A PROPOSAL FOR THE DEVELOPMENT OF AN ARTIFICIAL MARINE REEF IN THE CHURCHILL REGION

by

Sheila Thornton

A Practicum Submitted in Partial Fulfilment
of the Requirements of the Degree
Master of Natural Resources Management

Sheila Thornton
Natural Resources Institute
430 Dysart Road
Winnipeg, Manitoba
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A PROPOSAL FOR THE DEVELOPMENT OF AN ARTIFICIAL MARINE REEF IN THE CHURCHILL REGION

BY

SHEILA THORNTON

A practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

Development of artificial reefs has occurred for hundreds of years as a means of manipulating aquatic environments. Unfortunately, many of these projects are conducted without proper management plans and consequently are unable to provide maximum benefits to selected user groups.

This paper outlines an interdisciplinary approach to artificial reef creation by providing a method for managing a reef project from conception to completion. Development of a management protocol was conducted by identifying six primary areas of significance: User group identification, target species identification and investigation, material and site selection, administrative procedures, operational procedures and program development. This system was then utilized to design an artificial reef program for the community of Churchill, MB, located on the western Hudson Bay seaboard.

Investigation of benefits to the community identified possible user groups as recreational dive industry and ecotourism, northern educational programs and the scientific community. Preparation of the derelict vessel, S.S. Graham Bell and administrative procedures for sinking are documented. Analysis of control and experimental (sinking) sites include wet weight biomass of epifauna and qualitative observations on benthic and pelagic organisms. Suggested programs of use for these data are presented.

Evaluation of possible negative impact on the natural and socio-economic environments indicated that further investigation is required before initiating reef development. Careful consideration of ethical and cultural issues surrounding artificial reef development is strongly recommended.

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DEFINITIONS

benthic — Of, or pertaining to, or living on the bottom or at the greatest depths of a large body of water. Also known as benthonic.

endemic — Peculiar to a certain region, specifically referring to an organism which occurs more or less constantly in any locality.

epibenthic — Of or pertaining to organisms located on the surface of the ocean floor.

epifauna — Benthic organisms living on the surface of the ocean floor.

infauna — Benthic organisms living beneath the surface of the ocean floor.

kick cycle — Movement of each fin from upstroke to downstroke constitutes one kick cycle. Measurement of distance travelled during one kick cycle provides a diver with a means of measuring distance underwater.

littoral — Of or pertaining to the biogeographic zone between the high and low water marks.

macrobenthos — Benthic organisms of a body size greater than 1 mm.

sublittoral — The benthic region extending from mean low water to the edge of the continental shelf.

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Chapter 1

INTRODUCTION

Artificial reefs are intended to enhance a social or economic environment for people by enhancing the marine environment for a particular species. This intent, however, is not always fulfilled. Some projects begin with a management plan, identify user groups, but then are improperly sited and fail to meet the defined purpose. Others are successful in a biological sense, but are virtually inaccessible to users. A difficulty exists in that each unsuccessful project not only fails to provide benefits to the group initiating the reef development, but also creates a negative concept of artificial reefs in a holistic sense. With each failure, public opinion toward the concept is reduced and the likelihood of future reef plans coming to fruition is jeopardised.

The rationale for constructing artificial reefs is based on the belief that the presence of a stable substrate results in higher biomass than areas with unstable substrate (Janssen and Quinn, 1985). Recent studies have indicated that artificial reefs, when properly located and structured, significantly increase the biological productivity of the area (Popenoe, 1978; Carter et al, 1985). Although the fundamental question as to what attracts organisms to a reef remains essentially unanswered, the science of designing artificial reefs has progressed to a point where the population of a desired target species may be selectively increased (Grove and Sonu, 1983; Alevizon et al, 1985; Hueckel and Buckley, 1989). The recognition and exploitation of this affinity has created recreational and commercial fishing opportunities.

In addition to attracting fish, the concentration of marine benthic organisms that colonize artificial structures also attract non-consumptive users. The abundance of such organisms in the vicinity of an artificial reef is an important component of recreational diving (Pacific North Consulting, 1989). The use of reef structures by recreational SCUBA divers has motivated private interest groups to acquire and scuttle various types of vessels. The presence of a shipwreck at a travel destination is a primary trip selection criteria for the majority of divers (Earnst and Whinney, 1980).

Reef enhancement programs are receiving increasing use as sites for marine environmental impact studies, as they tend to concentrate benthic and pelagic communities within a smaller study zone, thus creating a more diverse array of species within a given area (Buckley, 1985). In order to create a suitable habitat for benthic and pelagic species, the reef should have a relatively high profile in comparison to the surrounding environment, high stability characteristics, and a long life expectancy (Brock et al, 1985). Vessels or derelict ships tend to meet all of these criteria, and consequently are utilized frequently in artificial reef programs.

In spite of continued research indicating the benefits of artificial structures, manipulation of the marine ecosystem is a difficult and inexact science. Actions designed to affect one organism will most likely affect many others. The repercussions from man's interference in the delicate balance of nature are far reaching and have been observed throughout the oceans of the world, causing many questions to be posed regarding the overall influence of an artificial reef. Preservation of natural environment has become the mandate of many ecologists and environmentalists, who place high priority on the intrinsic value of natural areas. Artificial reefs may be construed as a negative impact by certain groups of individuals.

Cultural considerations are an important aspect of reef development. Many aboriginal groups have close religious and traditional associations with the marine environment. Placement of an artificial structure on the ocean floor may violate the customs and beliefs of such groups. Careful examination of cultural ethics are required to reduce or prevent violating aboriginal rights and opinions.

Developing a management plan for the creation of an artificial reef involves detailed examination of operational, social, economic, legal and biological factors. This study utilized an interdisciplinary approach in order to maximize the potential benefits offered by successful establishment of an artificial reef.

1.1 BACKGROUND

1.1.1 The Study Community

The town of Churchill, Manitoba (pop. 1300) is located near the mouth of the Churchill River (58° 44' N, 94° 04' W), (Fig. 1). In 1929, Hudson Bay Railway completed a line to Churchill to capitalize on the natural harbour conditions, and in 1931 the first grain ship arrived. The Port of Churchill has the capacity to handle 860 to 890,000 tonnes of grain annually, however the actual average is closer to 570,000 tonnes per year.

The economic development of Churchill has fluctuated over the years since the inception of the port, with the establishment of Fort Churchill, a strategic Air Command Base during World War II, a rocket research range in 1957, and the Churchill-based northern marine resupply service for the central arctic region, Northern Transportation Company Limited. The northern airline, Calm Air International, was incorporated in 1981, and became the largest employer in the community. Closure of the army base in 1963, decreased use of the harbour and rocket range, and Calm Air's decision to transfer offices to Thompson have significantly reduced the population and economic status of the community. Wildlife-based tourism has now become an important source of livelihood and accounts for 40% of the local economy (Pelesh, 1988).

Churchill's coastal environment consists of mixed boreal, taiga and tundra biomes. The oceanographic character of the Churchill marine region is essentially arctic. Semidiurnal tides originating in the Atlantic Ocean dominate the water movement, overshadowing any local or arctic tidal effect (Grainger, 1960). Tidal flow is significant, with tidal height (the difference between high and low tide) surpassing 4 m. Water temperatures at depth range from 12°C to -1.8°C, and salinity is variable, affected by the freshwater outflow of the Churchill River and ice water melt (Prinsenberg, 1986a). The bay's summer circulation is

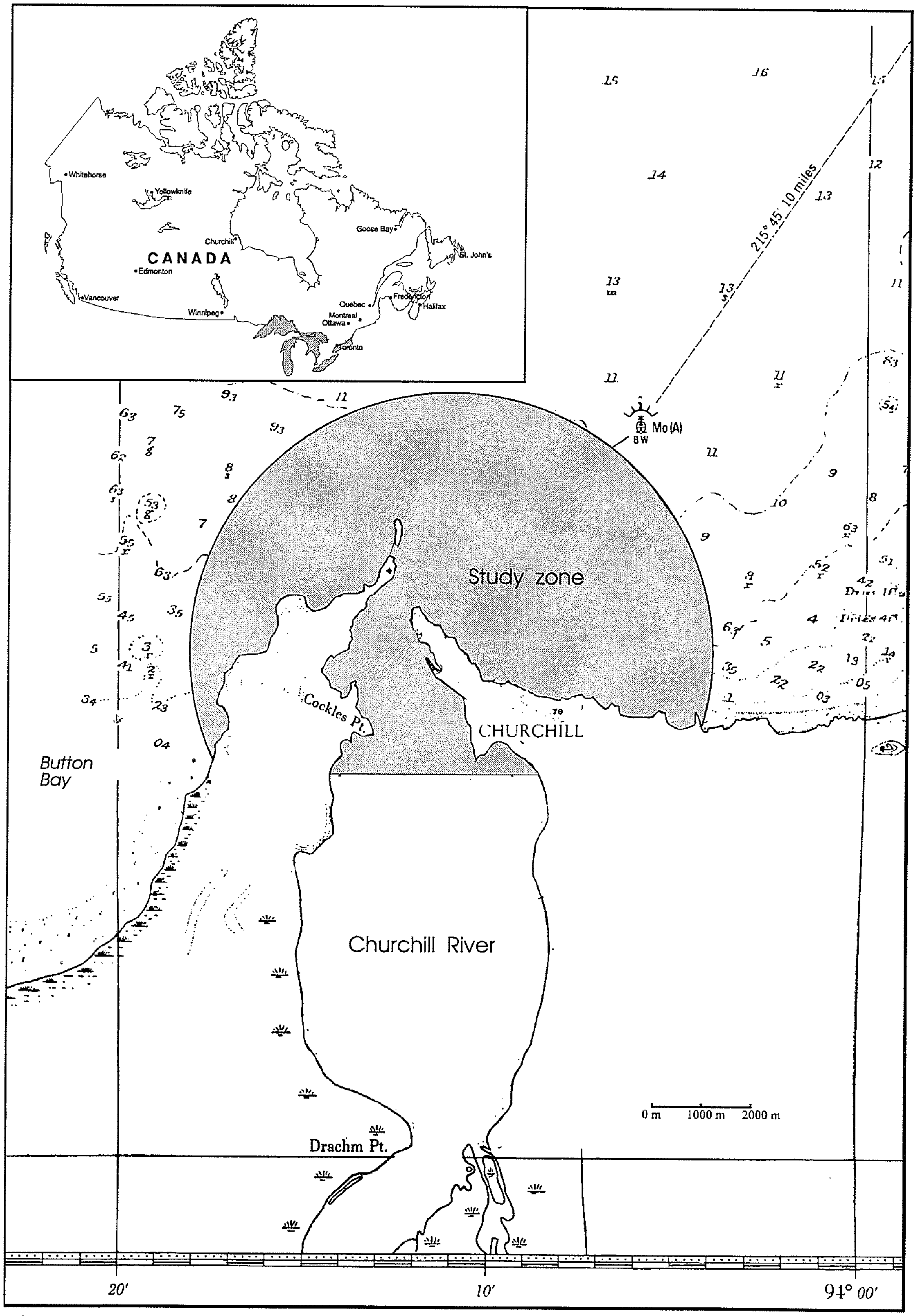

Figure 1. Churchill Region and defined study zone (shaded area).

cyclonic, with with a counterclockwise current carrying cold arctic waters southwestward from Hudson Strait (Barber and Glennie, 1964).

The faunal assemblage of Hudson Bay's undersea life is young, characterized by species of either Pacific or Atlantic affinity and notably few endemics (Dunton, 1992). Atkinson and Wacasey's data report 1989) indicates the presence of 279 species of marine invertebrates in Hudson Bay, but little is known about the community structure and distribution of marine organisms in the vicinity of the Churchill river estuary.

1.1.2 The S.S. Graham Bell

In 1929, the construction of a steam ship tug was commissioned by Canada Ports Corporation (CPC) for use at the Port of Churchill. The vessel sailed from Quebec and was employed as the primary tug for over three decades. In 1963, the S.S. Graham Bell was replaced by a diesel powered tug, "Twolon", but continued to provide service for the port until the fall of 1963, when she was permanently docked on the tidal mud flats on the east of the grain dock (Fig. 2). During the next two decades, there were numerous attempts to dispose of the vessel. The galley, wheelhouse and smokestack were removed with the intention of shipping the steel down south to be sold as scrap (Fig. 3a and 3b). Continued destruction of the vessel would prove to be economically unfeasible, and the vessel was returned to CPC. Consequently, the port of Churchill has been seeking a means of disposal for the derelict vessel.

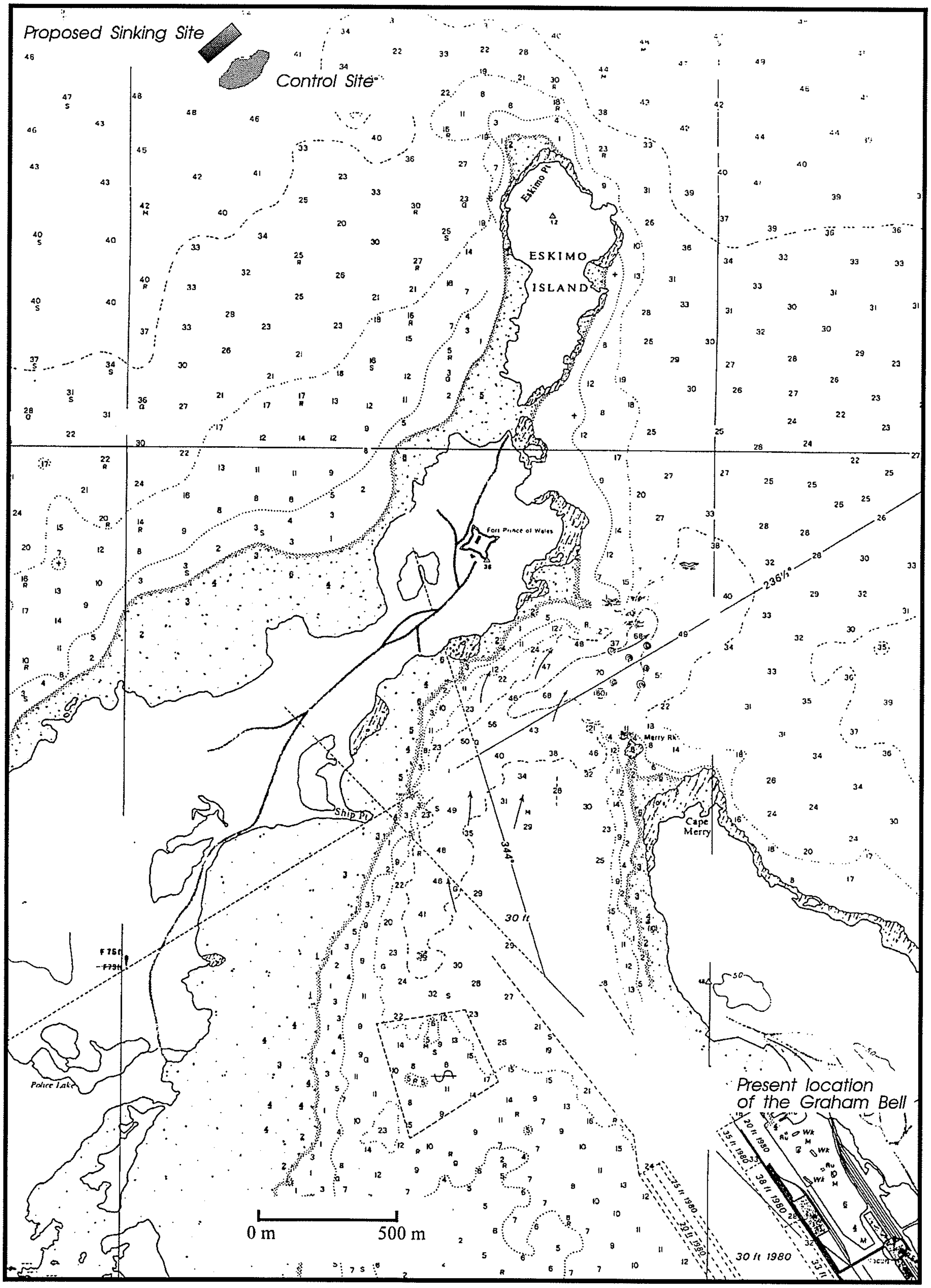

Figure 2. Port of Churchill. Present location of the Graham Bell, proposed sinking site and established control site are identified.

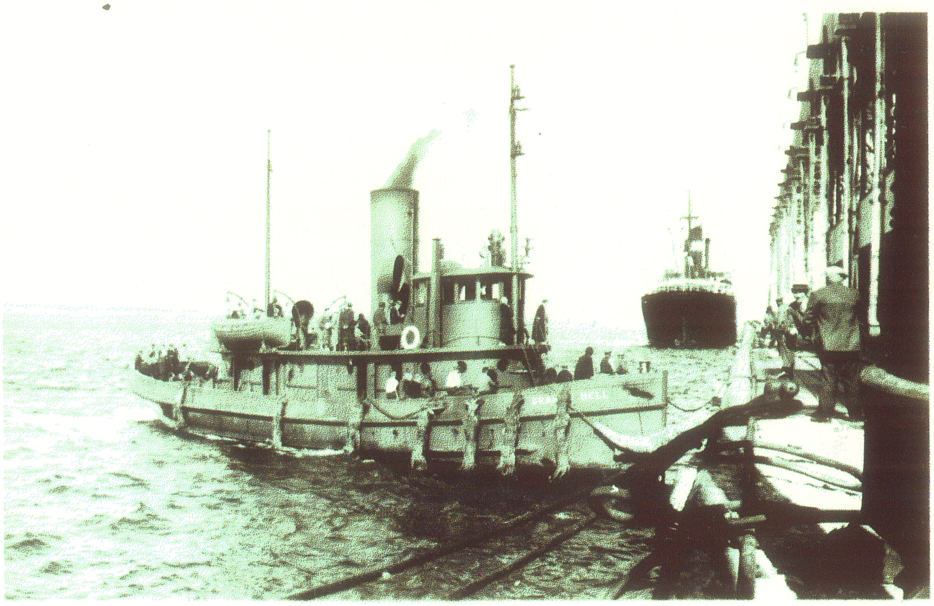

Figure 3a. S.S. Graham Bell, circa 1930, Churchill, MB.

Figure 3b. S.S. Graham Bell (1990) in dry docks at Canada Ports Corporation wharf.

1.2 ISSUE STATEMENT

The use of artificial reefs as a habitat enhancement tool has gained tremendous popularity during recent years. Many artificial reefs have been implemented by well-intentioned private interest groups to provide recreational opportunities for fishermen and divers alike. These reefs were often constructed and sited with little or no forethought or planning. Subsequently, numerous efforts have resulted in less than optimal results.

An opportunity to create an artificial reef from a derelict vessel has many potential benefits. The town of Churchill has such an opportunity, but what procedures should be employed in order to analyse the value of such a venture?

1.3 RESEARCH OBJECTIVES

The primary objective of this project was to document the processes leading up to the creation of an artificial reef utilizing the tug S.S. Graham Bell, and recommend programs of use to potential user groups. The specific objectives were:

1.3.1 Identify criteria utilized in site analysis, and document data regarding site selection for the artificial reef.

1.3.2 Generate a baseline species inventory for the study area, and document species diversity, density, and biomass in established control and experimental sites.

1.3.3 Document the administrative and operational processes required to create an artificial reef in the established experimental site using the tug S.S. Graham Bell.

1.3.4 Develop programs for three potential user groups, specifically:

1.3.4.1 Develop a program for the scientific community involving long-term colonization studies utilizing the data generated from the baseline study.

1.3.4.2 Provide the information and material necessary to create a multi-media information package for public education and educational institutes depicting marine research and basic ecological concepts.

1.3.4.3 Develop a program of use for recreational SCUBA divers, and utilize photographs and film footage obtained to promote diving tourism in the Churchill region.

1.4 SCOPE

The implementation of the research objectives was restricted to the specific areas as designated in Figure 1.

Data collection in the form of species sampling on SCUBA and photographic transect surveys occurred in a wider zone in order to enhance the data base.

Programs developed were recommended to potential user groups, however, the implementation of such programs was beyond the scope of this study.

Chapter 2
LITERATURE REVIEW

2.1 ARTIFICIAL REEFS

The concept of artificial reefs has been around for hundreds of years. Fishermen, having experienced consistently higher yields in the vicinity of sunken debris, frequent areas of shipwrecks and submerged logs. When the structure disintegrates, there is an incentive to replace it with other materials in order to maintain the fish population (Mottet, 1985). Although the utilization of artificial aquatic habitats has occurred for centuries, scientific description of their function and impact has been only recent. The majority of publications deal with artificial reef construction or are qualitative descriptive studies detailing successional change and observed species assemblages. Bohnsack and Sutherland (1985) report that few studies use quantitative experimental methods and many lack scientifically valid controls. Their review of 413 artificial reef publications indicated only 31% occurred in peer-reviewed journals.

In spite of the lack of scientific publications, the recognition of the importance of artificial reefs continues to increase. This interest is reflected in the rising number of artificial reef research projects, with peaks in frequency of publications occurring in years following major national or international meetings about artificial reefs. The focus is beginning to turn toward experimental manipulation and the formation of hypotheses to provide a sound basis for future artificial reef development.

Artificial reef construction has occurred mainly in Japan and the United States, with the primary purpose being improvement of fisheries by increasing the harvest of algae, lobster, other shellfish and fishes. In the United States, efforts have been focused on increasing the populations of adult fishes associated with artificial structures, while Japan has expanded their technology to include structures designed to improve spawning, recruitment and survival of earlier life history stages (Mottet, 1985; Grove and Sonu, 1983; Seaman et al, 1989). More recently, portions of Australia, Japan, southeastern Asia, the Caribbean and eastern and northern Mediterranean basins and the Pacific Islands have utilized the advancements in technology to increase fisheries production and yield (Seaman et al, 1989).

The construction of artificial reefs is not limited to the pursuit of enhanced commercial and recreational fisheries. Oil and gas platforms serve secondarily as artificial reefs. Breakwaters, erosion devices and environmental mitigation structures provide a stable substrate and protective environment for the development of benthic communities.

There have been two primary schools of thought with respect to reef construction and materials. In Japan and the Indo-Pacific the focus of reef building has been on fish aggregating devices (FADs), designed to increase the population of commercially valuable species. From 1980 to 1985, the Japanese government spent nearly a billion dollars on reef design and development. Another three billion was earmarked for future fishery enhancement (Mottet, 1985). The interest provided by the government, universities and private industry has resulted in new developments in reef technology. Modern modules used in Japanese reef structures are specifically engineered for strength, longevity, and stability. Many effective modular units are constructed from fibreglass reinforced plastic (FRP). This method is expensive, but yields high catch rates of commercially valuable species. In contrast to the significant funding allocations for designed artificial reefs, the Japanese government has refused to provide funding to projects utilizing waste materials for reef construction. Although local groups do build scrap reefs, the emphasis has been on developing reefs using manufactured components (Mottet, 1985).

In North America, the vast majority of reefs are constructed from scrap material. In many cases, the primary justification for creating the reef is an environmentally "safe" method for disposal of waste (Brock et al, 1985). The difficulty with scrap reefs is not their reduced effectiveness as a colonization site, but with their reduced durability. Low density materials such as wooden vessels, automobiles or scrap appliances often disperse or rust away, decreasing the ecological benefit. Durable scrap materials such as automobile tires have higher potential as reef building materials. The difficulty is designing suitable reefs utilizing this type of scrap is in developing techniques for piling it high enough to produce an effective fish attractor while retaining enough stability to resist dispersal during storms (Myatt, 1985). The tendency to break apart and drift in high energy environments is a major consideration when designing reef modules (Ryder, 1981). The areas of surge and current often supply optimal conditions from an ecological standpoint, providing high nutrient flow for filter feeders, but may have deleterious effects on the longevity of the reef structure. Goodyear Tire and Rubber Company has studied the feasibility of artificial reefs based on a modular tire bundle system (Candle, 1985). Results to date are indicating that recent designs are suitable for high energy environments.

A relatively inexpensive alternative may be found in concrete modules. If properly located and designed, concrete structures meet the criteria for successful artificial reef construction. The high density of the material reduces shifting during periods of intense water movement and they are often designed to interlock for increased stability (Brock and Norris, 1989).

The feasibility of using blocks of non-toxic waste material from coal fired power plants has been examined by a number of individuals (Carleton et al, 1982; Woodhead et al, 1985; Hockley and Sloot, 1991). Fly ash and flue gas desulfurization scrubber sludge from coal-burning power stations are compacted into hard, solid blocks. Data from an experimental reef near Long Island, New York have shown that the high density blocks maintained their physical integrity in sea water, and were rapidly colonized by an encrusting and sessile community of epibenthic organisms (Woodhead et al, 1985).

In spite of new technological advances in reef science, the oldest construction material is still popular. Derelict ships and barges have been utilized for artificial reef construction for hundreds of years, and continue as a favoured material. Sunken vessels provide a high profile, stable environment for invertebrate colonization while creating habitat for fishes by providing areas for predator avoidance. In Florida's artificial reef network, steel hull barges and ships have been among the most successful materials in the program (Dean, 1983). In 1970, Public Law 92-402 was passed, enabling the U.S. Maritime Administration to "make available to the states" surplus WWII Liberty ships for reef building purposes. Six of these vessels were allotted to the Tidewater Artificial Reef Association of Virginia (Meier et al, 1985), Mississippi and Alabama deployed five vessels each, and Florida received six vessels before the supply diminished.

The creation of Triangle Reef near the mouth of Chesapeake Bay was accomplished by sinking four retired Liberty Ships. Each vessel was partially scrapped to approximately the second deck level, and all propulsion equipment, machinery and floatable materials as well as internal compartments were removed. Plastic explosives were used as part of a training exercise conducted by the U.S. Navy (Meier et al, 1985). Well-established marine communities exist based on the superstructure provided by the wrecks. Wreck Alley, near Mission Bay, California contains numerous artificial reefs and has become a study site for the California Department of Fish and Game and Scripps Institute of Oceanography. Investigations of the evolving marine ecosystem as well as the impact of the reefs on the fish populations are present topics of research (Greenbaum, 1990).

In Canada, sunken vessels are gaining popularity as environmental enhancement tools and recreational SCUBA sites. A program developed by the Professional Association of Dive Instructors (PADI Canada) has contributed to the successful sinking of a number of vessels. The Artificial Reef Society of British Columbia oversees a number of sites along the west coast of Canada and is continually searching for derelict vessels to utilize in the program.

2.1.1 Biological Component

The biological communities associated with artificial reefs are diverse and largely unstudied as the majority of research into artificial reef ecosystems has focused on fish population dynamics or the biology of commercially marketable species. Controversy over whether the presence of a reef causes migration of organisms from outlying areas or actually increases recruitment is also prevalent in the literature.

This question as to whether reefs add to the biomass of an area or merely aggregate stocks from surrounding areas has persisted from early reef enhancement projects to present. Japanese research indicates that artificial reefs are used successfully in programs designed to increase the production of desired species (Sheehy, 1985). North American research has continuously debated whether organisms are attracted from surrounding areas, concentrate on the reef, or actually exhibit increased productivity. Pollard's (1989) study indicated that artificial reef biomass increased over time to a level approximately equal to the natural reefs in the area. During the period of reef development, the resident population of the natural reef was not reduced. This would indicate an increased carrying capacity of the local environment induced by the presence of the artificial structure.

While many local species of fish become permanently associated with a fishing reef, the ability of the reef to attract fish during seasonal migrations is the economically important function (Mottet, 1985). Assessing the benefits to fish derived from association with a reef involves examination of their behaviour with respect to the structure. Pelagic fish are believed to use the reef as a spatial reference around which the fish may orient themselves (Baynes and Szmant, 1989). Schools of fish are observed migrating from reef to reef, altering their route in order to accommodate reef structures. The mechanism for locating reefs is not clear, for alteration of route occurs at distances outside of visual range. The role of chemical factors has been tested, but one factor indicating other mechanisms are at work is the fish's ability to detect the presence of a reef while upcurrent from the structure (Mottet, 1985). Sound or pressure waves created by currents passing over or around the reef may be responsible for notifying fish as to the presence of a structure.

The physical structure of a reef on the ocean floor creates changes in water flow and current. The slowing down of the water as it passes through openings in the structure may provide larvae with the opportunity to attach to the site. Sedentary invertebrates require high flow rates of nutrient rich water to filter feed, while conditions must also allow for attachment and development without damage caused by high currents. The bottom composition of the surrounding area is important to the survival of filter feeders, for sediment laden water damages small filter feeding organisms attached to reef surfaces. This is particularly critical in marine reefs because invertebrates such as corals and sponges cannot tolerate high siltation rates. If the sediment has any organic content, the problem is exacerbated due to oxygen depletion resulting from decomposition. The build up of byproducts of decomposition such as carbon dioxide and hydrogen sulphide also have deleterious effects on filter feeding organisms (Mathews, 1985).

2.1.2 Economic ramifications

Benefits and costs of artificial reefs are evaluated with reference to the local community, regional economy, and private industry. To develop effective site plans, Chang (1986) suggests the following factors for consideration:

Value of recreational diving on artificial reefs;
Value of recreational fishing from artificial reefs;
Value of commercial fishing from artificial reefs;
Dismantling costs of artificial reef materials;
Transportation costs of artificial reef materials to reef site;
Potential sites for artificial reefs;
Salvage value of artificial reef materials.

The cost of annual maintenance, liability insurance premiums, installation costs and sources of funds for converting artificial reef materials to artificial reefs are also cited as parameters within the benefit/cost analysis.

Economic studies into reef siting and creation have dealt primarily with the fishing industry, however, a number of studies have examined the value of sport diving. In Louisiana, approximately fifty percent of divers depend on offshore petroleum structures for sixty percent of their diving (Roberts and Thompson, 1983). In an analysis of the Dade County, Florida Reef System, the annual economic impact of a new reef is estimated to be a minimum of $122,000. This figure includes angling and diving use by private boat owners only and does not reflect income increases to charter boat facilities (Milon, 1989). A similar study conducted in Michigan's Alger Underwater Preserve investigated the economic benefits of wreck diving. The revenue generated from food, transportation and diving related expenditures exceeded $1.2 million in 1986 (Pacific North Consulting, 1989).

Although literature on the economic impact of Canadian artificial reefs is scarce, studies detailing the tourism potential of wreck diving provide insight into the possible economic benefits. The contribution of sport diving to local economies has shown steady growth over the last decade. Ontario's Fathom Five National Marine Park, home of 19 wrecks, has shown increased attendance each year. A 1989 study undertaken by British Columbia's Ministry of Regional Development (Pacific North Consulting, 1989) examined the tourism potential of wreck diving in the province. A qualitative and quantitative assessment of potential economic gain to B.C.'s tourism industry revealed a strong market for artificial reef use and wreck diving in B.C. waters. The potential revenue generated and subsequent contribution to the provincial economy would outweigh the cost of producing artificial reefs from sunken vessels.

Recently, artificial reefs have been evaluated for their mitigative potential in nearshore marine habitats possibly impacted by operations of power plants, offshore petroleum exploration, and municipal sewage outfalls (Aquabio, 1981). The mitigative potential includes all valued resources (algae, invertebrates, and fish) within the potentially impacted habitat (Ashe, 1982). Pendleton Artificial Reef was constructed in southern California principally to assess the potential of utilizing reefs for mitigative purposes and ultimately to produce a biological community that compares favourably with surrounding natural reefs (Jessee et al, 1985). Thirty-five months after it was established, Pendleton Artificial Reef attracts significantly higher numbers of fish relative to nearby kelp forests and natural reefs. Early successional invertebrate and algal assemblages were observed and attributed to the high profile of the reef with respect to surrounding topography (Jessee et al, 1985). However, it is speculated that over time the artificial reef will develop slowly toward a natural condition. In the case of creating a reef to mimic natural conditions, it is recommended that the physical characteristics of the artificial reef should closely reflect those exhibited in the natural state.

2.1.3 Legal Process

Jurisdictional authority over the study area was investigated in order to establish permit requirements and liability. Jurisdiction in the general sense refers to the geographical area of application of a particular legal system. Under the third United Nations Conference on the Law of the Sea (UNCLOS III) the part of the sea next to a state's coast is called its territorial sea, and is subjected to the coastal state's laws and jurisdiction extend within it, almost as if it were part of the land. Territorial sea may be claimed for a distance of up to 20 km..

Transporting the reef material to the sinking site may cross jurisdictional boundaries, and care must be taken when assessing the legalities of the tow. There are two ancient legal maxims still utilized as the basis for defining liability of a tow. They are "The tug is servant of the tow" and "Tug and tow are one ship". In the common type of towage, a vessel navigated in confined waters with the help of tugs is under single command and that command is clearly placed on the bridge of the vessel under tow. When a tug tows a vessel or structure incapable of propulsion and steering by its own accord the navigational control of the operation lies aboard the tug (Grime, 1991). The question as to whether practical control lies aboard the tow or aboard the tug is the basis for assignment of liability.

In the unlikely event of the vessel sinking while under tow, the consequences could be in violation of the right of navigation. Common law affecting harbours states that there is a public right of navigation in the sea and tidal waters. Under the merchant shipping act, harbour and conservancy authorities are empowered to remove wrecks which are or may become "an obstruction or danger to navigation or the lifeboat service" within the area for which they are responsible or its approaches. Wreck raising authority may take action itself and charge the cost to the owner. The owner who was blameless in the collision or subsequent loss of the vessel is in no better position than the negligent party; the liability of ship owners to meet wreck raising expenses is strict. That liability, of course, may feature in a tort claim against the towage vessel, and losses may be recouped, however the initial responsibility lies with the ship owner.

Under the Canadian Navigable Waters Protection Act R.S., c. N-19, s.1., (NWPA), a person in charge of the vessel obstructing a navigable water shall:

a) forthwith give notice of the existence thereof to the Minister or to the collector of customs at the nearest or most convenient port; and

b) place and, as long as the obstruction or obstacle continues, maintain, by day, a sufficient signal and, by night, a sufficient light to indicate the position thereof .

Although the "person in charge of the vessel" at the time of incident would be the tug operator, debt cannot be assigned to that person, as the tug is owned by Canada Ports Corporation, and utilizes federal employees. Collection of this debt would not be possible for the source of the debt and the source of the payment are one in the same. The responsibility for this debt would most likely fall to the owner, who would have to initiate legal action in the form of a tort claim to recoup losses.

In addition to liability and jurisdiction, environmental concerns are paramount. The Ocean Dumping Regulations, 1988 state that pursuant to section 86 of the Canadian Environmental Protection Act, an application for a permit to dispose of a ship, aircraft, platform, or other anthropogenic structure at sea shall be submitted, using form 4 of the schedule (Appendix 1). Chapter 22 of the Canadian Environmental Protection Act [70.(1)] reads "no person shall dispose of any ship,...in any area of the sea ... except in accordance with a permit granted under section 71". A Notice of Intent regarding the disposal must be circulated in a local paper, and proof of circulation is required.

2.2 THE CHURCHILL REGION

Northern Manitoba is home to the largest wildlife management area in Canada. The Cape Churchill Wildlife Management Area was created in 1978 to maintain the unique ecological diversity found on the northeastern seaboard, and provide wildlife related outdoor activities for all Manitobans. Cape Churchill is a blend of taiga and tundra, salt and freshwater marshes and subtidal marine ecosystems. The diversity of animals inhabiting the region provides opportunities for tourism-based economic development and scientific research.

The area is characterized by geological formations typical of the Precambrian Shield. The region's wide coastal shelf slopes gradually to a relatively shallow seafloor that exhibits mixed bottom substrates. Sediment deposited by runoff are dispersed by the counter-clockwise current flow (Pelletier, 1986). These sediments grade from coarse Precambrian or Paleozoic gravels nearshore to fine silt and clay with a considerable organic carbon content offshore. Fluvial sediment distribution may be altered by ice scour and deposition of sediment load from drift ice. Coarse materials, such as boulders and cobblestones, are frozen into the coastal ice and released wherever the ice melts.

2.2.1 Biological Community

The marine environment in Hudson Bay is difficult to characterize as any one ecosystem type, as the influence of Arctic and Atlantic oceans create a unique blend of systems. Instead, the marine benthic fauna that inhabit the sublittoral shallows of Hudson Bay comprise a relatively young assemblage of organisms that consist of Atlantic or Pacific species with notably few endemics (Dunton, 1992).

The data for benthic species within Hudson Bay is sporadic, consisting mainly of data obtained from dredged samples and bottom drags. Grainger (1968) provides a species list for the area identifying less than two hundred species within the area, a relatively low figure compared to similar ecosystems. An updated literature search identifying benthic species of the Hudson Bay region indicated that 279 species have been identified by previous studies (Atkinson and Wacasey, 1989). The lack of data on community structure and distribution in Hudson Bay may effect future oil and gas exploration in the area. Impact studies require baseline data and inventories of surrounding areas in order to identify possible effects from anthropogenic structures on the ocean floor.

Lubinsky (1980) documents the presence of twenty-six species of molluscs in Hudson Bay and gives a general description of all marine bivalve molluscs that have been identified in the central and eastern arctic. Information on life history, key identifying features and a section of photographs aid in species identification. Maps denoting present range and distribution are also supplied.

2.2.2 Physical oceanography

Barber and Glennie (1964) provide salinity, temperature and dissolved oxygen data for Hudson Bay, with some data collection points in the vicinity of the mouth of the Churchill River. Various depths are recorded, but the point of interest is in the 0 to 30 m range. This study identifies the area to the south east of the mouth of the river as having a reduced salinity reading, but the reduction does not appear to be to the north west of the river mouth. This is consistent with Hempel's (1985) data, stating that the ocean currents are counter-clockwise through the bay.

Prinsenberg (1986a) published salinity and temperature distribution profiles for Hudson Bay indicating summer data collected from research vessels. A current meter mooring from 150 km northeast of Churchill collected year round salinity and temperature data. Results indicated that below the surface layer, the water becomes colder and more saline with depth, reaching salinities greater than 33 ppt and temperatures below -1.4°C. Prinsenberg (1986b) also documented the circulation pattern and current structure of Hudson Bay, indicating that the shallowness of the bay causes its marine environment to depend strongly on local influence of runoff, wind stress, annual ice cover and radiation heat flux.

Baker (1989) provides a comprehensive environmental assessment of the Nelson River estuary, outlining methods of site identification and sampling techniques. Measuring techniques for salinity, O_2 measurement, and temperature are discussed, with specific reference to the YSI-33 salinity-temperature-conductivity meter. Surface water samples were obtained, and nitrates, ammonia, suspended carbon, suspended solids, pH, nitrites, total dissolved nitrogen, chlorophyll a, dissolved organic and inorganic carbon, and soluble reactive silica determined for each site.

2.3 SAMPLING TECHNIQUES

Gamble (1984) indicates that SCUBA diving using air (as opposed to Heliox or other mixed gas systems) is the simplest and cheapest means of conducting *in situ* benthic research underwater but it is essential that the scientist is initially proficient in the diving techniques. In selecting a method of recording the data, consultation with other studies utilizing SCUBA for data collection indicates photographic recording and *in situ* accounts are the most effective. Holme (1984) documented reliable photographic techniques for underwater use, covering optical problems regarding air-glass-water interface, colour absorption and lighting techniques. Details on photographic transect methods contributed to development of biological sampling regime. A comparison is made between photographic surveys and other techniques, including trawl, dredge and diver sampling.

Sample collection techniques are identified and contrasted by Gamble (1984) and Eleftheriou and Holme (1984). Methods of removing invertebrates from the substrate, locating burrowing individuals and extracting species for identification are outlined. A thorough description of transect use, identifying field procedures for macrobenthic sampling, infauna extraction and quantitative photography is presented by Snow et al (1987) detailing methods used in the Baffin Island Oil Spill (BIOS) study of 1981-83. Airlift techniques for quantitative biomass analysis of benthic invertebrates are detailed, and methods of calculation are given.

A self-contained airlift sampler design was presented by Benson (1989), who described construction, operation and sampling capacity of a number of different models. Photographic quantitative sampling techniques for hard-bottom benthic communities are outlined by Bohnsack (1979), and deemed more practical, rapid, inexpensive and provided more information than direct observation or hand-collected biomass samples. This method also provided permanent records for future reference.

Dayton and Oliver (1979) address the value of field experimentation as compared to laboratory work. Varied experimental techniques for areas with a hard substrate marine bottom are identified, and possible errors regarding artifact data are recognized. Specific studies are cited, with the errors revealed, and suggestions are put forth in order to avoid such problems. Complementary laboratory and field experiment methods are documented and discussed with respect to various benthic systems.

2.4 PROGRAM DEVELOPMENT

2.4.1 Science curriculum in northern schools

Marine education programs within the local school are considered an important part of the biology program. The majority of children within the community are unaware of life under the arctic seas, and would benefit from understanding the biological ecosystem that exists in their local surroundings. The creation of a multimedia program introducing research methods and basic marine ecosystems would provide the educational community with a means of providing this knowledge. Interactive multimedia learning tools may be created using current technology in combination with actual recordings from the field. These programs may then be incorporated into the basic biology curriculum.

Public education in arctic marine ecosystems may be accomplished by incorporating information on the marine communities into tourism in the Churchill region. Pelesh (1988) identifies beluga whales as the most popular tourist species with respect to wildlife tours in the area. The majority of visitors view the whales through organized whale watching tours, oblivious to the vast ecosystem beneath the sea. By identifying the whale as one member of a complex food chain, and utilizing photographs, film footage and actual samples of species, each visitor may obtain a greater understanding of the marine inhabitants.

2.4.2 Tourism

Tourism accounts for 40% of the local economy in Churchill (Pelesh, 1988). The majority of activities involve non-consumptive use of wildlife, such as sightseeing and photography. The area is one of the most accessible arctic wildlife sanctuaries in the world, offering year round air and rail service. The establishment of the Cape Churchill Wildlife Management Area (CCWMA) in 1978 serves to provide outdoor recreational activities to Manitobans while promoting the restoration of the ecological diversity of the area.

A SCUBA survey was conducted in August of 1989 in order to assess the potential for dive tours in Churchill. The drawing card of such tours is the chance to interact with beluga whales. During the initial assessment, passive interaction with the whales occurred, and the conditions were deemed favourable for dive tours. The unique flora and fauna of the region, combined with the remote location are attractive features contribute to the potential attraction. Trends in diver preference and areas of expenditure indicate that "adventure travel" is rapidly becoming the preferred type of dive holiday. A recent survey by Skin Diver Magazine (Tzimoulis, 1987) concludes that there will be a growing trend toward educational dive vacations. It is predicted that divers will select specific resorts where they will dedicate their vacations to learning such skills as underwater photography, wreck exploration, underwater archaeology or marine life identification (Tzimoulis, 1987).

Wreck diving has long been the passion of a large majority of divers. Marine parks, such as Bruce Peninsula National Park in Ontario attest to this fact, admitting thousands of divers every year to view its 19 wrecks (Soegtrop, 1988). The addition of a wreck to the already appealing arctic dive environment will serve to increase diver interest and consequently will generate income for the residents.

Marine education of recreational SCUBA divers occurs during their initial training, if taught through the Professional Association of Dive Instructors (PADI). The introduction of Project AWARE (Aquatic World Awareness, Responsibility, and Education) in November of 1989 incorporates information on marine ecosystems and reef preservation (ADANAC Journal, 1989). Each diver is educated in proper diving techniques to avoid destruction of delicate organisms, and information on local conditions often involves a summary of the ecosystem. The inclusion of arctic ecosystem education into northern diving tours utilizing video and still photography will increase diver awareness and generate a sense of stewardship over the aquatic world and its inhabitants.

Chapter 3
METHODS

The stated objective of the research was to document the processes leading up to the creation of an artificial reef utilizing the tug S.S. Graham Bell. In order to establish the protocol for reef creation, a literature search was conducted to define specific criteria. A computerized search of data bases *Bios* and Department of Fisheries and Oceans *Waves* was conducted identifying the key words "artificial reef". Utilizing Annotated Bibliography of Artificial Reef Research and Management (Stanton et al, 1985) and artificial reef conference proceedings, pertinent documents were reviewed and specific criteria common to successful reef development were identified and formed the basis for subsequent areas of investigation. Six primary areas of significance were recognised:

1. User group identification
2. Target species identification and investigation
3. Material and site selection
4. Administrative procedures
5. Operational procedures
6. Program development

The methodology adopted to reach the stated objectives varied in response to field conditions. The nature of this study entailed research in an unpredictable environment, and required flexible methods to meet the changing conditions.

3.1 USER GROUP IDENTIFICATION

The creation of a reef is to meet the needs of the user, therefore identification of the user group is paramount. Literature reviews revealed the most common areas of interest are:

Fishers (recreational and commercial)
Recreational SCUBA divers
Tourism and education
Scientific community
Mitigation

Each group was assessed as to their presence in the Churchill community, potential benefits from the reef and ability of the reef to meet their needs. Selected user groups were then further analysed to identify specific requirements.

3.2 TARGET SPECIES IDENTIFICATION AND INVESTIGATION

Following user group identification, an examination of each group's needs was conducted. Projected benefits to each user group were defined based on existing knowledge of the local marine community. Identification of specific benefits were based on the following themes: 1) Individual organism, 2) Groups of organisms, 3) Ecosystems.

To effectively increase a local population of a species, an examination of the ecosystem and surrounding environment was required. Qualitative and quantitative sampling occurred during 1989, 1990 and 1991 to establish biology and distribution of selected species and general ecosystem components.

3.3 SITE SELECTION

Consultation with Canada Ports Corporation representatives was undertaken to define areas of preferred reef siting. Potential interference with shipping and navigation were of primary concern. Identification of the Button Bay area as a preferred site assisted in limiting selections and eliminated sites in the area south east of the mouth of the Churchill River.

3.3.1 Study zone

The study zone was defined as the marine environment within a 10 km radius of the present location of the S.S. Graham Bell (58° 48' 24" N, 94° 13' 06" W) (Fig.1). In 1989, an initial examination of the subtidal environment was conducted primarily to establish the feasibility of a recreational dive industry in the town of Churchill. Eight divers of varied experience (40-1000+ dives) conducted an evaluation of dive conditions at eleven sites throughout the study zone. Observations on currents, visibility, accessibility, bottom composition, biological life were recorded. Sites were then evaluated based on overall diver satisfaction and ranked in descending order. Each site was also assessed for its potential as a study site based on bottom composition and faunal distribution. Divers noted any evidence of ice scouring and disturbance of the substrate. Certain benthic species were targeted as potential reef colonizing fauna, and were sought out for further qualitative analysis.

3.3.2 Experimental and Control Site Criteria

Criteria for control and experimental sites were defined based on local conditions and consultation with literature detailing previous artificial reef projects. Data collection for site selection occurred between August 2 and September 6, 1989, and July 7 and July 28, 1990. Three initial criteria were established to limit the area of investigation for the experimental site.

1. Minimum depth of 15m (50 ft)
2. Sand/mud or gravel substrate with low benthic biomass
3. Minimum salinity of 28 ppt

Canadian Hydrographic Service charts (5400 and 5596) were consulted to determine areas that did not meet criteria 1 and 2. Possible sites were selected based on depth and bottom composition data, and subsequent observations were made using SCUBA equipment and benthic sampling techniques.

In 1990, sampling was carried out to establish depth, salinity, bottom composition and faunal distribution in selected areas. Sites not meeting the above criteria were systematically eliminated from the site selection procedure until the most suitable area was located.

While conducting the selection process for the experimental site, each area was evaluated for its potential as a control site. The following criteria were set :

1. Bedrock/cobblestone substrate with high benthic biomass
2. Close proximity (<1 km) from experimental site
3. Minimum salinity of 28 ppt

3.3.3 Physical Characteristics

In 1990 and 1991, depth, conductivity, temperature and Secchi disc readings were conducted from the boat prior to the dive. Using a conductivity meter and confirming temperature readings with diver gauges, readings were gathered for each site both at the surface and at depth. Discrepancies between diver gauge temperature reading and temperature probe readings were rectified by reading salinity using both temperatures. At the conclusion of the field season, the instrument was calibrated and data adjusted accordingly.

3.4 ADMINISTRATIVE PROCEDURES

The legal considerations for the siting, placement and biological investigation of the marine benthos include permitting, liability, and international law.

3.4.1 Permitting

Prior to formulating plans to sink the S.S. Graham Bell, consultation with the Port of Churchill and negotiation for ownership was undertaken. A meeting with Port Authorities in September of 1989 detailed the requirements and final approval of the project was withheld until the following were investigated:

> Assurance that the sinking will not result in pollution from oil or coal which might be present within the hull or any danger to navigation;
> Approval under the National Water Protection Act (sic);
> An Ocean Dumping Permit;
> Liability Insurance; and
> all other permissions required by applicable federal, provincial or municipal laws.

In researching the aforementioned requests, the following permits and legal considerations were investigated as to their applicability to this project:

> Ocean Dumping Permit
> Navigable Waters Protection Act (NWPA)
> Environmental Assessment Review Process (EARP)
> Liability insurance

A scientific licence to collect and sample invertebrates and fish for scientific purposes was required under Section 4 of the Canadian Fisheries Act. This permit was obtained through the Department of Fisheries and Oceans Canada for the 1990 and 1991 field seasons. This licence encompassed all sampling conducted in the marine waters in the vicinity of Churchill, Manitoba within a 10 km radius of approximately 50°48'N, 94°12'W (Fort Prince of Wales). A Scientific Research Licence from the Science Institute of the Northwest Territories was also obtained for the 1990 sampling season to licence sampling conducted outside the 10 km radius.

3.5 OPERATIONAL PROCEDURES

Initial investigation into the history of the vessel S.S. Graham Bell revealed the shipyard where she was constructed and date of sea trials. Efforts to locate the blueprints of the vessel were undertaken. Thorough examination of the Churchill Ports archives was conducted and the shipyard responsible for her construction was contacted. Finally, a request for assistance was sent to Canada Ports Corporation in Ottawa.

3.5.1 Initial Survey

In 1989, a thorough survey of the S.S. Graham Bell was undertaken. Film footage of the survey was obtained for review, and areas were marked for further investigation. Grating in the engine room and boiler room was marked for removal, as were areas on the coal bunker bulkhead and aft crew quarters. Topside engine room hatches were marked for removal, and potentially accessible areas were either widened or blocked off to reduce likelihood of diver entrapment and entanglement.

3.5.2 Vessel preparation

A request for assistance was submitted to the Canadian Army's 2nd Combat Engineer Regiment (2CER) in Petawawa, Ontario, for technical and operational assistance. In July of 1990, 13 members of the regiment arrived to survey the vessel and devise a plan for refloating and relocating the ship. Options for refloating the vessel were considered, and the decision was made to use external flotation. At high tide, the floats were hoisted off the wharf and into the river and towed into position surrounding the vessel. At low tide, holes were cut throughout the hull of the vessel and chains were attached to cross members and thwarts. Steel cables attached five floats to each side of the vessel by clamping onto chain loops, then doubling back around the float (Fig. 4a and b). As the tide flowed in around the vessel, the buoyancy of the floats was to act as a tidal winch, lifting the hull off the mud bottom and suspending it between two rows of floats (Fig. 5a). Quick release devices were designed and installed to assist in removal of floats at the site prior to sinking. Modifications to the steel floats were undertaken to reduce friction of steel cable on the sharp metal edges and prevent lines from snapping under load (Fig. 5b). To assist in loosening the suction on the hull of the ship created by the mud substrate, the local fire department brought in a pumper truck and directed high pressure water along the keel. To provide added force and assist in breaking the vessel free from its position, a cable was attached to the pintle of the rudder and a pulley system was devised. Two bulldozers were positioned on the wharf and set in position with blades firmly entrenched in the ground. A block was attached to one of the bulldozers, and the cable was run from the stern of the vessel through the block to a railway engine. At the highest tide mark, the engine took up the slack and attempted to dislodge the vessel from her position.

In 1991, repairs to the hull of the Graham Bell were undertaken in an effort to make her seaworthy. The chains and attachment points created by the 2CER were removed, and the hull surveyed to identify weak sections. Damaged areas above the waterline were welded and repaired with scrap steel, and where wet conditions and corrosion prevented welding repairs from occurring, plywood and sealant patches were utilized.

A six inch diesel pump was placed on the deck of the ship, and as the tide rose, the pump was used to prevent the water from rising above the repaired areas. This allowed for evaluation of the previous patching job and investigation of leak sites. At each successive low tide, further progress was made toward creating a seaworthy hull.

Figure 4a. Position of floats surrounding vessel.

Figure 4b. Cable attachment point on port bow of the Graham Bell.

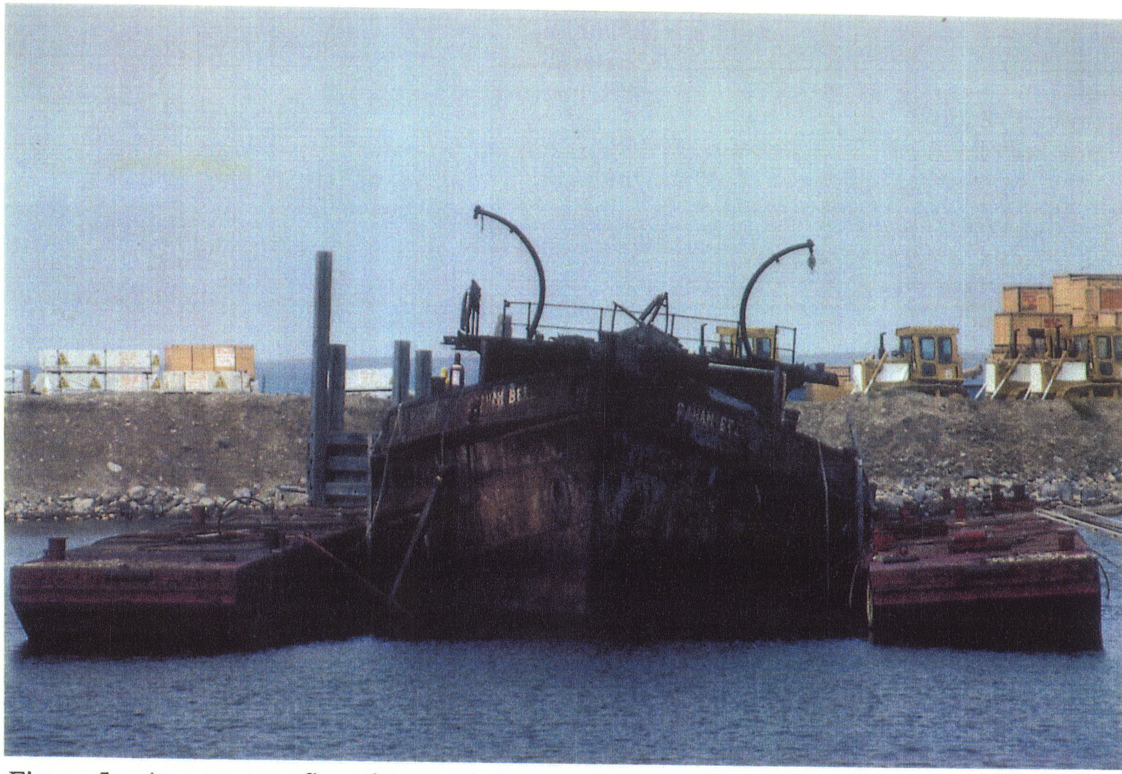

Figure 5a. Attempt to refloat the vessel Graham Bell utilizing a tidal winch system.

Figure 5b. Modification to floats designed to reduce cable abrasion.

Sections along the starboard keel were badly corroded, and remained immersed in seawater during low tide. Patching was undertaken with gasket sealant and insulating foam, then a layer of concrete was placed along structurally weakened areas to reinforce the patches and provide ballast for the vessel.

A three metre deep trench was excavated along the starboard side of the vessel. On the highest high tide, a backhoe was positioned approximately 30 metres off the starboard side of the vessel, and cables were placed fore and aft. As the tide rose, the backhoe increased tension on the cable, sliding the vessel westward into the trench.

3.5.3 Preparation for tow

Arrangements to place a 10 m^3 cement block on the experimental site were made with Churchill Port Authorities. A cable and float attached to the block would serve to tether the vessel in position when sinking occurred.

Dredging the channel south east of the port wharf occurred in 1991 to assist in moving the vessel from her current position out to the sinking site. The trench excavated for the floating procedure was extended to the tug channel adjacent to the wharf.

In order provide sufficient water for the vessel to clear the bottom at the entrance to the river, a 4.0 m tide was required. Sinking operations were planned to coincide with the highest tides, which occurred approximately once a month and provided four days of workable water levels.

3.5.4 Environmental Concerns

Approximately 80% of the coal was removed from the bunkers of the Graham Bell to reduce silting effect when diving on the vessel and to reduce particulate matter from the vessel. An inspection for hydrocarbons in the engine room and propeller shaft was conducted to assess the environmental risk. Loose material on the deck and in the cabins was removed and a general inspection of the vessel was conducted using the EARP guidelines. In 1991, a representative from Environment Canada was present to observe the procedures and ensure that all precautions had been taken with respect to environmental safety.

3.6 PROGRAM DEVELOPMENT

Programs of use for the artificial reef and data gathered were designed. A multi-user approach was used in developing each area, with consideration for future use. Three specific user groups were targeted:

Scientific community
Education
Tourism

3.6.1 Scientific community

The qualitative data gathered over three field seasons will be published as a partial species list for the Churchill region. Species have been distributed to scientific experts for further taxonomic identification. The development of an ongoing colonization study was initiated and the possibility of continued reef monitoring was explored.

3.6.2 Qualitative Sampling Techniques

During the 1989 and 1990 field seasons, epifaunal and epibenthic organisms were photographed in situ using Nikonos V and/or Nikonos III cameras with 35mm lenses and extension tubes. All photographs were taken using Watercolours® colour slide film and a

Nikonos 102 or Oceanic 2001 strobe. Organisms were then sampled by hand capture methods for further identification in the laboratory. Specimens were placed into individual sampling bags and surrounding environmental conditions were noted. Each exposure was recorded and marked on the sample to assist in identification and provide information on local environment.

In 1991, qualitative sampling continued, and included infaunal and pelagic organisms. Photographs were taken using a Nikonos III, extension tubes and an Oceanic 2001 strobe. Sampled organisms were photographed *in situ* and in the laboratory (Nikkormat, 50mm lens and a Vivitar 283 flash, Kodachrome 64 ASA colour slide film).

3.6.3 Quantitative Analysis

In 1991, 38 dives were conducted at the control and experimental site and surrounding areas to establish quantitative biomass. All surveys and sampling were conducted by divers using SCUBA unless otherwise indicated. Three contiguous transect lines were set in an east to west direction traversing the sites. Transect locations were determined by depth readings and sighting lines utilizing range markers ATL 1458 and ATL 1460. Accuracy of this method was determined by using underwater topography and markers indicating previous site analysis. The control site consisted of a rock reef, 200m long by 100m wide. Each transect line consisted of 6 sampling sites. Two samples were taken from sites IBRM, ITRM, and ORM (Fig. 6). Sites IBRM were taken at the base of the cobblestone wall, sites IRM were 25 kick cycles from the base of the reef, sites ITRM were taken from the smooth bedrock surface at the top of the cobblestone wall, and sites OTRM were 25 kick cycles from the ITRM area, and sites OBRM were a distance of 5 kick cycles from OTRM. ORM, or experimental site area, was 25 kick cycles from OTRM.

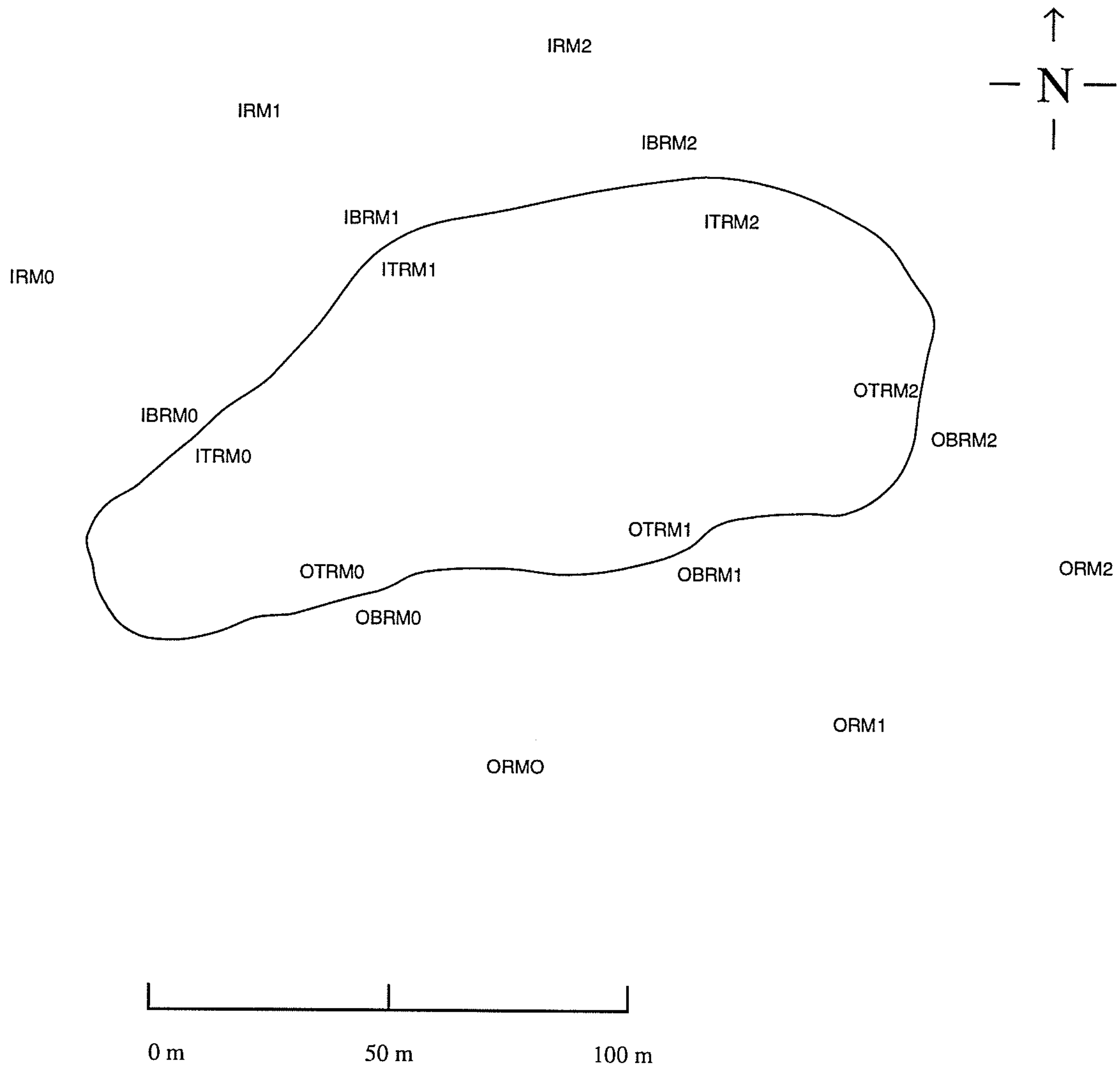

Figure 6. Control site with corresponding sample site transects.

Sampling was conducted using a 1/2 m2 PVC quadrat dropped from a height of 2m above the site. Photographic records of each site were taken prior to airlift sampling, and sites IBRM were photographed after sampling was completed (Fig. 7). Any motile epibenthic organisms (notably *Hyas* sp. and *Sclerocrangon* sp.) and large macroalgal specimens encompassed by the quadrat were immediately collected by hand and placed in sampling bags. Utilising a paint scraper and trowel, all visible epifaunal and infaunal organisms were dislodged from point of attachment and collected using a self contained diver operated airlift. Loose boulders and rocks were moved to ensure thorough sampling.

The airlift consisted of a 2m length of PVC pipe, 10 cm in diameter, fitted with a detachable sampling bag made of woven nylon screening. A low pressure hose with a flow through brass valve was attached to the bottom end of the PVC pipe. A SCUBA cylinder and first stage regulator supplied air to the mouth of the unit (Fig. 8). Suction was created by introducing a stream of fine air bubbles into the PVC pipe, and organisms flowed through the pipe into the sampling bag. The airlift was designed to allow for bag removal and replacement underwater.

Initial sampling equipment consisted of a $^1/_2m^2$ PVC quadrat with 1 m frame supports for the Nikonos and strobe (Fig. 9). The frame supports were found to interfere with airlift procedures and created resistance in currents, thus increasing likelihood of quadrat movement and increasing possible degree of error. Sampling continued with a single $^1/_2m^2$ quadrat held in place by the researcher, and photographs were taken by a diver hovering 1 m above the site. Three photographs were taken of each sampling site using Watercolors® slide film (Fujichrome balanced for underwater). For sites exhibiting high biomass, (sites IBRM0, IBRM1 and IBRM2), additional photographs were taken after the airlift sampling was conducted to estimate coralline algae cover and evaluate the effectiveness of sampling technique.

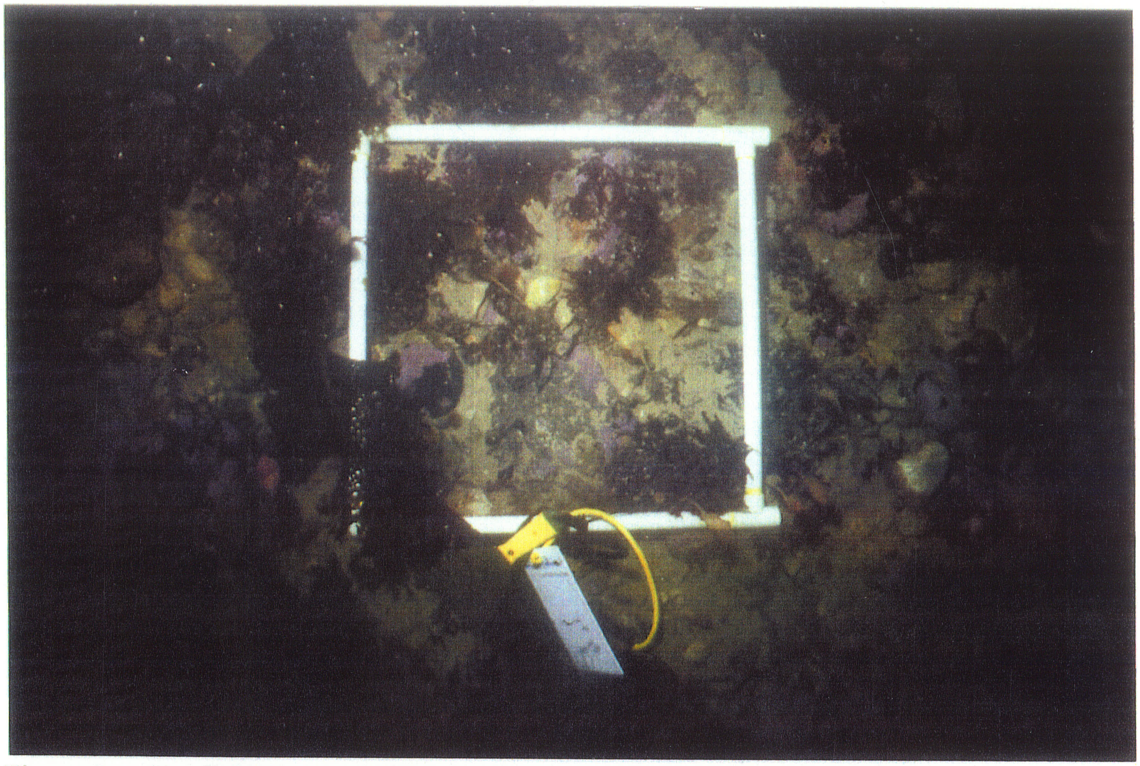
Figure 7a. Site IBRM1, photographed prior to benthic sampling with airlift.

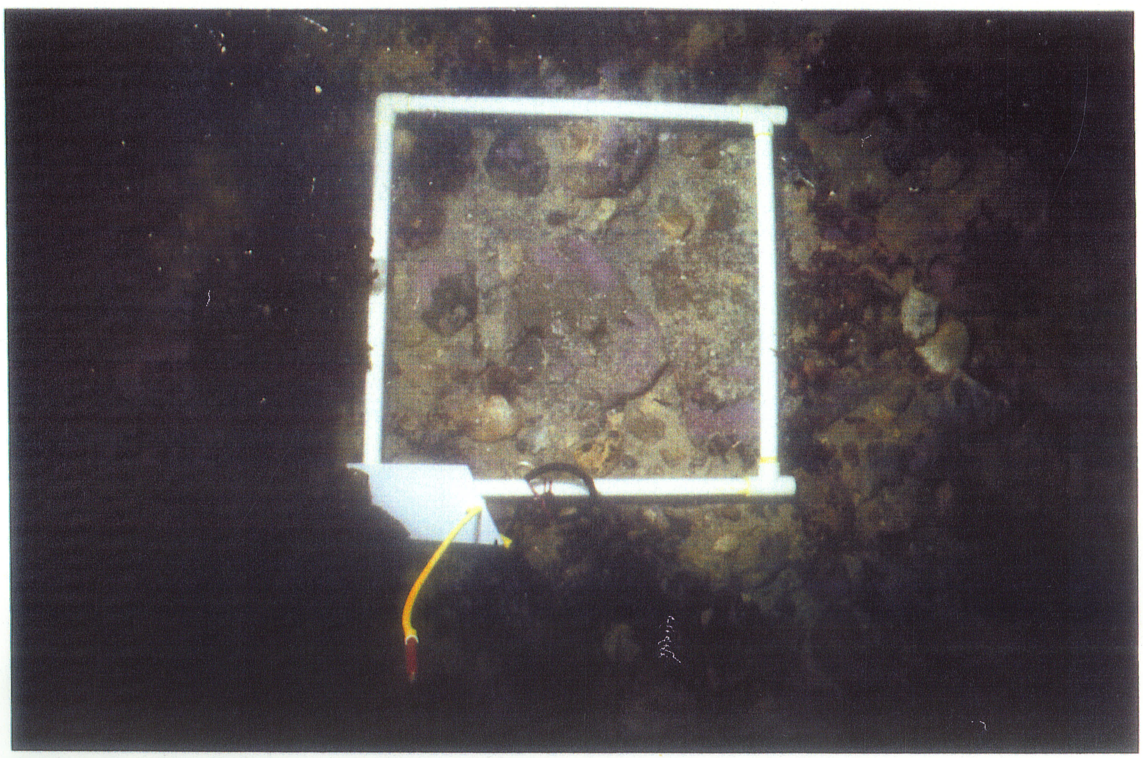
Figure 7b. Site IBRM1, post airlift sampling.

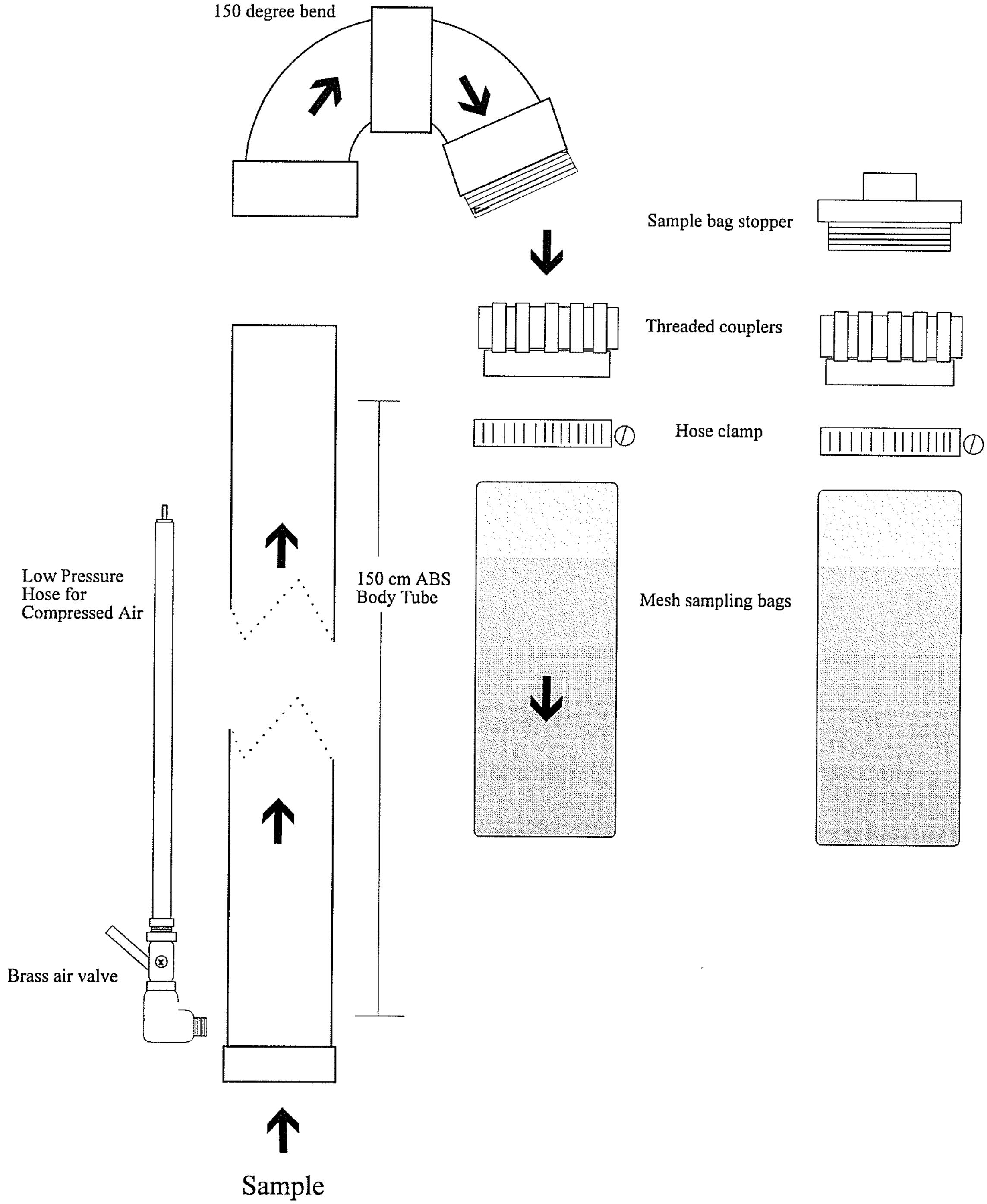

Figure 8. Details of airlift construction (after Benson, 1989).

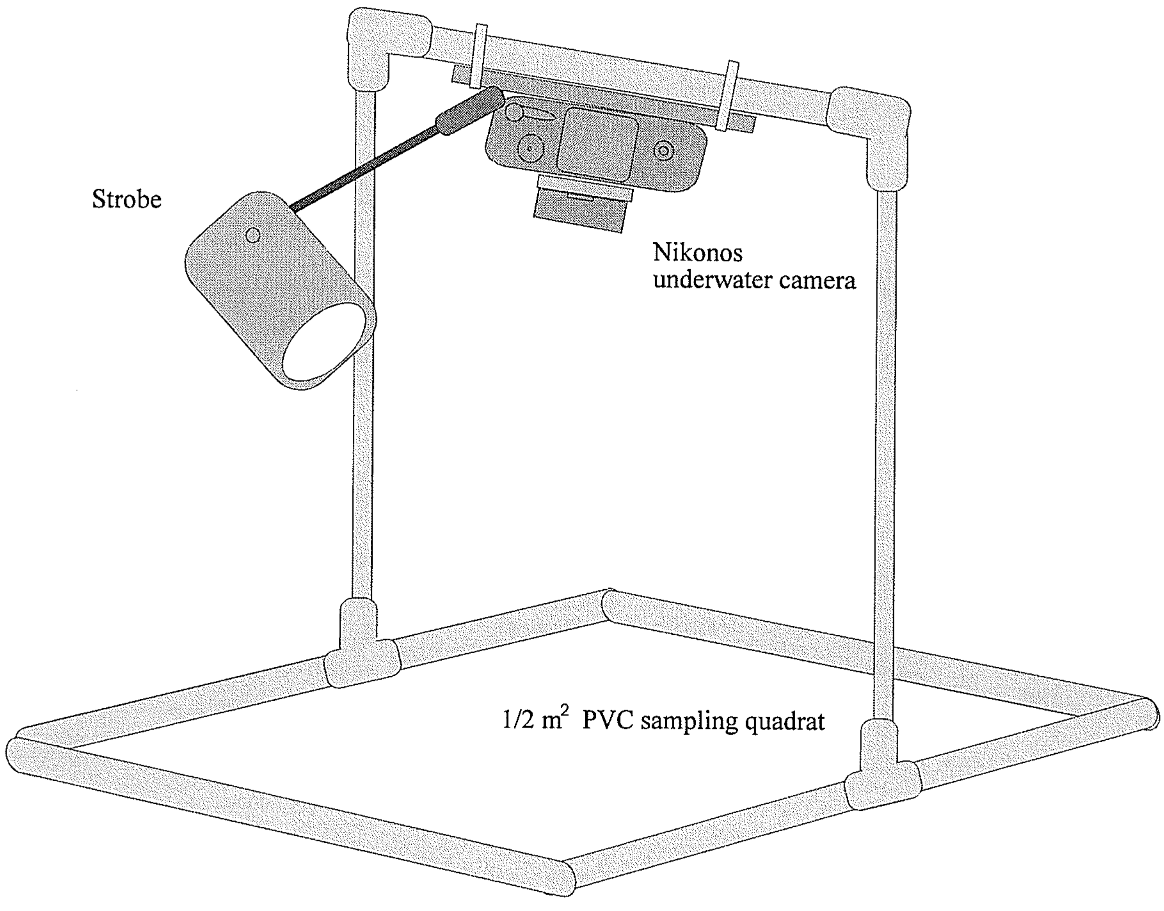

Figure 9. Quadrat, Nikonos underwater camera and strobe for quantitative biomass sampling.

Biomass data for control and experimental sites were analyzed by a one way analysis of variance (ANOVA, $p<0.0001$). A Newman-Keuls test at 5% probability was also conducted to establish homogeneity of variance.

3.6.4 Laboratory Analysis Procedures

All biomass samples were processed and weighed within 24 hours of collection. Airlift contents were placed in large plastic trays, and sample bags were rinsed with sea water to ensure all organisms were removed. The sample was sorted and foreign material removed. Excess water was poured out of the tray and organisms were removed using a nylon net. The net was placed on blotting paper for approximately 1 minute, then inverted onto a Meitser balance and weighed to the nearest milligram. Large samples were weighed in three separate quantities, and all biomass weights included mollusc shells but excluded polychaete tubes, which were difficult to discern from sediment and sand inadvertently collected during sampling. After weighing, airlift samples were stored in 10% formalin until further laboratory analysis occurred (1-3 months later). Samples were then transferred to 70% methyl alcohol in a three stage process (25%, 50%, then 70%). Airlift samples and specimens from qualitative sampling were forwarded to invertebrate taxonomists for further identification. These data will be reported in future publications.

Qualitative sampling was selective, with frequent sampling of large macroinvertebrates (>1 cm) and epibenthic organisms. All fish, holothuroidians and decapods were preserved in formalin immediately after sampling and transferred to 70% methyl alcohol within 1 week of sampling. Initial samples of echinoderms were preserved as described for holothuroidians, then removed from the alcohol and air dried. Some samples were photographed before transferring to alcohol to record colour and pigment.

3.6.5 Education

Photographs, slides and species descriptions were gathered for common marine species in the Churchill region. Representative species from many phyla were selected to emphasise the arctic marine energy flow. Examination of the northern science curricula was undertaken to identify areas where northern species education could be included. Basic concepts of the curricula were noted and alternate examples utilizing local northern fauna were identified. This information will be available to northern schools for incorporation into the science program. A letter detailing the information package has been composed, and pending approval, will be distributed to northern schools.

3.6.7 Tourism

Information on species distribution and ecosystem components was recorded for use by recreational diving tour groups and film crews. Location of sites considered to have high diver appeal were noted, and areas where whale contact was frequent were recorded. Underwater photographs and video footage obtained during the study are available for use by local business people to promote tourism in the Churchill area. The process of creating the artificial reef was documented by a professional cinematographer, and the footage archived for an historic production on the history of the Churchill port.

Chapter 4
RESULTS

The creation of an artificial reef is a systematic process encompassing various forms of data collection and information gathering techniques. The results of this study were collected from previous literature, personal observation and actual experience. Site selection, operational procedures and administrative processes are presented as a chronological documentation of the attempted creation of an artificial reef in the Churchill region.

Qualitative sampling and observation of biological organisms occurred throughout the study. General observations resulting from 1989 field season are reported in tabular form. Data gathered in 1990 consisted of observations, qualitative biological collection and photographs. Specimens collected for qualitative purposes have been distributed to the appropriate scientific authorities for identification. When identification process is complete, the collection will be donated to the Manitoba Museum of Man and Nature's invertebrate zoology library. Epifaunal organisms were of particular interest due to the likelihood of colonization on the artificial reef, consequently data reflects selection of organisms that would utilize a solid substrate as a point of attachment. Associated epibenthic and pelagic organisms were also sampled to assist in identification of the ecosystem. Qualitative data and observations from 38 dives in 1991 are reported in Appendix 2, while quantitative sampling data are listed by site and transect in Appendix 3.

The data from biological specimen identification will be reported in subsequent publications as it becomes available. Obtaining positive conformation of species found in the region proved to be difficult due to lack of literature and controversy over identification. Some specimens exhibited characteristics of two or more subspecies, and are the subject of further study. Further funding will be required to obtain expert identification of some of the specimens. However, a breakdown of biomass samples into taxonomic categories will be forthcoming.

4.1 STUDY ZONE ANALYSIS

4.1.1 Tourism potential

Eleven dives conducted during 1989 provided a basic overview of conditions within the study zone, and confirmed the shallow depths and varied bottom composition reported by Prinsenberg and Freeman (1986) and the Canadian Hydrographic Survey charts. The initial investigation into diving conditions revealed the possibility of establishing a diving tourism industry in the town of Churchill. Water temperature, an important factor in diver comfort, was not prohibitively cold for dive times of 1/2 hour or less. Divers in wet suits found that surface support was an important factor in diver comfort. If prompt assistance in gear removal was provided and the diver immediately changed into dry clothes, temperature was not considered a negative factor. The journey back from the dive site was found to be uncomfortably cold if wet suit divers did not change into dry clothes following the dive. Evaporative cooling had a negligible effect on drysuit divers, but a number of individuals noted the importance of dry warm head and handwear.

The type of vessel used was evaluated with respect to diver comfort. Open Zodiacs or inflatable vessels are commonly used for diving operations, but afford little protection from the elements. Entering the water was easily accomplished from inflatable vessels, and "silent entry" (sliding into the water with a minimum of noise and bubbles) was possible when attempting whale dives. Assembling equipment and gearing up created difficulties for novice divers, but it was not considered prohibitive. At the conclusion of the dives, some individuals found it difficult to remove gear and pass it to the boat tender due to reduced motor skills caused by the 0° C water temperature. Increased thermal protection under drysuits required additional weight on the weightbelt, thus increasing the effort required to pass the equipment to personnel aboard the vessel. Entering an inflatable without gear was accomplished by "bobbing" upward while grasping the vessel's side lines, and "finning" to gain momentum. Again, some novice divers experienced difficulty in executing this technique, and alternative methods were implemented.

The use of a 12 m aluminium whale watching vessel provided greater deck space for gearing up and down, but required a giant stride entry from a height of 1 m to initiate the dive. The presence of a platform at the stern of the vessel allowed divers to pass equipment up to personnel on board, but proved difficult in rough conditions as the platform would rise and fall at a different time frequency than the diver. Most dive sites were in relatively shallow areas close to shore, and required the boat operator to maintain control of the vessel at all times, consequently the engines continued to run while divers prepared to board. Divers found the engine exhaust to be uncomfortable, especially if required to wait for fellow divers to board the vessel.

The opportunity to observe arctic flora and fauna was considered a unique experience by divers, and the photographic opportunities were indicated as being a primary feature. All divers indicated contact with beluga whales (*Delphinapterus leucas)* as being the most attractive feature of diving in the Churchill region. Beluga were observed underwater on two separate dives in 1989, while whale song was heard on 5 of 11 dives. Sites exhibiting relatively high epifaunal and epibenthic biomass and rock/cobblestone substrate were rated higher than sand/mud substrate with relatively low infaunal and epibenthic biomass.

Participants in the 1989 dive excursion identified the need for another underwater feature in order to make the area competitive in the diving tourism market. The presence of a ship wreck was cited as a potential drawing card for many tourists, and recommended further investigation into possible wrecks in the vicinity. The creation of an artificial reef was considered a viable alternative.

4.1.2 Physical characteristics

Substrate composition

A quantitative system of grading substrate was not utilized in this study, however, the general qualitative guidelines were as follows:

Mud - material was fine enough to remain suspended in the water column when disturbed.

Sand - material would sink to bottom without appreciable amounts remaining suspended in the water column.

Gravel - rocks large enough to be picked up individually by a diver with gloves on, but small enough to fit in the palm of a hand.

Cobble - rocks that could be moved by a diver underwater, but could not be concealed in a diver's clenched hand.

Boulder - large stones or rocks that could be dislodged or moved from their location only if external force were applied.

Bedrock - immobile solid rock underlay.

Throughout the study zone, a great variation in substrate type and associated biomass was observed. General observations were made in 1989. Soft mud/sand substrate exhibited low biomass with occasional infaunal organisms, consisting mainly of serpulid worms and echiurans (Phylum Echiura). The absence of large infaunal bivalves (notably *Mya truncata*) was surprising as they were previously observed in the area (Lubinsky, 1980). Sites consisting of mixed sand/gravel and cobblestone substrate were observed most frequently in the 3-10 m range, and appeared to have well developed macroalgal growth and associated epibenthic populations. Out of the eleven sites examined in 1989, three exhibited cobblestone/bedrock substrates and appeared to have the highest diversity and biomass, consisting of macroalgae, epibenthic motile organisms and epifaunal organisms attached to large boulders and stable rock surfaces. Mud/sand substrate was observed on 5 of 11 dives, at depths greater than 12 m.

Observations in 1991 focused on the study site within the Button Bay study zone. The experimental site substrate consisted of coarse sand interspersed with areas of mud or clay (sites ORM0, ORM1 and ORM2). The control site and transition zone between the control and experimental site exhibited various substrate types. The transition zone, sites OBRM0, OBRM1 and OBRM2 consisted of coarse sand interspersed with occasional boulders.

On July 17th, 1991, a reconnaissance dive conducted in the transition zone revealed trenches in the sand and gravel (maximum depth 17 m). Direction and length of trenches varied considerably, and height of trench walls ranged from 20 cm to 150 cm. Occasional large boulders were observed (up to 60 cm wide), and significant epifaunal growth on the surface of one boulder (*Gersemia* sp. 10 cm in height) indicated stability of substrate. At the time of this dive, ice was present in the bay with some keels reaching 10 m beneath the surface. No evidence of trenches or ice scouring were observed on subsequent dives to the same general area.

The transition zone, or area between the sandy experimental site and the control site's bedrock reef gradually changed from sand to gravel to bedrock as it approached the control site. At the shallowest point, the top of the reef (8.5 m) was smooth bedrock with some sand/gravel overlay. A 2m drop to IBRM sites was characterised by large cobblestone/boulder wall. The base of the reef and sites extending southeast toward the coastline exhibited predominantly rock and boulder substrates (sites IRM0, 1 and 2).

Current

Dives conducted in the 0-10 m range were in areas of high water movement subjected to surge and tidal water flow (semidiurnal tidal pattern). In the 10-20 m range, tidal water flow created mild currents of sufficient speed to allow drift diving (<1 knot), where divers allow the current to carry them in the water column. Dives in the study site were conducted at or approaching high tide, and exhibited predominantly northeast tidal currents. The strength of current decreased from the top of the reef toward IRM sites, and increased toward ORM sites. Within the river, diving conditions deteriorated as the effect of the tidal flow increased due to the narrowing of the channel and created high currents, reduced visibility (<1 m) and suspended particulate matter. Tidal current at flood tide caused a rapid (>1 knot) flow upstream.

Visibility

Visibility ranged from 0 m to 15 m, and was negatively affected by strong winds and the presence of a halocline. Dives conducted in the river exhibited a maximum horizontal visibility of 1 m, with lowest visibility occurring during the ebb tide. Turbidity of the ocean water was difficult to measure due to the effect of freshwater surface layer, as the effect of the halocline created reduced vertical visibility. Secchi disc readings (vertical visibility through the water column) were consistently lower than diver visibility (horizontal visibility across the water column). Layering of water was noted on the majority of dives, with the lowest visibility occurring in the 0-5 m range.

Three dives were aborted due to reduced visibility. In 1989, gale force winds three days prior to the dive caused turbid conditions resulting in <10 cm visibility. In 1991, following two days of 30-50 kph winds, a dive conducted in Button Bay was aborted after 5 minutes due to reduced visibility. The sediment load in the water column was high enough to completely obliterate light penetration at 10 m, both from the surface and from diver held xenon lights. Physical contact with the substrate indicated a sand/gravel bottom. Three additional days of high winds contributed to continued turbidity. A distinct line between "brown" water of low visibility and "blue" water offshore was visible for approximately 5 km radius from the mouth of the port. Secchi disc readings in Button Bay were 60 cm, while south of the river mouth readings were 1 m.

4.1.3 Biological Characteristics

General biological composition of species on each dive correlated strongly with substrate type. Shallow dives (<11 m), in close proximity to shore with mixed cobblestone/bedrock substrate were dominated by blue mussels (*Mytilus edulis*), various species of anemones, red and green macroalgae and crabs (*Hyas coarctatus*).

Qualitative observations indicated that bedrock/cobblestone sites at depths greater than 15 m were visibly dominated by tunicates and soft corals. Sea cucumbers, starfish and sponges contributed to the impression of an area rich in epibenthic organisms. Areas that appeared to be highly colonized were associated with large boulders (>1 m) and bedrock. However, at the control site reef, the bedrock substrate that comprised the top of the rock reef (<10 m depth at datum) was visibly devoid of epifauna.

Mud and sand substrates at all depths were surprisingly barren. No evidence of clam siphons was found. On two occasions, while diving in areas exhibiting mud substrate, echiurid worms were observed. The presence of a large boulder in the substrate would be associated with epifaunal organisms, notably *Psolus chitinoides* and *Gersemia rubiformis.*

4.2 BIOLOGICAL FINDINGS

Wet weight biomass data from 27 airlift samples is recorded in Table 1. Quantitative biomass data from control and experimental site were analysed to establish homogeneity of variance. Results showed a highly significant difference between the high biomass sites at the base of the north wall, sites IBRM1, 2 and 3, and all other sites (ANOVA: $F_{(5,24)}$= 11.78, $p<0.001$). A Newman-Keuls multiple comparison test showed that set 5, IBRM1, 2 and 3, differed significantly from the other 5 sets, the latter forming a statistically homogeneous subset.

Biomass readings from Table 1 and site locations identified in Figure 6 were used in the above calculations. Observations and visual descriptions of each site are listed in Appendix 2.

Table 1. Biomass ($g \cdot m^{-2}$) of benthic epifauna and infauna at each sample site at control and experimental sites, Button Bay, Churchill, Manitoba, during July and August 1991.

Site		Biomass	Site		Biomass	Site		Biomass
080591	IRM0	59.51	080691	IRM1	9.05	072891	IRM2	1.96
080591	IBRM0	40.99	072791	IBRM1	68.41	080591	IBRM2	89.54
080491	IBRM0	102.10	072891	IBRM1	32.50	072991	IBRM2	17.28
080391	ITRM0	0.13	072791	ITRM1	0.04	072991	ITRM2	0.05
080491	ITRM0	0.04	072891	ITRM1	0.08	072691	ITRM2	0.04
080391	OTRM0	0.00	080891	OTRM1	0.03	072991	OTRM2	0.00
080491	OBRM0	0.20	072991	OBRM1	0.35	080391	OBRM2	0.00
072991	ORM0	0.00	080391	ORM1	0.00	080891	ORM2	0.00
072691	ORM0	0.00	080891	ORM1	1.64	080891	ORM2	0.00

Chapter 5
DISCUSSION

In documenting the process of reef creation using the derelict ship, S.S. Graham Bell, a general format for reef development has emerged. Previous studies have revealed that many projects do not begin with a proper management plan, nor do they examine the long term repercussions of a reef project. This management plan has provided for both a thorough pre-placement assessment and programs of continued use.

5.1 DEVELOPMENT OF A MANAGEMENT PLAN

In reviewing the literature, it was noted that most successful artificial reef projects utilised a basic formula for achievement: Identify a need and then meet it. This formula encompassed both the user group and the target species, thus providing parameters and criteria for project development.

This basic formula has been incorporated into the Graham Bell project and resulted in a series of actions designed to prompt project managers into setting criteria for development. The following steps were followed to develop a systematic management plan.

1. User group identification
2. Identification and investigation of need
3. Material and site selection
4. Administrative procedures
5. Operational procedures
6. Program development

The development of an artificial reef in Churchill has potential to generate benefits for many user groups. Initially, the concept revolved around three separate issues:

Disposal of a derelict vessel, the S.S. Graham Bell;

Creation of a dive site for recreational divers;

Monitoring growth and colonization rates of arctic marine organisms.

Other user groups were examined to assess both possible negative and positive impacts of an artificial reef.

Disposal of a derelict vessel located in the vicinity of the Port of Churchill would benefit Canada Ports Corporation by providing an inexpensive means of removing the ship. Churchill has come to be dependent on tourism for much of its revenue over the last two decades, and public appearance is an important issue. The ship and assorted parts of its superstructure are scattered south of the main wharf of the grain dock. Whale watching tours and historic tours to Fort Prince of Wales originate from the berth adjacent to the location of the wreck, and concern over the general appearance of the area has been expressed by both tour operators and tourists. Removal of the ship from the vicinity would be viewed as a benefit to Canada Ports Corporation and tourism industry of Churchill. The benefits to the port were clearly defined: removal and disposal of the vessel and positive publicity at a time when the port's future was uncertain. Possible negative effects were assessed as being an inadvertent placement of the vessel in the shipping channel, creating interference with incoming grain ships. The negative impact was offset by a liability policy covering removal costs or demolition of the vessel should it be lost at sea while under tow to the sinking site (Appendix 4).

In 1989, Tourism Manitoba funded an investigation into the feasibility of recreational diving industry in Churchill, Manitoba. The results of this ten day study were positive and indicated high potential for such an undertaking (Giberson, 1990). It is well recognised that wreck diving is a popular pursuit of recreational divers and the addition of a wreck dive to the itinerary of a northern dive tour would increase its salability in the competitive tourism market. If the vessel was sited beyond the safe limits of recreational diving, or in areas where currents and water conditions were too difficult for the experience level of an average diver, the benefits to this group would be lost. Distance from the town of Churchill should not be prohibitively far as to discourage recreational diving excursions from occurring.

Benefits to the scientific community are both incidental and intended. Observations and data gathered during the site selection phase, as well as investigation of target species yield important biological information pertaining to sub arctic benthic systems. Current literature does not contain any reference to benthic studies using SCUBA in the Churchill region and recent species lists were compiled from data gathered by dredges, nets and drags. *In situ* observations for the majority of benthic organisms in the region do not exist. Incidental sitings of beluga whales contribute to an aspect of beluga behaviour that is not often observed, as few underwater observations exist of beluga behaviour in the wild.

To provide ongoing benefits to the scientific community, the sinking of the Graham Bell was planned as a scientific experiment with an established control site in the vicinity. The results of this preparatory analysis yields information on the productivity of a selected area and will provide information on species diversity when biological analysis is complete. In addition to data gathered in the preliminary study, a program for ongoing monitoring would ensure that colonization data and growth studies could be gathered using predefined methodologies for collection.

The presence of the Churchill Northern Studies Centre draws a variety of researchers to Churchill each year to study the mixture of ecosystems present on the coast. This facility has freshwater wet/dry laboratories, accommodation and meals, and at present, the use of a 7 metre vessel for marine studies. Rail service to the area provides a reduced cost for supplying a field operation, thus allowing subarctic marine research to occur without the added expense of air freight. Churchill provides a viable site for marine studies with reduced expenses due to accessibility and availability of facilities.

Benefits to each of the identified user groups need to be defined as a specific result of artificial reef creation. Set criteria defining the parameters of reef use by each group assists the reef manager in meeting the needs of the users. In general, artificial reefs provide benefits to a population by enhancing the marine environment. The way in which the environment is enhanced and the composition of species targeted to receive the benefits provided by the artificial reef must be established so that further investigation of the situation may follow. In many cases, an increase in a local population of an organism is the desired benefit. This target species or community is studied to better understand the factors preventing an increase in local population. Identification of each organism's basic requirements allows the manager to observe the present environment and select areas where an artificial reef may provide increased resources to the organism. Failure to meet the needs of the organisms usually results in failure to increase the population, nullifying any benefits to the user.

Recreational divers are attracted to a highly diverse, colourful array of organisms colonizing a vessel. Diving in Churchill provides a unique environment, characterised by various substrates and associated ecosystems. Identification of a number of species that may colonize the vessel and produce such an effect resulted in a selection of epibenthic organisms for the target community. Species of soft corals, tunicates and holothuroidians require a stable substrate on which to attach and thrive. As filter feeders, they also require high nutrient levels and moderate currents to obtain food. Observations of epibenthic communities at the control site indicated that present physical conditions were conducive to survival. Absence of these organisms from the experimental site was assumed to be caused by the lack of stable substrate, as other environmental conditions were equal. Substrate types between the sites differed considerably; the bedrock/cobblestone control site exhibited comparatively high biomass (6.531 $g \cdot m^2$), while the sand/mud bottom of the experimental site revealed significantly less biomass(0.068 $g \cdot m^2$). The presence of an occasional boulder in the experimental site confirmed that conditions were correct for epibenthic growth, as available space on stable substrate was colonized by target organisms (Fig. 10).

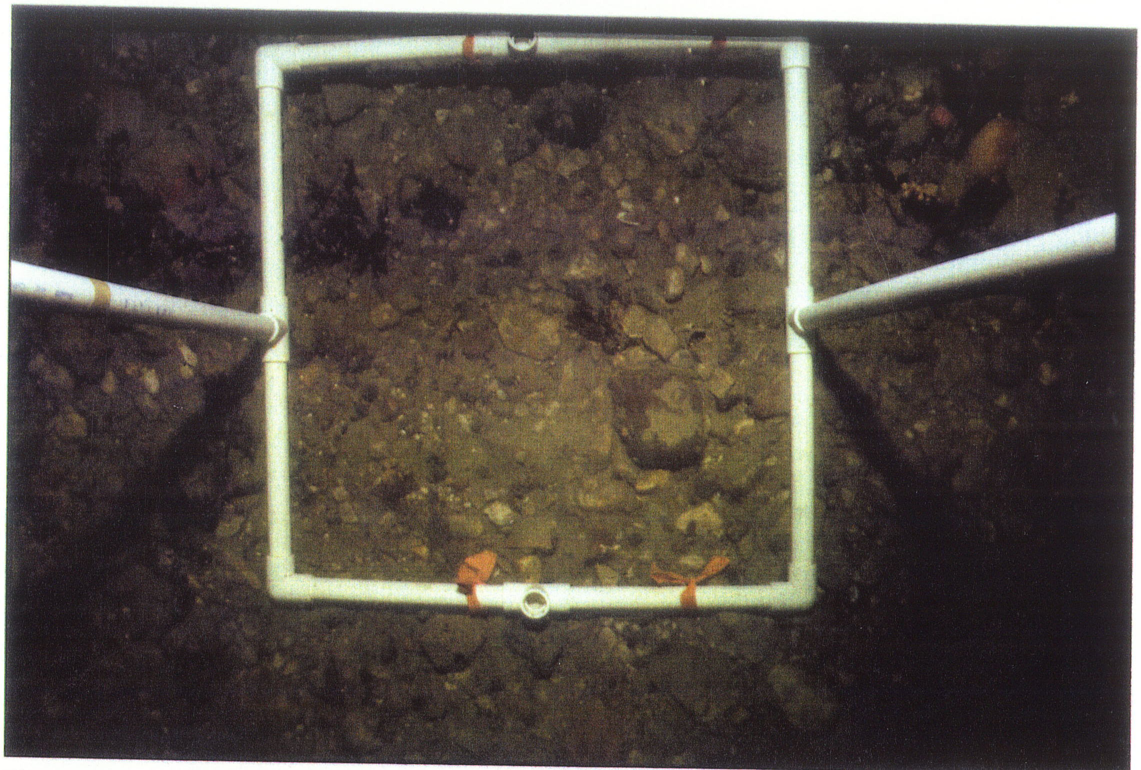

Figure 10a. Typical substrate and minimal biomass observed in ORM sites.

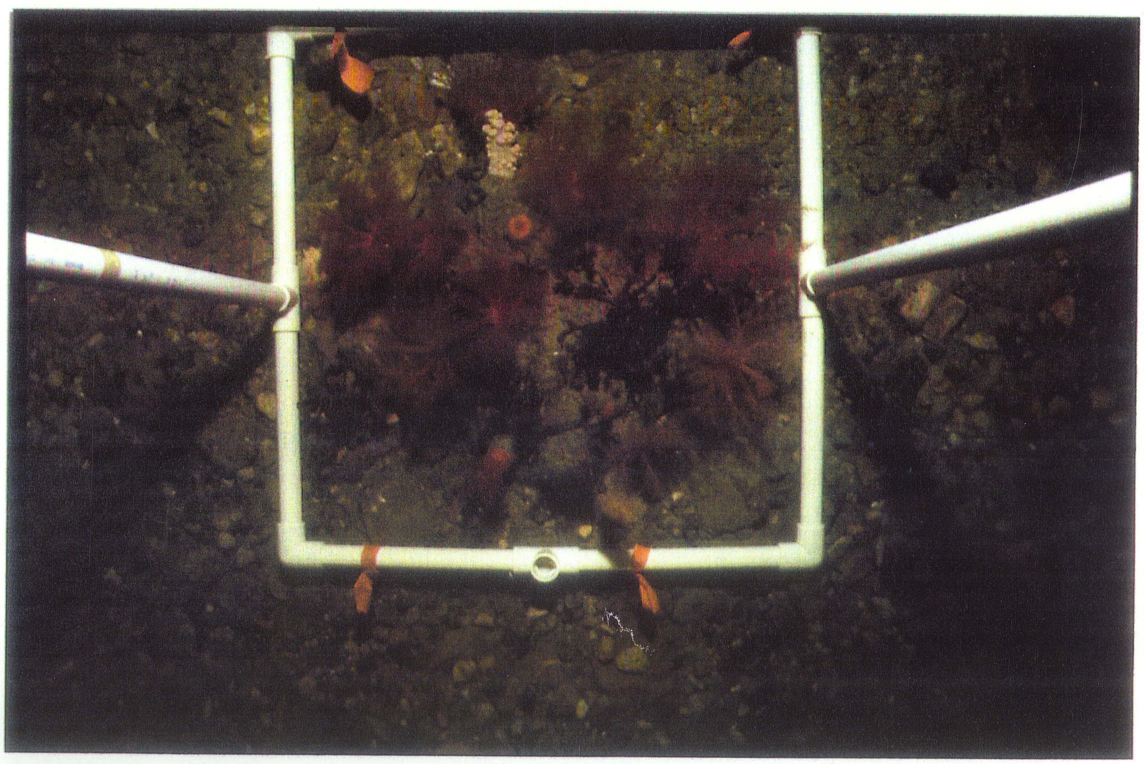

Figure 10b. Presence of stable substrate in ORM sites attracts relatively high numbers of epibenthic organisms.

This indicated that a possible limiting resource for growth of epibenthic organisms was the absence of stable substrate.

Although tunicates and holothuroidians were found in depths ranging from 6 m to 21 m in the study zone, soft corals (*Gersemia* sp) were not observed in depths less than 12 m To facilitate safe diving within recreational time and depth limits, the ship should not be deeper than 30 m, thus creating a narrow depth range at which to place the vessel on order to achieve stated benefits. Currents in the vicinity of the vessel must be fast enough to provide a proper environment for filter feeding organisms, but weak enough to allow larvae to settle and attach. Poor visibility and strong currents reduce diving conditions and adversely effect the quality of recreational diving. Selection of the reef placement site must consider these requirements to achieve success.

When considering disposal of the vessel S.S.Graham Bell at sea, the benefits accrued by Canada Ports Corporation are not directly affected by colonization on the reef, nor ability of divers to safely enjoy the shipwreck. However, the success of the reef as viewed by other users reflects on Canada Ports Corporation, as they are an instrumental force in the operational procedures, hence they will receive indirect benefits from the ability of the reef to meet other user's needs.

To provide value to the Canada Ports Corporation by developing an artificial reef, the ship's placement must be a reasonable distance from the shipping lanes as to prevent potential interference with navigation. The ship would have to be towed from its present location to the sinking site, therefore the distance should not be prohibitively long. As the vessel had not been seaworthy in many years, its ability to withstand extended periods afloat or unfavourable sea conditions was not known.

Development of an ongoing monitoring program for colonization and growth on the Graham Bell involves benthic biomass investigations and analyses of species diversity. Consequently, the vessel must be sited in an accessible area with conditions selected to facilitate repetitive diving. A reduced depth, (<30 m), light to no current (<0.5 knots) and sufficient visibility (>5 m) are required to create an effective study site.

Proper siting of an artificial reef is one of the most crucial factors to the success of the project (Mathews, 1985). Fine substrate material such as sand or mud in combination with underlying bedrock is ideal (Mathews, 1981). Some settling is desirable to support the reef structure, but an underlying layer of rock prevents reef from altering orientation over time. Soft sediments composed of primarily silt or clay should be avoided.

Physical characteristics of surrounding environment should be investigated and compared to requirements of target species. Salinity, temperature, turbidity, and other water quality parameters will influence the existence of organisms, affecting the success of reef colonization. Observation of existing organisms in potential sites will reveal information on the suitability of the environment. Thought should also be given to predator/prey relationships, competition with existing species and distance from established communities of organisms.

The criteria for site selection of the Graham Bell were developed by closely examining the requirements of recreational divers and the parameters of proposed scientific study. The marine shelf off the coast of Churchill is composed of various types of unconsolidated sediments overlying a base of Precambrian bedrock (Pelletier, 1986). This configuration of substrate types provides a wide array of choices for siting a reef. Placement of the structure on a sandy substrate would provide necessary attachment sites for such organisms in an area where stable substrate was considered a limiting resource. The presence of a rock reef in the vicinity would provide a control site for comparative colonization studies.

Identification of a target community containing epifaunal coelenterates, holothuroidians, and tunicates set depth criteria to <12 m datum. Shallower depths would jeapordize the success of target species colonization, and increase the likelihood of contact with pack ice. This remains a concern, for presence of trenches in sand substrate at depths of 18 m indicate the likelihood of ice scouring occurring at significantly deeper depths than previously reported. However, the shelf surrounding the mouth of the Churchill river is relatively shallow, with maximum depths reaching 24 m within a 10 km radius of the Port, which posed a problem in locating sites with sufficient depth.

Discussion with Churchill Port Authorities indicated a preference for sites in the Button Bay area to avoid potential interference with shipping. The exclusion map (Fig. 1) and qualitative observations collected in 1989 resulted in an area of focus for further investigations, and eventually led to the selection of experimental and control sites. A distinct rock reef, indicated on chart 5400 was selected as a site for further investigation, as it met many of the above mentioned criteria. This process of preplanning and exclusion mapping allowed site selection to proceed efficiently, and reduced the number of dives required to establish the site.

Material selection for this project was not a difficult task, for disposal of the 33 m steam ship tug was a primary motive for reef creation. Investigation into the suitability of this material to meet the requirements of user groups yielded a positive response. The structure would provide a large stable site for colonization of organisms, and would attract recreational divers, regardless of the biological community that would eventually utilize the reef.

5.2 ADMINISTRATIVE REQUIREMENTS

The legalities of artificial reef creation involve consultation with federal agencies to ensure compliance to environmental guidelines and navigational safety. In Canada, each reef development should be examined by the project manager to define jurisdiction of the project. When designing a reef for deployment in any body of water capable of being navigated by floating vessels for the purpose of transportation, recreation or commerce, the structure may require formal approval under the Navigable Waters Protection Act (NWPA).

Some projects may fall under Section 5(2) of the Act, which exempts works that are considered not to substantially interfere with navigation (Navigable Waters Protection Act. R.S., c.N-19, s.5.2). A letter of application for exemption and eleven copies of the plan showing the nature of the project should be submitted to the appropriate Coast Guard office.

In 1990, the Federal Court of Appeal ruled that the federal Minister of Transport is required to apply the "Environmental Assessment Review Process (EARP) Guidelines Order" to all Navigable Waters Protection Act applications before approval or exemptions are issued for works to be constructed in navigable waterways. The EARP process makes allowance for the exclusion of a number of works where there is no impact on the environment. Details as to measures taken to reduce environmental impact should be given in the NWPA application, or in a situation where environmental impact is suspected, details of mitigative measures should be submitted.

Federal Ocean Dumping Regulations (1988), Canadian Environmental Protection Act. s. 86 apply to all projects involving disposal of substances at sea. An application for a permit to dispose of a ship, aircraft, platform or other anthropogenic structure at sea is submitted using Form 4. This process involves the submission of an application and fee of $50.00 CDN to the appropriate Environmental Protection office. A Notice of Intent must be published in a local newspaper, and proof of publication received by the Environmental Protection office prior to forwarding the application to committee. Once information has been received, the Regional Ocean Dumping Assessment Committee reviews the project and assesses the impact on the environment. Processing takes a minimum of six weeks, and application must be published in the Canada Gazette prior to issuance of permit.

Investigating the legalities of creating an artificial reef using the S.S. Graham Bell proved to be one of the greatest challenges of the project. Establishing jurisdictional ruling for the reef site appeared to be the starting point. The selected site was in close proximity to the shipping lanes for the port of Churchill, within the riparian rights of the Province of

Manitoba, but in a federally regulated body of water. Consultation with both federal and provincial legislation was undertaken to ensure legalities were covered.

A request for exemption under the Navigable Waters Protection Act resulted in a letter indicating that permission to scuttle the vessel was not required from Navigable Waters Protection Programs Division. However, it is important to note that this did not release the project from responsibility of ensuring that the vessel was free of pollutants. It was also noted that "...should the vessel lose its tow while in transit and sink between Churchill Terminal and Button Bay and if the Coast Guard deem the vessel, at that position, to be a hazard to navigation, you will be directed to remove the vessel pursuant to the Navigable Waters Protection Act". As defined in NWPA, r.s., c.N-22, s. 18, if the vessel impedes navigation, it must be removed and the cost constitutes a debt to Her Majesty in right of Canada.

A liability policy was obtained for protection and indemnity on the vessel "S.S. Graham Bell" whilst being towed from Churchill terminal to Button Bay, Manitoba. The policy was underwritten by the Fireman's Fund Insurance Company, and obtained through Dale Intermediaries Ltd, Insurance Brokers, Vancouver. Coverage included cost or expenses of or incidental to the removal of the wreck of the vessel when such removal is compulsory by law (up to a maximum of $1,000,000). This policy was obtained in 1990 and in 1991, and extended to October in 1991 at a cost of $200.00 per issuance.

A clear definition of responsibility was not obtained with respect to the vessel once it had been scuttled. According to Section 20 of the Navigable Waters Protection Act, any vessel that is wrecked, sunk, partially sunk, lying ashore or grounded in any navigable water in Canada is deemed to be abandoned at the expiration of two years from the sinking. If the vessel were to be picked up by pack ice, or dislodged in a storm and washed onto shore prior to this two year period, the responsibility for removal is not clearly defined in the act and is subject to legal interpretation. No literature citing previous cases in Canadian law could be located.

Liability with respect to diver safety is another area of concern. In the event of diver entrapment or injury while diving the wreck, the assignment of liability is not firmly established. In surveying the vessel for areas of potential danger and informing divers of the existing hazards, it may be stated that due diligence has been applied in preventing an incident from occurring. However, consultation with legal council should be undertaken before commercial dive tour operators include wreck diving on their itinerary, and the use of a waiver of responsibility and acknowledgement of risk is recommended.

Scientific sampling and collection of organisms in Hudson Bay required scientific licences from both Federal Department of Fisheries and Oceans and the Science Institute of the Northwest Territories. Pursuant to Section 4 of the Fisheries Act, a Scientific Licence must be obtained to collect, sample and transport fish from location of collection. "Fish" is defined to include shellfish, crustaceans, marine animals and the eggs, spawn, spat and juvenile stages of fish, shellfish, crustaceans and marine animals in whole or in part. The Federal permit covered marine waters in the vicinity of Churchill, Manitoba, and within a 10 km radius of Fort Prince of Wales (50° 48' N, 94° 12' W). On occasion, diving was conducted outside this 10 km radius, and a permit was obtained from the Northwest Territories Sciences Institute to ensure that sampling was authorized. At the conclusion of each field season, a report tabulating the observational data and a map showing all collection locations was submitted. Upon completion of the study, a final report containing tabulated data and biological interpretation of data is requested by both institutes.

The permitting process that was undertaken for this project encompassed federal, provincial and municipal governments. Within the literature, there did not appear to be documentation of a comprehensive investigation into administrative procedures for artificial reef development in Canada. Reports on previous artificial reef projects in Canadian waters made reference to approval by Environment Canada with respect to environmental cleanliness, but did not outline any details as to the permit process. Efforts to seek out governmental departments that may have involvement in such a project assisted in locating proper channels to pursue authorization, and resulted in a list of agencies to contact for applications.

5.3 OPERATIONAL PROCEDURES

Once site selection has been carefully undertaken and administrative matters completed, transportation of reef material to the site may begin. This phase of reef development is project specific, but a number of basic principles apply. Extensive planning and effort has been expended to reach this phase, and many regard the siting as a culmination of the project. However, it is of paramount importance to maintain the objectives and delay siting if conditions are not suitable. Media attention, supporters and spectators provide pressure for the project manager, and have often resulted in hasty decisions to complete the project in order to please the public. The expense of repeating the transport and gathering assistance for siting may also influence decisions leading to improper placement. Alteration of reef site may result in reduced benefits and public criticism of the project, providing negative perception of such undertakings.

When planning to relocate the Graham Bell from its present location to the experimental site, the focus of discussion revolved around structural integrity and buoyancy of the vessel. When placed in dry docks in 1965, the tug was forcibly positioned on the mud flat during the highest tide to ensure permanent placement. Holes were then cut in the hull to prevent the vessel from floating should it become dislodged from the mud substrate. Initially, it was believed that the ship could not provide enough inherent buoyancy to support its own weight, and a system of external flotation was devised. Cradling the hull of the vessel between two rows of steel floats, supported on slings of cable or nylon webbing was thought to be the most plausible means of attaining positive buoyancy. This required cutting holes in the hull and consequently increased the water flow to the interior of the vessel. In effect, all attempts to float the vessel were based on the weight of the structure itself, not the combined weight of the structure and the water inside the hull as it filled with the rising tide. In retrospect, the flotation provided by the floats would not have been sufficient to support the vessel due to increased weight provided by inflowing water. However, at the time, the inability to refloat the vessel was attributed to suction of mud surrounding the keel and hull.

The value of remaining open to suggestions was emphasised by the support given to the project from local business people. Many residents of Churchill observed the Army Combat Engineer Regiment's attempts to move the vessel, and ideas for shifting the ship were expressed. Arrangements were made within the community for a second attempt slated for the summer of 1991. A local contractor and his employees began work on the vessel, repairing holes in the hull and sections weakened by corrosion in an attempt to make her seaworthy. Welding and patching was conducted at low tide, then sections of repair were observed as the tide flowed in around the vessel. Assessing effectiveness of repairs by continuous pumping as the tide rose proved to be a successful method. Concrete reinforcement was laid down over damaged areas along the keel and in the vicinity of the starboard coal bunker. This area retained too much water to safely weld sections of the hull, and consequently the repairs were not as effective.

Flotation of the vessel was achieved by pulling the ship into the excavation trench, where she continued to maintain positive buoyancy for the duration of the tide. The basic premise had been successful - repair the damage and the vessel will float.

Towing phase was set for the subsequent high tide, and final arrangements were made with Environment Canada and Canada Ports Corporation. A minimum tide of 4 m was required to allow the vessel to pass through the narrow entrance between the wharf and shore. Unfortunately, although a 4 m tide was predicted, the presence of a strong south east wind prevented it from reaching its full height, and the towing phase was aborted. The risk of damage to the hull's weakened keel was too high to allow the project to continue without full clearance, and the project was not allowed to progress. The vessel will remain in dry docks until another attempt at reef creation is undertaken.

5.4 PROGRAM DEVELOPMENT

To enhance and maximize benefits obtained from an artificial reef project, specific programs of use should be documented. Artificial reefs provide opportunities for research that have been largely ignored (Bohnsack and Sutherland, 1985). Designed programs of use assist in educating potential user groups in the benefits of artificial reefs, and provide a framework for realizing maximum potential. When a population is recognised as a possible recipient of benefits resulting from a project, efforts to inform that population and provide them with a program of use will increase likelihood of success.

Documenting and developing user programs is based on analysis of user groups and target species identification. Outlining specific strategies for optimizing benefits is a necessary component of reef development, but one that is not often communicated to the proper source. In assessing the feasibility of a development, thought is given to the wide range of benefits accrued by various groups of people. The dissemination of this knowledge seldom occurs, and reefs are left satisfying the needs of one or two small populations of individuals. By composing strategies of use and distributing these programs to the proper sources, the creation of ongoing benefits will increase the validity and value of the project, and reduce conflicting use by interested parties.

In reviewing the literature related to artificial reefs, it appears that much of the knowledge obtained during the reef development phase is not published. Information on site selection, operational procedures, biological assessment and user group analysis is often reduced to one or two lines in the methods section of a publication. Strategies for use are suggested, but many projects choose to let interested individuals seek out the reef and utilize the structure as they see fit. Management of a reef involves overseeing use before, during and *after* siting the structure.

When assessing the feasibility of the Graham Bell project, one of the concerns was that the vessel would be placed on the bottom of the ocean and no further benefits would come from its presence. In developing the management plan it became apparent that these programs would have to be self-explanatory and attractive enough to convince groups that the benefits are worth efforts expended to achieve them.

5.4.1 Diving Tourism

Development of diving tourism using the Graham Bell had to be approached with safety as a primary concern. Evaluation of wreck diving safety concluded that divers would be more likely to feel comfortable on a wreck if they have thorough knowledge of the layout and structure of the vessel (Pacific North Consulting, 1989). Film footage gathered during the assessment phase and operational phase is available for development of a pre-dive video. Blue prints of the vessel were also located, and areas of modification recorded to indicate sections of the ship that may be accessible to advanced divers only. This process of thorough pre-dive briefing increases the safety and level of enjoyment for the divers, and provides the tour operator with an opportunity to discuss rules and regulations of the excursion.

Knowledge gained from the biological aspect of the study is of interest to divers. Photography is often undertaken by divers, and knowledge of the types of organisms that will be seen on the dive will assist the photographers in selecting proper equipment, and increase satisfaction of the participants. Identification of species that are encountered on the dives will also lead to increased diver satisfaction, and information on life history and ecosystem interaction is often appreciated.

The town of Churchill has a growing number of certified divers. The possibility of hiring local qualified divers to act as guides on dive tours would provide term employment for residents and increase the quality and safety of the dive. Boat tour operators have expressed interest in developing the industry, as it would enhance employment opportunities and allow tourists to experience arctic marine life first hand. Churchill tourism revolves around local wildlife populations that are migratory by nature. Birding season, late May to June, is followed by the arrival of beluga whales in July to mid-August. The diving season is variable, but begins as soon as the ice clears the bay (or possibly before, if divers are interested in viewing the ice underwater). The season continues until early September, when the winds begin to increase and turbidity of the ocean reduces visibility significantly. This window of opportunity for diving tourism provides an additional source of revenue for whale tour operators, as the dive expeditions could be conducted between whale watching tours. The water temperatures are not conducive to repetitive diving, therefore divers would most likely be satisfied with one or two dives in a day. One of the main attractions for divers is the opportunity to view a beluga whale underwater, and their presence corresponds with the warmest and clearest water of the season, making the July to August time frame ideal for such an industry.

In addition to diving tourism, divers travel to Churchill to obtain underwater film footage for cinematographic productions. Information on diver/whale interaction and the location of prolific dive sites provides local operators with additional knowledge for guiding clients. In most cases, individuals travelling to Churchill would depend on local resources for information on ecology, sea conditions and logistical support for such an undertaking. The knowledge gained from this study will supplement wildlife tourism by providing information to local business people for economic benefits.

Underwater photographs and film footage are available for tourism promotion. A set of slides depicting undersea marine life will be submitted to the Churchill Chamber of Commerce for use in promotional publications and duplication for distribution.

5.4.2 Educational development

General knowledge of the marine life in Churchill's subarctic seas within the community is limited to identification of organisms caught in fishing nets. In an area dependent on wildlife tourism such as Churchill, information on ecosystem components is an important aspect of environmental education. Many of the tourists are attracted to the area by the presence of beluga whales, and actively seek out information on the ecology and behaviour of these animals.

In addition to tourism-related education, the opportunity to incorporate knowledge of marine life into the educational curriculum of the local school system is provided. Basic concepts of energy flow, food chains, interaction between organisms, photosynthesis and other scientific topics are a necessary part of the set curriculum for science. In general, teaching materials developed in southern locations utilize examples that would be familiar to southern children. For example, a food chain would be described using rabbits, foxes, and bears. By substituting local organisms and introducing the biology of species, this same concept could be taught concurrently with marine ecosystems. Identification of photosynthesising algae, mysids, capelin, beluga and humans would provide students with the required conceptual knowledge and serve to educate them on the ocean life of the region.

A slide show depicting marine life was presented to the local populace as an evening information session. The event was well attended, and many individuals requested further information on many of the organisms. Questions regarding life cycles of species were posed and most attendants were surprised to learn that the arctic benthic community was highly productive. A similar presentation was given to a group of 50 children in the hamlet of Chesterfield Inlet, NWT. Ages range was 6 to 15 years. Children were queried as to their present knowledge of marine life. Immediate recognition of beluga whales was noted, and children relayed stories of beluga hunts conducted by family members. Most children had seen a beluga, and could identify its food source. Recognition of shellfish photographs was attributed to its use as a food source. Blue mussel photographs were recognised by approximately half of the children, accompanied by the inuktitut name for a common recipe using mussels. When queried as to what organisms would eat mussels other than man, the children could not come up with suggestions other than beluga whales. When shown a photograph of a starfish, the majority of children could identify it, but stated that it couldn't live in the arctic. When shown photographs of soft corals, anemones, coelenterates and tunicates, the students were surprised to learn they were local organisms. Most believed that the ocean contained fish, whales, and little else.

Exposing children to local marine life could be accomplished with little effort. Photographs for educational use will be available through the Churchill Chamber of Commerce, accompanied by a brief synopsis of the species depicted. The possibility of developing a marine slide show for Canada Parks Service use has also been suggested.

5.4.3 Scientific study

Developing the scientific research benefits of this project was of primary concern during the site selection phase of reef development. Theories regarding reef success revolve around the provision of habitat and point of attachment for benthic organisms. In designing the scientific study, this theory was tested by establishing baseline biomass readings in two sites. The control site consisted of a rock reef subjected to the same current flows, temperature, salinity and water conditions as the experimental site. The adjacent experimental site was an area of sand substrate, shifting with the currents and exhibiting little epibenthic biomass. By establishing two sites in close proximity, the reduction in disparity of conditions would assist in establishing a more controlled environment for experimentation.

Data gathered during the 1991 field season included quantitative biomass readings from sites in the control and experimental areas. The selected control site's bedrock reef provided a natural environment of various substrates for biomass comparisons. Statistical analysis of this data indicated that the south cobblestone wall of the control site (IBRM sites) yielded the highest biomass readings, and resulted in a statistically homogeneous subset. The area at the bottom of the cobblestone wall may have been protected from ice scour and debris forced in towards shore by the presence of the rock reef. At the highest point on the reef, indicated by the ITRM sites, the dominant substrate was smooth bedrock with scrapes and gouges possibly caused by contact with boulders carried in the sediment load of drift ice. Small amounts of gravel or loose rock was noted in this area, but a distinct change in substrate and associated biomass was observed at the inside wall. Cobblestones and boulders formed a rock wall descending approximately 3 metres and running the entire length of the rock reef.

When all data was assessed and quantitative analyses and substrates were compared, a pattern emerged that was consistent with the following theory. During spring break up of ice, pans were forced southward toward the shores of Button Bay. The presence of trenches in the sand in the experimental site substantiates this theory (dive 7/7/91). As the ice was forced upwards across the top of the bedrock reef, it may have scraped organisms, boulders and rocks towards the shore. The ice may have lodged at this point, releasing its ice-rafted sediments as it melted. These sediments, consisting of boulders, rocks and gravel, would have dropped off the reef, accumulating along the inside wall. The presence of the bedrock structure may have protected epibenthic organisms from being dislodged by drift ice, as the organisms noted in the IBRM area were larger and more prolific than any other area observed during site selection.

This theory is also consistent with observations of compression ridge heights in Button Bay. When ice floes are pushed together, compression ridges form. The ridge keel (below-waterline portion) is usually 4.5 to 6 times greater than the sail height (above waterline portion)(Cammaert and Muggeridge, 1988). Local observations indicate sail heights often exceed 3 m, indicating that contact with substrate may occur in depths up to 18 m. This is also consistent with observations of ice floes observed on dives conducted on 07/09/91 and 07/14/91.

Devising a feasible means of obtaining data from the reef involves a consistent method of sampling. A program for ongoing monitoring was developed, based on initial site evaluation techniques. At the time of sinking, a baseline benthic biomass reading would be conducted in the control and experimental sites. Permanent markers would be placed along the transect lines of the control site and biomass within the quadrats would be sampled by airlift. Comparison of regrowth on the control reef would be compared to colonization on the vessel. Effect of migration from surrounding biomass may be inferred by resulting growth in the control area, and an indication of species colonization rates could be obtained. In many arctic species the planktonic stage is reduced, causing populations to recruit from local organisms (Feder and Schamel, 1976). The distance between the established colonies of the control site and the experimental site may affect colonization rates.

Accumulation of biomass data and photographs of designated areas on the Graham Bell once it is submerged may be used to identify the effects of the reef on the surrounding environment. A proposed method of gathering this data is to conduct research diving courses on the control and experimental site. Divers participating in dive tours often request "specialty" courses, which consist of designated training in fields such as underwater photography, wreck diving and research diving. By designing the course outline around an existing scientific study, the divers will benefit from the learning process and data on colonization will accumulate.

The Churchill Northern Studies Centre has expressed interest in the possibility of an arctic marine ecosystems course for university credit. Collection of data on the artificial reef may be incorporated into the course curriculum, providing students with an opportunity to dive in an established study site and participate in scientific research.

In summary, developing an artificial reef in the Churchill region is an economically feasible project that would provide ongoing benefits to a large number of individuals. However, over the course of the study a number of ethical questions regarding artificial reef development were examined. These issues should be addressed prior to any further attempts at reef placement.

Chapter 6
CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This study outlines the systematic process utilized to develop an artificial marine reef off the coast of northern Manitoba. Criteria for site selection, administrative and operational procedures and identification of user groups were developed as a general protocol to facilitate application to a wide range of ocean dumping projects.

This study concludes that a thorough management plan for artificial reef development increases benefits to the community and potential user groups. Identification of user groups prior to site selection allows for maximization of benefits by clearly defining criteria for reef placement. Careful consideration must be given to both positive and negative aspects of reef creation in order to develop a successful reef.

Investigation into the negative aspects of artificial reef creation yielded a difficult ethical question. Does the presence of an artificial structure on the ocean floor destroy or alter the intrinsic value of a "natural" marine environment? The value placed on unaltered spaces in the environment is increasing as development encroaches further and further into the untouched areas of the world. The physical presence of the reef may not negatively impact the surrounding environment in a biological sense, but the loss of an area of unaltered ecosystem may be construed as a negative impact. The estuarine area of Churchill has been subjected to significant alterations in water flow over the past three decades and is not considered an unaltered environment, but the ethical question remains unresolved.

Specific conclusions reached during this study are as follows:

1. Identification of user groups is a fundamental aspect of reef creation.

Desire to create an artificial reef is based on the knowledge that artificial structures placed on the ocean bottom concentrate biological life of the area. Identifying and examining the needs of each group affected by reef creation provides the project manager with a framework of requirements for priorization and attainment in order to achieve success.

Artificial reef development may also be construed as a negative event to some individuals. When formulating an artificial reef management plan, it is of utmost importance to consider the implications of reef placement on society as a whole. The reef may prove to be an obstruction to marine traffic, draggers or trawlers; it may alter flow patterns and create undesirable movement of sediment in adjacent areas; the mere presence of the reef may be viewed as a violation of the intrinsic value of an ocean floor free of man made structures. Cultural and ethical values must be given careful consideration when planning artificial reef development. Alteration in position of the reef, material used or changes in the orientation of the structure may be sufficient to nullify such negative impacts, and increase the overall benefit to society.

2. Development of an artificial reef should begin with material and site selection based on the needs of the relevant user groups.

In general, the specific needs of each user will involve an increase in the number or biomass of one or more species. Identification of these target species will dictate the type of material used to create the reef, and the environment in which it should be placed.

Research into the biology of the target species and associated ecosystem is required in order to provide a sound knowledge base for environmental manipulation. A properly designed artificial structure that meets the needs of the target species will allow the organism to compete more effectively in the marine environment. The resulting increase in species fecundity and growth will provide benefits to the user group.

In North America, many artificial reefs are created using scrap materials. The concept of scrap disposal at sea resulting in benefits to the marine environment is extremely promising, but must be handled carefully to avoid negative impact situations. In situations where material disposal is the primary objective, recognising the potential benefits and possible user groups will dictate placement of material, and assist in identifying the positive and negative aspects of the project.

3. Success of an artificial reef is based on the ability of the reef to meet the needs of user groups without creating a significant negative impact on others.

When an artificial reef project does not meet the needs of the identified user groups, it is unsuccessful in fulfilling the established requirements and objectives based on accrued positive benefits. If the presence of this reef provides a negative impact to others or to the environment, it not only fails to meet its set objectives but also reduces public acceptance for future projects.

6.2 RECOMMENDATIONS

1. Careful consideration of the ethical issues surrounding artificial reef projects must be considered prior to initiating reef development. Distribution of a survey or opinion poll in the community is recommended to assess potential negative impact on the local populace.

2. The biological data collected during the initial site selection and control site evaluation provides an opportunity to further investigate benthic marine life in Hudson Bay. Distribution of organisms for identification should continue.

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Appendix 1. Form 4 - application for a permit to dispose of a ship, aircraft or other anthropogenic structure at sea.

Environment Canada / Environnement Canada
Conservation and Protection / Conservation et protection

FORM / FORMULE 4

APPLICATION FOR A PERMIT TO DISPOSE OF A SHIP, AIRCRAFT OR OTHER ANTHROPOGENIC STRUCTURE AT SEA
DEMANDE DE PERMIS D'ABANDON D'UN NAVIRE, D'UN AÉRONEF OU AUTRE OUVRAGE ANTHROPOGÉNIQUE EN MER

PART A – BASIC INFORMATION / PARTIE A – RENSEIGNEMENTS GÉNÉRAUX

1 NAME OF APPLICANT / Nom du requérant — TEL. Nº / Nº de tél.

ADDRESS / Adresse — 2 TYPE OF BUSINESS / Type d'entreprise

3 NAME OF INDIVIDUAL RESPONSIBLE FOR DISPOSAL ARRANGEMENTS ON BEHALF OF APPLICANT — TEL. Nº / Nº de tél.
Nom de la personne chargée des dispositions d'abandon au nom du requérant
NAME / Nom — TITLE / Titre

4 GIVE FULL DESCRIPTION OF SHIP OR AIRCRAFT ETC. TO BE DISPOSED OF, INCLUDING, AS APPLICABLE:
Donner une description complète du navire, de l'aéronef, etc. à abandonner, y compris, s'il y a lieu

SHIP / Navire

- NAME OF SHIP / Nom du navire
- PORT OF REGISTRY / Port d'attache
- OFFICIAL Nº / Numéro officiel
- OVERALL LENGTH / Longeur hors tout
- EXTREME BREADTH / Largeur au fort
- OVERALL HEIGHT (Measured from bottom of keel to highest point of ship) / Hauteur hors tout (à partir de l'extrémité inférieure de la quille au plus haut point du navire)
- DEADWEIGHT TONNAGE / Port en lourd
- MAXIMUM DRAFT / Tirant d'eau max.
- HULL MATERIAL / Matériau de coque
- TYPE OF ENGINES (If left on board) / Type de moteur (s'il est laissé à bord)
- MAT'L AND WEIGHT OF BALLAST LEFT ON BOARD / Matériel et poids du lest laissé à bord
- NAME OF OWNER / Nom du propriétaire
- ADDRESS OF OWNER / Adresse du propriétaire

AIRCRAFT / Aéronef

- TYPE / Type
- MODEL / Modèle
- SERIAL NUMBER / Numéro de série
- NATIONALITY / Nationalité
- REGISTRATION MARKS / Marques d'immatriculation
- CONSTRUCTION MATERIAL / Matériau de construction
- ESTIMATED WEIGHT OF ENGINES IF LEFT IN PLACE / Poids approximatif des moteurs s'ils sont laissés en place
- TOTAL WEIGHT OF AIRCRAFT / Poids total de l'aéronef
- OVERALL LENGTH / Longueur hors tout
- OVERALL HEIGHT / Hauteur hors tout
- WINGSPAN / Envergure
- NAME OF OWNER / Nom du propriétaire
- ADDRESS OF OWNER / Adresse du propriétaire

UNREGISTERED VEHICLES PLATFORMS OR OTHER ANTHROPOGENIC STRUCTURES
Véhicules non immatriculés plate-formes ou autres ouvrages anthropogénique

- NAME OR NUMBER (If any) / Nom ou numéro (s'il y a lieu)
- DIMENSIONS / Dimensions
- TOTAL WEIGHT (Attach sketch or drawing, if available) / Poids total (Joindre un dessin ou un croquis si possible)
- PRINCIPAL MATERIALS OF CONSTRUCTION / Principaux matériaux de construction
- ESTIMATED WEIGHT OF EACH / Poids approximatif de chacun
- NAME OF OWNER / Nom du propriétaire
- ADDRESS OF OWNER / Adresse du propriétaire

WHAT WAS USUAL OR LAST CARGO? / Quelle était la cargaison habituelle ou la dernière cargaison?

HAVE ALL CARGO FUEL AND STORES BEEN REMOVED PRIOR TO DISPOSAL? / Est-ce que toute la cargaison, tout le combustible et tous les stocks ont été enlevés avant l'abandon?

IF NOT, COMPLETE THE APPLICABLE PORTIONS OF FORM 1 AND ATTACH TO THIS APPLICATION
Si non, remplir les parties de la formule 1 qui s'appliquent

5 REASON FOR DISPOSAL AT SEA Raisons de l'abandon en mer

6 STATE WHY ALTERNATE METHODS OF DISPOSAL ARE NOT ACCEPTABLE Indiquer pourquoi les autres méthodes d'abandon sont inacceptables

7 GIVE PARTICULARS IF DISPOSAL AT SEA OF SHIPS, AIRCRAFT, ETC., WAS CARRIED OUT IN THE PAST Donner les détails des opérations d'abandon en mer de navires, d'aéronefs, etc., effectuées par le passé, s'il y a lieu

8 NAME OF CARRIER (if not applicant) Nom du transporteur (s'il ne s'agit pas du requérant)	ADDRESS / Adresse	TEL. N° / N° de tél.
9 NAME OF CARRIER'S AGENT (if applicable) Nom de l'agent du transporteur (s'il y a lieu)	ADDRESS / Adresse	TEL. N° / N° de tél.

10 NAME OF INDIVIDUAL RESPONSIBLE FOR DISPOSAL ARRANGEMENTS ON BEHALF OF CARRIER Nom de la personne chargée des dispositions d'abandon au nom du transporteur	NAME / Nom	TITLE / Titre	TEL. N° / N° de tél.

PART B — DETAILS OF DISPOSAL ARRANGEMENTS / PARTIE B — DISPOSITIONS D'ABANDON

11 PROPOSED DATE OF DISPOSAL
Date proposée de l'abandon

12 DESCRIBE ROUTE TO BE FOLLOWED AND GEOGRAPHICAL COORDINATES OF PROPOSED DISPOSAL SITE
Donner la route qui sera suivie et les coordonnées géographiques du lieu d'abandon proposé

13 PORT OF DEPARTURE
Port de départ

14 DEPTH OF SEA AT PROPOSED DISPOSAL SITE
Profondeur de la mer au lieu d'abandon

15 WILL SHIP OR AIRCRAFT ETC., PROCEED TO PROPOSED DISPOSAL SITE UNDER ITS OWN POWER. IF NOT GIVE DETAILS
Le navire ou l'aéronef, etc., se rendra-t-il par ses propres moyens au lieu d'abandon proposé? Si non, préciser

16 ESTIMATED TIME REQUIRED AT DISPOSAL SITE TO CARRY OUT DISPOSAL OPERATION
Temps approximatif de l'opération au lieu d'abandon

17 HOW WILL THE SHIP OR AIRCRAFT, ETC., BE PREPARED FOR DISPOSAL TO ENSURE THAT IT WILL SINK AND REMAIN IN PLACE?
De quelle façon le navire ou l'aéronef, etc., sera-t-il préparé pour l'abandon afin qu'il coule et s'immobilise ?

18 DESCRIBE OTHER WORK CARRIED OUT TO ENSURE THAT THE SHIP OR AIRCRAFT ETC. DOES NOT EMIT SUBSTANCES SUBSEQUENT TO DISPOSAL
Décrire les autres préparatifs effectués de sorte que le navire, l'aéronef, etc. ne laisse échapper aucune substance après l'abandon.

When the applicant is a corporation, give the title or capacity and telephone number of the person signing this application.
Si le requérant est une société, donner le titre ou la fonction et le numéro de téléphone du signataire de la demande.

DATE	SIGNATURE OF APPLICANT / Signature du requérant	TITLE / Titre

TEL. NO. / N° de tél.

04-1606 (05-88)

Appendix 2. Qualitative sampling observations from each dive - 1989-1991.

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
08/02/89	58 47 22 N	94 16 20 W	3	cobble, sand	Strongylocentrotus droebachiensis, at least three species of tunicates, Aurelia sp, Cucumaria, bright orange eelpout
08/02/89	58 46 15 N	94 12 48 W	6	mud, sand	river bottom mostly sand, fine silt, some cobblestones interspersed among substrate. Coelenterates in water column
08/03/89	58 48 12 N	94 14 50 W	12	mud	Eschiurin worms, two species of sculpins, no boulders, no evidence of clam siphons
08/03/89	58 46 45 N	94 12 42 W	8	mud, sand	Pod of approx 9 whales circled round on surface, whale song was quite loud, sited two whales approx 10 ft away - contact 5 seconds. Brief 2nd siting - 3 seconds.
08/04/89	58 48 06 N	94 15 50 W	18	rock, cobble, sand	Large Phakketia bowerbankii , brachiopods, encrusting sponges,
08/04/89	58 45 50 N	94 12 28 W	8	mud, sand	No whale contact in river, but constant song. Aborted dive - polar bear sited swimming in river.
08/05/89	58 47 18 N	94 12 56 W	6	mud, sand, occ. rock	Whale contact - snorkelled on surface with whales, dropped down - 7 second contact with 2 whales - photo

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
08/05/89	58 47 40 N	94 14 45 W	11	bedrock, sand	Crabs (Hya sp), sculpins, anemones, red and green algae, epiphytes, photographed with Ewa bag - Mike Macri's camera
08/06/89	58 46 55 N	94 05 15 W	15	cobble	Gersemia, Pisasters, Leptasterias, ophiuroids, small Cucumaria, Solasters. Promising epifaunal growth
08/06/89	58 46 30 N	94 09 35 W	8	bedrock, cobble, sand	Mytilus everywhere, filamentous red algae, epiphytes, high biomass.
09/06/89	58 47 56 N	94 13 50 W	5	bedrock, cobble	Zero visibility, aborted dive.
07/07/90	58 47 56 N	94 14 28 W	11	sand, gravel, small boulders	sculpins, eelpout - check out dive - buoyancy neutral, wrist seals quite leaky
07/10/90	58 47 58 N	94 15 16 W	15	sand intersp. with sm.	Gersemia on boulders, liparids, no evidence of clam siphons
07/10/90	58 47 56 N	94 14 00 W	10	cobble, bedrock	Sculpins, Metridium like anemones, Psolus sp, Strongylocentrotus droebachiensis, Gersemia, highly prolifici area

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
07/11/90	58 46 30 N	94 12 30 W	13	sand, mud	Diving in dredged channel near wharf - light penetration poor, visibility reduced
07/11/90	58 48 30 N	94 12 50 W	9	cobble, bedrock, gravel	Solaster, unidentified nudibranch, plumose worm, Hyas sp., Phakketia sp, opiuroid, high biomass area.
07/12/90	58 48 15 N	94 13 24 W	8	sand and boulders	Stalked tunicates, 2nd spp of ophiuroid, swimming scallop , quite different from deeper sites, no Gersemia or Psolus, no sponges
07/14/90	58 48 24 N	94 13 06 W	8	cobble/boulder	2 spp fish, bryozoans on rocks and macroalgae, Macoma, limpets, Nereis, Pterogophora, Pleurophycus, Ulna, Rhodophyta
07/14/90	58 48 24 N	94 13 06 W	8	cobble, bedrock	2 spp fish, bryozoans on rocks and macroalgae, Macoma, limpets, Nereis, Pterogophora, Pleurophycus, Ulna, Rhodophyta
07/20/90	58 48 53 N	94 13 00 W	17	cobble, bedrock, boulders	Phakketia, stalked tunicates, Leptasterias, polychaetes. Highly prolific area, visually dominated by epibenthic organisms
07/22/90	58 48 40 N	94 13 40 W	18	cobble, bedrock, sm sand	Reasonably barren, a few nudibranchs, one Hyas, dropped down s. wall of reef, biomass appeared to increase dramatically. Substrate changed from bedrock to

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
07/24/90	58 48 48 N	94 13 34 W	18	cobble, bedrock, boulders	Top of reef - small nudibranch - photographed
07/24/90	58 47 23 N	94 11 30 W	12	sand dunes	Sculpin, nudibranch, little solid substrate
07/27/90	58 46 54 N	94 10 45 W	5	cobble overlying bedrock	Stalked anemones, large Mytilus beds
07/28/90	58 46 30 N	94 12 30 W	5	sand, mud	Snorkelled with whales for 8 minutes, descended to dive, visibility was poor. Whales could be seen passing by closely for duration of dive, but not descernable at all times due to
07/31/90	58 48 53 N	94 13 12 W	17	unknown	Aborted dive on descent - visibility < 1 foot.
08/07/90	58 46 54 N	94 10 45 W	10	large boulders and sand	Mytilus, Haliclystus salpinx (?), no nudibranchs, 4 spot fin fish,
07/09/91	58 46 55 N	94 13 06 W	5	sand, mud	Gear test, buoyancy test with Caroline Lewko

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
07/09/91	58 46 50 N	94 12 48 W	5	sand, mud	Gear test, buoyancy test with Pat Ewanchuk
07/09/91	58 49 42 N	94 09 15 W	11	sand	Iceberg dive, video camera - cable is negative, sig. drag. Laminaria stalk embedded in ice. Surfaced 8 min into dive to adjust camera. Many coelenterates, Beroe's comb jelly,
07/11/91	58 48 40 N	94 13 35 W	20	bedrock, cobble	Sampling dive - shrimp, 4" reddish carapace, Dendronotus, Leptasterias polaris, Hyas coarctatus, Tonicella sp, Phakettia sp,. Ice crystals in regulator, cold dive
07/13/91	58 47 15 N	94 11 10 W	8	cobble, bedrock, sand	Mytilus beds, 2-4', no nudibranchs, Rhodophyta, alaria, Fucus and young alaria, Myoxocephalus aenaeus, scorpius and quadricornis. Ice crystals in reg, minor free flow.
07/14/91	58 46 42 N	94 11 45 W	5	sand, mud	Photographic session - prop of Graham Bell at high tide
07/14/91	58 49 45 N	94 10 55 W	17	sand	Iceberg dive - video footage around base of berg. Surface indicated that a seal had been shot recently. Upon surfacing, adjacent berg flipped over - melting underneath occurrs faster
07/17/91	58 48 52 N	94 13 35 W	17	trenches, sand, gravel,	Current too strong to the SE, went with it to find trenches approx 8-12" deep, sand and gravel, some larger boulders, 2 Hyas, one Gersemia, 4-5" high, on large boulder approx 2 feet

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
07/17/91	58 48 25 N	94 13 15 W	8	sand, rock, cobble	No current, photographed anemones, caprellidans, Myoxocephalids, porifera and zoarcid.
07/20/91	58 48 46 N	94 13 35 W	17	gravel	Aborted dive- zero visibility. Lost light penetration at 20', continued down to 45'. Signalled to ascend - fins hit bottom, sandy gravel bottom. No thermocline, water well mixed after
07/20/91	58 46 52 N	94 10 35 W	8	sand	Equipment test - camera stand and strobe set up. Buoyancy is suitable. Visibility again was <1foot.
07/26/91	58 48 48 N	94 13 30 W	21	sand, mud, boulders, ice	Ice scoured area, Lupenus fabricii. boulders with sporadic growth in sandy expanses. Stalked ascidacians, some algae, no apparent infauna. Contact with beluga on ascent. Whale
07/26/91	58 48 42 N	94 13 41 W	11	bedrock, gravel.	Tested airlift, successful. Little life, ice scoured. Current reduced, approx .5 knot. Nudibranchs (Coryphella), tested exposures with camera set-up.
07/27/91	58 48 40 N	94 13 35 W	13	cobble, bedrock,	High biomass, sampled two sites, but airlift ran out of air on second. Stalked ascidacians, Pteraster, Terebratulla, Psolus, Phakettia, opuiroids, anemones. Altered method - dislodge
07/27/91	58 48 44 N	94 13 37 W	14	bedrock, cobble, boulder,	Sampled top and bottom of reef site, inside wall high biomass, top barren. Empty airlift tank is too buoyant to handle easily - modification may be needed.

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
07/28/91	58 48 42 N	94 13 36 W	18	bedrock	Top of reef, i nudibranch in quadrat. Dropped over wall to inside reef, large biomass, Strongylocentrotus, stalked ascidacianas, Gersemia, Myoxocephalus, Terebratula, 3 spp
07/28/91	58 48 40 N	94 13 39 W	18	sand/mud, occ boulders	Some trenches observed on SW end of reef, 6" deep, top of reef barren, SW end of inside wall appears to be most prolific area.
07/29/91	58 48 46 N	94 13 42 W	18	bedrock, mud/clay/sand	Little life on mud/clay/sand, but biomass increased on boulders. Sandy sites found polychaetes, errantia under rock.
07/29/91	58 48 44 N	94 13 41 W	13	cobblestone, boulders	Leptasterias polaris with young under curled arms, approx 150. Large biomass, but separated Lept to observe and photograph. Top or reef small biomass, top outside, none
07/29/91	58 48 40 N	94 13 40 W	14	bedrock, cobble, boulders	Strong current on top of reef. Nudibranchs on top of reef, Hyas, Beroe's comb jelly, little biomass.
08/03/91	58 48 46 N	94 13 32 W	16	bedrock, cobble boulders	At descent point, located and sampled brooding Leptasterias, moved to top of reef, first site one errantia, second site no biomass. Whale song was close and loud, but visibility too
08/03/91	58 48 48 N	94 13 28 W	18	sandy, mud, silt	No infauna on OBRM2, but ORMI altered to mud bottom, again no infauna. Whale song loud, but halocline reduced visibility to <5 feet at safety stop (15')

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
08/04/91	58 48 48 N	94 13 32 W	17	sand, gravel, boulder, rock	Small burrowing annelid in casing, large boulder (6') with epifauna, not as prolific as inside the reef.
08/04/91	58 48 45 N	94 13 37 W	15	cobble, boulder, bedrock	Agarum, high biomass, nudibranch sp (new, unknown), airlifted. Moved to top of reef, sampled one nudibranch in quadrat. Very cold dive. Ice crystals in regulator.
08/05/91	58 48 44 N	94 13 37 W	17	cobble, boulder, bedrock	Agarum, Hyas, Gersemia, Pycnogonic sp, stalked ascidacians, Terebratula, featherduster annelids, photographed before and after collection. Site IRMO contained 2 large gastropods,
08/05/91	58 48 40 N	94 13 39 W	16	cobble, bedrock, boulder	Whale contact on descent, 7 adults approached from below, rolled to expose ventral surface, returned for 3 contacts. Over 1 minute each. Sampled airlift, found new dorid, photographed
08/06/91	58 48 40 N	94 13 32 W	17	cobble, gravel, boulder	Prolific, large Psolus, some Strongylocentrotus droebachiensis, found what appeared to be a scour trench, prolific area except in trench. Sampled egg casings from what
08/08/91	58 48 46 N	94 13 44 W	19	mud/sand	Strobe fired once and would not fire again. Whale vocalization was intense, looked up to view 7 whales to the north - set camera F2 and shot ambient. Whales exposed ventral side,
08/08/91	58 48 45 N	94 13 40 W	18	sand, bedrock, mud	Strobe firing properly.

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
08/10/91	58 48 42 N	94 13 35 W	17	cobble, bedrock, gravel	Photographed nudibranchs and Gersemia, collected specimens. Photographed Pleurobrachia upon ascent
08/10/91	58 48 20 N	94 12 08 W	9	cobble, gravel, sand	
08/11/91	58 48 44 N	94 12 64 W	16	sand	Eider cove survey for IAEP
08/11/91	58 48 44 N	94 12 64 W	7		Eider cove survey for IAEP
08/11/91	58 48 44 N	94 12 64 W	6		Eider Cove survey for IAEP
08/17/91	58 48 08 N	94 13 32 W	9	cobble, mixed sand, mud	Solaster papposus, Psolaster chitonoides, Strongylocentrotus droebachiensis, prolific area, numerous spp of red and green algae. Ophiuroids, burrowing anemones.
08/17/91	58 48 10 N	94 11 40 W	14	sand/mud bottom	Whale contact three minutes into dive. Drifted midwater, 3 whales approached 25' away, contact continued sporadically for the duration of the dive.

Date	Latitude	Longitude	Depth (metres)	Bottom composition	Observation
08/18/91	58 48 40 N	94 13 40 W	18	cobble, rock, boulder	Sampling and photography dive. Gersemia actively feeding.

Appendix 3. Quantitative data on physical characteristics of the study zone (temperature at surface and depth, salinity at surface and depth, visibility and bottom composition).

Date	Latitude	Longitude	Depth (metres)	Temperature (surface)	Temperature (depth)	Salinity (surface)	Salinity (depth)	Visibility (horizontal)	Visibility (secchi)	Bottom composition
08/02/89	58 47 22 N	94 16 20 W	3					20		cobble, sand
08/02/89	58 46 15 N	94 12 48 W	6					15		mud, sand
08/03/89	58 48 12 N	94 14 50 W	12					10		mud
08/03/89	58 46 45 N	94 12 42 W	8					10		mud, sand
08/04/89	58 48 06 N	94 15 50 W	18					25		rock, cobble, sand
08/04/89	58 45 50 N	94 12 28 W	8					10		mud, sand
08/05/89	58 47 18 N	94 12 56 W	6					15		mud, sand, occ. rock
08/05/89	58 47 40 N	94 14 45 W	11					20		bedrock, sand
08/06/89	58 46 55 N	94 05 15 W	15					15		cobble
08/06/89	58 46 30 N	94 09 35 W	8					30		bedrock, cobble, sand
09/06/89	58 47 56 N	94 13 50 W	5					0		bedrock, cobble
07/07/90	58 47 56 N	94 14 28 W	11	5.	3	20.6	22.4	20	10	sand, gravel, small boulders
07/10/90	58 47 58 N	94 15 16 W	15	8	5	20.0	22.4	15	10	sand intersp. with sm. boulder

Date	Latitude	Longitude	Depth (metres)	Temperature (surface)	Temperature (depth)	Salinity (surface)	Salinity (depth)	Visibility (horizontal)	Visibility (secchi)	Bottom composition
07/10/90	58 47 56 N	94 14 00 W	10	9	5	21.6	26.3	15	5	cobble, bedrock
07/11/90	58 46 30 N	94 12 30 W	13					0		sand, mud
07/11/90	58 48 30 N	94 12 50 W	9	14	8	24.3	31.7	22	13	cobble, bedrock, gravel
07/12/90	58 48 15 N	94 13 24 W	8	14	8	25.1	32.3	25	14	sand and boulders
07/14/90	58 48 24 N	94 13 06 W	8	11	9	28	31	15	12	cobble/boulder
07/14/90	58 48 24 N	94 13 06 W	8	12	12	28	31	25	17	cobble, bedrock
07/20/90	58 48 53 N	94 13 00 W	17	8	2	28.6	32.1	10	3	cobble, bedrock, boulders
07/22/90	58 48 40 N	94 13 40 W	18	8	3	27.6	31.9	13	5	cobble, bedrock, sm sand patch
07/24/90	58 48 48 N	94 13 34 W	18	7	3	28.9	32.1	18	12	cobble, bedrock, boulders
07/24/90	58 47 23 N	94 11 30 W	12	8	6	26.5	30.6	15	13	sand dunes
07/27/90	58 46 54 N	94 10 45 W	5					10		cobble overlying bedrock
07/28/90	58 46 30 N	94 12 30 W	5					5		sand, mud
07/31/90	58 48 53 N	94 13 12 W	17	9	7	27.3	31	0	0	unknown

Date	Latitude	Longitude	Depth (metres)	Temperature (surface)	Temperature (depth)	Salinity (surface)	Salinity (depth)	Visibility (horizontal)	Visibility (secchi)	Bottom composition
08/07/90	58 46 54 N	94 10 45 W	10	7	4	24.5	27.9	15	10	large boulders and sand
07/09/91	58 46 55 N	94 13 06 W	5							sand, mud
07/09/91	58 46 50 N	94 12 48 W	5							sand, mud
07/09/91	58 49 42 N	94 09 15 W	11	7	-2	22.2	33.5	25	21	sand
07/11/91	58 48 40 N	94 13 35 W	20	5	-1	25.4	31.2	15	7	bedrock, cobble
07/13/91	58 47 15 N	94 11 10 W	8	7.5	-2	26.7	29.8	25	13	cobble, bedrock, sand
07/14/91	58 46 42 N	94 11 45 W	5		-2			10		sand, mud
07/14/91	58 49 45 N	94 10 55 W	17	5	-2	28.9	27.6	35	21	sand
07/17/91	58 48 52 N	94 13 35 W	17	5	-2	29.4	31.8	18	9	trenches, sand, gravel, bould.
07/17/91	58 48 25 N	94 13 15 W	8	7	0	25.9	28.2	20	9	sand, rock, cobble
07/20/91	58 48 46 N	94 13 35 W	17	9	2	27.6	28.9	0	0	gravel
07/20/91	58 46 52 N	94 10 35 W	8					0	0	sand
07/26/91	58 48 48 N	94 13 30 W	21	8	-1	21.8	32.5	20	8	sand, mud, boulders, ice scour

Date	Latitude	Longitude	Depth (metres)	Temperature (surface)	Temperature (depth)	Salinity (surface)	Salinity (depth)	Visibility (horizontal)	Visibility (secchi)	Bottom composition
07/26/91	58 48 42 N	94 13 41 W	11	7	-1	21.8	32.5	14	8	bedrock, gravel.
07/27/91	58 48 40 N	94 13 35 W	13	8	0	24.1	31.0	25	13	cobble, bedrock, boulders,sand
07/27/91	58 48 44 N	94 13 37 W	14	5	-1	28.7	31.4	10	3	bedrock, cobble, boulder, sand
07/28/91	58 48 42 N	94 13 36 W	18	6.9	-1	27.8	31.6	20	12	bedrock
07/28/91	58 48 40 N	94 13 39 W	18	5.9	0.6	28.4	31.7	25	7	sand/mud, occ boulders
07/29/91	58 48 46 N	94 13 42 W	18	7.9	2.5	26.2	32.2	20	14	bedrock, mud/clay/sand boulder
07/29/91	58 48 44 N	94 13 41 W	13	7.6	0.4	27.3	31.5	15	4	cobblestone, boulders
07/29/91	58 48 40 N	94 13 40 W	14	6.4	-1.2	28.2	31.9	15	6	bedrock, cobble, boulders
08/03/91	58 48 46 N	94 13 32 W	16	6.4	-1.8	27.6	32.1	13	3	bedrock, cobble boulders
08/03/91	58 48 48 N	94 13 28 W	18	6	-1.4	27.4	31.7	15	5	sandy, mud, silt
08/04/91	58 48 48 N	94 13 32 W	17	5.6	-1.3	26.7	31.2	15	7	sand, gravel, boulder, rock
08/04/91	58 48 45 N	94 13 37 W	15	7.4	-1.3	26.7	31.6	15	7	cobble, boulder, bedrock
08/05/91	58 48 44 N	94 13 37 W	17	6.1	-9.1	27.3	32.1	30	13	cobble, boulder, bedrock

Date	Latitude	Longitude	Depth (metres)	Temperature (surface)	Temperature (depth)	Salinity (surface)	Salinity (depth)	Visibility (horizontal)	Visibility (secchi)	Bottom composition
08/05/91	58 48 40 N	94 13 39 W	16	6.9	-1.2	28.1	31.6	15	8	cobble, bedrock, boulder
08/06/91	58 48 40 N	94 13 32 W	17	6.1	-1.7	28.3	31.8	15	6.5	cobble, gravel, boulder
08/08/91	58 48 46 N	94 13 44 W	19	7.2	-1.3	27.3	31.5	40	21	mud/sand
08/08/91	58 48 45 N	94 13 40 W	18	6.8	-1.5	27.1	31.2	35	18	sand, bedrock, mud
08/10/91	58 48 42 N	94 13 35 W	17	6.7	-1.4	27.5	31.7	25	12	cobble, bedrock, gravel
08/10/91	58 48 20 N	94 12 08 W	9	7.3	0.8					cobble, gravel, sand
08/11/91	58 48 44 N	94 12 64 W	16							sand
08/11/91	58 48 44 N	94 12 64 W	7							
08/11/91	58 48 44 N	94 12 64 W	6							
08/17/91	58 48 08 N	94 13 32 W	9	9.3	1.2	26.4	29.7	25	11	cobble, mixed sand, mud
08/17/91	58 48 10 N	94 11 40 W	14	7.8	0.7	27.1	30.4	20	8	sand/mud bottom
08/18/91	58 48 40 N	94 13 40 W	18	7	-1.5	27.1	31.5	25	9	cobble, rock, boulder

Appendix 4. Liability policy for protection and indemnity on the S.S. Graham Bell whilst being towed to the sinking site.

THIS POLICY . A CLAUSE WHICH
MAY L... ....OUNT PAYABLE

DALE INTERMEDIARIES LTD.
INSURANCE BROKERS
595 Burrard Street, Suite 873
Three Bentall Centre, P.O Box 49142
Vancouver, B.C. V7X 1J1
tel: (604) 681 - 0121 fax: (604) 681 - 4327

MEMORANDUM OF INSURANCE

VAN/637/91

INSURER(S): FIREMAN'S FUND INSURANCE COMPANY - 100%

INSURED: SHEILA THORNTON
C/O NATURAL RESOURCES INSTITUTE

ADDRESS: 177 DYSART ROAD
WINNIPEG, MANITOBA R3T 2N2

TYPE OF COVERAGE: PROTECTION AND INDEMNITY ON THE VESSEL "S.S. GRAHAM BELL" WHILST BEING TOWED FROM CHURCHILL TERMINAL TO BUTTON BAY, MANITOBA. COVERAGE TO ATTACH UPON COMMENCEMENT OF TOW AND TERMINATE ON RELEASE OF TOW LINE. EXCLUDING CREW, CARGO, TOWERS AND POLLUTION LIABILITY.

LIMIT OF LIABILITY: $1,000,000.00

TRIP OCCURRING DURING THE PERIOD: From: AUGUST 9, 1991 To: AUGUST 30, 1991 both 12:01a.m., Standard Time at the above address of the named insured.

PROVISIONAL PREMIUM: $200.00

DEDUCTIBLE: $1,000.00 EACH AND EVERY OCCURRENCE

NAME AND ADDRESS OF LOSS PAYEE: AS DIRECTED

In the event of cancellation of the contract, the earned premium will become due and payable. This memorandum is subject to all terms and conditions of the policy or policies to be issued.

IMPORTANT NOTICE: PLEASE NOTIFY US IMMEDIATELY OF ANY ERRORS, OMISSIONS OR NECESSARY CHANGES.

DALE INTERMEDIARIES LTD.

Date: AUGUST 9, 1991

Per____________________

PROTECTION AND INDEMNITY CLAUSES

This insurance covers all such loss and/or damage and/or expense as the Assured shall as owners of the vessel hereby insured become liable to pay and shall pay on account of the liabilities, risks, events and/or happenings herein set forth:

1. Liability for loss of life of, or bodily injury to, or illness of, any person, excluding, however, unless otherwise agreed by endorsement, liability to an employee (other than a member of the crew of the insured vessel) of the Assured, or in the case of death to his beneficiaries or any others, under any Compensation Act. Protection hereunder for loss of life or personal injury arising in connection with the handling of cargo of the vessel named herein shall commence from the time of receipt by the Assured of the cargo on dock wharf or on craft alongside the said vessel for loading thereon and shall continue until delivery thereof from dock or wharf of discharge or until discharge from the said vessel onto another vessel or craft.
2. Liability for hospital, medical, or other expenses necessarily and reasonably incurred in respect of loss of life of, personal injury to, or illness of any member of the crew of the vessel named herein or any other person. Liability hereunder shall also include burial expenses not exceeding Two Hundred Dollars ($200.00), when necessarily and reasonably incurred by the Assured for the burial of any seaman of said vessel.
3. Liability for loss of, or damage to, any other vessel or craft, or to the freight thereof, or property on such other vessel or craft, caused by collision with the Vessel, insofar as such liability would not be covered by insurance under a policy including the Canadian Hulls (Pacific) Clauses, sufficient in amount to indemnify the Assured for such liability.
   (a) Claims under this clause shall be settled on the principle of cross-liabilities to the same extent only as provided in the four-fourths running-down clause above mentioned.
   (b) Claims under this clause shall be divided among the several classes of claims enumerated in this policy and each class shall be subject to the deduction and special conditions applicable in respect of such class.
   (c) Notwithstanding the foregoing, if any one or more of the various liabilities arising from such collision has been compromised, settled or adjusted without the written consent of the Company, the Company shall be relieved of liability for any and all claims under this clause.
4. Liability for loss of or damage to any other vessel or craft, or to property on such other vessel or craft not caused by collision, provided such liability does not arise by reason of a contract made by the Assured.
   Where there would be a valid claim hereunder but for the fact that the damaged property belongs to the Assured, the Company shall be liable as if such damaged property belonged to another, but only for the excess over any amount recoverable under any other insurance applicable on the property.
5. Liability for damage to any dock, pier, harbour, bridge, jetty, buoy, lighthouse, breakwater, structure, beacon, cable, or to any fixed or moveable object or property whatsoever, except another vessel or craft, or property on another vessel or craft. Where there would be a valid claim hereunder but for the fact that the damaged property belongs to the Assured, the Company shall be liable as if such damaged property belonged to another, but only for the excess over any amount recoverable under any other insurance applicable on the property.
6. Liability for cost or expenses of, or incidental to, the removal of the wreck of the vessel named herein when such removal is compulsory by law, provided, however, that:
   (a) There shall be deducted from such claim for cost or expenses, the value of any salvage from or which might have been recovered from the wreck, inuring, or which might have inured, to the benefit of the Assured.
   (b) The Company shall not be liable for such costs or expenses, which would be covered by full insurance under the present standard form of policy on hull, machinery, etc., issued by the Association of Marine Underwriters of British Columbia.
   (c) The Company shall not be liable for such costs or expenses when the vessel was wrecked by or in consequence of hostilities or warlike operations, whether before or after declaration of war.
7. Liability for fines and penalties for the violation of any of the laws of Canada, or of any Province thereof, or of any foreign country; provided, however, that the Company shall not be liable to indemnify the Assured against any such fines or penalties resulting directly or indirectly from the failure, neglect, or default of the Assured or his managing officers or managing agents to exercise the highest degree of diligence to prevent a violation of any such laws.
8. Expenses incurred in resisting any unfounded claim by the master or crew or other persons employed on the vessel named herein, or in prosecuting such persons in case of mutiny or other misconduct.
9. Liability for extraordinary expenses resulting from outbreak of plague or other contagious disease, including such expenses incurred for disinfection of the vessel named herein or persons on board, or for quarantine, but excluding the ordinary expenses of loading and/or discharging, and the wages and provisions of crew and passengers; each claim under the provision is subject to a deduction of Two Hundred ($200.00) Dollars. It is provided further, however, that if the vessel named herein be ordered to proceed to a port when it is or should be known that calling there will subject the vessel to the extraordinary expenses above mentioned, or to quarantine or disinfection there or elsewhere, the Company shall be under no obligation to indemnify the Assured for any such expenses.
10. Net loss due to deviation incurred solely for the purpose of landing an injured or sick seaman in respect of port charges incurred, insurance, bunkers, stores, and provisions consumed as a result of the deviation.
11. Costs, charges, and expenses, reasonably incurred and paid by the Assured in defence against any liabilities insured against hereunder in respect of the vessel named herein, subject to the agreed deductible applicable, and subject further to the conditions and limitations hereinafter provided.

GENERAL CONDITIONS AND/OR LIMITATIONS

Warranted that in the event of any occurrence which may result in loss, damage and/or expense for which this Company is or may become liable, the Assured will use due diligence to give prompt notice thereof and forward to the Fireman's Fund Insurance Company of Canada, Ocean Marine Branch, Vancouver, B.C., as soon as practicable after receipt thereof, all communications, processes, pleadings and other legal papers or documents relating to such occurrences.

The Assured shall not make any admission of liability, either before or after any occurrence which may result in a claim for which the Company may be liable. The Assured shall not interfere in any negotiations of the Fireman's Fund Insurance Company of Canada for settlement of any legal proceedings in respect of any occurrences for which the Company is liable under this policy; provided, however, that in respect of any occurrence likely to give rise to a claim under this policy, the Assured is obligated to and shall take such steps to protect the Assured's (and/or the Company's) interests as would reasonably be taken in the absence of this or similar insurance. If the Assured shall fail or refuse to settle any claim as authorized by the Fireman's Fund Insurance Company of Canada, the liability of the Company to the Assured shall be limited to the amount for which settlement could have been made.

Whenever required by the Company, the Assured shall aid in securing information and evidence and in obtaining witnesses and shall co-operate with the Company in the defence of any claim or suit or in the appeal from any judgement, in respect of any occurrence as hereinbefore provided.

The Company shall not be liable for the cost or expense of prosecuting or defending any claim or suit unless the same shall have been incurred with the written consent of the Fireman's Fund Insurance Company of Canada, or the Company shall be satisfied that such approval could not have been obtained under the circumstances without unreasonable delay, or that such costs and charges were reasonably and properly incurred, such cost or expense being subject to the deductible. The cost and expense of prosecuting any claim in which the Company shall have an interest by subrogation or otherwise, shall be divided between the Assured and the Company proportionately to the amounts which they would be entitled to receive respectively, if the suit should be successful.

The cost of investigating and/or defending any claim or suit against the Assured based on a liability or an alleged liability of the Assured covered by this insurance shall be payable by the Company for the excess by which the amount paid in settlement and/or the costs and expenses of the investigation and/or defence exceed the amount deductible under this policy. Where the amount paid by the Assured either under a judgment or an agreed settlement based on a liability covered herein including all costs, expenses of defence and taxable disbursements exceeds the amount of deductible under this policy, the Company shall be liable for the excess over the amount so deductible.

The Company shall be subrogated to all the rights which the Assured may have against any other person or entity, in respect of any payment made under this policy, to the extent of such payment, and the Assured shall, upon the request of the Company, execute all documents necessary to secure to the Company such rights.

The Company shall be entitled to take credit for any profit accruing to the Assured by reason of any negligence or wrongful act of the Assured's servants or agents, up to the measure of its loss, or to recover for its own account from third parties any damage that may be provable by reason of such negligence or wrongful act.

Provided that where the Assured is, irrespective of this insurance, covered or protected against any loss or claim which would otherwise have been paid by the Company, under this policy, there shall be no contribution by the Company on the basis of double insurance or otherwise.

No claim or demand against the Company under this policy shall be assigned or transferred, and no person, excepting a legally appointed receiver of the property of the Assured, shall acquire any right against the Company by virtue of this insurance without the expressed written consent of the Company.

No action shall lie against the Company for the recovery of any loss sustained by the Assured unless such action is brought against the Company within one year after the final judgement or decree is entered in the litigation against the Assured, or in case the claim against the Company accrues without the entry of such final judgement or decree, unless such action is brought within one year from the date of the payment of such claim.

The Company shall not be liable for any claim not presented to the Fireman's Fund Insurance Company of Canada, Ocean Marine Branch, Vancouver, B.C. with proper proofs of loss within six (6) months after payment thereof by the Assured.

Either-party may cancel this policy by giving ten days' notice in writing; in which case there shall be a return of premium of 7% per month, with Underwriters in any event retaining a minimum of 40% of the original premium.

There shall be no cancellation or return of premium if vessel lost from any cause whatsoever.

The navigation limits in the policy covering the hull, machinery, etc. of the vessel named herein are considered incorporated herein.

This insurance shall be void in case the vessel named herein, or any part thereof, shall be sold, transferred or mortgaged, or if there by any change of management or charter of the vessel, or if this policy be assigned or pledged, without the previous consent in writing of this Company.

Notwithstanding anything contained herein to the contrary no liability attaches to the Company directly or indirectly:

For any loss, damage or expense which would have been payable under the terms of insurance under a policy including the Canadian Hulls (Pacific) Clauses (in which the sum insured is equal to the insured value stated therein), sufficient in amount to pay for such loss, damage or expense.

For or in respect of any loss, damage or expense sustained by reason of capture, seizure, arrest, restraint or detainment or the consequences thereof or any attempt thereat; or sustained in consequence of military, naval or air action by force of arms, including mines and torpedos or other missiles or engines of war, whether of enemy or friendly origin; or sustained in consequence of placing the vessel in jeopardy as an act or measure of war taken in the actual process of a military engagement, including embarking or disembarking troops or material of war in the immediate zone of such engagement; and any such loss, damage and expense shall be excluded from this policy without regard to whether the Assured's liability therefor is based on negligence or otherwise, and whether before or after a declaration of war.

For any loss, damage, or expense arising from the cancellation or breach of any charter, bad debts, fraud of agents, insolvency, loss of freight, passage money, hire, demurrage or any other loss of revenue; or as a result of the breach of any undertaking to load any cargo, or in respect of the vessel named herein engaging in any unlawful trade or performing any unlawful act, with the knowledge of the Assured.

For any loss, damage, expense, or claim arising out of or having relation to the towage of any other vessel or craft, whether under agreement or not, unless such towage was to assist such other vessel or craft in distress to a port or place of safety, provided, however, that this clause shall not apply to claims for loss of life or personal injury arising as a result of towing.

For any claim for loss of life or personal injury in relation to the handling of cargo where such claim arises under a contract of indemnity between the Assured and his sub-contractor.

For any claims for loss of, damage to, or expense in respect of cargo on board the vessel hereby insured.

For any loss, damage, cost, liability, expense, fine or penalty, of any kind or nature whatsoever, whether statutory or otherwise, imposed on the Assured, arising directly or indirectly, in consequence of, or with respect to, the actual or potential discharge, spillage or leakage of oil, fuel, cargo, petroleum products, chemicals or other substances of any kind or nature whatsoever. All terms, conditions and warranties expressly contained in this policy, or implied at law, shall be deemed amended to the extent necessary to give full force and effect to this clause.

For any liability of the Assured to Masters and members of the crew of the Insured Vessels and to all other employees of the Assured by reason of the Liability imposed upon or assumed by the Assured under any Workmen's Compensation or Employers Liability Laws.

It is expressly understood and agreed if and when the Assured has any interest other than as a shipowner in the vessel hereby insured, in no event shall the company be liable hereunder to any greater extent than if such Assured were the owner and were entitled to all the rights of limitation to which a shipowner is entitled.

Unless otherwise agreed in writing, liability hereunder shall in no event exceed that which would be imposed on the Assured by law in the absence of contract.

Liability hereunder in respect of any one accident or occurrence is limited to the amount hereby insured.