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FORT SMITH AREA
MUSKRAT HABITAT ENHANCEMENT PROJECT
FEASIBILITY STUDY

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JUNE, 1985

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Fort Smith Hunters and
Trappers Association
Box 673
Fort Smith, N.W. T.
XOE OPO

Attention: Mr. Jim Schaefer
President

Dear Sir:

RE : MUSKRAT HABITAT ENHANCEMENT PROJECT

Enclosed is the final report of the Feasibility Study for the Fort Smith Area Muskrat Habitat Enhancement Project. We have enjoyed working on this project, and we will be pleased to provide detailed design and construction supervision/management services when the project advances to implementation.

Yours very truly,

UMA Engineering Ltd.

D. J. Phelps, P.Eng.
Project Manager

cc : P. Gray, N.W.T. Renewable Resources

PERMIT TO PRACTICE
UMA ENGINEERING LTD.
Signature
Date
PERMIT NUMBER: P 329
The Association of Professional Engineers, Geologists and Geophysicists of Alberta

FORT SMITH AREA

MUSKRAT HABITAT ENHANCEMENT PROJECT

FEASIBILITY STUDY

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Whose extensive knowledge of site conditions over the years greatly assisted our work in defining historical conditions and in guiding.

Mr. Archie Mandeville

A retired NWT game officer with a great deal of experience in the area and who trapped along the Tethul River from 1927 to 1942.

The study was conducted on behalf of and with the support of:

J. Schaeffer, President, Hunters and Trappers Association
K. Hudson, Vice President, Hunters and Trappers Association
P. Gray, Supervisor, Habitat Management Section, Wildlife Management Division, Northwest Territories Renewable Resources
B. Bergman, Wildlife Officer, Northwest Territories Renewable Resources
D. Boxer, Regional Superintendent for Fort Smith, Northwest Territories Renewable Resources

Study team members were:

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M. LeBlanc, E.I.T., Project Engineer, Underwood McLellan Ltd.
R. Dagg, C.E.T., Technician, Underwood McLellan Ltd.
D. Barron, Environmental Consultant, MTB Consultants Ltd.
R. Ruttan, Senior Biologist, MTB Consultants Ltd.

SUMMARY

The Fort Smith Hunters and Trappers Association (HTA) approached the Northwest Territories Renewable Resources to have a study conducted into the feasibility of enhancing muskrat habitat by controlling water levels on designated creeks and rivers in the Fort Smith area. Underwood McLellan Ltd. (UML) was commissioned by the Habitat Management Section, Wildlife Management Division of Renewable Resources to assess the feasibility of implementing such a program.

The first of the two phase program is the completion of a bio-engineering feasibility study. Five sites were identified by the Fort Smith HTA which were situated on the Tethul River and its tributaries, north of Fort Smith. In the past, water levels have been steadily dropping and muskrat populations dwindling in this area. Previous studies have shown that to ensure winter survival, water levels must be maintained high enough to prevent freeze-out of food supplies. The purpose of this study was to assess the feasibility of building control structures in each area to return levels to their historic levels. Phase Two will involve the detailed design and construction of structures at three of the five sites.

The study began with a winter field trip conducted from April 2 to 6, 1984. Each of the five areas were examined both in the air from helicopter, and on the ground. Information gathered at proposed dam sites consisted of ice thicknesses, water depth, and soil types from auger holes, surficial geology and topography from level surveys. Information gathered from examination of habitat consisted of numbers, location and nature of muskrat push-ups and houses, vegetation, and basin characteristics.

Following the field trip, a preliminary feasibility assessment was performed and a preliminary report was subsequently submitted May 11, 1984, detailing the results. It was concluded that enhancement of muskrat habitat by dam construction was feasible in each of the five areas.

Following the submission, a spring field trip was conducted in order to gather additional biological and engineering data not available at the various sites during the winter field trip.

Following a helicopter reconnaissance of each habitat area, a detailed examination was conducted from the water by boats flown in by fixed wing aircraft. Final selection of each dam site was made and additional soils, topography and flow regime data was collected. Further examination of the habitat completed the data base on muskrat populations, vegetation, basin characteristics and other wildlife. Granular borrow areas were located by helicopter reconnaissance and samples obtained.

Air photos were taken of each habitat area at a 1 to 10,000 scale. Targets were placed prior to photography and ground surveys were performed during the spring field trip. The photographs were used for mapping the flooded area and for identifying relevant physical and biological features.

The engineering assessment involved assessing the technical feasibility and economics of constructing water retention structures in each of the five areas. The analysis consisted of examining each of the following:

- local surficial geology - bedrock and soils
- topography - both from ground surveys and air photography
- basin hydrology
- availability of construction materials
- construction logistics - haul routes, weather considerations
- relative construction costs

It is recommended that prior to detailed design, Contractors should be approached for cost estimates for construction of control structures at each site. Both the soil cement and rockfill alternatives for control structure construction should be cost estimated in order to determine which is most economical..

If the decision to advance to Phase Two of the project is reached, detailed design drawings and contract specifications should be completed on the three proposed sites. The contracts for the three sites should be tendered separately and/or as a single package to determine the potential cost savings in constructing the three sites within the same season, by one Contractor.

Marsh managment techniques for each habitat area should be examined in more detail. A monitoring program should be introduced once Phase Two begins in order to determine the actual impact of the enhancement project on the muskrat population. Two types of monitoring programs, population and habitat monitoring, are discussed in the report. . .

1.0 INTRODUCTION

1.1 BACKGROUND

The Fort Smith Hunters and Trappers Association (HTA) approached the Northwest Territories Renewable Resources to have a study conducted into the feasibility of enhancing the muskrat habitat by controlling water levels on designated creeks and rivers in the Fort Smith area. Underwood McLellan Ltd. (UML) was commissioned by the Habitat Management Section, Wildlife Management Division of Renewable Resources to assess the feasibility of implementing such a program. Terms of Reference for the study are included in Appendix C.

The first of the two phase program is the completion of a bio-engineering feasibility study. The second phase will involve the construction of three of the five sites which were proposed by the Fort Smith HTA.

The study area shown on Figure 1 is situated between 20 and 60 km north of Ft. Smith. Two trapping areas are located on the Tethul (Hanging Ice) River and three are located on its tributaries. The five areas have been trapped for many years and until recently have been producing sufficient muskrat to make trapping a viable enterprise. In the past, water levels have been steadily dropping and muskrat populations dwindling. Previous studies have shown that to ensure winter survival, water levels must be maintained high enough to prevent freeze-out of food supplies.

The purpose of this study was to assess the feasibility of constructing control structures in each area to return water levels to their historic levels.

1.2 METHODOLOGY

The study began with a winter field trip conducted from April 2 to 6, 1984. Those present were: D. J. Phelps, Project Manager, UML, D. Barron, Environment Consultant, MTB, R. Ruttan, Senior Biologist, MTB and R. Dagg, Senior Technician, UML. In addition the assistance of Louis Beaver was commissioned through the HTA as a guide. Each of the five areas were examined both in the air from helicopter, and on the ground. Information gathered at proposed dam sites consisted of ice thicknesses, water depth, and soils type from auger holes, surficial geology and topography from level surveys. Information gathered from examination of habitat consisted of numbers, location and nature of muskrat push-ups and houses, vegetation, and basin characteristics.

Following the field trip, a preliminary feasibility assessment was performed and a preliminary report was subsequently submitted May 11, 1984, detailing the results. It was concluded that enhancement of muskrat habitat by dam construction was feasible in each of the five areas.

A spring field trip was subsequently conducted by D. Phelps, R. Ruttan, L. Beaver and M. LeBlanc. M. LeBlanc, an engineer with UML, conducted a portion of the engineering aspect of the work. The purpose of the trip was to gather additional biological and engineering data not available at the various sites during the winter field trip.

Following a helicopter reconnaissance of each habitat area, a detailed examination was conducted from the water by boats flown in by fixed wing aircraft. Final selection of each dam site was made and additional soils, topography and flow regime data was collected. Further examination of the habitat completed the data base on muskrat populations, vegetation, basin characteristics and other wildlife. Granular borrow areas were located by helicopter reconnaissance and samples obtained.

Air photos were taken of each habitat area at a 1 to 10,000 scale. Targets were placed prior to photography and ground surveys were performed during the spring field trip. The photographs were used for mapping the flooded area and for identifying relevant physical and biological features.

The following report presents the findings of the feasibility assessment. The report contains a general biological and engineering assessment which contains items common to all the sites. Site specific information on the engineering and biological aspects of the study is then presented. A proposed monitoring program to assess the impact of construction on the environment is discussed followed by conclusions and recommendations.

2.0 ENGINEERING ASSESSMENT

2.1 INTRODUCTION

The engineering assessment involved assessing the technical feasibility and economics of constructing water retention structures in each of the five areas. The analysis consisted of examining each of the following:

- local surficial geology - bedrock and soils
- topography - both from ground surveys and air photography
- basin hydrology
- availability of construction materials
- construction logistics - haul routes, weather considerations
- relative construction costs

Based on these factors plus the required water "levels developed from the biological studies, a conceptual design of a water retention structures capable of passing design flows was advanced.

Using air photos, the water level increases and subsequent flooded areas were defined.

The following describes the approach used to define each engineering factor and to develop the concept designs.

2.2 SITE SELECTION

The Fort Smith Hunters and Trappers Association initially located five sites to be investigated as shown on Figure 100-1. These sites were examined for their engineering and biological suitability. The primary concern was to maximize the benefits of flooding. From an engineering viewpoint, the ideal site was one with favorable topography such as a narrow channel, steep rising banks and rock outcrops to serve as abutments. This in turn, aided in minimizing construction costs.

2.3 GEOLOGY

The study area is located at the western limit of where the Pre-Cambrian Canadian Shield outcrops. The bedrock, predominantly granite, is typically overlain by mineral soil, usually clays and silts. The topographically low areas are covered with muskeg. Granular deposits are frequently located amongst the rock outcrops.

Local soil and rock conditions were determined at each site by visual observation and soil borings.

2.4 HYDROLOGY

Flow estimates were based on pro-rating flows from rivers with drainage basins of similar magnitude and composition. The area is predominantly composed of swamp and marshes which tend to behave as a sponge during heavy rains. As a result, conventional rainfall-runoff mathematical models produced unrealistic results.

The analysis involved the processing of historical streamflow data from nearby Water Survey of Canada gauging stations and establishing flows for the various return periods. Flows for the proposed sites were computed by pro-rating on the basis of drainage basin size. See Appendix B for. detailed calculations.

Water levels at Site 1 and 4 should be easily maintained into the fall and winter due to the constant inflow. Maintaining the water levels at Sites 2, 3 and 5 may be a problem due to the lack of inflow and the loss of water through evaporation. A rudimentary water balance analysis has been performed for Sites 2, 3, and 5 in order to estimate the reservoir drawdown due to evaporation losses.

2.5 DESIGN

In general, the design considered various control structures capable of retaining water and passing the design floods.

In deciding on the type of control structure to be constructed, the existing site conditions, and available materials were considered.

Site conditions are such that the structure would have to be constructed on a soft foundation. The available construction materials are restricted to deposits of sand and gravel, silt and clay.

Using the above parameters, several types of control structures were examined as summarized in Table 2.1. The soft foundation eliminates such alternatives as the timber crib or concrete weir. The shallow depth to bedrock eliminates the sheet pile wall as there would be insufficient soil for imbedment.

A dam composed of soil cement filled geotextile bags (Alternative 6) was found to be most feasible based on the above conditions. It can be built on a soft soil foundation using the locally available material. The proposed structure will have a high local labour content and will employ locally available equipment. It will also prove to be secure against ice forces and beaver activity. The beaver would tend to block spillway type structures.

Building the entire structure out of soil cement bags would result in an extremely large number of bags. It is therefore proposed to have a compacted earth fill core armoured with soil cement bags. The core can be constructed with the silts and clays in the area. Prior to construction, it is necessary to remove all soft and pervious material.

Due to the high manual labour content of the soil cement alternative, producing shotrock for a rockfill dam may be as economical. The dam would be constructed out of shotrock produced from the exposed bedrock and the upstream side lined with a clay blanket to prevent seepage.

In comparing the two alternatives, the life expectancy and the required maintenance was examined. The exposed surface of geotextile bags deteriorate in about 3 to 5 years. However, the underside of the top layer of bags and the underlying bags will not deteriorate significantly with time. The long term durability of the structure will be controlled by the soil cement material. This material has been shown by applications in use now to stand up for extended periods of time. A life expectancy of 50 years is realistic. Maintenance costs should average out to in the order of $1-2,000 per year per structure.

TMLE 2.1

ALTERNATE STRUCTURES

TYPE	MATERIALS	ADVANTAGES	DISADVANTAGES
1. Earth Dam	Soil	- Lou Cost if Materials Available	- Availability of Appropriate Material - Requires Summer Construction Requires Large Equipment Requires Erosion Protection - Local Equipment May Not Be Available
2. Rockfill Dam	Shot Rak Boulders	- Erosion Resistant - Durable	- Permeable; Difficult to Prevent Leakage Under and Around High Cost of Producing Rock
3. sheet Pile Wall	Steel	- Secure - Good Hydraulic Control - Can Be Build in Winter - Low Maintenance	- Shallow Soil for Embedment Specialized Equipment Required - costly
4. Timber Crib	Wood, Fabric. Backfill	- Secure on Good Foundation - Can Take Stoplog Weir - Uses Local Materials	- Requires Good Foundation Good Control - Rots Unless Pressure Creosoted Materials Used
5. Concrete Weir	Sand, Gravel . Cement	- Secure if Foundation Good	- Aggregate May Not be Available - Requires Good Foundation - Forming Required - Costly
6. Soil Cement Bags	Soil, Cement, Geotextile	- Easy to Construct - Uses Local Materials - Uses Local LabOur Exclusively - Equipment Material Costs Low - Can be Built on Soft Soil Foundation	Availability of Material - Durability of Fabric

The shot rock structure is essentially permanent, i.e. infinite life expectancy. Maintenance would be limited to repairs from major flood events and average out to be in the order of $500-1,000 per year per structure.

Each of the five sites have been examined and a design proposed depending on the specific site conditions. In general, the structure will operate as an overflow weir and typically will have two sill elevations. The lower sill elevation will be controlled by the biological factors. This sill section will typically be the width of the channel and normal flows of 1 in 2 years will be confined to it. Flows in excess of this, up to the 1 in 100 year flow, will pass over the entire weir, confined within the abutments that are also elevated. A structure of extreme length will only have the centre portion, typically 40 m, armoured with soil cement bags. The remainder will be constructed from compacted soil, typically silts and clays available in the abutment areas and will not be armoured. This portion will be sufficiently elevated in order to confine all flood flows to the section armoured with soil cement.

The structure will have a 1 m top width with 2:1 side slopes. The top width will be increased to 2 m for the earth fill portions to facilitate construction. Aprons are provided on the upstream and downstream sides of the structure where erosion and scour may be a concern. The transition zone between soil and soil cement is protected with a layer of soil cement bags for a distance of 5 m.

All elevations are referenced to a water elevation of 100.0 m measured at dam locations at the time of site surveys. Bench marks have been set up in order to re-establish these elevations in the future. The extent of the flooding has been established by air photo interpretation. Air photography of the sites was conducted May 25 and 26, 1984. The mapping has been done using this photography with limited ground control.

2.6 CONSTRUCTION LOGISTICS

Examining the various water retention structure options and site specific conditions, it was concluded that structures should be constructed of either soil with soil cement filled geotextile bags for erosion protection or rock fill. Because of extensive marshes and creeks between Fort Smith, the nearest center, and the construction sites, winter roads will have to used almost exclusively to mobilize conventional earth moving equipment and materials. Movement of equipment between some sites during the summer construction season may be possible after detailed terrain analysis. One such possibility is transportation between Sites 2, 3 and 5. Potential access routes are identified in Figure 100-1. With the exception of the existing winter roads, these routes would require extensive clearing and travel would be slow. These routes are only approximate and would require the assistance of a guide for on site location.

An alternative to ground transport, is transport by air. This is dependent on the size of helicopters available in the area and in turn restricts the size of equipment that can be used.

At each site a construction area would be cleared for equipment storage and stockpiling of material. Borrow areas are nearby and summer haul roads are possible.

At each dam site, a diversion culvert was proposed to route normal flows around the construction area. costs to supply, install and block these culverts have been included. Culverts could be fixed with control gates at a cost of about $5,000 and opened in the spring to al low passage of fish, however, this would be the only time water could be routinely spilled from the habitat areas. Maintenance of culverts would be time consuming and costly since these would be blocked by beaver shortly after being unplugged.

Fish ladders, if deemed necessary, would be very costly and require high maintenance. Structures would typically be constructed of imported treated wood and would add in the order of $25-50,000 to the construction cost. Construction would be difficult due to soft foundation soils or shallow bedrock. Maintenance costs would probably run $2-5,000 per year.

3.0 BIOLOGICAL ASSESSMENT

3.1 INTRODUCTION

In order to assess the feasibility of muskrat habitat enhancement by water retention and to predict changes which will occur as a result of man made alterations in the hydrological regimes, it is important to understand both the dynamic interrelationships which created the existing habitat conditions and how they developed over the past six decades. For the former, indicators recorded in the brief field studies have been used. For the latter, both the oral accounts of trappers who spent many years in the area and the observations of published authors in the disciplines of wetland development, plant ecology and the field of muskrat ecology and management have been utilized.

Since conditions throughout the area are fairly uniform, much of the habitat condition description applies equally to all sites and will not be repeated at length in the individual site descriptions. Variations in conditions existing at specific sites and the effects of water retention on them, will be described in the appropriate sections.

3.2 HABITAT CONDITIONS

3.2.1 Vegetation

The entire study area lies within the High Boreal Wetland Region described by Zoltai and Pollett (1983) with all potential enhancement areas characterized by extensive “Fens” (ibid) which ecologically represent advanced stages in successional vegetation change from shallow open waters and “marsh” to “bog” forest.

Zoltai and Pollett (op. tit) clearly describe the type of fen most common in the study area as follows:

> "...peatlands characterized by surface layers of poorly to moderately decomposed peat, . . . They are covered with a dominant component of sedges, although grasses and reeds may be associated in local pools. Sphagnum is usually subordinate or absent, whereas the more exacting mosses are common. Often there is much shrub cover of low to medium height, and sometimes a sparse layer of trees."

These fens cover most (80% or more) of all the basins of the Tethul Rivers, Trout Creek and Warm Creek, as well as, large portions of the lakes within the study area. Many of the smaller lakes and marshes of the area have totally disappeared under the encroaching vegetation while others have been reduced to shallow ponds or marshy sloughs. Large forest species, including balsam and aspen poplars, black spruce and tamarack (larch) have also encroached at several places around the perimeters of the study area basins, particularly at those points which have not been seasonally flooded for a decade or more.

Many of the earlier as well as more advanced stages in seral development in wetlands described by Raup (1935), Moss (1953) , Daubenmire (1968) and others are also represented but the dominant feature of the habitat is the well developed sedge dominated fen.

These fens have developed over a substrate of soil (sediment) washed in from the rocky uplands after the forest and surface vegetation was removed by fire. The process of fen development is demonstrated by the vegetation patterns described below.

Existing vegetation patterns which are common to the area are illustrated in Figures 100-2 and 100-4 and are delineated in simplest form on the maps of each site. Typical patterns consist of irregular bands and enclosed areas of vegetation which can be identified by one or more of a dominant and visible species such as sedge (S), willow (W) etc. Where two or more species are intermingled they are presented in approximate order of dominance. For example, sedge with smaller amounts of willow is shown as S-W.

Dominant vegetation patterns and variations are described as follows:

Sedge dominated fens (S or S-R) which usually begin at the edge of open water and extend toward the basin edge, also contain varying amounts of cattail which encircles or covers smal 1, shallow pools or forms the border of the open water or channels. Emergents such as horsetail (goose grass), sweet flag (rat root), bulrush ("Scirpus" sp.), arrowhead and cattail also form narrow fringes at the edge of rooted (r) sedge meadows or floating (f) sedge mats or fens. These and other unidentified emergents are indicated as (R) on the maps. The rooted sedge fens (R) also include intrusions of willow (W) which occur as scattered individuals or as thick clumps or thickets depending on water levels. Other rushes (Juncus sp.) and grasses ("Calamogrostis canadensis" and others) also increase toward the outer edge of the basins.

Willow (w) dominates the inshore portions of the fens and exists as narrow bands or as thickets. It is usually associated with ground cover which ranges from pure sedge to mixtures of sedge, grasses, and other shrubs depending on water levels. Alder may also be present along the edges of streams or on the borders of inshore lagoons which are seasonally inundated or ponded as illustrated by (m) on the mapping. This willow zone may also include intrusions of swamp birch (Betula glandulosa) and young spruce developed on a moss/grass base, but as yet these intrusions are relatively rare.

Balsam poplar, aspen and birch (As on photomosaics) in clear or mixed stands usually form the outer borders of basin vegetation and have developed on the gently sloping deposits of soil which have drifted in from the basin slopes. This zone may also include alders, willows or spruce along with associated shrubs - depending on soil and moisture conditions.

The status and distribution of a few of the common plants of the area are provided in Table 3.1.

3.2.2 Water and Ice Conditions

Water levels are usually highest during spring run-off although in April and May 1984 levels seldom exceeded bank full conditions except above active beaver dams, one which exists at Site 3. In most areas, rooted sedge fens were several centimeters above the existing water levels of lakes and streams. These "raised" fens are often virtually dry during most of the summer and are only lightly used by muskrats.

Autumn water levels can reach or exceed bank full conditions when beaver repair or build dams, but in most cases, do not exceed bank full conditions. Flooded portions of fens are usually too shallow to support wintering muskrats, being frozen to the root systems at depths of about 20 centimeters or more.

TABLE 3.1

STATUS AND DISTRIBUTION OF SOME COMMON PLANTS
OBSERVED IN THE TETHUL RIVER STUDY AREA - May 1984

COMMON NAMES	SCIENTIFIC NAMES	STATUS AND DISTRIBUTION
Sedge	Carex spp.	Sedges (Carex) cover all of the rooted fens and many of the floating fens. Several species depending on water depth.
Cattail	Typha latifolia	Common but not abundant around shallow ponds and edges of channels and fens.
Sweet Flag, Rat Root	Acorus calamus	Common but not widespread in edges of deep water channels through floating fens and unconsolidated masses of vegetation roots and debris.
Arrowhead	Sagittaria cuneata	Common along streams, edges of channels through floating fens and on unconsolidated masses of vegetation roots and debris.
Burreed	Sparganium sp	Occasional along edges of deep water (1.0-1.5 in) channels.
Bulrush	Scirpus spp.	Small stands but sparse at edges of deep water and floating fens. Possibly Scirpus validus (Moss 1953) but could be others.

COMMON NAMES	SCIENTIFIC NAMES	STATUS AND DISTRIBUTION
Marsh Cinquefoil	Potentilla palustris	Common on floating fens and unconsolidated masses of vegetation roots and debris.
Goose Grass	Equisetum sp.	Extensive stands on Lower Hay Lake. Site conditions vary from solid bottom to floating fen. Probably E. fluviatile (Moss 1953) .
Yellow Pond Lily	Nuphar variegatum	Abundant in all lakes and most slow moving streams.
Milfoil	Myriophyllum sp.	Appeared to be major submerged plant in open water.
Pondweed	Potomogeton spp.	Sparse but present in all lakes and in the Tethul River. May include several species (Moss 1953).

During earl y snow melt periods, water often overflows large areas of frozen fen flooding occupied push-ups. When freezing occurs, these push-ups are frozen-out. This was observed at several points during the April field check and reported as a common cause of freeze-out in sedge covered fens (Louis Beaver personal communication).

Floating fens and unconsolidated root mats are also frozen although not as deeply. Even here, the open water space beneath the fen is very small and with the scarcity of vegetation, muskrats are restricted to the edge of the fen, nearest deep water. Currently, the only deep water is found within the channels of streams and open water areas of lakes where depths range from about 1.0 m to 3.0 m.

Ice thickness cannot be clearly related to climatic conditions/predictions in this area, since thickness varies widely with local conditions such as amount of snowfall at freeze-up and early winter, density and type of emergent vegetation and type of bottom materials. If several centimeters of snow occurs at or soon after freeze-up, ice will be thinner and overflow will occur as the weight of snow increases. If marsh vegetation is dense and tall (eg. cattail), ice is often very thin. Similarly, ice over dark organics is also much thinner than over mineral soil or silts. These factors were considered when deciding optimum dam heights.

Muskrats are most effected by ice when it freezes below the root systems of desired food plants and thus prohibiting their use, or when "runs" are frozen to the bottom. Fortunately, muskrats will survive where there is very little water beneath the ice cover as long as they can burrow beneath the ice to reach the roots or green shoots of food plants.

Ice thickness at occupied push-ups measured 0.5 m while in the deepest part of the lake was 0.7 to 0.8 m. River ice was thinner and variable with the thickest sections being about 0.3 m.

3.2.3 Summary of Habitat Conditions

The dominant habitat type is the sedge or sedge-willow covered fen without sufficient water to allow access to food plants other than those at the edge of the fen. The emergent food plants which are available to wintering rats are sparse and generally limited to narrow, discontinuous strips at the edges of deep (1 m+) water.

Sedge covered fens over a thick organic layer with advanced encroachment of terrestrial vegetation combined with sufficient water for winter survival found only on channels or open lakes, describes a type of muskrat habitat which is not represented in any of the available literature and is unique in almost every repect. Thus guidelines for enhancement provided by Geddes (1981), Ambrock and Allison (1973) and others particularly concerning suitable depths for both vegetation development and winter survival of muskrats, do not consistently apply. The status and condition of the habitat in the Tethul River basin is such that the encroachment of vegetation into the basin, must at least be retarded, if not caused to retrogress before the habitat can be significantly improved for muskrats. Furthermore, suitable foods are in short supply, because of the above described vegetation changes and also by the lack of water where they now exist. Consequently freeze-out is a major and continuing problem that can only be resolved at present by retention of sufficient water to prevent it. Level ditching or the creation of "pot-holes" prior to construction of water retention dams would also measurably improve conditions for winter survival and the development of suitable marsh vegetation.

It is a fact that most of the preferred food plants also thrive in relatively shallow water (ie. less than 1 meter). However, there are areas of existing vegetation which are near the outer edges of the basin which can only be utilized by muskrats by an increase of a metre or more of water at the dam site. Therefore, the recommended high increases in water level are more for the dispersion and winter survival of muskrat populations than for vegetation development per se.

Periodic draw down to stimulate vegetation growth cannot be used effectively here until such times as the basin vegetation has retrogressed to an earlier stage of seral development. Even then it would tend to accelerate seral development to today's point. The periodic flooding and drying along the main channel of the Tethul River at Sites 1 and 4 have created the present condition and are cases in point.

3.3 MUSKRAT POPULATIONS

3.3.1 Population Status

Muskrat populations as indicated by winter houses and push-ups observed in April and by feeding signs observed in May, varied somewhat between sites but in all areas were very scarce. During field investigations only one house was found (Site 1) and it was frozen and unoccupied. Push-ups or small houses hidden in vegetation or under snow drifts may have escaped detection but in view of low water conditions and extensive frozen ground, it is doubtful that many were overlooked.

3.3.2 Productivity and Mortality Factors

Litter production was difficult to determine because of the few female specimens examined. One adult female (nearly two years old) revealed two placental scars in one horn of the uterus. Another female showed no evidence of breeding and was identified as a yearling by the symmetrical priming pattern on the flesh side of the pelt.

Other factors, primarily the scarcity of preferred foods available to wintering muskrats, also suggest that initial productivity (i.e. production of young) is low. In view of the low numbers of houses and push-ups, it is unlikely that litter production has been greater than natural mortality in recent years.

Lack of winter food, because of its scarcity or because access to it is blocked by ice, is probably the principal mortality factor among muskrats in the study area. Even in relatively productive muskrat habitats of the Peace-Athabasca Delta, Ambrock and Allison (1973) found that the proportion of unoccupied or “frozen-out”, push-ups and houses was highest in areas where vegetation was relatively sparse.

Mink predation and the destruction of push-ups by mink and foxes, are common here. They should not, however, be regarded as primary causes of low muskrat populations or population decline. Errington (1963) discusses predation and effects of predation on populations and suggests that other factors such as lack of food, freeze-out or intraspecific aggression often "conditions" muskrats so that predation occurs.

3.3.3 Distribution and Habitat Utilization

Wintering populations (as evidenced by push-ups) are found mainly along river and creek channels and in smaller numbers near or on the edge of partially floating vegetation mats in 1 akes.

Shorelines were not checked for bank dens but it is unlikely that burrowing would be possible considering the rocky shorelines and the present distance from deep water. Bank "dens" were seldom seen even in past years, when conditions were much better. (Louis Beaver, personal communication).

Water depths associated with wintering use (i.e. 1.0 to 1.5 m) were similar to those found by Ambrock and Allison (1973), in the Peace Athabasca Delta, although habitat conditions, particularity vegetation and bottom conditions are considerably different in the "Delta".

Ice thickness varied considerably, being as much as 0.8 m in open water and as little as 10 cm on organic ooze and in dense vegetation cover. Information from Louis Beaver indicates that ice thickness was generally not a "problem" when the combination of feed and deep water (i.e. 1.0 meter or more including ice) were available. Early freeze-up without snow was much more serious since water would freeze to the bottom in shallow occupied areas (eg. pools in sedge-rush meadows) and as winter progressed overflow water would flood the push-ups, then freeze as the snow settled in the spring.

Several cases of this type of freeze-out were observed during the April field study.

Vegetation use in winter was difficult to determine by examination of push-ups, where only fragments of food plants remained. The push-ups themselves were usually constructed of submerged plant material which appeared to be largely Myriophyllum and Ceratophyllum combined with masses of fine rootlets (probably sedge) and pieces of emergent vegetation debris. Recognizable foods included shoots of arrowhead, pieces of lily root and rat root. In one case some green bulrush (possibly "Scirpus validus") stems were found in the push-up.

Summer use included all species of emergents, in their early stages of growth, found along the edges of the fens or the creek banks, including arrowhead, sedge, cattail, ratroot stems, etc.

3.4 OTHER WILDLIFE

The wildlife observed in the area is summarized on Table 3.2. Aquatic and semi-aquatic mammals in the area include beaver and mink. Otter are also present from time to time (Louis Beaver personal communication).

TABLE 3.2

OTHER WILDLIFE OBSERVATIONS
IN THE TETHUL RIVER STUDY AREA, April - May, 1984

COMMON NAMES	SCIENTIFIC NAMES	REMARKS
MAMMALS		
Moose	Alces alces	Common at all sites on year around basis. Observed 5 from air.
Black Bear	Ursus americanus	Common at all sites - one cinamon colored bear at Site 3, one large black at Site 1.
Timber Wolf	Canis lupus	Common in region. Fresh tracks near Upper Hay Lake. One wolf on Little Bent Tree in April.
Lynx	Lynx lynx	At low point in cycle. One observed on Tethul River in April .
BIRDS		
Canada Goose	Branta canadensis	Common in area. Observed pair with nest on Lower Hay Lakes.
Mallard	Arias platyrhyncus	Common on all sites.
Pintail	A. acuta	Common on all sites.

COMMON NAMES	SCIENTIFIC NAMES	REMARKS
BIRDS (cent’d)		
American widgeon	“Anas americana"	Common and nesting.
Shoveller	A. clypeata	Common on all sites.
Green-winged Teal	A. crecca	Common on all sites.
Lesser Scaup	A. affinis	Very numerous all sites.
Common Goldeneye	Bucephala clangula	Numerous on all sites.
Bufflehead	B. albeola	Site 1, 2, 4, and 5.
White-winged Scoter	Mellanitta deglandi	Site 1, 2, 3, and 5 common.
Surf Scoter	M. perspicillata	Site 2 and 5 several pairs.
Common Merganser	Mergus merganser	Site 1, 2 and 4 single malea.
Arctic Loon	Gavia arctica	Site 2 only - s ngle.
American Coot	Fulica americana	Site 2 and 5 numerous
American Bittern	Botaurus lentiginosus	Individuals at all sites.
Killdeer	Charadrius vociferus	Common at all sites.
Lesser Yellowlegs	Tringa falvipes	Common at all sites.

Moose sign was observed at many points. They probably make extensive use of the fens and lakes on a year around basis.

Tracks of three wolves were seen near Upper Hay Lake. One wolf was also observed on Little Bent Tree Lake in April.

One large lynx was also seen on the Tethul River.

Waterfowl were plentiful and included several species although diving ducks, particularly lesser scaup and goldeneye, appeared to be most common. Canada geese were observed on several occasions and were mostly paired. The activity of one pair (Big Hay Lake) suggested that a nest was nearby.

3.5 HISTORY OF HABITAT DEVELOPMENT AND POPULATION CONDITIONS

Although water availability and winter levels have been lower than normal for several years, they have not been totally responsible for the present conditions in any of the study areas. Drought and low run-off have been contributing factors in the development of the existing habitats but basin filling and the seral development of vegetation as described earlier, were the primary causes of present conditions.

Former trapper Mr. Archie Mandeville[1], who trapped muskrat and beaver in the area from 1927 to 1942 and Mr. Louis Beaver, a resident trapper who spent much of his life in the

1. Archie Mandeville is a retired N.W.T. Game Officer who now resides in St. Albert, Alberta.

area , described early conditions and the changes which occurred over the past +50 years. When Mr. Mandeville began trapping in Lower (Big) Hay Lakes in 1927, fen development was in its early stages, with many fens consisting of large floating mats of vegetation in open water and narrow fringes of solid and rooted fens around the perimeters of the lakes. For example, the fen surrounding the rock "island" on Warm Lake was absent 50 years ago (Magi iore Beaver personal communicantion). The development of rooted fens, that are so common today, was apparently retarded by annual spring "floods" of melt water combined with retention of high water levels in autumn by beaver which then occupied the area in fair numbers. Heavier summer rainfall may also have been a factor. Mandeville states that during the open water period of the spring hunt "we could paddle all over" including the vast plain between the Slave River and the Tethul. Louis Beaver also confirmed that such conditions persisted to some extent until the late 1960's.

Although fen development doubtless began before Mr. Mandeville's time, it was probably imperceptible. The first acceleration in this development probably began in the mid 1930's. At that time trappers who "came in from Alberta" (Mandeville personal communication) burned some of the marshes to remove dead vegetation - a common practice among southern trappers at the time. These fires escaped into surrounding areas with a two-fold effect. The burning of the marshes released nutrients into the water while the upland fires also allowed noticeable sedimentation of the basin to begin. Fortunately these fires were not extensive and the over-all effect was mainly an increase in marsh productivity.

The major turning point in the development of present habitat conditions was in 1953 when a severe fire devastated most of the forests (Carlson 1953). This fire not only charged the marshes with nutrients on which vegetation thrived but it also allowed large amounts of sediments to be washed from the surrounding rocks and hills. Run-off water from melting snow and sparse summer rains no longer filtered slowly into the marshes to maintain summer water levels and as the marsh vegetation developed, evapotranspi ration also increased and probably accelerated drying of the shallower marshes in low rainfall years.

Beaver continued to maintain winter water levels, at or near, present elevations at some points, however, all but the deepest ponds were gradually filled or much reduced in depth by the processes described earlier.

Many of the earlier beaver ponds were eventually abandoned and at present, long stretches of creek basins, such as those of Trout Creek and Warm Creek, consist of a series of filled and/or dry beaver ponds with existing beaver colonies found only on the main channel or in the open lakes. Old abandoned dams and logging canals, through the dry meadows to the basin edge, are common in all areas of the study. According to Louis Beaver, beaver populations and activity are much lower than they were in the early 1970's, although they still serve to maintain water at or near bank-full levels until after freeze-up. Unfortunately, however, the dams tend to leak or are broken and drained by otters during the winter, (Reid, 1982, Mandeville and Beaver, personal communication) thus exposing the muskrats, which inhabit the channels and floodplains, to freeze-out and/or predation. Before the river and lake basins were filled with sediments and organic matter, the loss of water through a broken or leaking dam, was not as serious as it is now since most of the upstream basins were deep enough to support substantial muskrat populations over winter.

Although early harvest records are not available at present, Mr. Mandenville recalls catching 500 - 600 muskrats each year in Lower Hay Lakes. Louis Beaver's father, Magliore Beaver, reported that he caught 1,000 in Warm Lake in one season in the mid 1930's.

The process of basin filling and present fen development was nearly complete by the late 1970's at which time a noticeable reduction in muskrat populations occurred (Louis Beaver personal communication). Although trapping records are not always reliable indicators of population status, the records of small harvests after 1979, as shown on Table 3.3, suggest that muskrat populations have reached a very low point.

TABLE 3.3

MUSKRAT AND BEAVER RECORDS [1] OF TETHUL RIVER TRAPPERS [2]

YEAR REPORT	MUSKRATS NO. OF TRAPPERS	MUSKRATS ANIMALS REPORTED	BEAVER NO. OF TRAPPERS	BEAVER ANIMALS REPORTED
1979	3	163	3	86
1980	4	81	4	92
1981	3	165	3	22
1982	2	46	3	20
1983	2	54	2	13
1984	Not available but reported to be low.			
TOTALS		369		234.

1. Obtained from Wildlife Officer, Fort Smith from Spring Trapping Records.

2. A total of five (5) Trappers are known to trap within the Study Area at irregular intervals.

Reports of muskrat distribution and habitat use (Mandeville and Beaver personal communi cation) are both interesting and valuable to the present study. Both stated that muskrat houses were most numerous on the floating sedge mats (floating fens) in the lakes, although fair populations also existed in the river and creek basins. Preferred emergent food plants such as bulrush, cattail, and burreed were also more plentiful and widespread and were heavily utilized by muskrats. Submerged plants such as pond weed ("Potomogeton" sp.) were also "plentiful in the deep water" areas. As the areas "dried out" lake populations dwindled and largest wintering populations were found on the creek basins where autumn water levels of "2 to 3 feet or more" were retained by beaver dams. In these areas, wintering muskrats also made much use of the "grass" (i.e. sedge) which was then common on the flood plains.

3.6 ASSESSMENT OF ENHANCEMENT POTENTIAL OR FEASIBILITY

At the beginning of the study, the primary concern in assessing enhancement potential or feasibility was whether sufficient water to prevent freeze-out of muskrats could be retained by dam construction. At this point the problem was purely technical and those sites, where a dam would retain sufficient water to prevent or reduce freeze-out, were deemed to be feasible. However, muskrats are dependent on vegetation which thrives within fairly precise limits in water depth - some of which are much less than are required to prevent freeze-out. Therefore, enhancement potential depended on both the depth of water that could be maintained and the amount of water that would provide the greatest improvement in vegetation type and distribution while preventing or reducing freeze-out conditions. With these conflicting factors in mind, it was decided that optimum water level increases at most dam sites should range from one meter to two meters depending on the physical characteristics of the basin and the distribution and conditions of the existing habitat. As will be shown in specific site descriptions, sane of the existing vegetation areas will be obliterated in order to restore suitable habitat conditions to larger areas which are now unproductive for muskrats. Depending on site characteristics and hydrological regimes, the enhancement potential will vary widely.

Some of the effects of flooding will be dramatic, particularly in the first few seasons after flooding. Others will be subtle and noticeable change will only be observed after a period of several years. Sane of the changes or effects of flooding on habitats and populations are described below.

3.6.1 Effects of Flooding on Vegetation

The immediate effects of flooding will be obliteration of some of the existing vegetation zones and increased development of others. The former will occur in areas where one (1) or more metres of water is added to rooted sedge fens, which for a time, will become and remain as shallow open water lakes having borders of well developed sedge. The latter will occur in areas where shallower water inundates poorly developed and dry sedge/rush and sedge/willow vegetation. However, most of the willows, trees and grasses now which thrive at or above the water table in these areas will die out although some willow species will persist for a long time in very shallow water. Sedge development will be rapid in these areas and will constitute a major food source for muskrats when flooding occurs.

Goose grass ("Equisetum" sp.) will also spread rapidly in newly flooded areas and will enhance the food supply

Unfortunately, some shoreline trees will also be damaged or destroyed by the first flood. Floating rafts of vegetation and other debris will collect in the drowned tree areas and will eventually serve as a basis for others to develop.

Floating sedge fens will not be adversely affected, although the poorly consolidated edges may break off and drift to new and shallower locations. Similarly, clumps of loosely rooted emergents will also float and drift into the shallow areas where they will eventually re-establish themselves. These alterations will serve to distribute seine of the preferred emergents such as cattail and rat root over a much larger area than they occupy at present.

Submerged plants may not change appreciably except to re-distribute themselves into the shallower portions of present deep water lakes and channels and increase in creek channels when flow ceases as a result of darning. These channels will become elongated, deep water ponds.

The re-distribution of preferred food plants will be very slow, since the existing supply of seeds, seedlings and living root clumps is quite low. Furthermore, muskrats will continue to use these plants intensively wherever they survive flooding. The most dramatic increase in vegetation and use by muskrats will be that of sedge and cattail which will develop rapidly in shallow (<0.5m) areas.

The changes in the newly flooded basin floor will be less apparent but no less important to development and distribution of vegetation. As the oxygen-charged water overflows and saturates the poorly developed peat and surface vegetation mat, decomposition will increase, frozen soils will thaw and the upper peat layers will settle or slump to varying degrees. Insects and other aquatic microfauna will also aid decomposition of peat and other plant materials.

Several years may elapse, however, in some areas before the bottom materials are suitable for useful vegetation growth.

3.6.2 Effects of Flooding on Muskrat Populations

The immediate effect of flooding will be a dispersal of resident populations into vegetation which has survived inundation or where new growth (e.g. sedge) is rapid. Other populations will construct winter houses in areas which are now virtually dry. Dispersal of muskrats into newly flooded areas has been witnessed" (Ruttan) at Cumberland House Saskatchewan in 1961 when level ditches were blasted into a ponded sedge meadow and when water levels were raised on shallow marsh in the Cumberland House portion of the Saskatchewan River Delta. Dispersal into extremely shallow or dry areas following flooding, was also noted by Ruttan on the Mackenzie River Delta in 1967 and on the Peace Athabasca Delta in 1971. Populations will also be augmented by muskrats from areas adjacent to the flooded basin. This also was observed at Cumberland House, Saskatchewan, during a tagging study in 1961.

Winter foods such as cattails and some sedge which are often unavailable because of deep freezing, will be utilized and losses of young muskrats through over-crowding, competition for food and fighting will also be reduced. Populations which survive the first winter will be more widely dispersed in spring and summer habitat which will also reduce competition for food and breeding sites. These changes should stimulate successful and increased litter production.

Since there are literally no published precedents for either the present habitat conditions or those that will occur as a result of flooding, it is extremely difficult to predict future muskrat production in any part of the study area. However, it is not unreasonable to suggest that production per unit area of the enhanced habitat will equal if not exceed that of relatively low production in more "typical" muskrat habitat. Ambrock & Allison (1973) estimated muskrat production on 10 lakes in the Peace Athabasca Delta. In 8 of the poorest producing lakes, muskrats per unit area of emergent vegetation were estimated to range from 0.25 per hectare to 7.0 per hectare and averaged 2.63 over a variety of vegetation types.

Although all the factors effecting these estimates are not known, they are consistent with early trapping production reported in portions of the study area which were then similar to portions of the Peace-Athabasca muskrat habitats. A. Mandeville (personal communication) reported that he often caught 500 - 600 muskrats on Lower Hay Lakes (Site 2) and when additional trappers were present the total harvest was 1000 - 1200. When an average of 2.6 muskrats/hectare is applied to the enhanced Lower Hay Lakes, it is interesting to note that the predicted population would approximate 800 muskrats.

Although actual populations cannot be predicted accurately at this time, substantial increases will occur in the first years after flooding. However, sustained high populations cannot be maintained without rigorous trapping pressure which will prevent over-use of the limited supply of preferred foods. The importance of such population control, particularly in the first years, cannot be over-emphasized.

Projected population estimates for specific sites, assume that population control will be carried on from the first year of flooding. In some cases, fall trapping may be necessary to reduce pressure on limited winter food supplies.

3.6.3 Effects of Control Structures on Fish Passage

With reference to the safe passage of fish, most of the sites presently have conditions which impede the passage of fish. The Tethul River has populations of whitefish, northern pike and probably suckers. However, it is unlikely that a bank-full dam at Site 1 would impede autumn whitefish movements any more than the large beaver dam which presently exists. A 2-metre dam at Site 4 would require a fish ladder for whitefish if a significant population summered downstream of the site. However, it is doubtful that a significant population of fish occurs between the falls and the proposed Site 4. As well, populations downstream probably cannot move up over the falls.

Trout Creek had a significant movement of whitefish to Little Whitefish Lake (near Site 2) and probably into Big Hay Lake until the 1930's. However, it is doubtful that the present creek conditions of shallow water and numerous beaver dams would allow any movement of whitefish upstream of the Tethul River to Site 2. The same situation would exist on Warm Creek (Site 5). Therefore, the construction of fish ladders or fish bypasses would serve no useful purpose under present conditions.

4.0 SITE 1 TETHUL (HANGING ICE) RIVER

4.1 GENERAL DESCRIPTION

Within this area, the Tethul River meanders through extensive marshlands. There is very little relief and during periods of high flows, there is extensive flooding. Several potential dam sites in the area have been examined and due to the little relief based on air photo interpretation, it has been concluded that only bank-full levels can be achieved. This would result in a 0.3 m rise in water level as measured at time of survey. Although at the various sites there seems to be rising banks to serve as abutments, these are only local highs and construction of a dam would result in the flow diverting around the structure. The recommended site is located upstream of a small island, where the river divides as shown on Figure 101-1.

The total area affected by the dam is difficult to determine at the scale of the present study. However, it has been noted that the existing beaver dam raised the water level for several kilometres upstream. It is also expected that bank-full conditions on the Tethul River will raise the permanent water table over a very large area and during peak flows will contribute several centimeters to off-river marshes. The enhancement area is estimated at 0.5 square kilometres at this time.

4.2 BIOLOGICAL ASSESSMENT

4.2.1 Habitat Conditions

Muskrat habitat consists of irregular flood plain fens and shallow open pools upon which terrestrial vegetation is rapidly encroaching as shown on Figure 101-1. The banks of the river are marked by a low and discontinuous levee overgrown by willow, alder, and swamp birch, as well as other low shrubs and grasses. The levees, with a heavy snow cover, may provide some winter shelter for muskrats.

Many of the adjacent fens are dry or only periodically inundated by spring floods and by water retained by autumn beaver dams.

Present muskrat wintering habitat consists of the edges of the river and a few shallow ponds off of the river. The beaver dam, which raises the water level at freeze-up, usually leaks or breaks during the winter with the result that many of the push-ups along the river and most of the off-river push-ups freeze out. The hanging ice condition allows greater access to food plants but also allows more frequent mink predation.

The winter foods include all of the species named earlier although sedge and submerged plants were present in the push-ups. Trappers also report that muskrats often make use of river clams which are common along the Tethul River.

4.2.2 Muskrat Populations

At freeze-up 1983, trappers reported that there were "more push-ups than they had seen in many years". In April, fourteen (14) push-ups and 1 house on a small island were counted, along the river but the house and several push-ups were frozen out or destroyed by mink. A few others, on backwater sloughs or ponds, were also frozen out.

Attempts to trap occupied push-ups resulted in 3 muskrats (1 male and 2 female) caught. This number is very low compared to other years. The three rats were only moderately fat, indicating limited food supplies.

4.2.3 Other Wildlife

Mink are reported to be plentiful - probably because of the fish as well as the muskrats. Whitefish and northern pike of fair size are often caught here by the trappers.

A large black bear was sighted at the beaver dam in May and another was taken by hunters in 1983.

Waterfowl were represented by many pairs of lesser scaup, golden eye and scoters, as well as some baldpate, shovelers, mallards and teal.

4.2.4 Enhancement Potential

The enhancement potential resulting from increases in water level to bank-full conditions only, is relatively low although the winter survival will be increased. With sustained trapping pressure, populations and yields of several hundred muskrats are anticipated.

4.2.5 Recommendations

The habitat adjacent to the river could be best improved by level ditching from the river into the ponds and fens prior to the construction of a weir which would ensure bank-full conditions at freeze-up. Techniques for level ditching by dragline and blasting are described by Mathiak and Linde (1956) and have been developed by Ducks Unlimited. With some modification these techniques could easily be applied here.

4.3 ENGINEERING ASSESSMENT

4.3.1 Site Selection

The site is located on the Tethul River, upstream of a small island as shown on Figure 101-1. Here the river divides into two channels, 15 m and 45 m wide, with the narrow channel being shallower. The overall shallow depth makes this site ideal for a bank-full structure as this reduces the required quantity of construction materials.

This site, unlike sites 2, 3 and 5 is situated on a river, where the water is continuously flowing. The two channels allow flow during construction to be diverted through one channel as construction proceeds in the other.

The shallow depth and the existence of the islands makes this an attractive location for a bank-full structure.

4.3.2 Geology

This area is underlain by bedrock, predominantly granite, with the topographically low areas covered by 1 to 3 metres of muskeg. Bedrock is most likely covered by a thin veneer (less than 1 metre) of mineral soil. There are a number of abandoned drainage channels present in the area, some of which are presently occupied by a series of small lakes. A significant number of the drainage channels are controlled by geologic structures.

At the particular site, the channel bed is composed of gravel and rock. Soil borings on the overbanks indicate a silty clay of medium plasticity. The soil samples contain inclusions of organic rootlets and varied between brown and grey in colour. Natural moisture content of the soil sample is in the order of 26%.

4.3.3 Hydrology/Hydraulics

The drainage area at this site is estimated at 5,000 km^2 and contains drainage areas of both Site 4 and Site 5. Upstream of Site 4, the area is composed of extensive sloughs and lakes. In the immediate area, the river meanders through extensive marshlands. It is expected that a bank-full structure will raise the permanent water table over a very large area and during peak flows will contribute several centimeters to the off-river marshes. The 1 in 2 year and 1:100 year flows have been estimated at 48 and 181 m^3/s respectively. Due to the continuous amount of flow in the river year round, maintaining water to bank-full levels should not be a problem.

4.3.4 Design

This structure could be constructed entirely out of soil cement bags. Construction entirely out of soil cement does not require the construction of diversion works such as a cofferdam which is more difficult and considerably more costly on a flowing river as opposed to the lakes at Site 2, 3 and 5. By constructing the structure entirely out of these bags, construction can proceed during open water. This is only feasible if a bank-full structure exists. If a higher structure was desired water would begin to backup behind the dam making construction difficult. The limited amount of material required also makes construction entirely out of soil cement bags feasible.

The structure is the simplest of all the proposed sites. The cross section is similiar to others in that there is a 1 m top width and 2:1 side slopes. There is only one sill set at elevation 100.3 m which is approximately bankful. The 1 in 100 year flow will pass over the weir at a depth of 1.8 m.

The structure will be constructed in two segments, 115 m and 45 m in width, with an approximate height of 1.3 m and 1.8 m respectively. No aprons will be constructed as scour should not be a problem due to the rock and gravel channel bed.

4.3.5 Construction Logistics

Construction staging will occur as discussed in the general section. Prior to construction, a construction site can be cleared on the right or east bank of the river. Here, the plant and camp facilities can be erected, and material stockpiled. Granular borrow areas have been identified some 5 km northeast of the site in a large ridge covered in Jack Pine. Due to the small quantity of material required, this deposit should be sufficient. This material can be excavated and stockpiled at the site. The required cement will have been hauled or airlifted during the mobilization of equipment. The granular borrow and cement can be mixed using water obtained from the river. Once mixed, the bags will be filled and hauled by way of front end loader. Hand placement of the bags in the required configuration should not be a problem providing the water depth is sufficiently low. This may require that actual construction be postponed until late summer or early fall, when lower flows are anticipated. These bags can be hand placed from boats or rafts anchored to each shore.

5.0 SITE 2 LOWER (BIG) HAY LAKES

5.1 GENERAL DESCRIPTION

Trout Creek is a narrow channel which flows northward from Upper (Little) Hay Lakes through Lower (Big) Hay Lakes, then westward to the Tethul River. The basin is almost entirely surrounded by high rocky hills from which most of the original jackpine and spruce has been removed by various fires. A two year-old burn is located at the potential dam site. The selected site is located on Trout Creek downstream of Lower Hay Lakes and approximately five km upstream of the outlet as shown on Figure 102-1.

The actual enhancement area includes all of the Lower (Big) Hay Lakes, two short segments of Trout Creek and Whitefish Lake. Approximately 3.2 km^2 of potential muskrat habitat would be effected by a 1.0 m high dam on Trout Creek.

5.2 BIOLOGICAL ASSESSMENT

5.2.1 Habitat Conditions

All of the variations of lake and creek habitat described earlier are present here. The lake basin is divided into Big Hay Lake, which is a larger deep water lake, surrounded by a sedge fen, and a second "lake" which has many variations in fen development. In the latter area, floating fens and loosely consolidated vegetation mats are common and early stages of seral development of wetland vegetation are represented. Food supplies for wintering muskrats are, as usual, limited to the creek and fen edges because of the present low water conditions and ineffectual beaver dams.

5.2.2 Muskrat Populations

Wintering muskrat populations were low with no houses and less than 50 push-ups observed. Most of these were on the lower basin or on the creek between this basin and the site. Others may have been along the creek which joins the two basins.

Evidence of a breeding population was observed at several points along the creek and along the edges of the fens, during the May visit.

5.2.3 Other Wildlife

This area supports a wide variety of other wildlife ranging from beaver, mink, moose and black bear to waterfowl. Although diving ducks, mainly lesser scaup and goldeneye were the most numerous species, the marshy lower lake with its floating fens appears to be excellent for many nesting ducks. Canada geese also nest here as evidenced by the activity of a mated pair.

5.2.4 Enhancement Potential

Because of the differences in the habitat of the upper (Big Hay) and lower basins and some differences in elevation, the area has been divided into two zones.

Zone A - The enhancement potential of this zone is excellent. The zone includes Trout Creek beginning at the dam site, all of the Lower basin and Little Whitefish Lake.

Water depth increases would vary from about 0.7 m at the upper end of this zone to 1.0 m at the dam site. Much of the creek side fens and portions of the fens around the lake basin would receive about 0.5 m or slightly less.

Water level increases usually increase the number of floating fens. This occurence should also improve the habitat on the rooted shoreline fens particularly nearest the basin edge.

Zone B - The enhancement potential of this zone is fair. The zone includes all of the perimeter fens around Big Hay Lake and Trout Creek where it joins the 2 basins.

The water level increase would vary from about 0.7 m on Trout Creek to about 0.5 m at the upstream end of the lake. Thus, most of the shoreline fens would be covered with about 0.6 m of water - a factor which would improve the growth of sedge and cattail near the basin edge and retard fen encroachment on the basin for many years.

5.2.5 Projected Populations

Muskrat populations will increase most rapidly on Zone A, since the largest amount of suitable foods occur in that portion of the basin. Actual populations are difficult to predict but should reach or exceed 800 in the first 2 years, and could peak at approximately 2,000 or about 6.25 muskrats per hectare. However, as stressed earlier in the report, such populations or production cannot be attained without rigorous trapping from the outset of flooding.

Twenty-one (21) were also observed along the river immediately upstream of the potential flood area and doubtless others were hidden in the crusted snow and shrubbery along the length of the river.

Feeding signs observed along the river in May, suggest that a fair breeding population survived the winter and the spring trapping season of 1983/84. However, the limited food supply and space available to muskrats severly limit summer muskrat production . The lack of winter houses suggest that litters are small and probably less than five per female. The apparently higher production of muskrats in this area may be the result of fairly regular spring trapping which thins out surviving populations and thus reduces summer competition for the limited food supply.

The natural mortality factors are freeze-out and predation by mink. However, in this area freeze-out is less common because of the increased water levels created by the rock fill. Trapping accounts for a portion of the surviving winter population but obviously does not remove all of the late winter population.

7.2.3 Enhancement Potential

Taking both ecological and basin morphological factors into consideration, it has been recommended that a maximum increase of 2.0 m in winter water levels would provide optimum conditions for muskrat habitat enhancement. Lower levels (i.e. 1 m) would be ineffective in improving more than the downstream third or less of the area while an increase greater than 2 m would be too deep for most of the area concerned. Thus assuming that a 2 m increase is acceptable, the enhancement potential, in terms of the effects of water level increase, are described below.

Because of variations in basin topography, stream gradient and the surrounding existing topography, the 2 m increase in water depth at the dam site will effect portions of the basin differently. The potential flood basin has therefore been divided into three zones A, B and C as shown on Figure 104-1 for prediction of the effects of flooding which follow.

Zone A

This zone includes the area upstream of the dam to a level of about 1 m above the present river level at the site. Thus a maximum of 2 m will be added to the channel, as much as 1.8 m to the adjacent floodplain and 1.0 m at the edges of this zone.

Unfortunately, the initial effect will be drowning out of all tree and shrub growth, most of the herb layer and the creation of an open "lake" in the lower portion of the basin. For some time after flooding, large portions of the lake surface will be covered with floating debris from this and adjacent areas. Submerged plants such as pond lily, pondweeds, milfoil etc. will eventually populate the shallower portions of the zone as the flooded vegetation decomposes and sediments accumulate.

Muskrat populations will make immediate use of all food plants which survive the initial flooding but will tend to distribute themselves to other areas where substantial amounts of vegetation occur. It is also expected that muskrats will make extensive use of drowned tree and shrub zones for winter house construction.

Significant increases in population are not expected in this zone during the first years after flooding although winter survival rates should be much improved. Considering all of the above the enhancement potential of this zone is low.

Zone B

This zone encompasses all of the basin above the present one m level contour and extends upstream to the mouth of Jackfish Creek. Depths will vary to about one metre because of the undulating nature of the basin floor.

All of the present tree and shrub growth to the edge of the basin will be drowned out. Emergent vegetation suitable for muskrats will be more widely dispersed and because of variations in depth will provide a diverse and productive habitat.

Although existing preferred food plants are scarce, the spring flows on the extensive upstream basin should serve to provide an adequate annual supply of seed and other vegetation disseminules such as root clumps.

This zone will show the first and probably the largest increases in muskrat with significant increases in productivity in the first year after flooding.

In view of all of the above, the enhancement potential is considered to be very high.

Zone C

This zone includes all of the downstream basin of Jackfish Creek from the junction of Written Rock Creek to the Tethul River and a portion of the Tethul River upstream. The maximum increase in winter water levels will be 0.3 m on the sedge covered flats and shallow pools but will not be deep enough to eliminate freeze-out except at the edge of the present creek channel.

Except for drowning of shrubbery and regression of the willow zone to the outer edges of the basin, vegetation patterns will not change significantly and most of the area will continue to be dominated by sedge. Preferred muskrat food plants which are now only along the edge of the creek channel will increase as the edges of the sedge meadows collapse or float.

Muskrats will make intensive use of the former edges of the flats and the backwater ponds where preferred species (bull rush etc.) develop. This zone would be much improved however, by the creation of deep (1.5 m to 2.0 m) potholes or level ditches prior to flooding. Because of its location, some plantings of preferred species may be necessary at the outset of any marsh management program.

The feasibility of improvement, therefore, should be moderate, without special management, but excellent with additional marsh management.

7.2.4 Project Populations

Because of the variations in zone habitat, it is extremely difficult to predict populations. By water level increase only, however, Zone B and the Tethul River upstream of Jackfish Rock will probably have the largest increase per unit area. A minimum population of 500 muskrats is expected for the entire area with increased production if some marsh management is conducted.

7.3 ENGINEERING ASSESSMENT

7.3.1 Site Selection

From an engineering viewpoint, Site 4 is an ideal location for the construction of a dam. The near vertical banks will serve as good abutments and the narrow passage will minimize the structure length. The combination of this favorable topography and nearby rock outcropping and granular materials makes this site very attractive.

7.3.2 Geology

Surficial materials in the immediate vicinity consist mainly of bedrock, with a thin veneer (less than 1 m) of mineral soil, and muskeg which occupies the topographically low areas at the site.

At the actual site, the structure will abut against rock outcrops. The channel bed is composed of gravel and rock.

7.3.3 Hydrology

Site 4 has a drainage area of approximately 4,200 km^2. The basis has a variety of topography ranging from flat lying sloughs to steep rising rock and soil banks. The 1:2 year and 1:100 year flows have been estimated at 40 and 155 m^3/s respectively. The reservoir level would be easily maintained due to the continuous flow in the river.

7.3.4 Design

Site 4 is located on a continuous flowing river and unlike Sites 2, 3 and 5, construction of diversion works is difficult. Diverting the river around the site, is further complicated by the rock outcrops on each abutment. Due to the height of structure, construction entirely out of soil cement would result in an extremely large number of bags making this alternative not feasible. Due to this unique situation, the construction of a structure out of shotrock is proposed. Although production of rock is expensive, the existing condition makes this the only feasible alternative.

The actual design is relatively simple, the shotrock would be produced and dumped directly in the river. Once the required elevation of 102.0 m is acquired, and the structure is stable, a clay blanket of minimum thickness of 0.5 m would be added to the upstream side to prevent seepage. The abutments will be raised 2.0 m, and the 1:100 year flow will pass over the 40 m structure at a depth of 1.7 m. Scour of the channel bed should not be a problem as the bed of the river is coarse cobbly gravel.

7.3.5 Construction Logistics

Construction will proceed as discussed in the general section. Equipment and material can be transported by way of existing winter road identified on Figure 100-1.

A rock quarry can be developed near either abutment and the material can be hauled and directly placed by front end 1 oader. Construction in the winter months is feasible because the present weir maintains open water conditions. Placement of the clay material on the upstream side of the weir may be difficult, however with time, the leaks in the weir should be plugged by beaver living in the area or natural sediment transport.

8.0 SITE 5 WARM CREEK

8.1 GENERAL DESCRIPTION

Warm Creek drains Warm Lake and several low lying sloughs and small lakes. The surrounding area consists largely of low rocky hills and expanses of forest, some of which have been burned over. The proposed dam site is downstream of the outlet of Warm Lake as shown on Figure 105-1. The channel from the lake to the site is not well defined and sometimes non-existant due to the encroachment of the vegetation as floating fens.

The potential enhancement area for this site includes a portion of Warm Creek adjacent to Warm Lake and several small lakes around the main basin. The latter includes only those lakes which lie below the approximate one m contour level. A total of 4.5 km^2 would be effected by a 1.4 m weir on Warm Creek.

8.2 BIOLOGICAL ASSESSMENT

8.2.1 Habitat Conditions

The area affected by the proposed weir consists of creekside and lakeshore fens and marshes similar to those described for Lower and Upper Hay Lakes (sites 2 and 3 respectively). However, rooted fens and willow encroachment is not as extensive as in other areas and more floating sedge-rush fen and deep water marsh occurs. These favorable conditions are most common in the upper reaches of Warm Creek and adjacent portions of Warm Lake.

Present water levels on the creek are only slightly below bank full levels (May). Beaver, which are plentiful, are largely responsible for the maintenance of water levels, the marsh conditions described, and for the original development of muskrat habitat along the creek basin. However, conditions have reached a point where beaver dams are less effective in maintaining muskrat marshes than they were in earlier years. Rooted sedge and willow have also encroached at several points. The floating sedge-rush fens which border much of Warm Lake shores are largely maintained by wave action from the open lake. Encroachment of rooted fens and willow is much more advanced in sheltered embayments.

Sedge is the most abundant plant but stands of cattail, rat root, and arrowhead were common at many points in floating and/or partially rooted fens.

8.2.2 Muskrat Populations

Muskrat populations appear to be slightly higher than in the Trout Creek sites. Thirty (30) push-ups were observed during aerial reconnaissance but most of these were found on Warm Lake near Warm Creek. Feeding activity during the May visit was highest on Upper Warm Creek where floating fens were common.

Soil covered elevations along the creek may be suitable for bank dens, although no clear evidence of dens or runs was observed during the May field check. However, portions of former habitat in these areas are dry or very shallow and may be uninhabitable.

8.2.3 Other Wildlife

Waterfowl including several species of ducks (Table 3.2) utilize this area for breeding and nesting. As usual, lesser scaup, goldeneye, green-winged teal and baldpate (widgeon) appeared to be most common. One occupied baldpate nest was observed on an elevated area near the proposed weir site.

Aquatic and semi-aquatic fur bearers include beaver, mink and possibly otter although no sightings or sign of the latter were noted. Several beaver lodges were recorded on the photomosaic maps but this does not include the entire population.

The willows, birch, aspen and assorted shrub species are reported to support substantial moose populations in winter while the shallow marsh areas are probably used extensively by this species in summer. Aerial photos revealed many game trails through the sedge fens near the large island at the entry of Warm Creek and along the west side of the lake.

8.2.4 Enhancement Potential

The enhancement potential by water retention is considered to be excellent for most of the area.

However, because of variations in basin topography, stream gradient and habitat distribution, the recommended increase in water levels will affect portions of the area differently. The area has thus been divided into two zones A and B as shown on Figure 105-1.

Zone A

This zone includes most of the Warm Creek basin upstream of the proposed weir site to the edge of Warm Lake and has the highest potential for enhancement.

Depth increases will vary considerably from about 0.5 to 1.4 m because of variations in present surface topography which will reduce rooted sedge fen encroachment and increase and diversify the marsh vegetation zones. Floating or loosely rooted sedge-rush areas will increase in number and size. Most of the rooted sedge near the creek channel will be obliterated and new growth will occur in the shallows near the edges of the basin. Willows and other shrubs and trees will be drowned out to the basin edge.

Muskrat populations will be able to utilize surviving and new stands of cattail etc. on a year round basis because of increased water levels. Shorelines where sufficient soil is accumulated should also be available for burrows and runs. Dispersal of populations will begin as water levels increase. Similarly, an influx of muskrats should begin in the spring following flooding.

The loss of willow and other growth may have a negative effect on moose populations.

Zone B

This area includes all of Warm Lake and some of the smaller lakes which drain into it. Enhancement potential is considered to be moderate since only about 0.2 m of water can be added to this area without damaging the downstream area. (Zone A).

However, the present, seasonally ponded sloughs will be improved by the increased water level both in vegetation development and in winter survival of muskrats.

Rooted sedge fen encroachment will only be retarded, not halted entirely, since a shallow increase in water will stimulate new growth.

Muskrat populations will increase but probably not as much as in Area A. Greater use of basin edge ponds by muskrat will probably result.

Moose populations will be effected by loss of willows etc. on the fens but to what extent cannot be predicted.

8.2.4 Projected Populations

The highest populations will probably develop in Zone A with densities in excess of four per hectare. The combined area however, should produce 1000 or more muskrats per year.

8.2.5 Special Recommendations

No special recommendations are made for this enhancement area, although transplants of vegetation and marsh blasting on the rooted fens around Warm Lake should be considered.

8.3 ENGINEERING ASSESSMENT

8.3.1 Site Selection

A site directly at the outlet of the lake was chosen to maximize the benefit to the Warm Lake area. A dam constructed in the area would have to be extremely long regardless of the particular location.

At this particular location, a steep rising left bank exists and will serve as a good abutment. The right bank rises slowly until it reaches a rock outcrop approximately 150 m away.

8.3.2 Geology

Surficial material in the immediate area consists of bedrock with a thin veneer of mineral soil, and muskeg which occupies the topographically low areas within the bedrock. The stream channel is expected to contain alluvial material comprised of sandy silt to silty sand.

The channel at the site is composed of approximately 2.0 m of organics and silty clay overlying bedrock. The left bank is steep rising and composed of organic peat overlying a silty clay. The right bank rises slowly until it reaches a rock outcrop rising approximately 100 m away. The silty clay is generally low to medium plastic, with high organic content and dark brown in colour. Natural moisture contents as high as 61% and 86% were obtained in the soil samples.

8.3.3 Hydrology

The site has a drainage area of approximately 135 km^2. The basin is composed of several low lying sloughs and small lakes. The actual enhancement area for this site includes a portion of Warm Creek adjacent to Warm Lake and several small lakes around the main basin. The actual enhancement area is 4.5 km^2.

The flows, as discussed in the general section, have been determined by pro-rating flows from a nearby stream gauging station. The extensive lakes and sloughs upstream of the site will have a routing effect and will tend to reduce the peaks. The 1:2 year and 1:100 years have been estimated at 1 and 4 m^3/s respectively. During an average year, reservoir drawdown due to evaporation is estimated at only 105 mm. Further losses may occur due to possible leaks in the structure.

8.3.4 Design

The design of this structure is similar to Site 3. The extreme length, dismisses construction of the structure completely out of soil cement bags as an economical alternative. All flows including the 1:100 year flood will be confined within a 40 m section bordered by the left abutment. This section will have an earthfill core and will be armoured by soil cement bags. The remaining structure will be elevated and constructed entirely out of compacted earth and not armoured. This portion is not expected to be overtopped during the 1:100 year event and will only retain the water.

The structure as shown on Figure 105-2 will typically have 2:1 side slopes. The armoured portion will have a 1 m top width and have two sill elevations.

The low sill elevation has been set at 101.2 m. The 1:2 year flow will pass over this section with a flow depth of 0.2 m. The upper sill elevation has been set at 101.5 and will pass the 1:100 year flow with a depth of only 0.2 m. The section constructed of compacted soil has been elevated to elevation 102.1 to ensure no flow is allowed to pass over it. Aprons upstream and downstream have been provided to protect the existing channel and overlook from erosion and scour.

8.3.5 Construction Logistics

Construction will proceed in the manner as described in the general section. Equipment and material can be transported by access route identified on Figure 100-1. Granular borrow material has been located on the left bank as shown on Figure 105-1 silts and clays for the earthfill core can be obtained from the abutment areas. Diversion works as with Site 2 and 3, will consist of cofferdams and culvert.

9.0 MONITORING PROGRAMS

Two types of monitoring programs by which the success of habitat enhancement programs on any site may be observed and measured are described below.

Population Monitoring - This program can be conducted entirely by trappers and is based on changes in population numbers and distribution.

Step 1 - Pre-Construction Check of Populations

a) A ground "census" of muskrat houses and/or push-ups should be conducted in spring before break-up (i.e. during the spring trapping season) prior to dam construction. The location and numbers of houses and/or push-ups should be marked on large-scale maps, such as copies of photo-mosaics and filed for future reference.

   The conditions of each house and push-up should be checked and recorded as occupied (live) or frozen (dead). A suitable map symbol can be used for this purpose. For example an "H" represents an occupied or "live" house and a circled "H" represents a frozen or dead house. Similarly an X = an active or live push-up and a circled X = a frozen push-up.

b) If trapping is being done a representative sample of muskrat caught before and after break-up should be checked and recorded as to sex and condition (i.e. fat,thin, parasites found in liver, etc.) The uteri of females should be checked for placental scars or embryos. This information is an important indicator of the health and productivity of the population.

Information concerning muskrats caught before and after break-up should be recorded separately in case of muskrats moving in from other areas after break-up.

Step 2 - Post-Construction Monitoring of Population

a) The first post-construction census and checks of populations should be conducted in the first season following construction. The procedure outlined above should be repeated and the information retained on file for comparison with pre-construction data.

b) Similar census procedures should be repeated each year for at least five years following dam construction.

Habitat Monitoring - Although the changes in populations are a good indicator of change in habitat conditions a more detailed type of habitat monitoring may be desirable. Since this type of monitoring primarily involves changes in vegetation types and distribution - the program should be conducted by a biologist or resource technician with training or experience in vegetation analysis. There are several variations in technique that might be used (e.g. see Dirschl 1970) depending on the level of detail desired. The following basic procedure, will allow an ongoing history of change to be recorded at any desired level of sophistication.

Pre-Construction

1. The habitat area should be photographed in mid-summer, preferably in color, or color I.R. with each photo coded as to location. Existing aerial photos may be used to delineate dominant communities, recording photos or locating sample areas.

2. One or more representative samples of habitats depending on variations, should be selected for each enhancement area.

3. Cross sections of habitat zones-from basin edge to the edge of open water could be obtained by permanent transects which are clearly marked in a permanent manner. These markers should be observable at some distance and should be graduated for recording changes in water levels. Their location should be marked on aerial photos.

4. When plants have reached full growth (i.e. have developed flowers) the vegetation along this transect line should be identified and described as to community type and distribution relative to water depth, species composition and relative size of dominant communities. Both submerged and emergent communities should be examined and recorded.

5. Water samples should be analyzed for at least pH levels.

6. Observations of current use of vegetation by muskrats should also be recorded.

NOTE : It may also be desirable to conduct a field check of vegetation composition in muskrat houses and push-ups during spring trapping season.

Post-Construction Monitoring - field checks and detailed analyses similar to the above should be conducted each summer following construction, for a period of at least five consecutive years.

Post construction monitoring should also include observations in water levels and distribution of impounded water.

10.0 CONCLUSION

1.0 It is technically feasible to construct water retention structures in each habitat area, and this will result in a significant increase in muskrat population. In addition to controlling water levels, marsh management such as marsh blasting will aid significantly in enhancing the muskrat habitat.

2.0 The proposed control structures are overflow weirs, and materials used for construction vary among the sites. There are basically three types; one constructed out of soil cement filled geotextile bags only, earth fill armoured with soil cement bags, and, rockfill. Construction logistics, available materials and existing conditions were considered at each site in determining the most practical design.

3.0 There has been no comparable work done in the area making cost estimating difficult.

4.0 Table 10.1 presents the required construction material quantities for each site and the associated benefits in terms of muskrat population.

TABLE 10.1

COST SUMMARY

SITE	CONSTRUCTION MATERIALS (m^3) EARTH FILL	SOIL CEMENT	SHOT ROCK	*INCREASE IN MUSKRAT POPULATION (MUSKRATS/YEAR)
1	-	330		200
2	220	160		2,000
3	840	590		1,000
4	-		840	500
5	510	500		1,000

It is evident based on the quantity of construction materials versus muskrat population, that Sites 2, 3 and 5 have the greatest potential.

* These estimates were developed based on a series of assumptions, the most important being rigorous population control measures required from the outset of flooding. These numbers indicate the potential for habitat enhancement within the various areas.

11.0 RECOMMENDATIONS

1.0 It is recommended that prior to detailed design, Contractors should be approached for cost estimates for construction of control structures at each site. This would provide firm costs and possible suggestions as to alternate construction methods. With these costs, decisions to advance to the design stage can be made.

Both the soil cement and rockfill alternative for sites 1, 2, 3 and 5 should be cost estimated in order to determine which is most economical.

2.0 If the decision to advance to Phase Two of the project is reached, detailed design drawings and contract specifications on the proposed sites must be prepared. Site specific details such as removal of soft and pervious soils from under the foundation of the control structures; size of soil cement bags; soil cement mix design; and quality control requirements must be considered and specified.

In the event that the HTA undertakes to provide construction equipment and labour for execution of the work, in order to assist in development of local expertise, an experienced construction manager should be engaged to direct and coordinate all work on at least the first structure.

Construction supervision, quality control and inspection services should be provided to achieve good standards of construction.

3.0 Marsh management for the selected habitat areas should be carried out. These marsh management techniques will further enhance muskrat habitat.

4.0 If any or all components of the project advance to Phase Two, a monitoring program should be carried out by the Fort Smith Hunters and Trappers Association as outlined in Section 9.0. This will monitor the actual impact of the enhancement project on the muskrat population.

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APPENDIX A

FIGURES

5.3 ENGINEERING ASSESSMENT

5.3.1 Site Selection

This site, located on Trout Creek, was selected due to its narrow width and steeply rising banks suitable as abutments. The left bank slopes at two horizontal to one vertical, while the right bank is slightly flatter at 3 to 1. The narrow width between these abutments reduces the overall length, making this structure the shortest of the five proposed sites.

5.3.2 Geology

Surficial materials in the immediate area are predominantly bedrock and muskeg. The bedrock, expected to be mostly granite, is covered by a thin mineral soil generally less than 0.5 metres thick. Depressions within the bedrock are filled with muskeg which is expected to be underlain by organic silts and clays.

At the site, the channel banks are composed of a firm silty clay with a shallow organic cover. The clay is generally medium to high plastic and brownish grey in colour. Organic inclusions were also observed in the soil samples. The channel bed is composed of 0.2 m of decomposed organics overlying a soft clay. The bedrock is presumed to be at a shallow depth. Natural moisture contents of the soil samples from the river bank and channel bed are approximately 30% and 66% respectively.

5.3.3 Hydrology/Hydraulics

A structure at this site will pass flows from an area of approximately 270 km^2, of which 140 are located upstream of Site 3. The basin is composed of a series of small lakes and sloughs, and Mistigi Lake, a relatively large lake, located upstream of Site 3. A 1 m high dam constructed at the site would effect an area of approximately 3.2 km^2 which includes all of Lower (Big) Hay Lakes, two short segments of Trout Creek and Whitefish Lake. The 1:2 year and 1:100 year flow has been estimated at 2 and 8 m^3/s respectively.

Due to these low flows, the amount of water lost through evaporation is of concern when maintaining a full reservoir level . A rudimentary water balance analysis was performed and indicated that drawdown due to evaporation losses in an average year will be in the order of only 65 mm. Additional losses may occur due to leaks within and beneath the structure. However, the HTA indicated that during the winter of 1984 - 1985, weak ice and open water was evident in the creek downstream of Site 2 indicating that the creek does flow during the winter months and would therefore further reduce these losses.

5.3.4 Design

An overflow type weir constructed of soil cement filled geotextile bags was considered to be most practical for this site, but construction of the structure entirely out of bags was not considered economical. Due to the extremely large number of bags required, an earthfill core armoured with the soil cement bags is proposed. This would greatly reduce the number of bags and therefore reduce the overall costs.

This site, unlike Site 1, is located in a creek with little current. This makes construction of cofferdams possible using the available silts and clays. By construction of these cofferdams and dewatering of the area within, the earth fill core can be constructed.

The structure as shown on Figure 102-2 will typically have 2:1 side slopes. It will be constructed from compacted silts and clays and armoured with 1.0 m of soil cement bags. In addition, aprons upstream and downstream will be provided where erosion and scour may be a problem. The lower sill has been set at elevation 101.0 m. The width of the lower sill section is approximately 6 m to suit the existing channel. The 1:2 year flow will be confined to this section with a flow depth of 0.3 m. The upper sill elevation is set at elevation 101.5 m and will pass the 1:100 year flow with a depth of 0.3 m over the entire weir. The entire structure will be 33 m long.

5.3.5 Construction Logistics

Construction staging will occur as discussed in the general section. Prior to commencement of construction, a construction site should be cleared on the north bank.

A sand and gravel borrow area was identified some 200 m downstream of the dam site on the north bank as shown in Figure 102-1. The sand is a shallow but very extensive deposit amongst rock outcrops. A similar deposit exists on the south bank which appears to be more extensive and deeper. There should be more than sufficient material in these deposits.

The materials for the earth fill core can be composed of silts and clays and should be available on the abutment areas.

Diversion works at the site would consist of a construction of a cofferdam upstream and downstream of the proposed structure. A culvert will be installed, allowing the flow to pass through. The cofferdams can be constructed of silts and clays. Prior to construction, the area within the cofferdams will be dewatered with the use of pumps. This would allow for a dry working area in which to construct the structure.

The earth fill portion will be constructed using material available on the abutment areas and compacted by several passes of the equipment.

Once the earth fill core is complete, the soil cement mixture will be mixed and the geotextile bags filled. These would be hauled to the site by use of the equipment and hand placed.

Once construction is complete, the culvert can be capped. The cofferdams will be removed and the material wasted to a disposal area.

6.0 SITE 3 UPPER (LITTLE) HAY LAKE

6.1 GENERAL DESCRIPTION

This dam site, as with Site 2, is also located on Trout Creek as shown on Figure 103-1. Within the area, there are extensive sloughs south and west of the lake that fill during periods of high flows. The channel meanders but is considerably more defined than that which exists at Site 2. Within this reach, the channel flood plain is 50 to 100 m in width. Site 3 is located about two km downstream of Upper Hay Lakes at an existing beaver dam.

This enhancement area includes Upper Hay Lake and approximately three km of Trout Creek. A total of 3.2 km^2 will be affected by a 1.4 m dam at a constriction in the Trout Creek basin as shown of Figure 103-1.

Much of the enhancement area is encompassed by rocky hills from which most of the jackpine and other conifers were removed by the 1953 fire. White birch and aspen now populate much of the area. Some small stands of white spruce and black spruce survived and have spread seedlings and young trees wherever suitable soils were available.

6.2 BIOLOGICAL ASSESSMENT

6.2.1 Habitat Conditions

The area includes creek side fens and shallow pools upstream of a large active beaver dam at the proposed weir site as well as extensive sedge and willow covered fens around the rapidly shrinking Upper Hay Lake. The area is not well supplied with water since no large streams empty into this part of the basin and most of the others are dammed by beaver.

Sedge is the dominant surface vegetation throughout the area with intrusions of willow and grass being most common around the lake basin. Alders also occur along the edge of the creek. Cattail, arrowhead and rat root are common along the edges of the creek, while sedge appears to be the only common food plant at the edge of open water in the lake.

In general, however the emergent food supply including sedge is small, being limited to the edges of the creek channel and the deep water (1.3 to 1.8 m) of the lake.

6.2.2 Muskrat Populations

The beaver dams maintain the water levels at slightly above the banks for some distance up the creek but on the upper end of the creek and on the lake, winter water levels appear to be lower than bank level by several centimeters. Consequently, vegetation growth and muskrat populations, are higher near the beaver dam. However, freeze-out is still a serious problem with most of the push-ups (90% on the lake and 70% on the creek) being frozen out in April. As usual in such areas, the only visible evidence of muskrats is found along the edges of Trout Creek and the fens which surround the lake.

6.2.3 Other Wildlife

Moose utilized this area on a year around basis. Tracks of three wolves were observed in April and one cinnamon bear was observed during the May visit to the site.

Beaver and mink are present in fair numbers. Five colonies of Beaver were observed within the Trout Creek and Upper Hay Lakes area.

Waterfowl include diving ducks, primarily lesser scaup and goldeneye. Mallards and teal are also present.

6.2.4 Enhancement Potential

Taking all factors into consideration, the enhancement potential for the total site 3 area is fair. However, because of the creek and lake basin gradient, the water level increase on Trout Creek would be much higher than on the lake basin, thus dividing the area into two Enhancement Zones.

Zone A

The enhancement potential of this zone is considered to be good.

The zone includes Trout Creek, to the edge of the broad lake basin as shown on Figure 103-1. It contains diverse habitat consisting of a complex of ponded sedge/willow fens and shallow marshes.

Water level increases would vary from 1.4 m at the weir to about 0.4 m near the lake. Although some of the sedge meadows would be obliterated, the opportunity for other emergents to spread would increase significantly. Several upstream areas which are now badly in need of water would be covered by approximately 0.5 m.

In portions of the area, the increase in water level would also allow bank burrows in soil deposits which occur at several points.

Zone B

This zone includes most of the lake basin almost to the mouth of Trout Creek and the “overflow” area much of which is now nearly dry. The water level increase from the dam would be about 0.2 m, however, which would do little more than saturate the extensive fens.

Although some improvement in the use of sedge fens is anticipated, the increase in vegetation and muskrat populations would not be large.

Enhancement potential by water retention alone is poor although winter use of sedges and cattail around the lake edge would be improved.

6.2.5 Projected Populations

Production will vary greatly between zones. However, it is expected that the Trout Creek portion of the area Zone A should produce upwards of 500 muskrats with fewer on Zone B.

6.2.6 Recommendation

Level ditching or pothole development around Upper Hay Lake would improve that area considerably.

6.3 ENGINEERING ASSESSMENT

6.3.1 Site Selection

Within this reach of Trout Creek, the bank relief is low rising and there is no location where ideal abutment conditions exist. A dam constructed to flood Upper Hay Lakes will have to be extremely long regardless of which site is selected.

Presently, the existing active beaver dam at the site is washed out but in the past has been successful in maintaining the upstream water levels. A dam constructed at this location of a more permanent nature will be suitable.

6.3.2 Geology

Surficial materials in the immediate area are muskeg, clay and bedrock. Bedrock is expected to be predominantly granitic. Muskeg of varying thickness (up to 2 metres) occupies topographically low areas.

At the particular site, soil borings indicate a silty clay on the abutment areas as well as at the channel bottom. The clay soil varies from low to high plastic depending on the silt content. The clay is generally soft, odorous and with organic inclusions. Natural moisture contents vary approximately from 23% to 59%.

6.3.3 Hydrology

The drainage area upstream of this site is estimated at 140 km^2. As described previously, the basin is composed of extensive sloughs and lakes that fill during periods of high flows and reduce the peak flows. A dam constructed at elevation 101.4 would effect an area of 3.2 km^2 and would encompass the smaller lakes such as the Upper Hay. The 1:2 year and 1:100 year flows are estimated at 1 and 4 m^3/s respectively.

A rudimentary water balance analysis indicates that during an average year, drawdown due to evaporation is estimated at only 90 mm. This may increase due to leaks in the structure. In the past, beaver dams have been successful in maintaining the water level during the open water season.

6.3.4 Design

An overflow type weir is also considered the most practical structure for this site. Due to it's extreme length it was necessary to use earth fill for most of the structure. Al 1 flows including 1:100 year will be confined to a central 40 m section. Within this section, the actual design will be similar to Site 2, as the core will be composed of compacted earth and the outside armoured with soil cement filled geotextile bags. The remaining structure will be elevated and constructed out of earth fill only. No soil cement bags will be added, as these sections are not expected to be overtopped during the 1:100 year event and will only retain water.

The structure as shown on Figure 103-2 will typically have 2:1 side slopes. The armoured section will have a top width of 1 m and typically will have two sill elevations.

The low sill elevation has been set at 101 and the width of this section is confined to the existing channel at 6 m. The 1 in 2 year flow of 1 m^3/S will pass over this section at a depth of 0.2 m. The upper sill elevation is set at 101.7 and confined to a 40 m length. The 1:100 year flow will pass over this weir with a flow depth of 0.2 m. The earth fill dam beyond this has been raised to an elevation of 102.3 and the top width increased to 2 m. The first 5 m of the earth structure will be armored with one layer of soil cement bags to prevent erosion. Aprons have been provided within the central 40 m section to protect against erosion and scour.

6.3.5 Construction Logistics

Construction will be carried out as outlined in the general section. The construction and camp site can be set up on the west or left bank. A granular borrow area has been located approximately 300 m west of the dam site. This deposit as with others, is probably shallow and it's horizontal extent not known. These deposits are scattered throughout the area, and obtaining the required amount should not be a problem. This area would be stripped and material stockpiled at site. The materials for the earth fill core should be available on the abutment areas.

Diversion works as with Site 2 will consist of cofferdams and a culvert.

7.0 SITE 4 TETHUL (HANGING ICE) RIVER

7.1 GENERAL DESCRIPTION

The Tethul River meanders through a variety of topography ranging from flat lying sloughs to steep rising rock and soil banks upwards of 20 m in height. Due to sedimentation, flooding and ice action in the distant past, the surface undulates more than any of the other sites. The perimeter of the basin consists of steep, rocky hills from which much of the jackpine and spruce have been removed by recurring fires. It has been replaced largely with birch, aspen and associated shrubs whereever there is sufficient soil.

Site 4 is located on the Tethul River approximately three km downstream from Jackfish Creek as shown on Figure 104-1. The selected site is located where the river narrows between two near vertical rock outcrops. At present a rock weir is constructed which maintains water at bank-full level in autumn. The total area effected by the proposed structure is estimated at 1.4 square kilometres.

7.2 BIOLOGICAL ASSESSMENT

7.2.1 Habitat Conditions

The existing muskrat habitat includes the irregular but generally narrow “flood plains” along the river and a few backwater lakes and ponds upon which sedge and willow-covered fens are rapidly encroaching. The river is the only deep water in the basin and varies from <1.0 m to >3.0 m with the average probably about 2.0 m. in depth.

The primary emergent vegetation in existing and potential habitat is sedge with very small amounts of cattail, bulrush, burreed, arrowhead etc, along the flood plain edges or around and in the small backwater lakes and ponds. The Jackfish Creek area vegetation is primarily rooted and raised sedge meadow with small amounts of cattail around shallow ponds. Willow and alder are well developed with the latter associated with the lower portion of Jackfish Creek and adjacent to the Tethul River.

The preferred muskrat foods are generally limited in distribution to the edges of the deep water (i.e. >1 m) on the channel and along the edges of the deepest ponds and constitute the only emergent food plants available to wintering muskrats.

Because of the rock fill at the proposed dam site, there is generally more water available, at freeze-up than in other areas. However, these levels are insufficient to prevent freeze-out in most of the ponds, sloughs and sedge meadows within the basin. In April the ice in the centre of the river was 0.1 m to 0.2 m below the bank edge. Spring and summer water levels which are slightly higher, are also insuffient and short-lived for significant growth of preferred plant species except along the river edge.

7.2.2 Muskrat Populations

Muskrat populations were reported to be low during the past six years, although observations during the April and May field trips indicate larger populations than in any other area. Eight large push-ups were observed between Jackfish Creek and the dam site and all appeared to be occupied.

APPENDIX B

APPENDIX B

In determining flood flows for Sites 2, 3 and 5, Water Survey of Canada Station 07S6009, Baker Creek Main Stem Near Yellowknife was used. This river basin was found to have similar topographical features and possessed a drainage basin of similar magnitude.

Using the available records, a flood frequency analysis was performed on Baker Creek using maximum daily flows. Flood flows for the specific sites were determined by pro-rating Baker Creek flows on the basis of drainage area.

Example:

$$Q_2 = \frac{DA_2 \times Q_B}{DA_B}$$

where Q_2 is the flood flow at Site 2.

Q_B is the flood flow at Baker Creek.

DA_B is the drainage area of Baker Creek.

DA_2 is the drainage area of Site 2.

The following table of flood flows were generated.

TABLE Cl

FLOOD FLOWS (m^3/s)

SITE	DRAINAGE AREA (Km^2)	RETURN PERIOD (YEARS) 2	5	10	20	50	100
Baker Creek	144	1	2	2	3	3	4
Site 2	270	2	4	4	6	6	8
Site 3	140	1	2	2	3	3	4
Site 4	135	1	2	2	3	3	4

Similar calculations were performed for Sites 1 and 4 using Water Survey of Canada Station 07QC003, Thea River near Inlet to Hill Island Lake.

The following table of flood flows were generated.

TABLE C2

FLOOD FLOWS (m^3/s)

SITE	DRAINAGE AREA (Km^2)	RETURN PERIOD (YEARS) 2	5	10	20	50	100
Thea River	9,630	92	142	183	228	294	349
Site 1	5,000	48	74	95	118	153	181
Site 4	4,200	40	62	80	110	128	153

APPENDIX C

TERMS OF REFERENCE

DRAFT

A PROPOSAL TO COMPLETE A FEASIBILITY STUDY

TO ADDRESS THE IMPLEMENTATION OF A

MUSKRAT HABITAT ENHANCEMENT PROGRAM,

FORT SMITH REGION, NWT

'December 1983

1.0 INTRODUCTION

The muskrat (*Ondatra zibethicus*) is an aquatic furbearer found in lakes, rivers, deltas, oxbows, sloughs, and marshes. It is the largest North American rat, and is one of the most numerous and economically valuable furbearers. In the Northwest Territories the muskrat is trapped for its fur, and is an important source of food for hunters and trappers. For example, between 1957 and 1979, 3,732,783 muskrat pelts were marketed for a total value of $5,557,464.00 (Tinling 1982). The average annual value of muskrats during this period was $252,612.00/year (Appendix 1).

Muskrat population levels are influenced by many factors, including food availability, water quality, water levels, parasites, disease, predation, trapping, productivity, immigration, and emigration. Researchers and managers throughout North America agree that water levels can assert the greatest influence on muskrat distribution and abundance. Water levels serve to influence the amount of habitat, food production, house and pushup locations, and dictate winter survival.

In the last decade, water levels within the Slave River drainage basin have decreased; many areas once suitable as muskrat habitat have been eliminated. The reasons for the decreased water levels are not well understood; however, it is likely a result of water use patterns in the south, climatic changes, and hydrostatic rebound.

In response to the desire to maintain and improve muskrat production, the Fort Smith Hunters and Trappers Association is proposing to assess the feasibility of developing and implementing a muskrat habitat enhancement program. This proposal addresses the first of a two phase program.

2.0 GOALS AND OBJECTIVES

In order to successfully implement a habitat enhancement program, the Fort Smith Hunters and Trappers Association is proposing to establish a two phase program consisting of:

(1) Phase 1 - completion of a bio-engineering feasibility study, and

(2) Phase 2 - completion of a muskrat habitat dam construction program implemented on the basis of results generated from Phase 1.

The program goals are:

(1) To restore muskrat habitat in selected areas and increase the population for the benefit of local hunters and trappers.

(2) To develop the local expertise required to successfully complete long-term habitat enhancement programs.

The goals of Phase 1 are:

(1) To complete a bio-engineering feasibility study.

(2) To complete a design for an ecological monitoring program.

The objectives of Phase 1 are:

(1) To determine peak flow regimes in selected drainages.

(2) To determine environmental factors which contribute to prime muskrat habitat in the Fort Smith area.

(3) To complete site visits of proposed and alternate dam sites.

(4) To locate sources of materials to be used in dam construction and to determine the costs and logistics associated with the use of these materials.

The specific goals and objectives for Phase 2 will be submitted in a second proposal generated from the feasibility study.,

3.0 ENHANCEMENT SITES

Three muskrat habitat enhancement sites have been proposed by the ' Hunters and Trappers Association:

(1) Site #1 is located on the Tethul River at approximately 60020′, 112°00'W (Figure 1). This river is locally known as the Hanging Ice River.

(2) Site #2 is located on a tributary of the Tethul River at approximately 60°32'N, 112°4'W (Figure 1).

(3) Site #3 is located immediately north of Little Hay Lake at approximately 60°28'N, 111°55'W (Figure 1).

In addition, the Fort Smith Hunters and Trappers Association recommends that the following alternative sites be examined:

(1) Site #4 is located on the Tethul River just west of its confluence with Kenneth Creek at approximately 60°13'N, 111°34°W (Figure 1).

(2) Site #5 is located on a tributary of the Tethul River at approximately 60°19'N, 111°45'W, 12 km west of Mabel Lake (Figure 1).

4.0 ENHANCEMENT TECHNIQUES

Habitat enhancement techniques vary and are dependent on numerous factors, including topography, soil composition, water level regimes, climate, bottom type and local vegetation. Artificial impoundment has been used successfully and extensively throughout North America. However, it is important to remember that a major objective is not to flood an area, but to control seasonally fluctuating water levels to ensure winter survival of muskrat populations and to manage food and cover conditions.

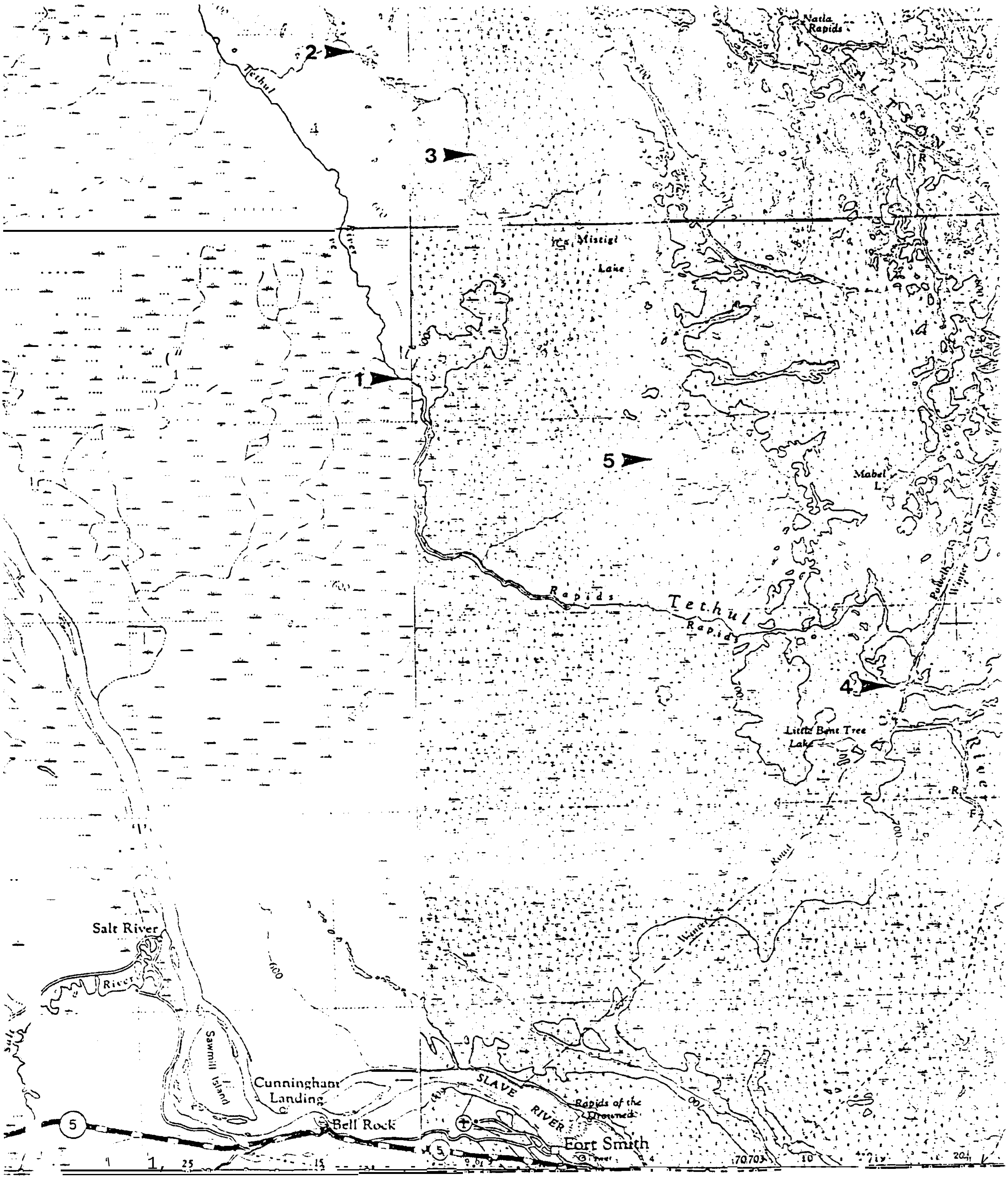

Figure 1. Locations of proposed dam sites, Muskrat Habi tat Enhancement Program, Fort Smith Region, NWT (Scale 1:250,000).

There are numerous types of structures used to control water to improve wetlands for wildlife. The importance of working with an engineer in developing construction requirements cannot be over-emphasized.

Earthen dams will be constructed to create impoundments. All earthen dams should meet the following criteria:

(1) The dam should be designed so that destruction through erosion is prevented.

(2) The spillway should have sufficient capacity to safely pass the expected peak flow for the drainage area.

(3) Freeboard should prevent overtopping by wave action at maximum high water.

(4) The maximum height of the structure must contain an amount of water at least equal to the wave height plus wave run up the slope.

(5) In areas of deep frost, an additional amount must be added to allows for damage from frost actions.

(6) The foundation must be designed to support the load imposed by the embankment and live-loads placed on it.

(7) Any dam which will be used for travel, or on which maintenance will be performed should have a minimum crown width of 2.5 m; 3.5 is preferable.

(8) Earthen dams are limited to heights of 3.5 m or less.

(9) The most suitable soils for dams are clays comprised of a fair proportion of sand and gravel (one part clay to two or three parts grit). Soils with a high proportion of clay crack badly upon drying and are apt to slip when wet.

(10) The watershed above the dam should be large enough to provide sufficient water to fill the reservoir, but not so large that excessive flows will damage the spillway or wash out the dam.

(11) The most economical site is one along a natural drainage where the channel is narrow, relatively deep, and the bottom is easily made watertight. The channel grade immediately above the dam should be as flat as possible.

(12) Wildlife should have easy access to the water.

(13) The dam should be located, if possible, to take advantage of natural spillway sites. Otherwise, an adequate spillway must be incorporated into the development.

(14) The base thickness of the dam must be equal to or greater than 4½ times the height plus the crest thickness. The slopes of the dam should be 2½:1 on the upstream face and 2:1 on the downstream face.

(15) The fill of the dam should be carried out at least 10 percent higher than the required height to allow for settling.

(16) Freeboard (depth from the top of the dam to the high water mark when the spillway is carrying the estimated peak run-off) should be not less than 61 cm. The spillway should be designed to handle twice the largest known volume of run-off and should be constructed at a level which will prevent the water from ever rising higher than within 61 cm of the tope of the dam. A natural spillway is preferred. It should have a broad, relatively flat cross section; take the water out well above the fill; and re-enter the main channel some distance downstream from the fill. When a spillway is built, it should be wide, flat-bottomed, and protected from

washing by riprapping (facing with rocks). The entrance should be wide and smooth and the grade of the spillway channel wide so the water will flow through without cutting.

(17) Where necessary, the safe passage of fish and other aquatic species must be insured.

5.0 ECOLOGICAL STUDIES

Ecological studies are important in order to:

(1) Assist in the selection of suitable dam sites.

(2) Determine the effectiveness of habi tat manipulations through ecological monitoring studies.

(3) Guide the implementation of future programs. The ecological parameters examined during the feasibility study will include:

(1) Density estimates of muskrat populations

(2) Emergent and submergent vegetation (species composition, distribution, and abundance)

(3) Muskrat houses

(4) Muskrat pushups

(5) Water depth

(6) Bottom substrate

(7) Banks

(8) Soil composition

(9) Topography

6.0 SCHEDULE AND PRODUCT

It is anticipated that the contract will be let in March 1984 and completed no later than 31 July 1984. The report submitted will serve as the basis for a proposal to implement Phase 2 of the program.

7.0 LITERATURE CITED

Tinling, R. 1982. Northwest Territories Fur Production 1957-58 to 1978-79. NWT Wildlife Service Information Report No. 1. 45 pp.

8.0 APPENDIX 1

APPENDIX 1

MUSKRAT PRODUCTION, NORTHWEST TERRITORIES

Year	No. of Pelts	Average Value	Total Value
1957-58	182,880	.48	87,782.40
1958-59	157,790	.60	94,674.00
1959-60	206,561	.60	123,936.00
1960-61	214,514	.60	128,708.40
1961-62	244,156	.69	168,467.64
1962-63	193,460	1.08	208,936.80
1963-64	133,054	1.08	143,698.32
1964-65	151,930	.97	147,372.1o
1965-66	183,919	1.32	242,773.o8
1966-67	181,207	.64	115,972.48
1967-68	248,658	.66	164,114.28
1968-69	272,875	1.05	286,518.75
1969-70	114,108	.98	111,825.84
1970-71	86,824	1.29	112,002.96
1971-72	97,722	1.68	164,172.96
1972-73	46,106	1.94	89,445.64
1973-74	130,555	2.01	262,415.55
1974-75	138,116	1.90	262,420.40
1975-76	183,726	3.69	677,948.94
1976-77	276,518	3.07	848,910.26
1977-78	184,068	3.47	638,715.96
1978-79	104,036	4.58	‘76,651.70
	3,732,783		$5,557,464.46

22 year: average number of pelts - 169,671
average value of pelts - $1.48
average total value - $252,612.02

(Source: Northwest Territories Fur Production 1957-58 to 1978-79
N.W.T. Wildlife Service Information Report No. 1.
page 33.)