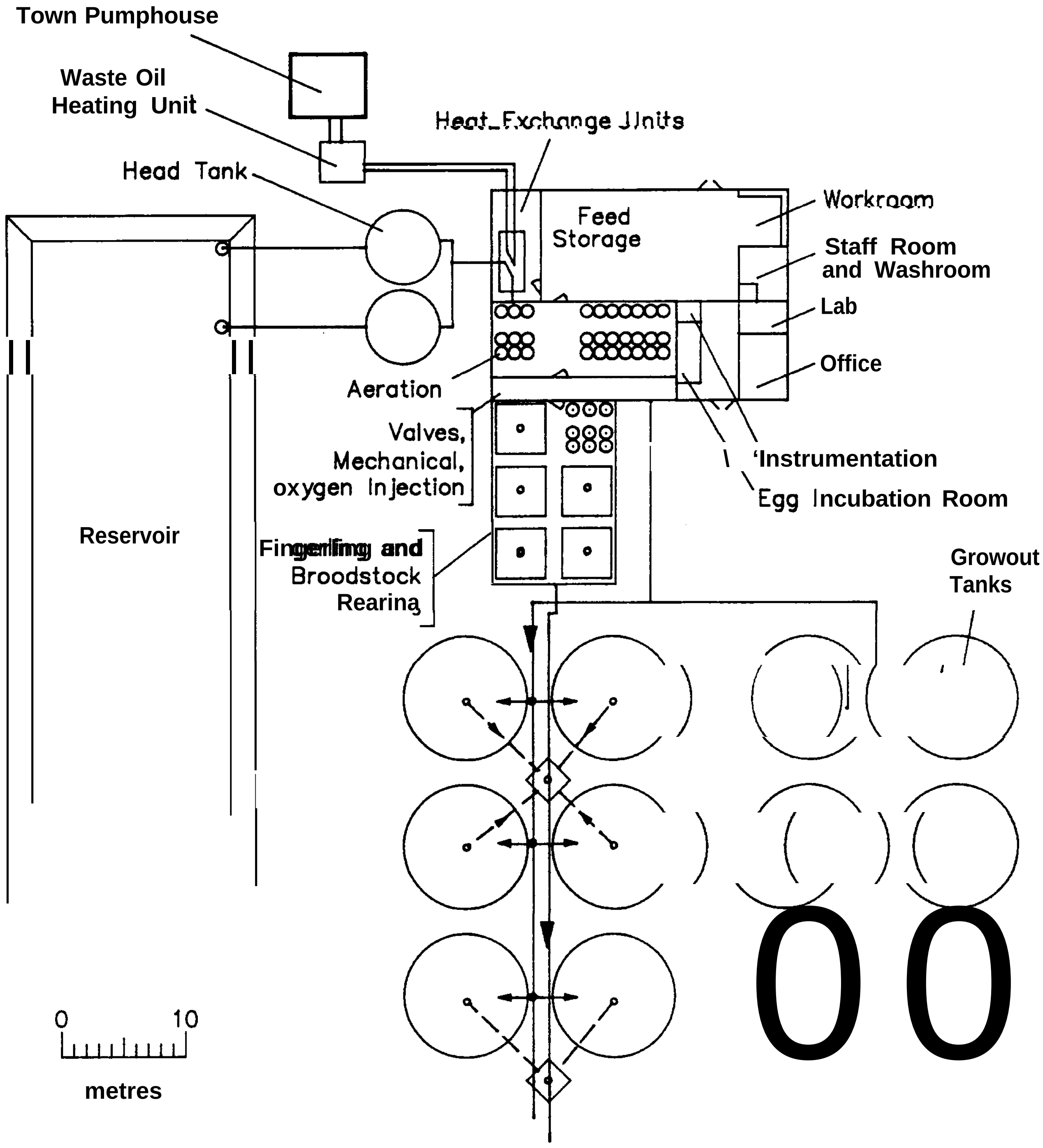


FIGURE 7.3:

Conceptual Layout of Arctic Char 200–350 Tonne Commercial Production Facility – Plan View



APPENDIX 1

POSSIBLE EGG SOURCES

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POSSIBLE EGG SOURCES

Egg sources for Arctic char are very limited compared to those for other cultured salmonids (salmon and trout). The choice of sources will be determined in part by the disease and genetic background of the egg stock, biological performance and costs. Potential egg sources include hatchery stock and direct collection from wild sources.

Hatchery sources

In Canada, Arctic char eggs are presently available from the federal Rockwood Hatchery in Winnipeg, the Huntsman Marine Laboratory in New Brunswick and a private farm in Saskatchewan. Arctic char eggs are also likely available from sources in northern Europe (Norway), subject to their acceptability according to Canadian importation regulations (discussed below), and will likely be available shortly from private facilities in the Yukon and Manitoba.

The Rockwood Hatchery has recently been raising Arctic char on behalf of the Government of the Northwest Territories. Fry from this facility are scheduled for transport to the Northwest Territories this year (1989).

Movement of eggs or fish from fish production facilities requires compliance with government stock transfer regulations intended to minimize disease and ecological risks. Normally, eggs must be obtained from facilities that are certified to be free of certain diseases specified in the federal Fish Health Protection Regulations Manual of Compliance. If the facility expects to sell eggs or fingerlings to others for ongrowing, they must establish their own disease free record as early as possible.

Experience with Arctic char culture in Canada is primarily for stocks obtained from northern Labrador and the Northwest Territories, though strains from Norway heve also been examined A high variability in growth performance and other characteristics is evident amongst Arctic char stocks. The Labrador stocks appear to display slightly better growth compared to strains from the Northwest Territories. Other strains of Northwest Territories Arctic char likely have better growth characteristics and generally growth rates will likely improve for subsequent cultured generations.

Wild Sources

Arctic char could be obtained from wild stocks within the Northwest Territories However, this perhaps should not be considered as the initial or mainstay egg supply for the facility. Egg collection timing can be uncertain and collection can be costly given a short period over which the char are in proper spawning condition and potential logistic and weather difficulties (M. Papst, personal communication). The spawn timing must be monitored closely so that field personnel and equipment are in place when spawning occurs.

Certain stocks of char in the Northwest Territories are known to carry serious diseases. Infectious Pancreatic Necrosis has been identified in fish occupying streams draining into the MacKenzie Delta region and, consequently, are recommended not to be transferred out of the region (Souter et al. 1986). Bacterial Kidney Disease has been identified at a number of dispersed locations (Souter et al. 1987). Consequently, the disease status of stocks must be evaluated before large egg collection activities are undertaken. After eggs are collected, they must be maintained in quarantine while disease tests are undertaken on the collected eggs themselves.