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Since delivery of this report in April 2008, the CIMP Secretariat has been working to establish standardized protocols for four (4) biophysical VC's (vegetation, permafrost & ice, and climate).

The full report is available online at www.nwtcimp.ca.

**STANDARDIZED PROTOCOLS FOR
COLLECTION OF MONITORING
INFORMATION FOR THE NWT
CUMULATIVE IMPACT MONITORING
PROGRAM WORKING GROUP AND
VALUED COMPONENTS ADVISORY TEAMS**



SUBMITTED TO:

INDIAN AND NORTHERN AFFAIRS CANADA

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Abbreviations and Acronyms

µm	micrometre
ACAAF	Agriculture and Agri-Food Canada
AES	Atmospheric Environment Service
ARQP	Air Quality Processes Research Division
AVHRR	Advanced Very High Resolution Radiometer
BAM	beta attenuation mass monitor
BC	British Columbia
BC MLPRIB	British Columbia Ministry of Land, Parks and Resources Inventory Branch
BCR	Bird Conservation Region
BFL	Birds in Forested Landscapes
CALM	Circumpolar Active-Layer Monitoring
CAMNet	Canadian Atmospheric Mercury Measurement Network
CAPMoN	Canadian Air and Precipitation Monitoring Network
CASA	Clean Air Strategic Alliance
CASES	Canadian Arctic Shelf Exchange Study
CCCma	Canadian Centre for Climate Modelling and Analysis
CEOS	Centre for Earth Observation Science
CFS	Canadian Forest Service
CLDN	Canadian Lightning Detection Network
CLIMo	Canadian Lake Ice Model
cm	centimetre
CNFI	Canada's National Forest Inventory
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COY	cubs of the year
CRYSYS	Cryospheric System in Canada
CTECS	Canadian Tundra Ecosystem Carbon Study
CWEA	Canada Wind Energy Atlas
CWS	Canadian Wildlife Service
dbh	diameter at breast height
DFO	Department of Fisheries and Oceans
DNA	deoxyribonucleic acid
DOE	Department of Environment
DUC	Ducks Unlimited Canada

e.g.	for example
EC	Environment Canada
EIS	Environmental Impact Statement
EMAB	Environmental Monitoring Advisory Board
EMAN	Ecological Monitoring and Assessment Network
ENR	Department of Environment and Natural Resources
FJMC	Fisheries Joint Management Committee
FWS	Fish and Wildlife Service
GIS	Global Information System
GNWT	Government of the Northwest Territories
GPR	ground penetrating radar
GPS	Global Positioning System
GRRB	Gwich'in Renewable Resource Board
GSA	Gwich'in Settlement Area
GSC	Geological Survey of Canada
GTN-P	Global Terrestrial Network for Permafrost
GTOS	Global Terrestrial Observing System
i.e.	that is
IGC	Inuvialuit Game Council
INAC	Department of Indian and Northern Affairs Canada
IPA	International Permafrost Association
ISR	Inuvialuit Settlement Region
ITEX	International Tundra Experiment
km	kilometre
l/s	litres per second
m	metre
m ²	meters squared
m ³ /s	cubic meters per second
MAAT	mean annual air temperature
MAGT	mean annual ground temperature
MGP	Mackenzie Gas Pipeline
min.	minute
MLPRIB	Ministry of Lands, Parks and Resources Inventory Branch
mm	millimetres
MSC	Meteorological Service of Canada

NAD	North American Datum
NAPS	National Air Pollution Surveillance Network
NAtChem	National Atmospheric Chemistry
NCE	Northern Climate Exchange
NCP	Northern Contaminants Program
NOAA	National Oceanic and Atmospheric Administration
NRCan	Natural Resources Canada
NSB	North Slope Bureau
NSIDC	National Snow and Ice Data Centre
NSISW	National Snow Information System for Water
NTPC	Northwest Territories Power Corporation
NWRSP	Northern Water Research Studies Program
NWT	Northwest Territories
NWT CIMP	Northwest Territories Cumulative Impact Monitoring Program
NWTWB	Northwest Territories Water Board
OC	organochlorine
PC	Parks Canada
PCB	poly-chlorinated biphenyl
PM	particulate matter
POP	persistent organic pollutant
ppm	parts per million
PRISM	Program for Regional and International Shorebird Monitoring
SOP	Standard Operating Procedures
SRRB	Sahtu Renewable Resource Board
SWE	snow water equivalent
TK	Traditional Knowledge
TOEM	tapered element oscillating microbalance
TSP	thermal state of permafrost
TSP	total suspended particulates
US	United States
UTM	Universal Transverse Mercator
UV	ultra-violet
VC	Valued Component
VDG	vertical displacement gauge
VHF	very high frequency

VOCvolatile organic compound
Wwatts
W/m² watts per square metre
WEMP Wildlife Effects Monitoring Plan
WSC..... Water Survey of Canada
YOY young of the year

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1 INTRODUCTION

One of the goals of the Northwest Territories Cumulative Impact Monitoring Program (NWT CIMP) is to assess how land use in the NWT and associated deposits of waste affect the environment. The program is based in land claims and legislation, and aims at community-based monitoring of socio-economic and biophysical parameters of the environment (NWT CIMP Website 2007a).

The NWT CIMP is designed to:

- encourage community-based monitoring and community capacity-building;
- provide resources to fill the gaps in current monitoring activities;
- report on the health of the environment, which includes biophysical, social and economic components;
- help with better decision-making to protect the environment;
- include both scientific and traditional knowledge; and
- help coordinate monitoring and reporting in the NWT.

Through past initiatives, the NWT CIMP Working Group (the Working Group) has identified a list of Valued Components (VCs) that are considered important to monitor the health of the socio-economic and biophysical environment in the NWT. This report summarizes current monitoring protocols that have been developed for selected VCs. It focuses on protocols that have been developed or applied within the Northwest Territories (NWT), Canada. If no current protocols were available through a comprehensive literature review and interviews with specialists, those developed or applied outside the NWT were considered. The report is intended to be used by the NWT CIMP Working Group and the Valued Component Advisory Teams as well as NWT Aboriginal organizations / communities, federal and territorial government departments / agencies and university recipients of NWT CIMP funding to help establish standardized means for collecting monitoring data.

1.1 Background

The NWT CIMP Working Group is comprised of representatives from federal and territorial government and regional Aboriginal organizations. Through past initiatives, the Working Group has identified a list of VCs that are considered important for the NWT.

The Working Group defines VCs as "elements of the cultural, socio-economic and biophysical environment that people see as important" (NWT CIMP Website 2007b).

For the purpose of this report, the following VCs have been identified by the Working Group:

- water quantity;
- snow, permafrost and ground ice;
- fish quality;
- moose;
- terrestrial mammals;
- marine mammals;
- avian wildlife;
- vegetation;
- climate; and
- air quality.

The Working Group has determined that the identification and / or development of standardized monitoring protocols for the list of priority VCs is its next objective. This report has been prepared to assist the Working Group accomplish this objective by consolidating information about monitoring protocols currently used for VCs in the NWT.

1.2 Objectives

It is important that work conducted by different agencies across the NWT is as consistent as possible in terms of study design, sampling procedures, sample and data analysis and reporting methods. This report is intended to assist the Working Group to establish a standardized method of collecting monitoring data for selected VCs. It presents relevant technical and scientific information (through references and in the ten detailed appendices) and also summarizes identified protocols in a comprehensible way for use by a broad range of users.

The primary objectives for this study were:

- to identify and evaluate any current protocols that have been developed for the listed VCs; emphasis was given to protocols developed or applied within the NWT;
- in the case that no available monitoring protocols have been established in the NWT, protocols from outside the NWT that may be applied to the NWT were considered; and
- to summarize technically sound and peer-reviewed documents in a coherent way for use by a broad range of users.

2 METHODOLOGY

2.1 Collection and Review of Available Information

This report was developed through a review of existing documents (including reports, websites and databases) on protocols relevant to research conducted in the NWT and interviews with specialists to obtain additional undocumented information. The information has been compiled, reviewed, evaluated and presented in this document.

Information sources included scientific publications, databases, independent studies, government and non-government departments / agencies and specialists. All literature reviews and interviews were conducted over the winter and spring of 2007/2008. Key information sources for this report included:

- Ecological Monitoring and Assessment Network (EMAN);
- Government of the Northwest Territories, Department of Environment and Natural Resources (GNWT, ENR; Wildlife, Environmental Protection and Forestry Divisions);
- Indian and Northern Affairs Canada (INAC);
- Environment Canada (EC), the Meteorological Service Canada (MSC), Water Survey Canada (WSC), and Canadian Wildlife Service (CWS);
- Department of Fisheries and Oceans (DFO);
- Ducks Unlimited Canada (DUC);
- Universities (such as Trent University, Ontario);
- studies conducted for Aboriginal organizations, government or industry; and
- peer-reviewed scientific research.

A wide variety of research studies have been conducted throughout the NWT over time. Many of the resulting reports described sampling protocols in their study methodologies. The strategy for this report was to determine specific and / or generalized baseline monitoring protocols that have been used in multiple studies and / or may have been recommended by an overseeing body (e.g., government agencies). Emphasis was placed on protocols developed for or used within the NWT.

It was beyond the scope of this study to review all research projects that have been conducted in the NWT. For example, environmental monitoring as it pertains to climate change is not examined in detail. Although Section 3.9, Climate, describes current monitoring protocols for collecting baseline climatic parameters as well as links to archived climate information, a comprehensive review of the multitude of ongoing

climate change studies and monitoring programs is beyond the scope of this report. To assist and guide readers to learn more about climate change monitoring, a reference list of relevant agencies is provided.

Although it is recognized that local and Traditional Knowledge (TK) studies are significant and valuable sources of information for the NWT, this report is not intended to incorporate an assessment of these types of studies. Some important references are made to monitoring carried out with or enhanced by TK, such as community-based monitoring research conducted and compiled by the Arctic Borderlands Ecological Knowledge Co-op (Arctic Borderlands 2007), but a thorough assessment of TK studies and how they contribute to environmental monitoring in the NWT is not included in this report.

2.2 Identification of Monitoring Programs and Protocols

For the purpose of this report, biophysical VCs, as identified by the NWT CIMP Working Group, are considered in individual sub-sections under Section 3, Standardized Protocols for Valued Components. Each sub-section is organized uniquely to present the information in the most effective manner. Topics within each sub-section may be organized according to monitoring agencies, monitored parameters, monitored regions or otherwise. The protocols and documents are ordered under sub-headings from most recent to oldest protocols / documents. Protocols may be described in the actual text of this report or referred to in the appendices. For large documents (i.e., over 100 pages) or documents with only limited relevant information, references are provided as citations and / or website addresses.

The individual sub-sections of Section 3 are structured as follows:

- 3.1** Water Quantity;
- 3.2** Snow, Permafrost and Ground Ice;
- 3.3** Fish Quality;
- 3.4** Moose;
- 3.5** Terrestrial Mammals;
- 3.6** Marine Mammals;
- 3.7** Avian Wildlife;
- 3.8** Vegetation;
- 3.9** Climate; and
- 3.10** Air Quality.

Specific protocols that have been used in the NWT for measuring selected VCs are summarized in the applicable chapters. Depending on the VC, information for protocols specifically developed for or used within the NWT may be limited. Additional relevant biophysical baseline monitoring protocols used throughout Canada and internationally are included.

Summary tables are provided in each of the ten appendices for each of the VCs. The purpose of these tables is to summarize the most relevant studies and protocols discussed in this report and other information sources in an easily accessible format. These tables present the selected VC, monitored parameters, geographical scope, and information source (e.g., author, agency). The monitoring protocols described are listed and a detailed reference source provided for easy referral. These tables are presented at the beginning of each appendix for the selected VCs.

For interest, and to augment the required information presented in this report, tables are provided on additional research that has been conducted for several of the VCs. These tables include summaries of studies, their spatial scope, protocols used and references to the source. The tables are presented after the protocol tables at the beginning of the appendices for the applicable VCs.

The appendices also contain complete documents that have developed or involved the use of important monitoring protocols relevant to the VCs of this report. The size of these reports has been considered a limiting factor, and only reasonably sized documents (e.g., under 100 pages) are included in these appendices. For the larger documents, references are provided in the appendix tables.

In each of the following report sections, the information source precedes the information, including the agency, author, year, and / or website. The study title (or a shortened version of it) *or* a specific topic *or* primary monitoring agency is shown first in bold, whichever is most appropriate to introduce the subject matter that follows. Additionally, a reference is made to the appendices if the document is included in either the table or the appendix itself.

3 STANDARDIZED PROTOCOLS FOR VALUED COMPONENTS

3.1 Water Quantity

3.1.1 Introduction to Water Quantity

This section describes monitoring protocols that address data collection to assess water quantity in the NWT. The Working Group determined that the key monitoring indicators that assess this VC are water levels, stream flow and ice phenology.

Hydrometric measurements are measurements that record hydraulic parameters of water bodies flowing above or below ground, in lakes, reservoirs and underground formations (EC 2006). Stream flow (or discharge rate) measures the quantity of water flowing past a point on a river in a unit of time. Common units are liters per second (l/s) or cubic metres per second (m³/s). Changes in water levels and stream flow rates may affect the habitat and populations of fish and other aquatic species found in that body of water. Changes in river flow may also affect shoreline erosion, channel scouring and sediment deposition (GNWT 2005).

The section discusses two topics. First, literature and protocols are discussed that investigate stream flow and discharge rates (including ice jams). In the second section, ice phenology protocols are described. Each section is structured according to the agencies or authors that conduct the research in the NWT or in Canada. Supplementary information for the sections below as well as details on the described parameter's monitoring protocols are provided in Appendix I (Table I-1).

3.1.2 Stream Flow and Discharge Rates (Including Ice Jams)

Indian and Northern Affairs Canada

Water Resources Division

http://nwt-tno.inac-ainc.gc.ca/wrd_e.htm

INAC, in conjunction with EC and the territorial governments, carries out hydrometric monitoring in Canada's territories. This research forms the basis for water management in the north (INAC 2007a). The monitoring may include measurements of surface water flow rates, rain and snow. Water quantity data enhances knowledge on basic hydrological conditions and assists with flood forecasting. These targeted studies are often part of the Northern Water Research Studies Program (NWRSP).

INAC's Water Monitoring Business Plan (INAC 2006) summarizes the agency's involvement in water monitoring in the NWT and Nunavut. The *Water Quality / Quantity Baseline Network* is a long-term stable source of data gathered through water monitoring in the NWT and Nunavut. *Specific Water Monitoring Studies* are carried out

when specific information is required, e.g., through environmental assessments or water licensing hearings (INAC 2006). Another program within the water monitoring framework is the *Applied Research* which includes programs that enhance our understanding of northern water resources. Snow accumulation and evaporation are also measured on an ongoing basis to help determine water balance in lakes and river basins (INAC 2006).

INAC and the Department of the Environment (DOE) Water Survey of Canada (WSC) manage the operation of hydrometric (i.e., measuring water quantity) stations in the NWT. This network provides, amongst others, comprehensive information on the availability and distribution of water in the north. There are 139 hydrometric stations in the NWT (INAC 1991). DOE provides highly qualified staff to operate the hydrometric stations and collect data three to four times per year (INAC 2006).

The Water Resources Division of INAC is supporting Dr. Faye Hicks of the University of Alberta in field observations along the Hay River in an effort to understand the effects of meteorology and hydrology on ice jam occurrence and severity of dynamic river ice break up (INAC 2007b). To date, nothing has been published to indicate how the observations are being conducted.

Water Quantity Baseline Network (INAC 2007c) The Water Resources Division of the DOE operates the NWT and Nunavut portions of the National Hydrometric Network. Stream flows and lake levels are measured routinely at approximately 90 sites. Data are published annually and are available from the INAC website (see above). This site also includes real-time hydrometric data for many river stations.

Dendrochronology (INAC 2007b) Dendrochronology is the dating of past events through the study of tree rings. This method is currently being used to help researchers reconstruct up to 300 years of annual and seasonal stream flow information from selected sites. This helps to place hydrologic fluctuation into a long term context thereby assisting with environmental management practices and impact assessment decision making. This is a valuable resource as most hydrometric data collection in the territories began in the 1970's which does not give a long enough time frame to review and analyze long-term environmental fluctuations.

Snow Survey Network (INAC 2007c) The Snow Survey Network measures the volume of snow at the end of the season from a variety of sites throughout the NWT. The volume of snow is measured as a snow-water equivalent which gives the amount of water produced per unit of area if the snow is melted. This allows for annual data to be compared from one year to the next. The data is collected from 39 snow survey stations and a small meteorological network that includes 8 stations.

Evaporation Program (INAC 2007c) The Evaporation Program has been in effect since 1993 and operates at various mine sites to improve water management in mine tailings disposal areas. Specific withdrawal parameters are measured and recorded with automatic stations located near the mine tailing ponds. The data are used to calculate daily and seasonal evaporation rates. There are six stations within the NWT and Nunavut.

Environment Canada, Water Survey of Canada - Hydrometric Program

EC 2006

Appendix I

http://www.wsc.ec.gc.ca/hydrometric/main_e.cfm?cname=hydrometric_e.cfm#Top

The Environment Canada, WSC hydrometric program is carried out by INAC and EC based on the formal agreement signed between EC and INAC in 1975 under the *Canada Water Act*. This is an agreement that organizes the collection of surface water quantity and sediment data. The two groups meet annually to review and adjust the program according to current needs (EC 2006).

Hydrometric (or gauging) stations are defined as a location where systematic records of stage (water level) or stage and discharge are obtained (Turgeon 1999). These stations are either non-recording (manual) or recording (automatic) gauging stations and they measure both water levels and discharge rates. Most of the country's stations are located in southern provinces and the data to describe hydrologic characteristics decrease towards the north. Hydrometric stations are located on lakes, rivers, and streams and range from small drainage basins to large watersheds such as the Mackenzie River Basin (EC 2006). There are currently 85 active stations in the NWT. Data, including archived data from stations no longer monitoring water quantity, are stored in the national HYDAT database (EC 2006).

At the hydrometric stations, water levels are continuously recorded. Flow rates (discharge rates) require several measurements of river depths and velocities to determine averages. These rates help define the relationships between water levels and discharge, and generate stream flow data from recorded water level data. However, the technology used for recording water levels at different stations is not consistent, with older analogue recorders at some and modern digital recorders at others. Nearly half of the network stations have been fitted for telemetry to gain real-time data processing and dissemination. This real-time technology is important for managing dams and reservoirs, water quality and water supply, flood forecasting and for hydroelectric operations (EC 2006).

Results from EC's Hydrometric Program are used in many ways. Examples of the uses of hydrometric data in Canada include (EC 2006):

- aquatic ecosystem research;
- climate change research;
- environmental impact studies;
- fisheries management;
- flood forecasting;
- floodplain management;
- forest management;
- hydro-electric power generation;
- infrastructure planning and design;
- inter-jurisdictional water apportionment (also between Canada and US);

- irrigation and drainage;
- operation of dams and reservoirs;
- recreation (e.g., boating);
- regional resource inventories and water management
- sediment and water quality studies;
- transportation / navigation;
- water resource assessment / inventory;
- water resources research;
- water supply studies; and
- watershed studies.

**Environment Canada, Water Survey of Canada - Types of Gauging Stations:
Hydrometric Technician Career Development Program**

Turgeon 1999

Appendix I

http://www.wsc.ec.gc.ca/CDP/index_ie_e.htm

The Hydrologic Services Supervisor for the WSC Northwest Territories / Nunavut (NWT / NU) recommended reviewing a series of instruction manuals known as the *Hydrometric Technician Apprenticeship or Professional Training Package* (R. Wedel, WSC, pers. comm. March 2008). One training package was designed by Turgeon (1999) for the WSC to inform hydrometric technicians about the basic types of WSC gauging stations prior to collecting or computing field data. It provides the general information on gauging stations but subsequent lesson packages provide more detailed information (EC 2006). The essential features of gauging installation, various combinations and variations of water level recording equipment, discharge measurement facilities, and operation schedules (e.g., seasonal, continuous or miscellaneous recording) are all topics described in Turgeon's package.

Detailed protocols are provided for hydrometric station operations. These include operating and using non-recording (manual) instruments and techniques, such as:

- wire-weight gauge;
- electric tape (contact) gauge;
- crest-stage gauge;
- slope gauge;
- cantilever gauge;
- surveyors level / bench mark;
- weighted steel tape and a known point of elevation;
- high-water marks;
- marking water levels with stakes; and

- photographs.

The two main types of recording (automatic) gauge systems are the analog (strip chart) recorder and the digital data logger. The package lists the three main components to recording systems as well as the two types of automatic gauge systems used. Protocols are discussed in detail for the installation and operation of:

- stilling well with float-actuated recorder systems; and
- pressure-actuated systems.

Discharge measurement facilities are described. These include choosing a location for the stations and the three main components of them. Details are provided for:

- water level gauges;
- stream control; and
- discharge measurement facilities.

Operating schedules are important aspects of water quantity monitoring programs. Data may be collected seasonally, continuously or miscellaneously from hydrometric stations, depending on the anticipated uses of the data. Descriptions are provided for the operation of seasonal stations (e.g., typically from May to October), continuous operation stations (these are checked at various frequencies, from monthly for most water level stations or whenever possible for remote northern stations) and miscellaneously operated stations (e.g., for specific studies).

Additional older field manuals that contain protocols which may be applicable for use in the NWT for monitoring water quantity include:

- EC (1981). *Hydrometric field manual: Measurement of streamflow*. Inland Waters Directorate, Water Resources Branch. Ottawa, ON.
- EC (1983). *Hydrometric field manual: Measurement of stage*. Inland Waters Directorate, Water Resources Branch. Ottawa, ON.
- EC (1984). *A guide to gauging station inspection*. Inland Waters Directorate, Water Resources Branch. Ottawa, ON.
- EC (1995). *Safety and health manual, for hydrometric field activities*. Atmospheric Environment Service, Water Survey of Canada.
- United States Geological Survey (1982). *Measurement and computation of streamflow: Volume 1: Measurement of stage and discharge*. Water Supply Paper 2175. Washington, DC.

Experimental Study of Ice Jam Thickening under Dynamic Flow Conditions

Healy and Hicks 2006

http://staff.civil.ualberta.ca/water/FEHicks/Papers/Healy_Hicks_JCRE_06.pdf

Healy and Hicks (2006) have studied the potential impacts of sudden flow changes on developing river ice. The study was conducted in a laboratory setting using a 32 m long flume to represent a waterway. In the experiment, stable ice accumulations formed under steady carrier discharge and were subjected to sudden and significant flow increases, while associated variables such as ice thickness, flow velocity, water levels and ice cover consolidation rates were monitored to provide a quantitative time varying record of a dynamic response (Healy and Hicks 2006). Plywood and hard Styrofoam insulation were used to imitate intact ice cover and varying sizes of polyethylene used to represent ice floes. Water level, ice thickness, point velocity and discharge data were collected using a magnetic flow meter, specialized tubes equipped with pressure transducers and an automated water level transmitter.

River Water Flow Monitoring

Parks Canada 2004

http://www.pc.gc.ca/docs/v-g/rs-rm2003/sec7/page1_e.asp

A River Water Flow Monitoring program is conducted in the Firth River (Ivvavik National Park) and the Hornaday River (Tuktut Nogait National Park) to determine current water cycles and to detect possible changes in the amount of water flowing in these rivers and the timing of peak and low water levels (Parks Canada; PC 2004). River flow information is also used to study relationships between water flow, fish habitat and fish productivity.

Automated stations that measure water flow are located on the Firth River in Ivvavik National Park (at 69° 19' 37" N; 139° 34' 8" W) and on the Hornaday River near Tuktut Nogait National Park (at 69° 10' 41" N; 123° 15' 01" W).

The years of data recording include:

- Firth River station from 1972-1994 and since 1997; and
- Hornaday River station since 1998.

Partners in monitoring include:

- EC, Water Survey Branch;
- DFO;
- Fisheries Joint Management Committee (FJMC); and
- Polar Continental Shelf Project.

Data is kept at the following locations:

- PC, Inuvik; and
- EC, Water Survey Branch, Yellowknife (PC 2004).

Assessment of MAGS Observational Network

Mackenzie GEWEX Study 1996

<http://www.usask.ca/geography/MAGS/>

In the early 1990's the Global Energy and Water Cycle Experiment (GEWEX) was initiated worldwide in major watersheds. The objective was to gain knowledge of how high latitude water cycles influence global climate and its changes (NWT CIMP Working Group [CIMP] 2007). Canada's Mackenzie GEWEX Study (MAGS) was initiated to assess the energy and water cycles of the Mackenzie River and its influence on global climate patterns (MAGS 1996).

Canadian GEWEX Enhanced Study 1996

http://ccrp.tor.ec.gc.ca/CAGES/assess/gewex_toc.htm

The Canadian GEWEX Enhanced Study (CAGES) was designed to provide knowledge on aspects of the water and energy budget parameters beyond the knowledge gained with routine measurements. The parameters recorded by the program include (CAGES 1996):

- precipitation data (with gauges);
- weather data (e.g., with weather radars such as IPIX radar, x-band radar, c-band weather radar);
- hydrometric data (see below);
- upper air soundings (i.e., moisture flux convergence measurements); and
- radiation information (e.g., surface radiation, evaporation).

Hydrometric stations - Enhanced stream discharge measurements are recorded during the spring breakup period at locations along the Mackenzie River including the main channels and the river's tributaries. The operations include five visits per season according to the following:

- a pre-breakup visit to activate the station;
- a post-break-up visit to reinstall washed out lines;
- a post-spring flood visit;
- a late summer / fall visit; and
- a post-freeze-up visit to shut down the station for the winter.

Handbook on the Principles of Hydrology

Gray 1973

This handbook focuses on the principles of hydrology, emphasizing Canadian conditions (Gray 1973). It describes hydrological processes in detail and includes a section on river hydraulics and flow measurement. It describes protocols for measuring river / stream flows to indicate aspects of channel hydraulics that help to determine

average river / stream discharge through a particular cross section of the river or stream. Descriptions and formulas for determining velocity distributions in channels are included for laminar versus turbulent flow, velocity distributions in natural channels, and theoretical velocity distributions. The effects of channel roughness and unsteady flow effects are also discussed as they relate to river hydraulics and flow measurement. Protocols for flow measurements are also provided as they relate to velocity measurements, measurements of stage (water level), calculation of discharge and discharge measuring structures that do not require the use of velocity measurements (e.g., through the use of weirs) (Gray 1973).

Handbook of Applied Hydrology

Chow 1964

In Chow's (1964) *Handbook of Applied Hydrology*, the rotating current meter is described as the most common device used for gauging streams. This device is considered to have a high degree of precision, and each instrument responds to the effects of turbulence and the angle of flow. Chow's book offers protocols on calibrating the device, assessing the precision of its operation, and field comparisons of results of water velocity.

Protocols are also provided for velocity observations. The distribution of the vertical velocity, setting the current meter, timing the current meter rotation, dealing with meter circuitry (i.e., electrical contacts), timing procedures (i.e., in data collection) and counting and recording automat procedures are all described. Determination of water depth protocols are described using the wading rod, cable and weight and fathometre methods, as well as methods for dealing with sources of error. Discharge measurements are also addressed in the book (Chow 1964).

3.1.3 Ice Phenology

Freshwater Ice Phenology Protocols

Global Learning and Observation to Benefit the Environment 2007

Appendix I

http://www.globe.gov/fsl/pdf/Strand_2C_GLOBEFreshwaterIcePhenologyProtocols.pdf

The annual development and deterioration of ice on waterbodies (i.e., ice phenology) are considered important indicators of climate change in Canada and may be of particular importance in the NWT where an abundance of ice can be monitored for freezing and thawing events each year.

Global Learning and Observations to Benefit the Environment (GLOBE) is a worldwide hands-on, school-based science and education program through which students, teachers and scientists collaborate in study and research about the dynamics of the environment. Announced in 1994, GLOBE includes representatives from 110 participating countries, including Canada (GLOBE 2007).

Ice phenology describes the freeze-up and break-up dates and the period of ice cover. It may be described according to the following:

- freeze-up: period of time between initial ice formation and the time of complete ice-cover;
- freeze-up date is the date of complete ice cover;
- break-up: period of time between the onset of snow melt and complete disappearance of ice; and
- break-up date is the day when the waterbody is completely ice free.

The purpose of this protocol is to monitor freeze-up and break-up dates and periods of easily accessible waterbodies to determine the period of ice cover.

Air temperature and precipitation are the primary factors driving ice formation and decay (GLOBE 2007) and making daily observations are recommended. One hour per day is required to take notes and pictures. The protocol calls to record exact locations using a Global Positioning System (GPS) and use data sheets to record the following:

- date;
- name of waterbody;
- location;
- weather (i.e., environmental conditions); and
- ice cover (i.e., per cent cover, ice type, fractures, flooding, movement etc.).

Once these steps are complete, researchers are to submit their completed data sheets and photographs.

Ice Phenology

Environmental Monitoring and Assessment Network 2004

<http://www.eman-rese.ca/eman/ecotools/protocols/marine/ice/intro.html>

Information for the collection and documenting of ice phenology data is provided by EMAN (2004). Protocols are provided for required equipment, monitoring location choice, and sampling methods including for data collection. A background of the relevance of studying ice phenology in northern Canada is also provided.

Simulation of Ice Phenology on Great Slave Lake

Ménard *et al.* 2002

Appendix I

http://www.easternsnow.org/proceedings/2002/001_Menard.pdf

Ménard *et al.* (2002) used a one-dimensional thermodynamic lake ice model (Canadian Lake Ice Model or CLIMo) to simulate ice phenology on Great Slave Lake in the Mackenzie River basin, NWT. Model simulations were validated against freeze-up and break-up dates, as well as ice thickness and on-ice snow depth measurements at three sites on the lake (Back Bay near Yellowknife, 1960-1991; Hay River, 1965-1991; and Charlton Bay near Fort Reliance, 1977-1990). Freeze-up and break-up dates from the lake ice model were also compared with those derived from microwave imagery

over the entire lake surface (1988-1999). Results showed a very good agreement between observed and simulated ice thickness and freeze-up / break-up dates over the 30-40 years of observations, particularly for the Back Bay and Hay River sites.

IceWatch Protocols

NatureWatch - IceWatch 2002

Appendix I

<http://www.frogwatch.ca/english/icewatch/>

NatureWatch - IceWatch (2002) describes protocols that citizens can follow to gather ice phenology data on their own and contribute it to a database maintained by EMAN. Accurately recording and analyzing "ice on" and "ice off" events is described as one way to evaluate how climate change is affecting the environment. With IceWatch's EMAN-based protocol (NatureWatch - IceWatch 2002), scientists are studying the natural freeze-thaw cycles of Canadian waterbodies. Protocols for these studies are described on the IceWatch website (i.e., under the "How to IceWatch" link). It describes the procedures for selecting a waterbody for monitoring, selecting an observation point, selecting a part of the waterbody to observe, collecting observations for freeze and thaw events, recording observations and submitting observations to EMAN.

Seasonal differences in the ice cover of lakes and rivers are influenced by climate and can have important effects on ecosystems, such as changes in:

- the migration patterns and breeding seasons of birds;
- food supplies for fish and mammals; and
- water temperature and water chemistry.

The specific dates when ice first covers and disappears from the surface of waterbodies have been reported regularly at a small number of locations across Canada but scientists have realized that there are huge spatial gaps in the present monitoring network. This program addresses the public to act as "Icewatch volunteer observers" (NatureWatch - IceWatch 2002). The steps to become a volunteer are:

- to choose a location to watch for winter "freeze-up" and spring "break-up" on a nearby waterbody;
- to record observations (as per protocol; Appendix I); and
- to send observations to the IceWatch website.

All collected information is entered into a database and becomes publicly available as a map. Step by step IceWatch instructions are described as follows (under the website's "How to IceWatch" link):

- select a waterbody;
- select an observation point;

- select the part of the waterbody that will be observed (delineate);
- collect fall freeze-up information (the date the ice completely covers the waterbody and stays intact for the winter; and
- collect spring break-up information (the date the ice goes out or completely disappears from the lake, bay or river).

Daily observations have to be made during the freeze-up and break-up periods. These two dates provide the length of ice duration and the associated length of the ice-free season of a waterbody. Additional information is to be collected on the following two other events:

- the first date the ice completely covers the waterbody; and
- the first day of ice disappearance from the waterbody.

The combined information from these four days will provide a better understanding of the process of ice formation and break-up and their timing. Observations may be recorded on the *IceWatch Observation Form* and then submitted to the EMAN Coordinating Office.

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

The manual produced by ITEX (1996) provides protocols for selecting a lake and monitoring and classifying lake ice stages.

3.2 Snow, Permafrost and Ground Ice

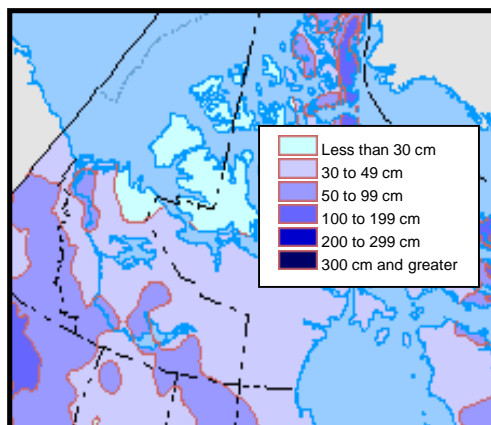
3.2.1 Introduction to Snow, Permafrost and Ground Ice

After an initial introduction, this section first covers snow monitoring protocols, listed by agencies that are conducting the relevant studies. Permafrost and ground ice are discussed in the second part of this chapter. Additional information and details on protocols for all parameters are provided in Appendix II (Table II-1).

Snow, permafrost and ground ice play important and interactive roles in the NWT's environment. Although these parameters can be measured independently, they are interrelated components of northern environments. Each factor affects is affected by the others. For example, the depth of snow can influence the development, maintenance or degradation of permafrost, but measuring snow depth is not necessarily a good indicator of permafrost conditions (SENES Consultants Ltd. 2005; Appendix II).

Snow

Snow is defined as an ice particle formed by vapour sublimation in the atmosphere *and* a collection of those loosely bonded ice crystals deposited from the atmosphere; permafrost is ground that has remained at or below 0°C for two or more consecutive years; and ground ice is ice contained in freezing and frozen ground (National Snow and Ice Data Center [NSIDC] 2007; SENES Consulting Ltd. 2005; Appendix II).

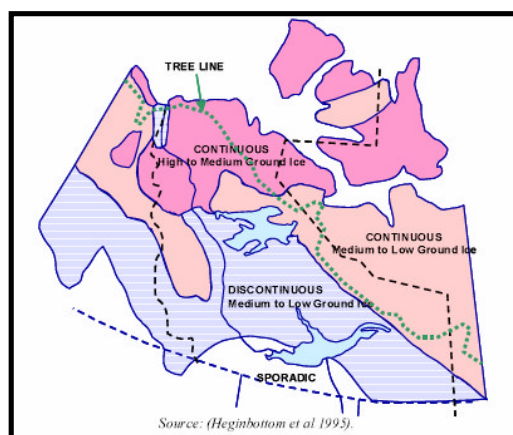


Average maximum snow cover depths vary across the NWT, from less than 30 cm depth up to 100 cm depth according to measurements taken between the years of 1979 and 1997 as shown in Figure 2.1 (NRCan 2007).

Figure 2.1 Average maximum snow cover depths across the NWT (Source: Natural Resources Canada [NRCan] 2007).

Snow cover is considered an important environmental component of the north because it is a major source of water (released during the spring melt period), it acts as an insulator that can reduce the depth of soil freezing, and it is highly reflective, influencing energy exchanges between the earth's surface and the atmosphere (Cryospheric System in Canada [CRYSYS] 2003).

Permafrost and Ground Ice



The NWT has zones of continuous permafrost in its northern latitudes, discontinuous permafrost in its mid-latitudes and sporadic permafrost in its most southern latitudes (Figure 2.2), with the discontinuous and sporadic zones covering more than half of the territory (SENES Consulting Ltd. 2005). Figure 2.2 also shows the average ground ice content for the different zones in the NWT.

Figure 2.2 Permafrost zones in the NWT (Source: SENES Consulting Ltd. 2005)

3.2.2 Snow

Monitoring snow patterns such as maximum annual snow depth is typically done at weather stations throughout the NWT (often positioned at local airports) by various agencies including EC, INAC, the territorial government (GNWT), Nav Canada, and volunteers (SENES 2005; C. Dixon, Meteorological Survey of Canada [MSC], pers. comm. January 2008). There are 35 weather stations in the NWT providing daily updates on general snow conditions across the territory to EC (e.g., light snow, drifting snow; Weatheroffice 2008). These stations do not follow a standardized protocol for the collection of snow data, but the most common measurement methods are with a snow stick (e.g., metre stick) or Nipher snow gauge (see EC 2007 and Woo 1997, Appendix II, for Nipher details) (Arctic Borderlands 2007; EC 2007; C. Dixon, MSC, pers. comm. January 2008).

Note – In this report, snow as a climatic parameter (e.g., precipitation rates) is considered further in Section 3.9.6 Climate - Precipitation (snowfall). Snow on the ground (e.g., snowcover) that is monitored in other contexts is described below.

General Snow Information

A Guide for Ground Based Measurement of the Arctic Snow Cover

Woo 1997

Appendix II

<http://www.socc.ca/snow/atlas/Woo.pdf>

Woo (1997) reviews a diversity of snow measurement procedures used in northern Canada. The information gathered is based on field work conducted in the Arctic. Detailed protocols for the different methods of measuring snow cover are described, including their inadequacies. Topics described include:

- precipitation gauges;

- old-style snow boards;
- snow-pits and snow surveys (along a transect);
- non-routine snow surveys (e.g., snow stakes);
- snow cover mapping;
- snow-free zone delineation;
- formulas for calculating snow density; and
- methods for snowfall record corrections.

Snow Cover

Snow cover in the NWT varies both spatially and temporally, with snow measurements taken at localized stations providing only indications of the true extent and nature of the territory's snow cover. Snow measurements in the NWT are compiled by EC's MSC and the information is available for review through the National Snow Information System for Water (NSISW 2008). Using information gathered from these different sources and using specific protocols (unavailable for this report), a map was developed for the temporal extent of snow cover in Canada, including the NWT (CRYSYS 2003).

Snow Depth

Environment Canada 2008

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Weather stations across the NWT measure and submit precipitation events to EC. The results are posted on EC's website and include daily reports on total precipitation, total snow, and snow on the ground at different stations as well as monthly and almanac summaries (i.e., information for the same day every year) for NWT stations (EC 2008). There are no standardized protocols in place for collecting these data although using a metre-stick and the Nipher snow gauge are considered the most common methods (C. Dixon, MSC, pers. comm. January 2008; Arctic Borderlands 2007; EC 2007; Woo 1997).

Ecological Monitoring and Assessment Network 2004

Appendix II

http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/soil_temp/intro.html#protocol

The Ecological Monitoring and Assessment Network (EMAN) is a cooperative and diverse network designed to coordinate organizations and individuals conducting ecological monitoring in Canada. The EMAN Coordinating Office was initiated by EC to improve ecosystem monitoring across the country. Its protocols recommend that soil temperature measurements be taken in conjunction with snow cover depth whenever applicable. The EMAN website provides a comprehensive study design for gathering detailed soil temperature and simple snow depth information, including equipment used and monitoring activities to be completed (EMAN 2004).

Snow Density / Snow Water Equivalent

Because gathering snow cover and density measurements from the ground is labour intensive and not very practical for remote areas, passive and active remote microwave data are being used on an increasing basis to help determine snow water equivalencies (SWE) across Canada (snow depth x density = SWE). SWE studies have been used extensively in the prairie provinces (CRYSYS 2003) but are also developed for forested and sparsely forested regions (NSISW 2008). Rees *et al.* (2005) investigated the practicality of using remote sensing methods to determine snow depth, density and SWE in tundra areas of the NWT (see below).

Assessing Snowpack Water Equivalent Distribution in an Open Tundra Environment Using Various Scales of Passive Microwave Data

Rees *et al.* 2005

Appendix II

<http://www.easternsnow.org/proceedings/2005/rees.pdf>

A study conducted between 2003 and 2005 was designed to assess tundra snow cover properties and distributions in the Coppermine River basin of the NWT. Field samples of snow were collected and the variable SWE determined. SWE data from the study was intended to improve the use of satellite passive microwave remote sensing to determine snow cover attributes across remote tundra regions (Rees *et al.* 2005). The collected snow data confirmed that the current MSC open ground algorithm for measuring SWE is not reliable for tundra conditions where heterogeneous snow properties can be a function of different wind-blown snow depths, the influence of forest-tundra transitions, variable snow density / grain size and proportion of lake snow cover. The topography and landscape of the study area were found to be the most influential factors for snow cover and density, although within terrain types snow density was more consistent. Detailed protocols for this study are provided in the report.

Snow Phenology

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

The International Tundra Experiment (ITEX) Manual (1996) is a comprehensive manual describing protocols for monitoring its stations. ITEX stations exist in Arctic Canada in Nunavut at Alexandra Fiord, Hot Weather Creek, Sverdrup Pass, Baker Lake and Truelove Lowland. An ITEX station is also located in Churchill, Manitoba. In Alaska, ITEX stations are established at Barrow and Toolik Lake. Although not located within the NWT, the protocols used for ITEX monitoring are considered applicable for use within the tundra region of the NWT.

Snow cover, duration and disappearance are discussed in the ITEX (1996) manual, particularly as it relates to snow melt timing. The manual (Appendix II) provides protocols for establishing permanent plots or sample points and permanent transects for monitoring snow cover and snow phenology (i.e., change of snow cover over time).

Snow Banks

Internal Structure and Environmental Significance of a Perennial Snowbank, Melville Island, NWT.

Lewkowicz and Harry 1991

Appendix II

<http://pubs.aina.ucalgary.ca/Arctic/Arctic44-1-74.pdf>

One report published in 1991 (Lewkowicz and Harry) describes sampling protocols for snow cores in a perennial snow bank north of Ross Point on Melville Island. At the time, this site was located within the former boundaries of the NWT, but is now located just east of the border within Nunavut. Its protocols are included because the methodology would still be applicable for other potentially similar sites throughout the NWT. The methodology described includes

- drilling equipment and procedures,
- snow core sampling locations within a snow bank,
- core handling, and
- processing and analyses.

Additional Information

Numerous and diverse snow-related studies are presented annually at both the Western and Eastern Snow Conferences. These organizations, including US and Canadian members, are designed to encourage information sharing between scientists, engineers, students, professional, environmental managers and others to advance knowledge on snow and related hydrologic sciences. Extended abstracts and articles are available at the following websites:

<http://www.westernsnowconference.org/> (Western Snow Conference); and
<http://www.easternsnow.org/> (Eastern Snow Conference).

3.2.3 Permafrost and Ground Ice

Monitoring permafrost and ground ice changes, particularly as they apply to the permafrost's thermal state and active layer thickness, is considered not only on a regional scale but also globally. Agencies have been developed that integrate monitoring information derived from the NWT, Arctic Canada in general, and numerous other polar countries in both hemispheres. The International Permafrost Association (IPA) coordinated the Global Terrestrial Network for Permafrost (GTN-P) in 1999 to monitor permafrost activities, analyzed under two monitoring networks: Thermal State of Permafrost (TSP) and Circumpolar Active-Layer Monitoring (CALM) (Global Terrestrial Observing System [GTOS] 2007). Collected CALM data are archived by the NSIDC. Many of the monitoring instruments established in the NWT follow monitoring protocols that are used internationally in attempts to create globally consistent long-term databases.

General permafrost information for the NWT is also derived from measurements recorded at weather stations across the territory. The mean annual air temperature (MAAT) is considered an important additional indicator of permafrost conditions because of correlations with the mean annual ground temperatures (MAGT) (SENES Consultants Ltd. 2005).

Active Layer and Soil Temperature

National Snow and Ice Data Centre 2007

Appendix II

http://nsidc.org/data/docs/fgdc/ggd353_activlayer_canada/index.html

Approximately 60 instrument sites have been established in the Mackenzie Valley and Delta (over a 1200 km transect) since 1990 to monitor the region's variable soil thaw depths both temporally and spatially (NSIDC 2007). Different stations measure active layer or ground temperature parameters (Geological Survey of Canada [GSC] 2007) and the data acquisition methods for these stations are described on the NSIDC website (2007).

Measurement Protocol

Circumpolar Active-Layer Monitoring 2007

Appendix II

http://www.geography.uc.edu/~kenhinke/CALM/active_layer.html

Thirteen of the 60 NSIDC Mackenzie Valley and Delta soil thaw monitoring sites have been selected to contribute to data being gathered for the CALM Program for the IPA as part of an effort to monitor permafrost activities globally (Tarnocai *et al.* 2004). The CALM Program involves monitoring more than 100 sites in 15 different countries (Brown *et al.* 2000) and follows common protocols for active layer monitoring methods, including monitoring activities carried out in the NWT.

The protocols used by CALM (2007) are provided in Appendix II and on the CALM website. The protocols discussed include sampling designs, such as the standard grid method including:

- establishing the grid;
- selecting the sampling locations; and
- selecting measurement methods.

The protocols also include some information on probing, frost tubes and soil temperature and moisture measurements.

There are also protocols on the CALM (2007) website that describe other methods for monitoring important permafrost-related parameters. These are found in Appendix II or at the following websites, including discussions on the following protocols:

- soil moisture content (e.g., gravimetric measurements, stationary measurements and spatial measurements)

http://www.geography.uc.edu/~kenhinke/CALM/soil_moisture.html;

- vertical displacement gauges (VDGs; e.g., VDG description and installation and VDG measurement)
<http://www.geography.uc.edu/~kenhinke/CALM/vertical.html>; and
- properly reporting the location of monitoring sites as for a fixed geographic position within a spatial framework, including the degree of error associated with geopositioning (e.g., positioning from a map, positioning from a GPS unit)
http://www.geography.uc.edu/~kenhinke/CALM/site_location.html.

Protocol for the Monitoring of Drilling-Waste Disposal Sumps

Northwest Territories Water Board 2005

Appendix II

http://www.nwtwb.com/Drilling_Waste_Disposal_Sumps_Oct.05.pdf

In order to monitor the conditions of abandoned sumps within the Inuvialuit Settlement Area a specific set of protocols was developed by the Northwest Territories Water Board (NWTWB 2005). It involves measuring active-layer and ground-temperature parameters for five years so that change over time can be determined. Specific protocols are provided for measuring active-layer depths along transect points and at particular intervals, as well as points and locations to be monitored on sump caps. Required monitoring equipment is outlined.

Methods for Measuring Active Layer Thickness

Nelson and Hinkel 2003

http://www.unis.no/40_about_unis/4030_staff/staff_webpages/geology/ole_humlum/per_iglacialhandbook/activelayerthicknessmethods.htm

Various CALM protocols are also described in Nelson and Hinkel's 2003 document *Methods for Measuring Active-Layer Thickness*. Protocols discussed for measuring active layer thickness include methods for mechanical probing, frost / thaw tubes, soil temperature profiles and remote methods (i.e., ground penetrating radar [GPR] and satellite measurements) (Nelson and Hinkel 2003).

The Circumpolar Active Layer Monitoring (CALM) Program: Research Designs and Initial Results

Brown *et al.* 2000

Appendix II

<http://www.geography.uc.edu/~kenhinke/CALM/polargeog/calmtxt.pdf>

Additional information on monitoring methods can be found in Brown *et al.*'s 2000 report on CALM's research designs. Protocols discussed in this document include methods for probing, frost / thaw tubes, soil and permafrost temperatures, soil moisture (affecting active layer), and vertical movement (i.e., frost heave and thaw subsidence).

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

ITEX's 1996 Manual lists protocols for depths at which to insert soil temperature probes for consistency between their climate stations.

Ground Ice

The amount of ice content in the ground can be measured using visual identifications, physical measurements of ice lenses and by melting fine-grained soils to determine ice volume. Because of its high variability within soils (particularly around developed sites such as roads and pipelines), it is best to determine ground ice content on a site-by-site basis (SENES Consultants Ltd. 2005).

Protocol for the Monitoring of Drilling-Waste Disposal Sumps

Northwest Territories Water Board 2005

Appendix II

http://www.nwtwb.com/Drilling_Waste_Disposal_Sumps_Oct.05.pdf

A specific set of monitoring protocols involving measurement of ground ice have been developed for sumps within the Inuvialuit Settlement Region (ISR). In a description of each major soil unit, observers record excess ice content and thaw stability in the upper 5 to 10 m. Sample intervals are provided (i.e., depths below ground surface) as well as parameters to be measured in laboratory analysis of the soil such as moisture content and excess ice content (NWTWB 2005).

Recent Warming Impacts in the Mackenzie Delta, Northwest Territories and Northern Yukon Coastal Areas

Wolfe *et al.* 2000

<http://dsp-psd.pwgsc.gc.ca/Collection-R/GSC-CGC/M44-2000/M44-2000-B1E.pdf>

In 1999, a field study was conducted to assess the condition of ice wedges along northern Richard Island (Mackenzie Delta, NWT) and the Yukon coastline. Historical air temperature data, ongoing active layer monitoring data and field measurements for ice wedge observations were compiled, and the results were compared to similar previous studies. Generalized methodologies are provided throughout the report (Wolfe *et al.* 2000).

3.3 Fish Quality

3.3.1 Introduction to Fish Quality

The quality of freshwater and marine fish found in the NWT is not well understood, with studies of fish quality being sporadic and typically occurring in localized areas. Parameters of concern that can be measured as indicators of fish quality include fish habitat, population and harvest (not part of this study) as well as parameters such as reproduction, growth, health and mortality, fish diseases, parasites, and contaminants / toxins (discussed below). Another method of assessing fish quality is to determine fish palatability to humans through taste and texture sampling.

The fish quality section is organized so that detailed protocols for individual freshwater fish quality studies conducted within the NWT are presented first, followed by fish quality studies conducted in coastal and marine environments. Protocols developed to assess fish quality through studies conducted across Canada are presented last. Additional information and protocol details can be found in Appendix IIII (Table III-1).

3.3.2 Freshwater Fish

Slimy Sculpins as a Lake Monitoring Species

Baron *et al.* 2007

Appendix IIII

This protocol was developed through conducting monitoring studies at the Diavik Diamond Mine at Lac de Gras, NWT and carried out by the DFO and the Canadian Rivers Institute to monitor toxins in fish populations (Baron *et al.* 2007). It uses slimy sculpin as a local species that is non-migratory and can be present in numbers that allow adequate sample sizes to be taken so that their health can be used as an indicator of local aquatic conditions.

Site selection under this protocol is fairly specific and requires two areas of study. One area is defined as an exposure area. This is located in an area potentially influenced by metals leaching from dikes and by mine water effluent plumes. The second area is defined as a reference or control site without potential contamination. A minimum of three separate sites are required for reference in an area of natural substrate and outside of industry influence (Baron *et al.* 2007).

Fish collections occur in the late summer to early fall using backpack electroshock techniques. The catch per unit effort or fish per second is documented as well as water quality measurements (pH, temperature, dissolved oxygen, conductivity). This protocol advises that an attempt is made to capture 100 non-young-of-the-year (non-YOY) slimy sculpin from each exposure and reference site. Of the 100 fish, 10 males and 10 females are sacrificed and sampled for metal and metallothionum analysis (detailed instructions on anaesthetizing methods are provided in the report). The largest fish is to be used for chemical analysis and sex determination.

All of the sacrificed fish are subjected to the following procedures:

- weighed and measured;
- livers extracted and weighed;
- guts removed and weighed;
- gut contents examined and recorded;
- preserved in individual vials of 70% ethanol solution; and
- otoliths removed for aging purposes and stored separately.

Fish livers and carcasses are to be placed in individual sterile plastic bags, labelled and frozen on dry ice and sent to the lab for analysis of metals and metallothionein (Baron *et al.* 2007).

Fish that are not sacrificed are measured for length and weight and then released alive. These measurements provide information that allows analysis of:

- size distribution;
- growth;
- survival;
- condition; and
- reproductive success.

Fish are examined to determine the presence of abnormalities, lesions, tumours and parasites. Finally, the document gives specific information on how to use the above collected information to determine the effects of industry on the fish population through comparison of sample groups (Baron *et al.* 2007).

Arctic Red River Index Netting Study

Harris 2004

Appendix III

http://www.grrb.nt.ca/publications_fisheries.htm

The Arctic Red River Index Netting Study in the Gwich'in Settlement Area (GSA) was initiated as a long term monitoring program to collect information on vital rates and biological characteristics of the Arctic Red River (NWT) fish stocks. This study was designed to mirror the Peel River Fish Study of 1998-2003. It used a fishing method that incorporates a single gill net with various sizes of mesh in order to catch a range of fish sizes within a population. The collected data may be used to detect potential changes over time and the original data can act as a baseline for future studies.

A local community member was hired and trained to monitor the nets and record the data, consisting of:

- the presence of fish species;

- gathering baseline biological characteristics of fish species; and
- documenting the timing of migrations.

Sex and maturity were determined, ovaries from all mature females were preserved for future analysis, and fins were clipped or otoliths were removed to verify fish age. Sampling occurred each year between Sept 8th and October 27th every Monday, Wednesday and Friday for the duration of the study. The study, however, was not successful and did not collect the data that were anticipated (N. Miller, Gwich'in Renewable Resource Board [GRRB], pers. comm. February 2008).

Diavik Project Fish Palatability Study

Environmental Monitoring Advisory Board 2003

Appendix III

<http://www.emab.ca/>

In August 2002, a fish palatability study took place near the Diavik Diamond Mine site at Lac de Gras. The study was the result of an attempt to create a baseline for monitoring fish quality and fish health in the future using both scientific practices and the traditional knowledge of Elders (Environmental Monitoring Advisory Board [EMAB] 2003).

The fish were evaluated fresh and not compared to fish caught in any other locations. Forty-six fish were caught in five nets. They consisted of lake trout, cisco and whitefish (EMAB 2003). Protocols for fish evaluation included that the specimens were:

- weighed and measured;
- photographed;
- observed visually for sex and stage of maturity;
- sampled for metal analysis (tissue);
- investigated for stomach contents and visible parasites;
- aged; and
- analyzed for chemicals released from tissues using an electronic sniffer.

Fish were then selected for cooking and tasting. Fish were observed before and during cooking. No spices were used when cooking the fish. A rating system from 1-5 was used by each community group participating in the study to rate the palatable quality of the fish. The study was deemed a success and a permanent camp was set up near the mine to conduct future testing. It was recommended that the taste testing be completed every five years, but it was decided to repeat the study every one to two years (EMAB 2003).

The Peel River Fish Study

Toyne and Tallman 2000

Appendix III

Walker-Larsen 2001

Appendix III

VanGerwen-Toyne, M. 2002 and 2003

http://www.grrb.nt.ca/fisheries_research.htm

The Peel River Fish Study (NWT) was developed to collect population baseline data for broad whitefish and other coregonids in the Peel River due to concerns of the Gwich'in communities about potential developments near the Peel River causing a decline in fish stocks. The timing of spawning migrations of the broad whitefish as well as detailed spawning areas were investigated. The study additionally collected baseline data, such as fork length, weight, sex, maturity stage and fecundity for all fish caught (Toyne and Tallman 2000).

The study used community-based monitoring and employed three people from a nearby community. Monitors were trained in fish sampling procedures for measuring fork length, weight, sex, maturity stage, gonad weight, and on how to collect aging structures such as scales, pelvic fin rays and sagittal otoliths (earbones). Monitors also removed the females' gonads to be bagged and frozen for fecundity analysis (Toyne and Tallman 2000).

Biophysical parameters, such as air temperature, water temperature, sky cover, wind speed, water level, amount of debris in the water and water clarity were recorded. Fish livers were weighed as a stress indicator and muscle samples were collected to be examined for contaminants. The number of fish caught each day was recorded to estimate the timing of the migration (Toyne and Tallman 2000).

In 1998 the river was scanned by helicopter to see if aggregations of broad whitefish could be seen under the ice. In 1999 an application was made to use radio tracking to locate the spawning sites, but airtime could not be accessed. There were no further attempts to investigation spawning sites (Toyne and Tallman 2000).

In 2000, the study continued with two monitors. It was started earlier in the season to collect information about inconnu, lake whitefish, Arctic cisco and least cisco in addition to the broad whitefish. Monitors fished with multi-meshed nets. (Walker-Larsen 2001; VanGerwen-Toyne 2002; VanGerwen-Toyne 2003).

EMAN Freshwater Ecosystems: Parasites of Fishes in Fresh Water

Marcogliese and the Parasitology Module Steering Committee 2002

Appendix III

http://www.eman-rese.ca/eman/ecotools/protocols/intro_rec.html

The Marcogliese and the Parasitology Module Steering Committee protocol explains how to survey for parasites in fresh water fish communities in Canada, including the NWT. It states that all organisms examined for parasites should come from the same habitat and not be pooled across habitats. Twenty to 30 organisms are required for a general parasite survey and should come from age or size classes that are representative of the population. Analysis of data by age, size, sex or season requires 30 host animals in each class (Marcogliese and the Parasitology Module Steering Committee [Marcogliese] 2001).

Host organisms should be examined fresh for parasites or be frozen as soon as possible after capture. Fish should be euthanized by pithing if they are small, by clubbing over the head if large, by cervical dislocation or by an overdose of anaesthetic. All hosts should be individually bagged to prevent loss of ectoparasites and labelled appropriately with collection date. Any fish returned to the laboratory alive should be examined within a few hours to prevent parasites with direct life cycles from spreading between hosts or increasing on infected hosts. Parasite surveys should be done twice annually in spring to early summer and late summer (Marcogliese 2001).

The laboratory procedures for macroparasites are as follows, with all examinations of tissues done using a stereomicroscope:

- record the type of host, date and location of capture, and the method of collection;
- record the name of the collector and the name of the examiner;
- measure and weigh the host fish;
- rinse the surface of the fish, collect the rinse water and examine it for ectoparasites;
- rinse and examine the buccal cavity, remove the eyes and dissect;
- remove the otoliths, fins or scales for the aging of the fish;
- examine the fins;
- open the body cavity of the fish ventrally and record the sex of the fish;
- examine the cavity and surface of the internal organs for parasites and then separate into Petri dishes with water;
- separate the stomach, pyloric caeca and the intestine, open longitudinally and examine;
- cut the organs and tissue into smaller pieces, compress between glass plates and examine;
- rinse the body cavity, collect the rinse water and examine it;
- thinly slice and inspect the musculature;
- record the number of parasites found in each species and their location within each fish on a data sheet; and
- kill and store all parasites found using methods in the protocol for each type of parasite prior to examination for identification to genus.

The protocol offers several methods for data analysis but specifies prevalence, mean abundance and mean intensity as being the most common measurement of parasite population levels in hosts. A sample data sheet is provided in the appendix of the report as a guide to ensure that all measured parameters are recorded (Marcogliese 2001).

Biological Characterization of the Snare River System

Rescan Environmental Services Ltd. 2001

Appendix III

<http://www.ntpc.com/yellow/environment/reports/Rescan%20Report.pdf>

A study was conducted by Rescan Environmental Services Ltd. (Rescan 2001) for the Northwest Territories Power Corporation (NTPC) to identify the potential effects of hydroelectric development on aquatic development in the Snare River System north of Great Slave Lake, NWT. Five following main components of the system were assessed:

- water quality;
- sediment quality;
- benthic macroinvertebrate communities;
- fish communities; and
- bioaccumulated mercury.

Sampling protocols followed during project research are summarized below and detailed protocols are outlined in the full report which is available on the NTPC website. Statistical analysis methodologies are also provided, including formulas for assessing each of the study's parameters (Rescan 2001).

Fish communities sample collection and processing - Samples for the fish community surveys were taken from seven water bodies in late July / early August using both gillnets and beach seines (Rescan 2001).

Gillnetting - Each water body was fished with gangs of gillnets consisting of six panels of differing mesh sizes to allow for a catch of a broad range of fish sizes. Gillnets that were used were sinkers with lead lines at the bottom and float lines at the top. They were set along the bottom of the lake parallel to shore. The nets were set during the day and left overnight for an average of 22 hours. A minimum of two overnight sets were made at each water body. A variety of habitats were fished based on water depth, bottom substrate (hard / soft) and presence of vegetation. Deep sets (deeper than 10 m) were placed outside the edge of the flooded forest located with a depth sounder (Rescan 2001). The following information was collected from each set:

- site number;
- UTM coordinates;
- date;
- start / finish times;
- water and air temperatures;
- water depth at each end of the net;
- dissolved oxygen;
- wind speed and direction;
- sampling zone;

- substrate type; and
- presence of vegetation.

The following was recorded for all fish species captured:

- species and number per species;
- length measurements (fork and total length);
- weight; and
- mesh size the fish were caught in.

The fish were sampled for aging structures. Any aging structures collected (e.g., fin rays, dorsal spines, scales and otoliths) from dead fish were labelled and stored for future analysis. Live fish were released after being identified by clipping pelvic fin and marking fish over 300 millimetres (mm) with a uniquely identified Floy anchor tag which helps to provide information on fish movement and growth if the fish is recaptured. Dead fish were dissected to determine their sex, maturity, reproductive status and stomach contents. Muscle tissue was collected from northern pike for mercury analysis (Rescan 2001).

Beach Seining - Beach seining caught smaller fish species and juveniles by sampling along the shoreline with beach seines. It was conducted in late July / early August at the same time that the gillnetting was being done. The seine was positioned perpendicular to shore using a boat and forming an arch while progressing back to shore where the seine is drawn up onto the beach and the captured fish removed (Rescan 2001). For each haul the following information was recorded:

- site number;
- UTM coordinates;
- date;
- start / finish time;
- water and air temperature;
- water depth;
- dissolved oxygen;
- wind speed and direction;
- lake bottom substrate;
- presence of aquatic vegetation; and
- fish captured are identified to species, enumerated and released.

3.3.3 Coastal and Marine Fish

EMAN Marine Ecosystems: Protocols for Marine Parasitology

Burt and MacKinnon 2001

Appendix III

http://www.eman-rese.ca/eman/ecotools/protocols/intro_rec.html

The EMAN Marine Ecosystems Protocol for Marine Parasitology for measuring the numbers of parasites found in a host population of fish stresses the importance of examining the host while it is submersed in sea water (Burt and MacKinnon 2001). The protocol recommends that the following data should be recorded for each host organism studied:

- host name (i.e., genus and species);
- host sex, size and condition;
- place of collection (local and regional);
- relevant habitat data (e.g., water temperature, depth collected, substrate);
- date of collection;
- method of collection; and
- name of collector.

It is necessary to sample a minimum of 20 fish. If the data are analyzed according to sex, age etc., then there should be 20 fish in each category. The protocol specifies that fish should be examined as soon as possible after collection. If this is not possible, alternatives are discussed within the protocol. All examinations are done under a dissecting microscope (Burt and MacKinnon 2001).

The protocol differentiates between lamprey and other fish studies. For lampreys the following procedure is to be used:

- collect blood sample;
- examine the outer surface, buccal cavity, gill slits and gill arches;
- examine internal organs;
- the spiral valve can be opened and a smear should be made of any unusual tissue; and
- examine musculature.

Other fish species are hosts to parasites including protozoa, platyhelminthes and nematoda (Burt and MacKinnon 2001). The following additional procedures should be used:

- once open, the body cavity should be rinsed and examined for any parasites that were flushed out;

- examine surfaces and organs for larger parasites;
- open and examine the stomach, intestine, urinary bladder and heart; and
- examine musculature for helminths or cysts.

The protocol outlines the procedures of specimen preparation for blood smears, tissue smears, and tissue examination. It also provides guidelines on how to store and prepare various parasites for identification and later work (Burt and MacKinnon 2001).

Tariuq (Ocean) Community Based Monitoring Program

Cobb *et al.* 2002

Appendix III

http://www.nwtcimp.ca/documents/cimpProjects/TariuqReport/Tariuq_Progress_Report_2001_02.pdf

The Tariuq Monitoring Protocol is a community-based monitoring protocol that uses monitors fish habitat and fish health in the Mackenzie Delta and southern Beaufort Sea, NWT. It monitors biophysical parameters such as water temperature, fish species composition, abundance and health. Index gill netting is used to collect fish samples using a range of mesh sizes within one net to allow for representative sampling of all species present at the sample time. Nets are checked twice a day or more depending on the numbers of fish being caught, to allow for live release of sample fish. All fish are identified to species, sex, length, weight and maturity. Aging structures are collected. Live fish are released after sampling and dead fish are given to the local community for use after aging and tissue sampling.

Fish samples act as indicators for environmental change through the presence and abundance of fish species, contaminant loading and overall health determined through vitamin analysis. Therefore, tissue samples are collected to test for contaminants. Analysis of data collected in the first year provides baseline information on coastal, marine, and anadromous species.

This protocol uses a “catch per unit effort” to correct for disparities in sampling procedures, environmental conditions and time of day between monitoring communities.

An initial study using the Tariuq Protocol was conducted in 2001 and 2002 based out of Aklavik, NWT and Tuktoyuktuk, NWT. Temperature gauges were installed from July until freeze up to monitor water temperature. Index gill netting was conducted in September of 2001 and 2002 for one week. A July sample was added in 2002 but a DFO representative in Inuvik, NWT indicates that this protocol is not currently being used to monitor fish (C. Wenghofer, DFO, pers. comm. February 2008).

3.4 Moose

3.4.1 Introduction to Moose

Wildlife species in Canada, including moose, may be ranked under the Government of Canada's Species at Risk Act (SARA), first legislated in 2003 (SARA 2007). SARA designates a national classification for species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). These include species designations as 'special concern' (may become threatened or endangered from combination of biological characteristics and identified threats), 'threatened' (may become endangered if not protected from factors leading to extirpation or extinction), 'endangered' (facing extirpation or extinction), 'extirpated' (no longer existing in Canada but does elsewhere in the world), and 'extinct' (no longer existing anywhere) (SARA 2007). If a species becomes listed as 'extirpated', 'endangered' or 'threatened', people are legally prohibited from killing, harming, harassing or capturing species individuals, nor can they damage or destroy their habitat (SARA 2002).

COSEWIC was created in 1977 to provide an assessment of Canadian species and develop a national classification for wildlife species at risk. In 2003, COSEWIC was moved under SARA's mandate to act as its advisory body, and it continues to provide ongoing evaluations of the status of Canadian species. The Committee uses the same designations as SARA does for species classifications, but these rankings are not necessarily accepted by SARA (COSEWIC 2007).

The GNWT's ENR department has established an assessment program for species found within the NWT. Since 1999, the GNWT has been collecting information on species and has developed The NWT General Status Ranking Program, used as a tool for conservation management. Under this program, species ranks must be reviewed every five years. Species may be ranked as 'at risk' (have been assessed in detail or ranked by COSEWIC as threatened or endangered), 'may be at risk' (may be at risk of extinction or extirpation; the highest rank for species under GNWT General Status Ranking system), 'sensitive' (may require protection to keep from becoming at risk), 'secure' (not at risk or sensitive), 'undetermined' (insufficient information to determine status), 'not assessed' (not assessed under program), 'alien' (introduced through human activities), 'extirpated / extinct' (no longer found in the NWT / world), 'vagrant' (infrequent and / or unpredictable occurrences, outside normal distribution range) and 'presence expected' (species not yet recorded but expected to occur in the NWT).

Note: The above description of wildlife ranking also applies to Section 5, Terrestrial Mammals and Section 6, Marine Mammals.

This section is organized so that individual studies conducted within the NWT and their associated protocols are presented according to the primary monitoring technique used. Many moose studies and surveys have been conducted across the NWT. This report describes only a selection of representative studies in detail. Further information on additional moose monitoring studies and protocols that have been used

is provided in Appendix IV (Table IV-1). To supplement this table, a second table in Appendix IV highlights additional moose studies (Table VI-2).

General Research Methods

For ungulate research in general, the primary method of data gathering is through aerial surveys, but information on ungulates may also come from radio telemetry, track surveys, pellet group surveys, browse surveys, and harvest studies (Kranrod *et al.* 2006). When compared to aerial surveys, browse, pellet group, track and harvest studies are low cost and can be conducted by personnel with a minimum of training. However, survey types such as aerial surveys, browse, pellet group, and track surveys cannot provide researchers with information on actual numbers, sex ratios, or age structures of given populations; they can only provide numbers on subamples and then researchers must extrapolate from the sub samples to reach population estimates. Radio telemetry studies are costly in both equipment and training, but provide more accurate, year-round population data (Kranrod *et al.* 2006; Appendix IV).

The NWT CIMP advocates monitoring moose through the following indicators (CIMP 2007):

- total moose numbers;
- bull to cow ratios;
- cow to calf ratios;
- indications of the health of regional populations including
 - presence of disease;
 - parasites; and
 - contaminants;
- number harvested;
- twinning estimates; and
- areas of recent burns.

Currently, monitoring of moose populations is conducted by the GNWT near Wrigley, Fort Simpson, Jean Marie River, Nahanni Butte, Fort Liard, Tulita, Norman Wells, Fort Good Hope, Fort Providence, Fort Resolution and Fort Smith (CIMP 2007). The GRRB and Sahtu Renewable Resources Board (SRRB) are also working on moose monitoring projects. The GRRB, SRRB, and Inuvialuit Joint Secretariat are all currently working on moose harvest studies.

Although not a report on monitoring protocols, the Mackenzie Gas Project's Environmental Impact Statement (EIS) (Volume 3, section 10.3.1.3) provides valuable background information on moose in the NWT (Mackenzie Gas Project 2004). Information is given on the animal's abundance and distribution, population density, and occurrences within the GSA, Sahtu Settlement Area, Deh Cho Region and north-western Alberta. Population trends, human influences, mortalities, seasonal influences, predator-prey relationships, movement patterns, home ranges and habitat uses are described in the report.

Aerial Surveys

A workshop on moose population assessment was held in Yellowknife, NWT in May 2003 and established the geospatial aerial survey method as the standard for the NWT (D. Cluff, ENR, pers. comm. January 2008; Cluff 2005). This technique is a version of the method developed in Alaska by Gasaway in 1986 (Kranrod *et al.* 2006; Gasaway 1986) with important modifications on grid pattern, block size and eliminating the need for sightability corrections (Lambert-Koizumi 2006; Cluff 2005).

Moose Aerial Survey in the Gwich'in Settlement Area

Lambert-Koizumi 2006

Appendix IV

http://www.nwtcimp.ca/documents/cimpProjects/Gwichin_Lambert_Moose_FinalReport_05_06.pdf

One 2006 study in the GSA (Lambert-Koizumi 2006) conducted aerial surveys using a stratified random block survey design, the standard technique adopted for use in the NWT. The survey was conducted at the end of March, in accordance with the recommendations of the BC Ministry of Sustainable Resource Development. The survey collected total numbers of moose and classified the moose as either a bull, cow, or calf. Stratification of the area into different moose densities (low, medium, high) was accomplished through information given by harvesters and elders during community meetings and combined with vegetation classification maps from DUC. Lambert-Koizumi (2006) randomly selected 14% of grid cells to be flown. Two observers flew over the selected cells in a fixed wing aircraft at an elevation of about 350 m to detect, count and classify each moose present in the selected cells. Transects were approximately 800 m apart.

Survey of Moose Abundance in the Boreal Forest around Yellowknife, Northwest Territories

Cluff 2005

Appendix IV

http://www.mveirb.nt.ca/upload/project_document/1175209340_EA0506-006%20ENR%20Moose%20Survey%20Report.pdf

Similar to the Lambert-Koizumi (2006) survey, a geospatial survey of moose was conducted in the Taiga Shield ecozone around Yellowknife and Great Slave Lake's north shore (Cluff 2005). The base procedure followed for this study was as follows:

- the survey area was selected;
- the area was stratified into high and low moose density grid cells of approximately 4 km² (2 minutes of latitude by 5 minutes of longitude);
- a minimum of 100 cells were randomly selected although approximately 10% of the cells may have been manually selected to cover perceived gaps in the random selection process; and
- the survey units were flown over in March by a fixed wing aircraft with one navigator and two observers.

Cluff (2005) stratified the grid cells based on the proportion of deciduous vegetation. Areas with more deciduous vegetation were considered to be higher quality moose density habitat. The grids were further modified by incorporating data from actual sightings of moose during previous aerial surveys for bison and with community rankings of specified grid cells. 10.8% of grid cells were randomly selected to be surveyed. Two observers flew over the selected cells in a fixed wing aircraft at an elevation of about 350 m to detect, count and classify each moose present in the selected cells. Transects were approximately 800 m apart.

Biological Sampling

Monitoring Wildlife Populations and Health in the Sahtu Region

Sahtu Monitoring Project 2006

Appendix IV

<http://wildlife1.usask.ca/Sahtu/monitors.php>

The ENR, GNWT and SRRB are jointly running a Wildlife Health Monitor Program, which depends on six monitors to collect biological samples from moose or caribou. Each monitor is trained by GNWT officials to take samples and is offered the incentive of \$100 of gas for each set of samples submitted, for a value of up to \$1,000 (Veitch and Kutz 2007; Appendix IV). Monitors collect the following samples for analysis:

- left kidney;
- a piece of liver;
- lower jaw;
- left lower leg bone; and
- samples of feces and blood.

Monitors measure the rump back fat and note the animal's sex, age, body condition, presence of calf and lactation status (Sahtu Monitoring Project 2006). The kidney fat, and bone are used to determine the condition of the animal and the lower jaw is used to determine the age. The feces are examined for parasites. The kidney and liver are frozen and used to determine contaminant levels. The blood is frozen and used for deoxyribonucleic acid (DNA) and disease studies (Sahtu Monitoring Project 2006).

3.5 Terrestrial Mammals

3.5.1 Introduction to Terrestrial Mammals

Note: See Section 3.4.1, Moose, for a description of the wildlife ranking systems used in Canada and the NWT.

This section includes monitoring protocols and studies on grizzly bear (*Ursus arctos*), Dall's sheep (*Ovis dalli dalli*), mountain goats (*Oreamnos americanus*) and wolverine (*Gulo gulo*) as indicators for the VC Terrestrial Mammals. Across the NWT, these animals are monitored in various ways. Each terrestrial mammal sub section is organized uniquely to best present the protocol information gathered. Further information is provided in Appendix V on monitoring protocols for these animals (Table V-1). To supplement this table, a second table in Appendix V highlights additional terrestrial mammal studies (Table V-2).

3.5.2 General Protocols for Terrestrial Wildlife

Mammal Categories

Species at Risk

SARA 2002

Appendix V

http://www.sararegistry.gc.ca/the_act/SARA_e.pdf

When dealing with animals that are species of special concern, protocols must be met as identified by the federal *Species at Risk Act* (SARA). SARA provides protocols such as what classifications of species may not be captured (e.g., threatened species), general prohibitions (e.g., killing and selling of wildlife) and recovery strategies and management plans for species of concern (SARA 2002).

Capturing and Handling Wildlife

ENR 2006

Appendix V

<http://www.nwtwildlife.com/WCC/info.htm>

Wildlife researchers in the NWT must comply with Standard Operating Procedures (SOPs) as identified by the GNWT for capturing and handling (non-fish) wild vertebrates. Lists of the responsibilities of the investigator as well as the GNWT Wildlife Care Committee are provided at the above website. There is also a link on this site to view the Protocol Review Template, a checklist for researchers to ensure that they are following required protocols.

Trapping Standards

Fur Institute of Canada 2004

<http://fur.ca/index-e/index.asp>

(including the *Agreement on International Humane Trapping Standards* 1997
<http://fur.ca/index-e/pdf/AIHTS.pdf>)

An agreement was signed in 1997 called the *Agreement on International Humane Trapping Standards* between the European Community, Canada and the Russian Federation (Official Journal of the European Communities 1998; Fur Institute of Canada 2004). This agreement outlines trapping methods and the certification of traps for various wild terrestrial and semi-aquatic mammals. It describes trapping protocols to be followed for wildlife management purposes (e.g., pest control), fur, skin and meat collection, and mammal capture for conservation purposes. The GNWT endorses this agreement for grizzly bear management.

Multi-Animal Studies

Dall's sheep, Wolves and Grizzly Bears

Lambert-Koizumi 2007

Appendix V

<http://www.grrb.nt.ca/pdf/wildlife/Richardson%20Project%20Progress%20Report%20007.pdf>

A study undertaken by the GRRB analyzes interactions between Dall's sheep, wolves and grizzly bears in the Richardson Mountains, NWT. Specifically, the study investigated the population and spatial dynamics of these animals, quantified the interactions between them (particularly as they related to spatial dynamics, predation, diet and behaviour), assessed habitat feature impacts on interactions (e.g., snow and climate) and documented Gwich'in TK on the animals. In the 2007 progress report methodologies are provided for:

- GPS telemetry tracking;
- snow monitoring;
- Dall's sheep behaviour observations;
- diet analysis (i.e., with fatty acid signatures and stable isotopes);
and
- TK interviews.

3.5.3 Grizzly Bear

In 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the north-western grizzly bear population under the category of 'special concern'. This means that it could become 'threatened' or 'endangered' because of its biological characteristics and identified threats to the species (COSEWIC 2007). It is not listed under SARA (SARA 2006). As of 2007 the grizzly bear was designated under the status of 'sensitive' by the GNWT meaning that they are not at risk of extinction or extirpation but are susceptible to becoming at risk unless measures are taken to protect them. More information about grizzly bear status in the NWT can be found on the GNWT Infobase (ENR 2007a).

Grizzly bears in the NWT are a challenge to monitor because of their solitary nature, low population densities and inactivity during the winter months. Monitoring techniques such as scat counts, winter tracking and aerial surveys are not highly suitable for this animal (Kranrod *et al.* 2006) but other methods such as radio telemetry and biological assessments are commonly employed.

This section is organized according to generalized studies of grizzly bears in the NWT, followed by individual studies according to the primary monitoring protocols used.

The Western NWT Biophysical Study - Grizzly Bears in the Mackenzie Delta

The Western NWT Biophysical Study aims to ensure that adequate baseline data is available to mitigate and monitor the impacts of any future development activities in the region. Multi-year, multi-party research projects were initiated in 2004 under ENR's mandate to assess wildlife, wildlife habitat, forests and air quality parameters.

One component of the overall study was to develop baseline data on grizzly bears in the Mackenzie Delta region. This includes describing grizzly bear distribution and movement patterns and identifying key grizzly bear habitats within the region. The objective of the study was to develop baseline data that could be used in the future to understand how bear habitat selection and movement patterns might be affected by increased human activity and pipeline-related development in the area (ENR 2007b). The following articles are associated with this grizzly bear study and describe the monitoring protocols employed in various ways.

Denning Habitat and Foraging Ecology of Grizzly Bears in the Mackenzie Delta, NWT

Barker 2007

Appendix V

http://www.biology.ualberta.ca/faculty/andrew_derocher/?Page=5696

Barker (2007) summarizes a study conducted on grizzly bears in the Mackenzie Delta and provides methodologies for:

- selecting den sites from databases and models;
- using models, bear movement data, site investigations and stable isotopic analysis to determine importance of ground squirrels in grizzly diets; and
- assessing ground-squirrel preference for treed habitats.

Habitat and Movement Ecology of Grizzly Bears in the Mackenzie Delta, NWT

Edwards 2005

Appendix V

<http://pubs.aina.ucalgary.ca/arctic/Arctic59-4-453.pdf>

Edwards (2005) describes a study using GPS collars on grizzly bears in the Mackenzie Delta. Generalized protocols are provided for:

- measuring annual and seasonal home range sizes and distributions;
- the identification of important habitats through tracking grizzly bear movements over time; and
- comparing grizzly bear habitat use with vegetation types (determined through existing sources and field surveys).

Grizzly bear movement and home range locations were imported to ArcGIS 9.1 and that information assessed using Resource Selection Function (RSF) analysis.

Annual Report of the Western Northwest Territories Biophysical Study

ENR 2007b

Appendix V

<http://www.nwtwildlife.com/Publications/PDF/Biophysical%20Report%202006-2007.pdf>

The summary report for the *Biophysical Study* for 2006/2007 summarizes the overall study protocols used for the grizzly bear including the following procedures:

- capture, collar and monitor bears with GPS / Argos satellite-linked telemetry (quantifies fine-scale habitat use / movement patterns);
- use the data to develop habitat selection models (i.e., identify key habitats);
- assess potential effects from potential pipeline development;
- develop models to compare grizzly movement patterns and human activities;
- develop a Vegetation Classification Model and Arctic ground squirrel distribution model (from remote sensing, image analysis, training site surveys); and
- use grizzly bear hair, claw shavings and prey items for stable isotope analysis to conduct dietary analysis.

Grizzly Bear Research in the Inuvialuit Settlement Region

Grizzly Bear Research

The Wild Times 1994

Appendix V

http://www.enr.gov.nt.ca/plc/wildtimes/spring1994/wild_times_wintspring_1994_page_14.htm

Protocols followed in the ISR for grizzly bear research starting in 1987 are described under the following procedures:

- the research team spots a bear from a helicopter;
- the bear is shot with a tranquillizer dart;
- all bears are given ear tags;

- some bears are given radio collars;
- bears are weighed and measured and a tooth extracted (for ageing and blood sampling);
- the bear's lip is tattooed;
- collared bears are located four times per year using a fixed-wing aircraft; and
- radio collars are set to transmit for three years.

Radio Telemetry

Radio collaring and tracking, particularly when combined with information gained from monitoring through genetic material sampling, can provide information about grizzly home ranges, survival rates and reproduction rates for captured animals (Kranrod *et al.* 2006).

A Review of Information on Moose, Woodland Caribou and Grizzly Bear Populations within the Gwich'in Settlement Area

Kranrod *et al.* 2006

Appendix V

http://www.nwtcimp.ca/documents/cimpProjects/GTC_Hawkins_FINAL_Report_05_06.pdf

Kranrod *et al.* (2006) recommend protocols for the radio collaring and tracking of grizzly bear populations within the GSA. Protocols are provided for study area and sampling design as well as procedures, such as bear locating, collaring, transmission timing and frequency.

The Demography of Barren-Ground Grizzly Bears (*Ursus arctos*) in Nunavut and the Northwest Territories

McLoughlin and Messier 2001

Appendix V

<http://www.nwtwildlife.com/NWTwildlife/bears/grizzlybear/DemographyReport.pdf>

A comprehensive study was conducted to assess grizzly bear demographics in the central Arctic in a 235,000 km² area centered 400 km northeast of Yellowknife. The study assessed survival rates, reproductive parameters and the rate of population increase from the data. The study incorporated information from existing harvest and telemetry data and analyzed population risks through computer simulations. The report provides detailed protocols for the following:

- study area delineation;
- satellite collars and very high frequency (VHF) radio-telemetry details;
- aerial search and capture techniques;
- bear immobilization and drugging;

- bear data collection (e.g., weight, girth, tooth extraction, bioelectrical impedance analysis, blood sampling etc.);
- collection of grizzly bear records for capture and telemetry data including field notes, legal harvest, problem kills, and suspected illegal mortalities;
- assessment of demographic parameters including formulas to determine:
 - survival rates (for cubs of the year (COY), yearling [age 1], sub-adults [ages 2-4] and adult [over age 5] categories);
 - reproduction;
 - population rate of increase; and
 - density and population size.

A thorough risk analysis was conducted through using the RISKMAN program to model risks of population decline for the grizzly bears of the central Arctic.

Spatial Organization and Habitat Selection Patterns of Barren-Ground Grizzly Bears (*Ursus arctos*) in the Northwest Territories and Nunavut

McLoughlin *et al.* 1999

Appendix V

<http://www.nwtwildlife.com/WKSS/PDF/SpatialHabitatGrizzlyFinal.pdf>

Between 1995 and 1999, over 150 barren-ground grizzly bears were captured in the lower Arctic tundra of mainland Nunavut and the NWT. A study conducted by McLoughlin *et al.* (1999) analyzed the spatial organization and habitat selection patterns for the bears. Methodologies and protocols are provided for designing the study area, animal capture and telemetry, population delineation, habitat analysis, assessing home ranges and movements, denning habitats and assessing the potential impacts of mining on the animals.

Biological Assessments (Genetic Materials, Feces etc.)

A Review of Information on Moose, Woodland Caribou and Grizzly Bear Populations within the Gwich'in Settlement Area

Kranrod *et al.* 2006

Appendix V

In a 2006 report, Kranrod *et al.* provide protocols for monitoring grizzly bear populations within the northern portion of the GSA using DNA sampling coupled with radio telemetry. Specific protocols are provided for study area and sampling design, setting up barb-wire snags and collecting hair samples.

Grizzly Bear (*Ursus arctos*) Studies in the Northwest Territories

Gau and Case 1999

Appendix V

<http://www.nwtwildlife.com/WKSS/PDF/GrizzlyNutritionalEcologyFinal.pdf>

In 1998, Gau and Case completed a study investigating the nutritional and physiological nature of barren-ground grizzly bears in the Central Arctic as part of a larger effort to assess the animals' status. They used fecal analysis, direct observation, stable nitrogen isotope analysis and bioelectrical impedance analysis to assess feeding patterns and nutritional-related stress in the bears. Throughout the report protocols are provided for designing the study area, collecting grizzly feces, conducting and recording ground observations, conducting stable nitrogen isotope analysis, assessing haematology and serum chemistry, conducting bioelectrical impedance analysis and statistical testing (Gau and Case 1999).

Ground Surveys

Wildlife Effects Monitoring Plans

Golder Associates (D. Panayi, pers. comm. February 2008)

Appendix V

At Barrenland Mines, NWT and Nunavut

Golder Associates (Golder) has been contracted through several different mines (e.g., Doris North Gold Mine [Nunavut], Snap Lake Diamond Project [NWT]) to develop Wildlife Effects Monitoring Plans (WEMP) to assess the impacts that mines may have on wildlife in their vicinities, including grizzly bears. These plan objectives may assess:

- wildlife habitat (direct and indirect mine alterations to habitats);
- disturbance to wildlife (e.g., wildlife abundance, movement, distributions, behaviours, den and nest sites, nest success); and
- wildlife incidents (numbers of mine-related incidents with wildlife).

In order to assess how mines might affect grizzly bear health and survival, ground surveys are carried out in study areas that encompass a specific radius around the mine sites (e.g., 30 km). Golder has developed a set of protocols for monitoring wildlife effects within these study plots. The surveys are conducted every spring and summer in seasonally preferred habitats. Quasi-randomly selected plots containing preferred habitat (e.g., sedge wetlands and riparian zones) are the first plots searched within the study areas, but depending on the mine location, eskers and outcrops within 1 km of the plot centre are also searched (D. Panayi, Golder, pers. comm. February 2008).

Observations are recorded for bear signs (attempting to differentiate between grizzly and black bears) such as beds, digs, tracks, scat, hair and prey remains. Observations are only recorded for signs that appear to have been left within the past year. Survey time is limited (e.g., one hour per plot) and is conducted by a specific number of experienced people (e.g., three). The parameters assessed from these observations include the amount and frequency of observed bear signs among plots as well as changes in relative proportions of plots with bear signs over the years. Spring and summer data are analyzed separately to assess trends over time, comparing baseline data against mine operations to determine potential mine-related influences on wildlife and temporal changes in local grizzly bear abundance (D. Panayi, Golder, pers. comm. February 2008).

3.5.4 Dall's Sheep

Dall's sheep, one of two sub-species of the thinhorn sheep, are found throughout Alaska, the Yukon, western NWT and north-western British Columbia (BC) (ENR 2008). In the NWT they are considered a 'secure' species (ENR 2007a) and are not listed under COSEWIC (2007) or SARA (2006).

This section is organized according to surveying technique and describes different monitoring protocols that have been or are planned to be used within the NWT.

Aerial Surveys

The first broad investigations on Mackenzie Mountain Dall's sheep were run by the CWS in the period between 1966 and 1974 (ENR 2008). A complete survey of the Mackenzie Mountains has never occurred, but the mountains have been surveyed in individual blocks by fixed wing aircraft (formerly) and by helicopter (more recently).

Ground-Based Surveys - General

Dall's Sheep

ENR 2008

Appendix V

<http://wildlife.enr.gov.nt.ca/NWTWildlife/DallsSheep/dallssheeptop.htm>

2006 Research

SRRB 2006

Appendix V

<http://www.srrb.nt.ca/research/r2000.html#p3>

Trained Sahtu hunters in Fort Good Hope, Norman Wells, and Tulita collected and recorded sheep data in 1998 and partially in 1999 (ENR 2008 sheep; SRRB 2006). The project aimed to complete a census of Mackenzie Mountain Dall's sheep, determine the age and sex structure of the population, estimate recruitment based on yearling observations, and reproduction based on lamb observations (SRRB 2006). The research design calls for ground-based surveys because sheep have been shown to be sensitive to the sound of aircraft (ENR 2008). Ground based surveying is also less costly and provides opportunity take samples and detailed observations (SRRB 2006).

Dall Sheep, Grizzly Bear, and Wolf Interactions in the Richardson Mountains

Lambert-Koizumi 2007

Appendix V

<http://www.grrb.nt.ca/pdf/wildlife/Richardson%20Project%20Progress%20Report%20007.pdf>

A GRRB study posted a camp of six people to observe Dall's sheep behaviour for 24 days (Lambert-Koizumi 2007). The protocols involved pairs of researchers who were assigned a morning, evening, or night shift and used binoculars or spotting scopes to observe the sheep. Total counts, sex, and age class were recorded. Individual sheep were watched for periods of 30 minutes and their energy budget and behaviour was

recorded. The study was supplemented by a study that collected Gwich'in TK from elders and active land users from open-ended, individual interviews.

In addition to these ground-based surveys, satellite telemetry and biological sampling were conducted. Six Dall's sheep ewes were netted and fitted with GPS satellite collars and their positions typically collected six times per day (12 times per day during lambing season). Hair samples were taken during capture for future analysis (Lambert-Koizumi 2007).

Ground-Based Surveys - Health

Richardson Mountains Dall's Sheep Productivity and Lungworm Infection Survey

Nagy 2002

Appendix V

http://www.grrb.nt.ca/pdf/wildlife/dallssheep/Dalls_sheep_RWEDsurveys.pdf

ENR drafted plans to conduct a Productivity and Lungworm Infection Survey on Dall's sheep in the Richardson Mountains. The report describes that a field crew was stationed in areas of known sheep locations and fresh fecal samples were collected. The fecal samples were to be studied to determine the distribution, prevalence, and intensity of lungworm and muscle worm infections in each survey block. Samples were to be stored on ice in the field and then frozen in the lab (Nagy 2002).

New Host and Geographic Records for Two *Protostrongylids* in Dall's Sheep

Kutz *et al.* 2001

Appendix V

<http://www.jwildlifedis.org/cgi/reprint/37/4/761.pdf>

In order to assess the distribution of the *Protostrongylidae* parasite in Dall's sheep in the NWT, a study was conducted that included the analysis of fecal samples and six dead adult sheep. For the purpose of the study, six adult Mackenzie Mountain Dall's sheep ewes were killed. Four sheep lungs from hunter-killed animals were also examined for pulmonary nematodes. The detailed protocols described for the examination of these animals includes the following procedures:

- the bodies were skinned and eviscerated within 3 hours of death, chilled with wet cloths and examined within 48 hours of death for pulmonary nematodes;
- individual muscles were cut into fine slices and abnormalities were sliced into finer sections and examined under a dissecting microscope;
- lung tissue samples were removed and preserved in formalin;
- lungs were flushed with water and the wash microscopically examined;
- intact, adult nematodes were preserved in an ethanol / glycerin solution and compared to other Dall's sheep parasites; and

- rectal feces from the ewes were examined by beaker Baermann technique. Isolated larvae were heat fixed onto a glass slide and preserved in an ethanol / glycerin solution.

Satellite Telemetry

The Northern Richardson Mountains Dall's Sheep Ecology Project

Auriat and Nagy 2005

Appendix V

http://www.grrb.nt.ca/pdf/wildlife/dallssheep/N.Rich_sheep-eco.pdf

One habitat ecology project studied the movements, distribution and seasonal habitat use of sheep in the Black Mountain area of the northern Richardson Mountains (Auriat and Nagy 2005). In this study, eight rams were fitted with GPS collars to examine seasonal ranges, movement rates, and corridors. The collars collected three locations per day and these locations were sent to researchers every other day. Twenty-one randomly chosen locations were visited by researchers to record habitat data such as slope, aspect, vegetation, snow depth, snow density, distance from escape terrain, and distance from licks. During the collaring process, blood samples were collected for cell blood counts and parasite and trace mineral analysis. Additionally, fecal samples were collected to be analyzed for parasites and diet content. Researchers recorded individual measurements of the following parameters:

- age;
- chest girth;
- shoulder height;
- overall height; and
- horn length.

3.5.5 Mountain Goat

Mountain goats have not been well studied in the NWT, with limited aerial surveys conducted to monitor the animals. The goats are not considered important animals for subsistence hunting, and monitoring data may rely on the submission of voluntary information from hunters and guides (e.g., for inclusion in the GNWT's Mackenzie Mountain Harvest Study reports; Larter 2004). In the NWT they are considered a species that 'may be at risk' (ENR 2007a) but they are not listed under COSEWIC (2007) or SARA (2006).

This section presents selected available information for monitoring mountain goats according to the information source.

Mountain Goat Survey Flat River area, Western Mackenzie Mountains

Larter 2004

Appendix V

<http://www.nwtwildlife.com/Publications/ManuscriptReports/pdf/157.pdf>

Larter's 2004 survey of mountain goats used a helicopter to fly through alpine valleys targeting peaks, ridgelines, cliff faces, and cirque basins in the Flat River area near the Yukon - NWT border (Larter 2004). The flight path was tracked on a GPS unit and locations of animals were observed with binoculars and their positions marked. The project plan called for photographs to be taken of large groups of animals for subsequent identification of sex and age. Collected data was entered into an Excel spreadsheet.

Mine Impacts and Effects on Wildlife

City and Bureau of Juneau 1999

Appendix V

<http://www.juneau.lib.ak.us/cdd/Kensington/wildlife.htm>

A plan was developed to monitor the effects of the Kensington Mine operations (near Juneau, Alaska) on a range of animals including mountain goats (City and Bureau of Juneau [CBJ] 1999). The monitoring plan consists of protocols for observing the population from aerial surveys. The first two or three years of aerial surveys established benchmark population levels and then future surveys were to be compared to these initial levels. A population drop of 50% or greater was defined as 'significant' and will trigger a halt to operations and closer examination of the mountain goat populations.

Monitoring the Effectiveness of Mountain Goat Habitat Management

Wilson 2005

Appendix V

http://www.for.gov.bc.ca/hfp/frep/site_files/values/Wildlife_Mountain_Goat_Habitat_Mgmt-2005.pdf

The BC Ministry of Water, Land, and Air Protection has established monitoring protocols for mountain goat habitat (Wilson 2005). These involve identifying limiting habitat and habitat attributes required to fulfill critical life requisites of mountain goats, identifying threats to mountain goat habitat and populations, and developing indicators that address the following:

- different levels of monitoring intensity;
- desired outcomes or results (in relation to a stated management goal); and
- required frequency of measurement.

Wilson (2005) identifies a systematic aerial inventory as the best way to identify mountain goat habitat since researchers may record detailed topographic and vegetative characteristics in addition to mountain goat presence. If resources are not available, a less desirable method is to identify "potential" habitat based on a topographic and forest cover model (Wilson 2005).

For population inventories, Wilson (2005) advocates total count survey by helicopter. Sightability corrections for mountain goats were not developed. Because it is unknown what proportion of the population is found in atypical terrain and / or below tree line, it

is not possible to calculate absolute abundance. Changes in sex and age ratios and changes in relative abundance can be used to arrive at an index of population status. Additionally, total harvest, hunter effort, and sex ratio of the harvest can be used to index trends in mountain goat populations.

Aerial-Based Inventory Methods for Selected Ungulates

Resources Inventory Committee 2002

Aerial-Based Inventory Methods

Appendix V

<http://www.ilmb.gov.bc.ca/risc/pubs/tebiodiv/ungulatesv2/unga%20ml20%20final.pdf>

Wilson (2005) cites the Resource Inventory Committee (RIC) of the BC Ministry of Sustainable Resource Management's *Aerial-based Inventory Methods for Selected Ungulates* as being the standard reference for mountain goat inventory in BC.. This study lists protocols for every step of the inventory process for mountain goats (RIC 2002). It lists total aerial counts as being the most common survey method for mountain goats. It recommends that the total count method be used within stratified land units and that mark / resight methods be employed to correct survey results for missed animals. The study advises that late August to mid-September is thought to be the best time for surveys in the northern interior of BC.

3.5.6 Wolverine

COSEWIC lists the western population (part of which occupies the NWT) as a species of 'special concern' (COSEWIC 2007); SARA does not list this species (SARA 2006). Development activities in the NWT continue to be a concern for potential impacts on wolverine populations. Because of these threats and low reproductive rates they are ranked as 'sensitive' in the NWT (ENR 2007a).

This section is organized according to the territory or province for which monitoring protocols are described.

Northwest Territories

Wildlife Effects Monitoring Plans

Golder Associates (D. Panayi, pers. comm. February 2008)

Appendix V

At Barrenland Mines, NWT and Nunavut

Ongoing studies are conducted for wolverines in the NWT (e.g., Snap Lake Diamond Project) and Nunavut (e.g., Doris North Gold Mine) to determine the effects that mining activities may have on their survival and reproduction. Golder has designed protocols for monitoring wolverine activities around mine sites (D. Panayi, Golder, pers. comm. February 2008). These include detailed methodologies for conducting snow-track surveys along transects and hair snagging on wire. In summary, to study direct and indirect effects on wolverine populations, the protocols are:

- to define the study area;

- to conduct an annual study between late March and April;
- to define the transects; and
- to record incidents of wolverine tracks along the transect lines.

A study designed and conducted by Golder Associates at one mine site in Nunavut used hair snagging and snow-track counts to monitor wolverine (D. Panayi, Golder, pers. comm. February 2008). Snow track counts are intended to be collected annually from 50 transects, each 4 km in length. Transects were randomly placed in areas of favourable habitat. Transects were run by two researchers on snowmobiles, approximately 20 m apart. Track density was calculated by number of tracks per survey distance in km per day since the last wind or snowfall event because these factors influence the tracks' visibility.

Hair snagging was achieved by placing 98 wood posts in the snow, wrapped with barbed-wire and with a commercial carnivore lure and bait of meat on the top of the post. These posts were used for two 10-day sessions. Hair snagged on the wire was removed and post identification, date, and location recorded for each hair sample (D. Panayi, Golder, pers. comm. February 2008).

At a different mine in Nunavut, wolverine were identified as a VC and studies were designed to monitor them (D. Panayi, Golder, pers. comm. February 2008). Snow tracking was used to determine probable wolverine density. Surveys were conducted along 38 transects in 2005 and 41 transects in 2006. Track counts were weighted by the number of days since the last wind or snowfall event.

Wolverine Ecology, Distribution, and Productivity in the Slave Geological Province

Mulders 2000

Appendix V

For the West Kitikmeot Study Society

A general study of wolverine was conducted in the area around the Coronation Gulf in the central arctic, in an area that straddles the NWT and Nunavut (Mulders 2000). The study describes methods used to attempt to measure wolverine range sizes and to estimate annual wolverine productivity.

In this study, wolverines were captured in the fall (November and December) or in spring (March and April) using baited barrel traps (Mulders 2000). Barrels were set for 5-7 day periods within the study area and checked daily. Bait included fish, beef, and caribou scrap and commercial animal lures. Captured animals were immobilized with Telazol or Zotelil via a short range dart gun. Cuts and lesions were treated with antibiotics and penicillin. Wolverine were sexed, aged, weighed, measured, and assessed for tooth wear and physical condition. Hair follicle samples were taken from each captured animal and stored for future genetic analysis. Wolverines were fitted with an aluminum ear tag with the animal's sex and an individual identifying number. Animals were fitted with VHF radio transmitter collars. Captured animals were released into a constructed safe shelter.

To capture home range data, aerial radio telemetry flights from a small fixed-wing aircraft were flown at 2 to 4 week intervals throughout the study period to obtain relocation data from the VHF collars (Mulders 2000). Locations separated by a 24-hour period were used in conjunction with spatial analysis software to calculate estimates of home range size.

To find natal den sites, researchers examined telemetry data between February and May and concentrated efforts on likely denning females (Mulders 2000). During collaring sessions, researchers noted lactating individuals. Visual confirmation of young or tracks of young at suspected site between April and June was necessary.

Researchers solicited wolverine carcasses from hunters in nearby communities and offered \$25 per carcass as compensation (Mulders 2000). Body measurements and age (from tooth analysis) were taken from the carcass. Litter size was obtained from in utero examination of the carcasses. Feeding habits were determined from stomach contents.

Alberta

Alberta Wolverine Experimental Monitoring Project

Fisher 2005

Appendix V

Alberta Research Council

<http://www.wolverinefoundation.org/research/Alberta2005.pdf>

A wolverine monitoring station study was conducted in Alberta with procedures similar to those used by Mowat *et al.* in 2003 (Fisher 2005). Sixty monitoring stations were set up with hair traps for non-invasive genetic tagging. Previous studies had shown that hair trapping studies underestimate animal abundance, so 11 stations were fitted with remote cameras to determine an appropriate correctional factor to apply to the other 49 stations' results.

Testing Methods for Detecting Wolverine

Mowat *et al.* 2003

Appendix V

Alberta Department of Sustainable Development

http://www.srd.gov.ab.ca/fishwildlife/speciesatrisk/pdf/SAR_71.pdf

Mowat *et al.* collected wolverine hair samples from baited traps for genetic analysis (Mowat *et al.* 2003). Detections were too few for conclusive results, but the best results were achieved by a baited barbed wire corral. The protocol followed used a 3 m to 5 m diameter barbed wire enclosure strung around an impenetrable, hung baited box. Wolverines entering the area snagged their hair on the barbed wire and researchers collected it for genetic analysis.

British Columbia

Wolverine Ecology and Habitat Use in the northern Columbia Mountains

Krebs and Lewis 1999

Appendix V

<http://www.llbc.leg.bc.ca/Public/Pubdocs/bcdocs/356278/wolverine99.pdf>

In BC, Krebs and Lewis used live trapping to conduct wolverine studies (1999). Forty traps of different types were distributed throughout a 4,000 km² core of the 7,000 km² study area, stratified according to dominant vegetation. Wolverine caught in the traps were immobilized with Telazol at 10mg/kg with a jabstick, ear-tagged with numbered tags, weighed, sexed, and examined for reproductive status. The upper left premolar was removed for laboratory aging analysis. The wolverines were then radio-collared with a collar designed to fall off after approximately two years of service. Reproduction was recorded by telemetry flights targeting denning females from March to June to visually identify kits. Mortality was examined through mortality sensors built into the radio collars. Only in cases where the carcass was recovered was mortality recorded. Distribution and habitat use were studied through biweekly flying of a fixed-wing aircraft from mid-February to late April. When an animal was found, researchers recorded Universal Transverse Mercator (UTM) co-ordinates (North American Datum [NAD] 27), Forest Cover Polygon Label (i.e., species, age, height, crown closure), habitat type (from seven categories), biogeoclimatic subzone, elevation, aspect, slope and activity of the animal. Total population was estimated using mark-recapture data (Kreb and Lewis 1999).

Inventory Methods for Medium-Sized Territorial Carnivores: Coyote, Red Fox, Lynx, Bobcat, Wolverine, Fisher & Badger

BC Ministry of Lands, Parks, and Resources Inventory Branch 1999
Appendix V

<http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/medcarn/assets/mstc.pdf>

Species Inventory Fundamentals

BC Ministry of Lands, Parks, and Resources Inventory Branch 1998
Appendix V

<http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/sif/assets/spifml20.pdf>

BC's Ministry of Lands, Parks, and Resources Inventory Branch (BC MLPRIB) has published general standards for species inventories (BC MLPRIB 1998). According to these guidelines, species inventories have three main objectives:

- to obtain baseline data on the abundance and distribution of species;
- to monitor changes in abundance, composition, and / or distribution; and
- to measure the direction and extent of these changes.

Possible survey methods used to achieve these three goals include total counts, sample counts, and mark-recapture / re-sight studies. The Ministry also has specific guidelines for inventorying medium-sized carnivores, including wolverine (BC MLPRIB 1999). These protocols include suggestions on standardized personnel training, study timing, and habitat stratification and offer detailed points on consulting harvest and hunter records, making public appeals, and inventory survey methods. The guidelines recommend snow tracking at very large bait stations coupled with hair snares and cameras.

Studies looking to establish the presence of wolverine should concentrate search efforts only in high quality habitat. Studies using bait stations should use unattainable bait with commercial lures to produce a scent strong enough to attract wolverine. Two to three large bait stations should be set up per 100 km². Stations should be left for a maximum of 30 days and checked every 2-3 days. Remote cameras should be used in conjunction with bait stations. If hair collection is necessary, it should not be done during the shedding season as the hair follicles necessary for DNA analysis are likely to be lost. Using scat to attempt to identify animals is described as an unreliable technique (BC MLPRIB 1999).

Canada and International

National Recovery Plan for the Wolverine (*Gulo gulo*) (Eastern Population)

Fortin *et al.* 2005

<http://dsp-psd.pwgsc.gc.ca/Collection/CW69-11-26-2004E.pdf>

Although there does not appear to be a universally accepted method for estimating wolverine population, Fortin *et al.*'s (2005) national recovery plan for the eastern population of wolverine recommended an Alaskan-developed technique of estimating numbers based on snow track counts along parallel transects by plane or helicopter. This survey type was used on wolverine in Ontario in 2001; however, it is expensive and its accuracy has not been established (Fortin *et al.* 2005).

Aerial Surveys for Wolverine in the Southwestern Yellowstone Ecosystem

Heinemeyer *et al.* 2001

Appendix V

http://gis.ucsc.edu/Projects/gulo2000/report2000_final.pdf

Within the Yellowstone ecosystem (i.e., portions of Idaho, Wyoming and Montana), researchers worked to develop an alternative surveying technique for monitoring wolverine populations in the area. The protocol involved the use of spatially-explicit Geographic Information System (GIS) models to determine potential wolverine habitats and then low-altitude aerial surveys were conducted based on those maps to observe tracks and other wolverine signs (Heinemeyer *et al.* 2001). A helicopter was used between mid-February and mid-April to fly the track transects. During this flight, spotted signs were photographed and the GPS co-ordinates were captured.

3.6 Marine Mammals

3.6.1 Introduction to Marine Mammals

Marine mammals that are considered VCs by the NWT CIMP Working Group include polar bears, beluga whales and bowhead whales. Protocols that have been used for monitoring these animals in the Beaufort Sea, adjacent Chukchi Sea, and western Hudson Bay are described below. Further study details are provided in Appendix VI (Table VI-1).

Note: See Section 4, Moose, for a description of the wildlife ranking systems used in Canada and the NWT.

According to ENR, the polar bear is considered 'sensitive', the beluga whale is considered 'secure' and the bowhead whale is considered 'sensitive' (ENR 2007).

Under SARA's classification system, the polar bear is considered 'special concern,' the beluga is 'not at risk', and the bowhead is 'special concern' (SARA 2006).

According to COSEWIC, the polar bear is considered 'special concern', the beluga (Eastern Beaufort Sea population) is considered 'not at risk', and the bowhead (Bering-Chukchi-Beaufort population) is of 'special concern' (COSEWIC 2007).

This section is organized so that research protocol subjects are described under the individual marine mammal being described, but information on parasitology studies for marine mammals in general is presented first.

Marine Mammal Parasites

Protocols for Marine Parasitology

Burt and Mackinnon 2001

Appendix VI

<http://www.eman->

[rese.ca/eman/ecotools/protocols/marine/parasites/parasites_marine_e.pdf](http://www.eman-rese.ca/eman/ecotools/protocols/marine/parasites/parasites_marine_e.pdf)

Standardized protocols for examining marine parasites on various hosts including marine mammals have been developed for EMAN (Burt and MacKinnon 2001). The protocol calls for only one marine mammal to be examined at a time because of their large sizes and the detail of examination required. Details are provided for mammalian specimen preparation, sampling and analysis. Detailed protocols are also provided for the preparation of the parasite specimens including how to fix different types of samples (e.g., blood smears, tissues) and treatment procedures for various parasites.

3.6.2 Polar Bear

Polar Bear Management Agreement (NWT and Alaska)

Polar Bear Management Agreement, Southern Beaufort Sea

Brower *et al.* 2002

Appendix VI

<http://pubs.aina.ucalgary.ca/arctic/Arctic55-4-362.pdf>

Polar bears historically have been harvested by hunters from the NWT, Canada and Alaska, US. The two countries have independently managed the harvest for their bear populations. In the NWT polar bear harvest numbers began to be restricted in the late 1960s; in the mid 1970s the types of bears harvested (e.g., denning bears) as well as the harvest season became restricted. In Alaska subsistence harvesting was unregulated. In 1988 the two countries, represented by the Inuvialuit Game Council (IGC) in the NWT and the North Slope Bureau (NSB) in Alaska came together to sign the *Polar Bear Management Agreement* for the Southern Beaufort Sea (Brower *et al.* 2002). This Agreement placed restrictions on the type and timing of polar bear harvests for the two countries' populations.

Brower *et al.* (2002) investigated how the Agreement had affected hunting in the region by comparing harvest data from both countries collected both prior to (i.e., for 8 years) and after (i.e., for its first 10 years) the implementation of the Agreement. Protocols described included how to assess harvest parameters such as:

- harvest size;
- number of females harvested;
- proportion of dependent (COY and yearling cubs) bears harvested; and
- accuracy of harvest-monitoring data.

Methodologies and protocols are provided for collecting the harvest data including how to age and sex bears from teeth and baculum. The study concluded that the Agreement has been an overall success, with harvest numbers maintained within sustainable limits across the southern Beaufort Sea (Brower *et al.* 2002).

Monitoring Persistent Organic Pollutants

Immune Response and Chlorinated Environmental Pollutants

Derocher *et al.* 2000

Appendix VI

http://www.npolar.no/transeff/Effects/Polar_Bear/Progress/4189%20NP%20-%20sluttrapport%20-%20faglig.doc

Scientists from both Norway and Canada collaborated on a study in the late 1990s to understand how persistent organic pollutants (POPs) can affect polar bear immune systems, particularly poly-chlorinated biphenyls (PCBs) and their relationship with

polar bear immune globulin levels, antibody production to various vaccines and lymphocyte proliferation. The Canadian component of the study was carried out in the Hudson Bay on 30 male polar bears with low PCB levels compared with bears from Svalbard with higher levels of exposure (Derocher *et al.* 2000). During the project the bears were immunized with microbial antigens to induce antibody production and immune responses and were recaptured 5-6 weeks later. The project also involved lymphocyte stimulation with mitogens and antigens and the *in vitro* exposure of lymphocytes to congeners. Haematology, hormone analysis and immune globulin and antibodies measurements were also conducted.

Protocols were developed during the study for the assessment of white blood cell activities while in the field, with implications for understanding polar bear cell biology, physiology and immunology. Protocols are provided for measuring cell-mediated immunity to microbes and assessing the relationship between lymphocyte function and environmental pollutants, infections, nutritional factors, starvation and stress. Detailed protocols are given for sampling methodologies, organochlorine (OC) analysis, the assessment of immunological parameters as well as hormonal parameters and strategies for understanding study results, including *in vitro* exposure to PCBs (Derocher *et al.* 2000). Specifically, the study provides protocols and methodologies for investigating the relationships between:

- PCB exposure and lymphocyte proliferation;
- *in vitro* PCB congener exposure of lymphocytes;
- PCB exposure and immune globulin levels;
- PCB exposure and antibody production relationship;
- PCB exposure and infection resistance;
- PCBs and reproductive hormones, thyroid hormones and retinol;
and
- PCBs and the immune system / hormone homeostasis.

The study also recommends developing methods and biomarkers that would assist in monitoring how polar bears are affected by toxic chemicals.

Mark-Recapture

Mark-Recapture of Polar bears in the Beaufort Sea

Amstrup *et al.* 2001

Appendix VI

http://www.west-inc.com/reports/big_game/Amstrup%20et%20al%202001.pdf

Polar bears have been captured since the 1960s to better understand how humans have been affecting polar bear populations in the southern Beaufort Sea. However, because the capture probability for individual bears is considered highly variable and heterogeneity in survival probabilities is suspected, population estimates have not been reliable over time. Amstrup *et al.* (2001) combine information gathered through actual captures and archived capture data since the early 1970s in their study. Brief

polar bear capture protocols for drug immobilization, age determination, marking, radio transmitter fitting and tracking are provided.

Aerial Survey

Polar bear aerial survey in the Eastern Chukchi Sea

Evans *et al.* 2003

Appendix VI

<http://pubs.aina.ucalgary.ca/arctic/Arctic56-4-359.pdf>

In August 2000, a line-transect survey was conducted in the eastern Chukchi Sea and western Beaufort Sea (northern Alaska) from helicopters. The pilot study aimed to estimate polar bear density in the area and assess whether ship-based aerial surveys were an appropriate method for determining population estimates. The protocol called to estimate bear density by modeling encounter rates and sightability of polar bear groups as a function of distance from certain sighting lines. It was concluded that additional surveys in late fall would be needed to effectively monitor population trends of polar bears in the study area.

Satellite Telemetry (Norwegian and Western Russian)

Using Satellite Telemetry to Define Spatial Population Structure in Polar Bears in the Norwegian and western Russian Arctic

Mauritzen *et al.* 2002

Appendix VI

http://www.biology.ualberta.ca/faculty/andrew_derocher/uploads/abstracts/Mauritzen_et_al_2002.pdf

Similar to the situation between the southern Beaufort Sea polar bear population, whose management is shared between Alaska and Canada, it has been determined that polar bears across the Norwegian and the western Russian Arctic are also one population requiring shared management between the countries. In order to assess the spatial population structure, satellite telemetry data was analyzed for a 12-year period for 105 female bears. Cluster analyses and home-range estimation methods helped distinguish different population units relative to sea-ice and prey characteristics (Mauritzen *et al.* 2002).

The study aimed to explain how spatial population structures of polar bears can help evaluate polar bear ecology, bear-seal interactions and the effects of climate change on bear habitat. Protocols discussed in the study's report include study area delineation, a brief description of the darting drug used and what animals were collared (i.e., all females), details on how telemetry data was gathered (i.e., at what frequency and duration), and spatial population structure analysis (Mauritzen *et al.* 2002).

3.6.3 Beluga and Bowhead Whales

Monitoring protocol for Marine Mammals in Canadian Waters

Gaskin 2001

Appendix VI

http://www.eman-rese.ca/eman/ecotools/protocols/marine/mammals/mammals_marine_e.pdf

The EMAN protocols for monitoring marine mammals in Canada are very detailed and provide an excellent reference for different monitoring strategies starting with basic protocols. Detailed protocols are provided for monitoring whales from land sites, boats and air as well as through acoustic surveys. The problems associated with different monitoring strategies for marine mammals are also provided. Examples of the details presented in the EMAN protocols include information on equipment lists, observation periods (i.e., duration), data requirements, record conversions, surveying vessels and observation methodologies (Gaskin 2001).

Elements in Bowhead and Beluga Whales of Arctic Alaska

Woshner *et al.* 2001

Appendix VI

<http://www.jwildlifedis.org/cgi/reprint/37/4/693?maxtoshow=&HITS=10&hits=10&RESU LTFORMAT=&fulltext=woshner+2001&andorexactfulltext=and&searchid=1&FIRSTINDE X=0&sortspec=relevance&resourcetype=HWCIT>

Beluga and bowhead whale tissue samples collected between 1983 and 1997 from Arctic Alaska and north-western Canada were evaluated to determine the concentrations of 12 essential and non-essential elements (arsenic, cadmium, cobalt, copper, lead, magnesium, manganese, mercury, molybdenum, selenium, silver and zinc). Concentrations of these elements were evaluated in terms of comparisons to previously reported levels. Concentrations were also compared between whales of different ages, tissue types, gender and species. Elemental interactions and 'normal ranges' of essential elements were also examined and the implications of biomagnification for whales and human subsistence hunters were considered. Protocols are provided for conducting metal analysis in whale tissues (including details on mercury analysis), statistical analyses of element concentrations, and the interpretation of results for each whale species (Woshner *et al.* 2001).

3.6.4 Beluga Whale

Aerial Survey

An Estimate of the Western Hudson Bay Beluga Population Size in 2004

Richard 2005

http://www.dfo-mpo.gc.ca/csas/Csas/DocREC/2005/RES2005_017_e.pdf

A research document series investigates the fisheries resources in Canada and provides progress reports on research being conducted. One study in the western Hudson Bay estimated its beluga population in 2004 by using a combination of aerial visual line-transect surveys and photographic surveys. Although not a definitive reference on such surveys, the document provides protocols for required equipment, crews, visual observation procedures, survey design and timing, survey photography, and methods for line transect estimations, adjusting for missing distances, photo strip transect estimations, availability bias estimation and adjustment and regional population estimation (Richards 2005).

Harvested Whale Survey

The Harvest of Beluga Whales in Canada's Western Arctic

Harwood *et al.* 2002

Appendix VI

<http://pubs.aina.ucalgary.ca/arctic/Arctic55-1-10.pdf>

In the Mackenzie Delta and Paulatuk, NWT, beluga whales have been monitored by subsistence hunters since the 1970's and 1980's, respectively. The hunters collect data on the number and timing of whales harvested and hunting efficiency (i.e., number of whales struck, landed and lost). Since 1980 the length and sex of the whales have been recorded and biological sampling conducted as well. In 1980 more extensive protocols were developed for beluga monitoring which involve measuring fluke and flipper widths, collecting lower mandibles, tooth examination and conducting interviews with hunters. Details on these protocols and many other aspects of hunter-based beluga monitoring in the NWT, including data analysis and the relevance of derived information gathered from these sustainable beluga hunts, are provided in the Harwood *et al.* (2002) report.

Satellite Telemetry

Satellite Tracking of Eastern Chukchi Sea Beluga Whales

Suydam *et al.* 2001

Appendix VI

<http://pubs.aina.ucalgary.ca/arctic/Arctic54-3-237.pdf>

A study investigating beluga whales in the Chukchi Sea used live-capture and satellite-linked depth recorders to track the travels of five male belugas in 1998. It was discovered that the animals moved from Kasegaluk Lagoon (eastern Chukchi) to and from areas of the Beaufort Sea and Mackenzie Delta, including distances of over 2000 km in just over 100 days. The study's report provides detailed protocols for the live-capture and tagging of the belugas in Kasegaluk Lagoon as well as how to analyze the data from the satellite-tagged whales. GIS programs also allowed for the comparison of sea ice coverage with average daily whale movement in the study area (Suydam *et al.* 2001).

3.6.5 Bowhead Whale

Monitoring of Organochlorine Levels

Organochlorine Contaminant Levels in Eskimo Harvested Bowhead Whales

O'Hara *et al.* 1999

Appendix VI

<http://www.jwildlifedis.org/cgi/reprint/35/4/741?maxtoshow=&HITS=10&hits=10&RESU LTFORMAT=&fulltext=ORGANOCHLORINE+CONTAMINANT+LEVELS+IN+ESKIMO +HARVESTED+BOWHEAD+WHALES&andorexactfulltext=and&searchid=1&FIRSTIN DEX=0&sortspec=relevance&resourcetype=HWCIT>

A study was conducted to determine the organochlorine (OC) levels of 20 bowhead whales taken during a subsistence harvest at Barrow, Alaska in 1992 and 1993. These whales represent the Bering-Chukchi-Beaufort Sea population of bowheads. Documentation included whale identification, gender and length, and tissue sampling included blubber and liver specimens. A slight modification to standardized protocols was followed for analyses of blubber and liver samples to determine OC levels and percent lipids. These are explained as well as OC levels in bowheads relative to 'safe' human consumption levels (O'Hara *et al.* 1999).

3.7 Avian Wildlife

3.7.1 Introduction to Avian Wildlife

Birds across the NWT are monitored in a variety of ways. Most migratory species cannot be monitored by NWT agencies alone but are studied by organizations and agencies across Canada, across North America and beyond, depending on the species.

This section is organized so that monitoring protocols applicable for birds in general are described first. Many surveying methods are applicable for a range of bird species and categories (e.g., can be used for waterfowl and songbirds). Those protocols that have been developed for or in the NWT specifically are presented first, followed by protocols applied in Canada, then North America and finally beyond North America. The final sub-sections present monitoring protocols for specific categories of birds that may be monitored in the NWT (e.g., raptors as a group). Descriptions are provided for known and available reports. Appendix VII (Table VII-1) provides detailed summaries of many monitoring protocols. Table VII-2 lists additional avian wildlife research studies where generalized methodologies or protocols are known, and their general information sources. Table VII-3 lists additional research where the protocols are not known but general references (e.g., author's names) are provided for further interest. Several complete documents that describe avian wildlife monitoring policies complete the appendix.

In many instances, TK studies are carried out parallel to the monitoring studies described below. They are not specifically addressed in this report but are important contributors to baseline knowledge gathered for the NWT. Various monitoring agencies (e.g., Arctic Borderlands) and local groups (e.g., social and cultural institutes, renewable resource boards) may hold valuable TK information that can complement other research conducted in the NWT and northern Canada.

Northwest Territories

Over 90% of the NWT's bird species are migratory, and use the territory's variable landscape as breeding, moulting and staging habitats (Johnston 2007). The monitoring of the NWT's birds is described generally below but additional specific studies are presented in Tables VII-1 and VII-2 (Appendix VII). Commonly used bird monitoring protocols employed in the NWT include aerial surveys, annual counts and the checklist survey.

Northwest Territories / Nunavut Bird Checklist Survey

Environment Canada 2006

Appendix VII

<http://www.mb.ec.gc.ca/nature/migratorybirds/nwtbcs/dc20s03.en.html>

<http://www.mb.ec.gc.ca/nature/migratorybirds/nwtbcs/Form8x11Apr04.pdf>

The *Northwest Territories / Nunavut Bird Checklist Survey* has been an important method for assessing the distributions and abundances of birds over large expanses of land since 1995 (EC 2006). This method of data collection may not be considered very precise because it counts on untrained observers and observing sessions that are not standardized from year to year, making comparisons between month and day of questionable scientific value. However, it provides valuable information in distribution shifts and range expansions for the *NWT Species Monitoring Infobase* (ENR 2007; Working Group on General Status of NWT Species [NWT Species Working Group] 2006).

Copies of a checklist of birds thought to occur in the NWT are printed and made publicly available by the CWS. These lists act as reference guides for identification of local birds. Volunteers, who collect the forms, mark the number and species of birds seen as well as any evidence of breeding behaviour. Collected information is divided into above and below tree line locations. Dates and times of the sightings are recorded and name and contact information are collected on each form providing some degree of accountability for information collected. Data is grouped into four categories:

- geographic coordinates;
- individual species;
- species groups; and
- national parks or territory.

A sample survey form is provided in Appendix VII. The collected data is publicly accessible at the Species Access Canada website (Species Access Canada 2003) where information and results can be searched for the NWT or Canada at:

http://www.cbif.gc.ca/portal/digir-class.php?p_classid=2&p_lang=en.

Space for geographical information and information to help determine the reliability of the data is also provided, such as weather conditions at the time of sighting and a self evaluation of the volunteer's bird recognition skills.

General Status Ranks of Wild Species in the Northwest Territories

Department of Environment and Natural Resources 2007

http://www.nwtwildlife.com/enr_infobase/asp/search.asp

Working Group on General Status of NWT Species 2006

Appendix VII

<http://www.nwtwildlife.com/monitoring/NWTSpecies.pdf>

In 1999, the GNWT (as part of a federal initiative across Canada) initiated the *NWT General Status Ranking Program* in an effort to collect and build on existing wildlife knowledge in the NWT. Its objectives are to monitor the status of species over time and to facilitate the development of conservation strategies for species of concern. Its protocols are similar to those used in comparable programs across Canada's other territories and provinces. Every five years a report is produced on the *General Status Ranks of Wild Species in the Northwest Territories*. In the most recent report for 2006-2010, over 270 bird species were assessed (NWT Species Working Group 2006). The

report describes protocols for how it developed a ranking system for the wild species, and it is a valuable reference for monitoring activities taking place across the NWT, including references to monitoring agencies for reporting different wild species concerns or observations (e.g., wildlife diseases, plant observations).

The *NWT Species Monitoring Infobase* (the Infobase) is an on-line searchable database that provides the most current information and status ranks gathered for the NWT's assessed wildlife species, including birds. The Infobase can be searched at the above link (ENR 2007).

Canada

Different protocols are applied for different monitoring activities but consistency across the country allows for easier comparison of study results between the territories and provinces. The following section identifies individual protocols that are followed for monitoring avian wildlife across the country.

Population Status of Migratory Game Birds in Canada

Canadian Wildlife Service Waterfowl Committee 2007

Appendix VII

http://www.cws-scf.ec.gc.ca/publications/status/nov07/nov07_e.pdf

A 2007 CWS Waterfowl Committee report (2007) describes the status of Canada's migratory game bird populations. It briefly describes monitoring agencies and the population status for various bird groups and species being monitored, as well as protocols for regulating overabundant species (e.g., through using electric calls and bait for harvesting purposes).

General Migratory Birds

Canadian Wildlife Service 2006

Appendix VII

<http://www.cws-scf.ec.gc.ca/mbc-com/default.asp?lang=En&n=CF4732B8-1>

The CWS Migratory Birds Conservation Division plays an important role in organizing information on Canada's migratory birds (CWS 2006). Additional monitoring information can be found through the above website's links, particularly under the Monitoring and Reporting section.

Additional Canadian monitoring references through CWS include the following:

- The environmental assessment guideline for forest habitat of migratory birds is available at:
http://www.cws-scf.ec.gc.ca/publications/eval/forest/index_e.cfm.
- The migratory birds environmental assessment guideline is available at:
http://www.cws-scf.ec.gc.ca/publications/eval/mig/index_e.cfm.
- The wetlands environmental assessment guideline is available at:

http://www.cws-scf.ec.gc.ca/publications/eval/wetl/index_e.cfm.

National Harvest Survey

Canadian Wildlife Service 2005a

<http://www.cws-scf.ec.gc.ca/nwrc-cnrf/default.asp?lang=en&n=CFB6F561>

The *National Harvest Survey* aims to gather information on migratory game birds including harvest estimates and the age and sex of harvested species. Hunting permit holders from zones across the country (including the NWT) participate in the survey (CWS 2005a). Information on this and other related survey efforts are described at the above website.

Parasites of Birds

McLaughlin 2001

Appendix VII

[http://www.eman-](http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/parasites_of_birds/intro.html)

[rese.ca/eman/ecotools/protocols/terrestrial/parasites_of_birds/intro.html](http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/parasites_of_birds/intro.html)

A report produced by McLaughlin (2001) that was produced for EMAN provides detailed descriptions on protocols used to collect and process endoparasites, ectoparasites and blood parasites in avian hosts. In addition to explaining methodologies for sampling procedures such as field and laboratory work, the report also explains permitting needs, quality controls and database management.

North America

Due to the international interests surrounding migratory birds, there is a substantial amount of co-operation between avian research groups in Canada and the US. These are described below.

North America Breeding Bird Survey

Canadian Wildlife Service 2007a

Appendix VII

<http://www.cws-scf.ec.gc.ca/nwrc-cnrf/default.asp?lang=en&n=5EE0ADBA>

The North American Breeding Bird Surveys are conducted by volunteers, overseen by the CWS throughout Canada including places in the NWT (CWS 2007a). It is used to collect information on breeding birds. The CWS site (2007a) provides extensive protocols for conducting breeding bird surveys.

Information is provided on a variety of parameters related to:

- collection information including requirements;
- sky condition codes;
- scouting, route problems;
- when to run routes;
- record keeping;

- starting;
- scannable field sheets;
- stop locations;
- coversheets;
- counting birds;
- reporting results;
- which birds to count;
- internet data submission;
- counting vehicles;
- deadlines;
- excessive noise;
- processing of results;
- acceptable weather;
- wind speed codes; and
- equipment checklist.

General Protocols

Birds in Forested Landscapes 2007

Appendix VII

<http://www.birds.cornell.edu/bfl/surveyinstr2.html>

Since 1997, Birds in Forested Landscapes (BFL) has acted as a monitoring program in North America designed to assess the habitats and conservation needs of forest bird species. Volunteers, land managers and professionals collaborate on gathering and distributing information following a strategic scientific method. The BFL website offers comprehensive guides for protocols for forest bird studies. The protocols described include instructions for:

- observation periods;
- playbacks and behaviour watching periods;
- choosing species to study and study sites;
- study timing, roles of observers;
- mapping; and
- accounting for negative data and other important considerations.

Bird Banding Ethics

Canadian Wildlife Service 2005b

Appendix VII

<http://www.cws-scf.ec.gc.ca/nwrc-cnrf/default.asp?lang=en&n=943B7A4D>

The US Fish and Wildlife Service (FWS) and the CWS co-operate on banding studies at Willow Lake, Mills Lake, and Stagg River in the NWT. The CWS offers a code of ethics for banding practices to which it adheres for its studies in the NWT and throughout Canada (CWS 2005b). The CWS's Banders' Code of Ethics policies are presented at the above website. Protocols are provided on the website and include describing bird banding, the handling of birds, monitoring bird traps and nets, and general banding ethics.

Bird Banding Procedures

Gustafson *et al.* 1997

<http://www.pwrc.usgs.gov/bbl/manual/manual.htm>

Banding studies are often used to study a diversity of bird species. Banding studies are useful for determining migration routes, migration times, and survival rates (Gustafson *et al.* 1997). Canada and the US worked together to jointly produce the draft *North American Bird Banding Manual*. This manual attempts to standardise banding across the US and Canada. The manual covers material such as permit application processes and information collection codes to signify species, sex, age class, and region codes, but does not offer regulations governing the banding information itself.

Duck banding projects involving the GNWT, CWS and the US FWS aim to monitor changing duck distributions, survival rates and harvest trends. In the NWT, duck banding is carried out at Willow Lake, Mills Lake, the Stagg River and near Inuvik (DIAND 2002).

International

The Great Backyard Bird Count

The Great Backyard Bird Count 2008

Appendix VII

<http://www.birdsource.org/gbbc/>

The Great Backyard Bird Count (GBBC 2008) takes place over four days each year in North America including at several locations in the NWT. It is a user-friendly program designed to incorporate all recorded bird counts from backyard feeders to wildlife refuge areas. In 2007 over 11 million individual birds were counted across the program's span. These counts help monitor bird species and population fluxes over time. The simple protocols for this program are provided on the above website under the "How to Participate" link.

Overwintering Birds

Audubon 2004

Appendix VII

http://www.audubon.org/bird/cbc/pdf/compiler_manual.pdf

The Christmas Bird Counts, instigated in 1900, are overseen by the Audubon Society and are an internationally used method of collecting data on overwintering birds (Audubon 2004). In the NWT, Christmas Bird Counts are conducted in Yellowknife,

Hay River, Norman Wells, Fort Simpson, Fort Smith, and Inuvik (C. Dockrill, CWS, pers. comm. January 2008). As this count takes place in the winter, it does not assess migrating birds. The protocols described include compiler's roles, timelines and deadlines, guidelines for scouting and recording information (e.g., weather, participant effort, unusual species). The results provide data on winter ranges of birds and are complementary to those of the Breeding Bird Surveys described above (CWS 2007a).

3.7.2 Aquatic Birds

Seabirds

Protocols for Monitoring Seabirds

Diamond 2001

Appendix VII

<http://www.eman-rese.ca/eman/ecotools/protocols/marine/seabirds/>

A manual was developed specifically for monitoring seabird colonies in Canada (Diamond 2001). The protocols in this manual include:

- selection of colonies and species;
- study plots;
- colony description;
- weather; and
- breeding phase of the birds.

Shorebirds

Boreal shorebirds

Sinclair *et al.* 2004

Appendix VII

<http://www.bsc-eoc.org/download/Borealshorebirdmonitorpaper.pdf>

Program for Regional and International Shorebird Monitoring (PRISM)

Bart *et al.* 2002

Appendix VII

ftp://diablo.manomet.org/PRISM/PRISMOverview_01.doc

2007 PRISM Field Manual

Canadian Wildlife Service 2007c

Appendix VII

Canada and the US have a joint program for monitoring shorebirds that follows a unified set of protocols, the *Program for Regional and International Shorebird Monitoring* (PRISM) (Bart *et al.* 2002). In the Arctic, PRISM aims at monitoring population sizes and changes in breeding shorebirds. The program provides a standard protocol for baseline and ongoing monitoring of both shorebirds and songbirds. In 2001, the CWS Northern Shorebird Program implemented Arctic PRISM; CWS coordinates the surveys and maintains the database. The program became fully

operational in 2004. It is anticipated that by 2012 the first population estimates for all of the Canadian Arctic will be made available (CWS 2007b).

Concerns exist because there is a relative lack of monitoring of the breeding shorebirds found in northern boreal forests. As identified in a 2004 PRISM document, the NWT encompasses three different Bird Conservation Regions (BCRs; Figure 1 in Appendix VII, Sinclair *et al.* 2004). While not designed as a protocol manual, this document outlines considerations and recommendations for various monitoring strategies including off-road point counts, ground-based wetland surveys during breeding seasons and aerial surveys over breeding grounds within each of the BCRs. Bart *et al.*'s 2002 document also outlines the objectives of PRISM and the different monitoring strategies used, such as for the Arctic and boreal breeding surveys.

The protocols followed under PRISM are described in a manual produced by CWS (2007c). It addresses Arctic and boreal breeding bird surveys. PRISM protocols for the Arctic use a method called "double-sampling" where large numbers of sample plots are quickly sampled and a smaller subset of the plots are more completely sampled. Systematic differences between the quick samples and the complete samples can be used to adjust the quick survey results.

Tundra Swans

Monitoring the Numbers and Productivity of Tundra Swans

Swystun *et al.* 2005

Appendix VII

<http://www.nwtcimp.ca/documents/cimpProjects/TUSW/TUSWRegionalTechReportMay2005.pdf>

CWS conducted a study over 2001 to 2003 to determine the numbers and reproductive success of tundra swans in the Mackenzie Delta region (Swystun *et al.* 2005). Protocols discussed include:

- methods for developing the study area;
- selection of study plots;
- survey strategies for the June breeding and August productivity seasons; and
- methods of data analysis.

Methodology details are provided such as:

- surveying plot size and the nature of plots (i.e., control versus treatment sites);
- aerial survey procedures (i.e., height and speed); and
- determination of swan status.

The methods for this NWT survey were adopted from the US FWS Trumpeter and Tundra Swan Survey protocol.

3.7.3 Landbirds, Song Birds and Forest Birds

Noncolonial Landbirds

Monitoring Bird Populations in Small Geographic Areas

Dunn *et al.* in 2006

Appendix VII

http://www.cws-scf.ec.gc.ca/publications/spec/PDF/mon_e.pdf

A detailed manual of protocols was developed by Dunn *et al.* in 2006 for CWS to describe monitoring of bird populations in small geographic areas. It is a comprehensive manual with descriptions of

- study design;
- project planning;
- data collection; and
- site-specific checklist surveys.

References are also provided throughout for other survey protocols that are used in similar studies.

Landbirds

Canadian Landbird Monitoring Strategy

Downes *et al.* 2000

Appendix VII

http://www.cws-scf.ec.gc.ca/mbc-com/FD5E754F-D977-4123-B6DF-B464893D86C4/strat_e.pdf

In 2000, a document was produced outlining monitoring strategies for Canadian landbirds (Downes *et al.* 2000). It identifies existing monitoring needs and describes many of the different monitoring programs carried out across Canada. General overviews of monitoring protocols are provided in the manual.

This manual can be compared to the US-produced *Handbook of Field Methods for Monitoring Landbirds* (Ralph *et al.* 1993); see below.

Landbirds / Songbirds / Forest Birds

Handbook of Field Methods for Monitoring Landbirds

Ralph *et al.* 1993

Appendix VII

<http://www.fs.fed.us/psw/publications/documents/gtr-144/gtr-144-content.pdf>

This document describes point counts and territory mapping as the typical method for gathering information of forest song birds. Specific application of these methods such

as the length of the time period to count birds and how many visits to make to the sample location are not standardized, but vary between researchers.

CWS's Inuvik office cited the 1993 US Department of Agriculture publication, the *Handbook of Field Methods for Monitoring Landbirds* (Ralph *et al.* 1993) as an important additional guide to constructing surveys for song birds (C. Dockrill. CWS, pers. comm. January 2008). Protocols are described for monitoring bird populations (e.g., age and sex ratios) as well as methods for estimating population sizes, measuring demographic factors, and conducting habitat assessments.

3.7.4 Raptors

General Raptors NWT

The Northwest Territories / Nunavut Raptor Database

Shank 1997
Appendix VII

The GNWT has been developing its Northwest Territories Raptor Database (the NWT / NU Raptor Database) since 1982. The *Northwest Territories Raptor Database: A User's Manual* (Shank 1997) provides protocols for the collection and management of raptor information on:

- nest site location;
- nest productivity and banding; and
- incorporation of data into the NWT Raptor Database.

The manual provides a biological background on various raptor species as well as field names and explanations for a nest site description database. Protocols are covered extensively and include:

- collection protocol (e.g., flying, observing, recording nests);
- data storage (e.g., hardcopy sheets, maps, databases);
- nest description and nest visit data sheets;
- nest description and nest visit databases;
- field names and descriptors for observations;
- banding database (including field names and explanations);
- mapping; and
- completing authorizations and security concerns.

The appendices include one raptor nest description form, one raptor nest visit form and one list of community codes for reporting, which are provided in Appendix VII.

General Raptors outside the NWT

British Columbia Ministry of Sustainable Resource Management 2001

Appendix VII

http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/raptors/version2/rapt_ml_v2.pdf

BC's Integrated Land Management Bureau has a comprehensive set of inventory methods aimed specifically at raptor monitoring (BC Ministry of Sustainable Resource Management 2001) which contains protocols very similar to those for the NWT, particularly in regards to aerial surveys (S. Carriere, ENR, pers. comm. 2008). Protocols are extensively covered in the *Inventory Methods for Raptors* and include:

- survey standards (i.e., personnel, weather, survey timing, habitat data, survey types, raptor signs, data entry and analysis, survey design);
- inventory surveys (i.e., species-specific surveys); and
- descriptions of various other survey options (i.e., call playbacks surveys, foot surveys, ground nest searches, roadside surveys, stand-watches, migration surveys, aerial and boat surveys).

Information is also provided on data analysis as well as species accounts and survey notes with detailed descriptions of many raptor species and appropriate survey strategies for each species.

Peregrine Falcons

The two "sub-species" of peregrine falcon found in the NWT (anatum: *Falco peregrinus anatum* and tundra: *Falco peregrinus tundrius*) are sometimes considered the same bird because they are virtually genetically indistinguishable (Brown *et al.* 2004). They are now listed as 'sensitive' species in the territory in the *NWT General Status Ranking Program* (as opposed to the previous categories of 'at risk' [anatum] and 'may be at risk' [tundra]; Rowell 2002) and of 'special concern' by COSEWIC (instead of 'endangered' and 'threatened' as previously categorized) (COSEWIC 2007).

Peregrine Falcon Surveys

Carrière and Mathews 2005

Appendix VII

<http://www.nwtgeoscience.ca/forum/2005Talks/enviro/CarriereMathews%20Peregrine%202005.pdf>

Since the 1970s, peregrine falcon surveys have been conducted throughout the NWT, particularly along the Mackenzie Valley. Originally done annually, the surveys were changed to five-year survey periods in 1990 and are now referred to as the *Five-Year Mackenzie Valley and National Peregrine Falcon Surveys*. Surveys are conducted by air, boat and ground to determine nest occupancy and productivity rates (Carrière and Mathews 2005; CIMP 2007) and follow protocols established for the NWT Raptor Database *User's Manual*. These surveys are part of the five-year North American peregrine falcon surveys which contribute to the International Recovery Plans for the

birds. Surveys of approximately 100 sites in the Mackenzie Valley are done in mid-July and include chick banding to assess migration and survival information (Carrière and Mathews 2005).

Arctic Peregrine Falcon Removal from Listing

United States Fish and Wildlife Service 1994

<http://www.epa.gov/EPA-SPECIES/1994/October/Day-05/pr-5.html>

Breeding Population of Tundra Peregrine Falcons

The Wilson Bulletin 1993

Appendix VII

<http://elibrary.unm.edu/sora/Wilson/v105n01/p0188-p0190.pdf>

The US FWS (1994) provides information on the Arctic peregrine falcon and the history of their population dynamics over the 20th century in Alaska and northern Canada. Statistics are provided for three locations in the former NWT area (i.e., Coppermine [Kugluktuk], Rankin Inlet and Hope Bay) where the number of breeding pairs of birds were monitored from the early 1980s. Due to a recovery in population numbers, the US and Canada determined that the peregrine falcon is no longer a threatened species. In an effort to continue monitoring the birds across both countries, together with various non-government organizations as well Canadian agencies, the US FWS provides a list of research parameters for consideration for ongoing monitoring (US FWS 1994). These include:

- numbers of breeding pairs (across North America);
- reproductive performance (number of young per territorial pair);
- contaminant exposure (using blood and eggs); and
- migration counts (passing fixed points along migration corridors).

The protocols followed for monitoring the number of breeding pairs of falcons at Coppermine and Hope Bay are provided in a report in The Wilson Bulletin (1993).

3.8 Vegetation

3.8.1 Introduction to Vegetation

This section is a compilation of the protocols most commonly used in the NWT for monitoring vegetation. The section is structured so that monitoring protocols for general vegetation, forests, tundra and salt marshes are described separately. Finally, protocols to monitor vegetation phenology are provided.

Protocols describe include those found in the following sources:

- the *NWT Vegetation Inventory Standards* and *Canada's National Forest Inventory Ground Sampling Guidelines*, which are used by the Forestry Resources Division of ENR;
- the *Terrestrial Vegetation Biodiversity Monitoring Protocols*, which are EMAN's standard protocols;
- guidelines to long term study and experiment monitoring from ITEX; and
- the *Field Methods Manual* of the US FWS (Region 5) for monitoring wetlands.

Additionally, DUC was contacted (A. Korpach pers. comm. 2008). DUC has not been involved in any monitoring programs in the NWT and so does not currently have a protocol. All relevant guidelines and protocols are described briefly below. More detailed information is available for review in Appendix VIII (Table VII-1).

3.8.2 General Vegetation

Terrestrial Vegetation Biodiversity Monitoring Protocols

Roberts-Pichette and Gillespie 1999

Appendix VIII

<http://www.eman-rese.ca/eman/ecotools/protocols/terrestrial/vegetation/>

Terrestrial vegetation biodiversity monitoring protocols developed for EMAN (Roberts-Pichette and Gillespie 1999) cover the following topics:

- canopy tree stratum biodiversity;
- shrub and small tree stratum biodiversity;
- ground vegetation stratum biodiversity; and
- vegetation gradient biodiversity.

All of these protocols are based on the use of permanent square plots used for monitoring vegetation in Canada. The 20 m x 20 m stand-alone quadrat has been recognized as being most useful in Canada, although the one-hectare plot is the internationally used standard (Roberts-Pichette and Gillespie 1999).

These monitoring plots aim at assisting with the interpretation of changes that are observed by satellite. The focus is on above-ground vascular plants, lichen and mosses. The plots are designed to be used in a long-term monitoring strategy in conjunction with monitoring protocols for other terrestrial organisms. Monitoring sites using the EMAN protocol have been set up throughout the NWT including in Gwich'in Territorial Park, the Nahanni, Tutktut Nogait and Aulavik national parks.

Canopy Tree Stratum Biodiversity Monitoring Protocols

The Canopy Tree Stratum Biodiversity Monitoring Protocols are used in stands with no strong vegetation gradients and trees that are at least 10 cm in diameter at 1.3 m above ground level or "diameter at breast height" (dbh). Plots measuring 20 m x 20 m square are recommended for dwarf forest stands such as those found in the northern taiga forests (Roberts-Pichette and Gillespie 1999). The protocol includes the following descriptions:

- number of plots;
- size of plots;
- 1 hectare (ha) plots may be used where the tree stands are large enough to accommodate them, and the majority of trees making up the canopy are over 10 cm dbh;
- 20 m by 20 m stand-alone permanent quadrats are ideal when resources are not as plentiful as they are relatively inexpensive to establish and allow more flexibility in the way they are set up;
- position of the randomly places plots;
- survey of plots:
 - equipment list;
 - timing of survey (fall survey is recommended, in five-year intervals);
 - staking and numbering of plots;
 - documentation (parameters and descriptions);
 - data / information collection methods (e.g., identification of trees, specimen collection, record keeping; tagging and measuring of trees, determination of age and condition); and
 - data compilation and processing.

Shrub and Small Tree Stratum Biodiversity Monitoring Protocols

The Shrub and Small Tree Stratum Biodiversity Monitoring Protocols are used for monitoring woody shrubs (over 1 m tall and less than 10 cm in diameter, often multi stemmed). Small trees and saplings are single stemmed woody plants measuring between 4 cm and 10 cm in diameter. Monitoring shrubs and small trees provides

information on rates of growth and mortality of saplings and replacement rates of canopy species. Vines are also included in this category (Roberts-Pichette and Gillespie 1999).

The monitoring protocol for shrubby species is similar to that of tree canopies. Plots should be checked a minimum of every five years. The document presents information on the following topics:

- plot size and location;
- timing and method of survey; and
- record keeping.

Ground Vegetation Stratum Diversity Protocol

Ground layer vegetation is comprised of moss, lichen and fungi together with small trailing and rosette plants and field layer vegetation. These species are finely tuned to their environment and provide valuable information because they respond quickly to changes in the environment. Potential changes are more likely to be detected earlier by monitoring ground vegetation than tree and shrub populations, which beneficial for land management strategies. However, little long-term information is available on ground vegetation, as current monitoring in the NWT has mostly been focused on tree canopies (Roberts-Pichette and Gillespie 1999). The EMAN protocol refers to ITEX (1996; see below) as being appropriate to use in conjunction with this protocol when dealing with Arctic plants. The following steps are described in the Ground Vegetation Stratum Diversity Protocol:

- a 1 m x 1 m plot size is recommended;
- timing of survey (i.e., several times per year);
- number and arrangement of plots / quadrates;
- record keeping (i.e., baseline data, reporting); and
- measurement schedule (mapped quadrates should be re-mapped, re-measured and re-photographed in intervals).

Vegetation Gradient Biodiversity Monitoring Protocols

The Vegetation Gradient Biodiversity Monitoring Protocols are used for measuring changes in biodiversity in areas where the vegetation type changes from one community to another so abruptly that the area of one or more of the constituent vegetation communities is too small to use any of the methods described above. Rapid change can be due to elevation, moisture or other environmental gradients. Monitoring across gradients can yield data that is useful for showing plant response to a variety of environmental changes. Information derived from long term monitoring can distinguish between cyclic phenomena and long-term change (Roberts-Pichette and Gillespie 1999).

This protocol uses permanent transects with a series of quadrats arranged contiguously in a straight line along each transect. The width of any transect is determined by the types of communities found across the gradient. It is generally recommended that transects be 5 m wide for use in areas where there large trees, small trees or large shrubs dominate the community. Transects 1 m apart can be used when low shrubs and ground vegetation dominate. The length chosen for transects depends on the monitoring site. A minimum of three to five transects are used to monitor small areas of vegetation, sloping prairie or tree line dynamics. However, more may be needed depending on the scale of what is being monitored. Transects are oriented at right angles to the gradient and start and finish well into the ecosystems on either side unless a natural barrier such as a cliff occurs (Roberts-Pichette and Gillespie 1999).

A method that reduces inadvertent bias should be used when choosing locations for transects. This protocol provides a possible method for selecting transect locations.

Surveying should be done in the fall before major snow accumulates to minimize damage to vegetation. If the survey involves a water body, summer may be more appropriate. Latitudes and longitudes must be recorded from the base reference stake from which all transects are measured. The protocol gives direction on how to correct for slope and how to nest the ground vegetation quadrats on the outside line of transects. Meticulous record keeping is essential. Plots must be checked every year for the first two years and then every five years following or as necessary (Roberts-Pichette and Gillespie 1999).

3.8.3 Forests

Northwest Territories Vegetation Inventory Standards

Forest Resources 2006
Appendix VIII

The *Northwest Territories Vegetation Inventory Standards* are used by ENR for collecting forest vegetation inventory information from satellite or air photography (Forest Resources 2006). Currently, approximately 5 million hectares in the NWT have been inventoried based on this standard protocol (L. Smith, ENR, pers. com. January 17 2008). This standard can be used in conjunction with the *National Forest Inventory Guidelines* (see below). The document gives detailed instructions on how to interpret aerial photography taken at a scale of 1:20,000 or 1:40,000 (Forest Resources 2006). It allows for a hierarchical classification and database of vegetated and non-vegetated areas within a forested area. It encourages as much compatibility as possible with previous inventories.

This standard protocol allows for both low flight observations and ground observations once classification by photograph has been completed. Ground and flight observations are used primarily to verify tree or shrub species, associations between vegetation types and biogeographic conditions. Additionally, they are used to identify disturbances and land uses, determine stand structure and to calibrate heights and ages for species or stands of trees (Forest Resources 2006).

Canada's National Forest Inventory Ground Sampling Guidelines

Canada's National Forest Inventory 2004
Appendix VIII

Canada's National Forest Inventory Ground Sampling Guidelines protocols are used by the GNWT to inventory forested permanent monitoring plots in all regions across the NWT (L. Smith, Inventory Forester for ENR, GNWT, pers. comm. January 2008). The protocol is comprehensive and covers the following aspects (Canada's National Forest Inventory [CNFI] 2004):

- plot design, timing and equipment list;
- field orientation and navigation;
- plot establishment;
- large tree plots;
- age, height, and growth information;
- small tree plots and stump measurements;
- woody debris transects;
- surface substrate;
- ground plot site characteristics and micro plot; and
- soil measurements.

The methods provided in the sampling protocols are detailed and it is assumed that it takes one full day for a team of three specialists (one soil specialist, one ecologist and one forester / forest technician) to complete measurements for one permanent monitoring plot. ENR's Forestry Division is interested in partnering with agencies and organizations that would potentially collect or use this type of information.

This protocol was designed by the CNFI (2004) and has been designed for use throughout Canada, but is only intended for forested areas. The design calls for a minimum of 50 forested permanent ground plots across all ecozones in the study area. For ground sampling, 10% of the predetermined photo plots are selected at random. Ground sampling is located at the centre point of a photo plot (CNFI 2004). Ground plot inventory data are used to verify interpretation of the photo plots and are meant to enhance the attributes and data collected from the photo plots by providing the following data:

- species names of all plants in a plot;
- mortality due to stress;
- total above ground biomass;
- current volume growth;
- forest floor organics and soil carbon;
- current land use;
- ownership;

- protection status;
- access;
- human influence;
- conversion of forest land; and
- introduction of exotic species.

These permanent plots assessed change in the vegetation by repeated sampling, analysis and interpretation of both the photo and ground plots (CNFI 2004).

The following sections summarize components of the CNFI ground sampling guidelines (2004).

Ground Plot Design

The Ground Plot Design protocol uses circular plots (with a radius of 11.28 m), but does allow for a square plot (i.e., 400 m²) design. Each of the main plots (i.e., large tree plot), which are used to collect information on large trees, should include the following components:

- two line transects (30 m in length) to measure small and woody debris and surface substrate;
- one small tree plot (radius of 3.99 m or 50 m²);
- four micro plots with a radius of .56 m and 1 m² area to measure the biomass of small trees and shrubs, herbs, fine woody debris, moss and lichens;
- one soil pit (located outside of the plot) to measure soil attributes; and
- one ecological plot (radius of 10 m) to list all of the species present and the percentage of cover found in that area.

Modifications by the provinces and territories using this protocol are expected (CNFI 2004). More information on ground plot criteria and a diagram of the preferred plot is provided in Appendix VIII.

Field Orientation and Navigation

The Field Orientation and Navigation protocol explains how to locate the ground plot centre that corresponds with the correct UTM coordinates for the sample. It provides guidelines to mark and document the location and navigation points to allow for long and short term sample relocation (CNFI 2004).

Plot Establishment

The Plot Establishment component explains the procedure to establish permanent plots, including the incorporation of photo records prior to plot measurements (CNFI 2004).

Large Tree Plot / Small Tree Plot

The Large Tree Plot / Small Tree Plot protocol provides guidelines for recording, tagging and measuring living and dead trees in the plot (e.g., genus, species and variety, life status, diameter and height, stump measurements and biomass, crown class, live crown length and height to live crown). These measurements are aimed at assessing the future growth and yield, wildlife use, and decay, and provide forest health information. Additionally (in the large tree plot only), age, height and growth information is gathered using core sampling (CNFI 2004).

Woody Debris Transect

The Woody Debris Transect protocol provides methods to account for all woody debris (i.e., downed and dead wood) along the 30 m transects. Information on surface substrate is used for reports on climate change, criteria and indicators of sustainable forest management, biodiversity and forest health. An evaluation of the surface substrate classifies ground surface into various types that create significant differences in the micro climate for vegetation establishment. Surface substrate may include organic matter, buried wood, decaying wood, bedrock, rock or cobbles and stones, mineral soil or water (CNFI 2004). Guidelines on measurement and recording are provided.

Micro Plot

In the Micro Plot protocol, four micro plots are used to measure the biomass of shrubs, small trees, herbs, grasses, lichen, moss and fine woody debris. The protocol provides an extensive list of definitions and information on vegetation description, collection and preservation of specimens and recording of data (CNFI 2004).

Soil Pit

The Soil Pit protocol provides methods to measure total carbon and involves analysis of both physical and chemical properties of soil to determine the potential for erosion of nutrient rich soils, the storage and cycling of nutrients and water, the availability of nutrients and water to plants, carbon sequestration, deposition of toxic metals from pollution and acidification of soils due to pollution. Additionally, methods for soil sampling in wetlands and in frozen soils (i.e., permafrost) are provided (CNFI 2004).

3.8.4 Tundra Vegetation

International Tundra Experiment
Jónsdóttir 2004

Appendix VIII

<http://archive.arcticportal.org/313/01/ITEX.pdf>

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

ITEX is a scientific network of experiments focusing mainly on the impact of climate change on selected tundra plant species. It combines both long-term and short-term experiments with monitoring protocols and is designed to examine the effects of temperature change by carrying out similar experiments at multiple sites. Each site operates a warming experiment usually using open-top chambers to warm the tundra, and collects data according to standardized protocols (Jónsdóttir 2004; ITEX 1996).

The goals of ITEX are to determine the responses of tundra plants to climate change, whereas climate change is described as primarily warming of the environment. Standardized experiments are carried out across circumpolar sites and the phenological growth and reproductive responses of selected, widely distributed tundra plant species are measured (Jónsdóttir 2004). The length of monitoring programs for each experiment is determined by funding available to each individual project. The *ITEX Manual* (1996) is provided in Appendix VIII.

3.8.5 Salt Marshes

Field Methods Manual for Salt Marsh Protocols

James-Pirri *et al.* 2002

Appendix VIII

<http://www.members.cox.net/mjjamespirri/Monitoring%20Protocols.pdf>

The *Field Methods Manual* for the US FWS (Region 5) salt marsh vegetation monitoring protocol recommends sampling vegetation using permanent plots and the point intercept method. A minimum of 20 vegetation plots are required per study area. Permanent quadrats should be arranged in transects and spaced a minimum of 10-20 cm apart to maintain independence between plots. Random location of transects is important and the first permanent plot is randomly placed in the study area with each following plot systematically placed along each transect (James-Pirri *et al.* 2002).

Vegetation is sampled once per season, usually toward the end of the season. It requires two people to sample vegetation. The protocol provides a detailed equipment and materials list (James-Pirri *et al.* 2002).

Site Selection and Sample Location

The study area is to be selected and sampled as follows (James-Pirri *et al.* 2002):

- study area should be systematically divided into segments;
- define boundaries of the control and experimental areas;

- random transects have to traverse the main gradient from creek bank to upland edge of marsh;
- from aerial photography transect start points have to be selected; transects should be parallel, should be at least 10 m apart and should be dispersed throughout the study area to ensure that the vegetation plots are representative of entire study area;
- vegetation plots are located along each transect; there is no recommended plot size as they can be made to suit the needs of the study; however, a minimum of 20 plots are required for each study area;
- the first plot of each transect is randomly located within the low marsh zone; once the first plot is located, all subsequent plots are systematically placed a minimum of 10 m apart along the length of each transect;
- label transects and plots; and
- recording of location and distance between plots should use latitude and longitude, UTM coordinates etc. using GPS with sub-metre accuracy.

Sampling (Point Intercept Method)

Individual sample plots are separated into quadrats for the point intercept method. Dowels (with a scale to measure height) are used to mark the test points, providing 50 evenly spaced points in each quadrat. All species present within the sample quadrat are listed. A thin rod is held vertically to the first sampling point and lowered through the vegetation canopy to the sample point on the ground. All species that touch the rod are recorded as a hit on the data sheet for that point. The process is repeated for all 50 points in the quadrat. Sampling should occur when the marsh surface is not flooded so vegetation is not concealed (James-Pirri *et al.* 2002). This method can also be used in marshes with taller vegetation canopies such as those dominated by shrubs. It requires a longer rod and the observer has to record taller species that occur as well.

Water Table Level Monitoring

The water table level monitoring protocol provides information on how to monitor water levels within a marshland area. Water table levels provide information on the amount of drainage that is occurring in a marsh and monitoring water levels over time provide information on potential causes of vegetation changes. It is measured using ground water wells and it is recommended that a watertable level well be placed in association with each vegetation sampling plot (James-Pirri *et al.* 2002). The protocol provides detailed information on construction and installation of the wells.

Soil Salinity Monitoring

Soil salinity is an important factor controlling the patterns of salt marsh vegetation. To monitor this parameter, measurements are taken from the portion of the sediment that

has the most active roots and rhizomes, generally 10-15 cm deep with a soil probe. Salinity sampling should coincide with ground water sampling (James-Pirri *et al.* 2002). Details on sampling design are provided in the protocol.

Soil Sulphide Monitoring

Testing for sulphides in soils can contribute to the understanding of vegetation pattern changes over time. Sulphides are tested on a monthly basis, using a probe similar to the salinity monitoring (James-Pirri *et al.* 2002). Details on sampling design are provided in the protocol.

3.8.6 Vegetation Phenology

Vegetation phenology monitors the timing and rate of green up (i.e., budding) and growth either by satellite imagery or by ground observation.

Forest Management Division, Inuvik

M. Gravel, ENR, pers. comm. February 2008

Since 1999, ENR's Forest Management Division in Inuvik has been conducting a phenology survey between Inuvik and Tsiigehtchic for coniferous and deciduous trees (i.e., white spruce, black spruce, tamarack, white birch, balsam poplar and trembling aspen). Individual trees were selected and tagged. In this study, each tree's development is monitored throughout the spring (i.e., the last week of May through to the middle of June). The goal is to monitor seasonal changes in the weather, the transitional changes from south to north and the associated timing of leaf-up (M. Gravel, ENR, pers. comm. February 2008).

Methods involve photographing and recording the changes seen in the development of the trees with each visit. The tagged trees of all species are revisited each year at the same time. During each visit the following parameters are recorded:

- site number;
- species;
- latitude and longitude;
- air temperature;
- tag number; and
- date.

Monitoring for coniferous trees includes:

- bud burst;
- needle emergence (in stages: 10%, 50%, 100%);
- shoot growth; and

- status of pollen release.

Monitoring for deciduous trees includes:

- bud burst;
- state of catkins;
- leaf out (in stages: 10%, 50%, 100%); and
- status of pollen release.

PlantWatch

NatureWatch - PlantWatch 2007

Appendix VIII

<http://www.naturewatch.ca/english/plantwatch/>

The Canadian Nature Federation and Environment Canada's EMAN's Coordinating Office have formed a joint venture using volunteers to observe and record the flowering times of selected plant species. The observations help researchers track the responses of plant species to climate change and track where the changes are taking place in Canada and at what rate. There are currently 15 different species that have been chosen for monitoring in the NWT. The PlantWatch website provides protocols for monitoring plants under the "How to PlantWatch" link (NatureWatch - PlantWatch 2007).

Research and Monitoring in National Parks of the Western Arctic

Parks Canada 2003

Appendix VIII

http://www.pc.gc.ca/docs/v-g/rs-rm2003/sec5/index_e.asp

Satellite Monitoring of Northern Ecosystems

Sparling *et al.* 2002

science.nature.nps.gov/im/monitor/meetings/StPetersburg_05_rs_pa/PDFfiles/TNaughten_N_Ecosystems.pdf

Vegetation and Terrain Surveys

Kennedy and Smith 2002

http://www.pc.gc.ca/docs/v-g/rs-rm2002/sec3/page1_e.asp

PC currently uses satellite monitoring to track northern ecosystems and their changes (Sparling *et al.* 2002). This protocol uses the Advanced Very High Resolution Radiometer (AVHRR) onboard the National Oceanic and Atmospheric Administration (NOAA) meteorological satellites to determine the timing of the onset of green-up in sites which are located in 11 different northern national parks. The Normalized Difference Vegetation Index is used to calculate the productivity or growth of vegetation (PC 2003).

The timing of green-up is important for identifying and describing the effects of climate change on a regional scale. Satellite images are taken from April through October each year. Finished images are then created by combining the best images taken over a 10 day period. This protocol uses fragmentation analysis to measure the ecological integrity of an area. In addition to using the AVHRR images, PC also

periodically sends a survey crew into the parks to visit the sites in early July. The survey crew describes the species and relative abundance at each site as well as the location of the site, depth to permafrost, elevation, aspect, slope, amount of bare soil, amount of invasion of bare soil by vegetation, the location of the slope with respect to the surrounding terrain, and the soil characteristics (Kennedy and Smith 2002). These field trips help to identify any changes in vegetation occurring in the study areas.

3.9 Climate

3.9.1 Introduction to Climate

Climate in this report is described in a meteorological context and considers climatic variables such as air temperature, wind, lightning, solar radiation, evaporation, precipitation (rain and snowfall) and ice phenology. Further considerations for monitoring snow are provided in Section 3.2, Snow, Permafrost and Ground-Ice.

There is no standardized set of protocols that guides the gathering of climatic information across the NWT. Weather stations that collect the data are highly variable. Some are manned, others collect information automatically, while some are a combination of manned and automatic systems. There are also discrepancies in the recording intervals for climate data, with data recording ranging from hourly to once or twice daily at different stations. Additionally, to add to the likelihood of inconsistencies across climatic protocols, the NWT's weather stations have diverse operators. Individual stations may be run by the territorial government, or Nav Canada or even volunteers, with different stations having a diversity of climate monitoring equipment (C. Dixon, MSC, pers. comm. January 2008).

Traditionally, climatic variables were measured across the NWT and Canada at stations that captured weather information at specific points in time (i.e., every six hours) and sometimes from weather balloon releases. Today, there is a stronger dependence on meteorological information derived from remote sensing methods (i.e., radar and satellite) but weather stations across the NWT still provide ongoing climate information to EC's Weatheroffice (Weatheroffice 2008).

Climate is monitored extensively across the northern hemisphere to understand the causes, trends, effects and overall nature of regional and even global climate change. Many projects are either ongoing or planned across the north, with many being very localized and specific in terms of monitoring climate change. For example, Arctic Borderlands (2007) conducts many TK studies in the Porcupine caribou herd range of the northern Yukon and north-west NWT. These studies often focus on interviewing long-term residents of the area but also incorporate data from other sources to understand how local events are changing over time (e.g., variable annual snow depths in specific locations). Arctic Borderlands and other agencies collect and distribute relevant information on climate change, but that is not the objective of this NWT CIMP report. This report describes climatic parameters as they are currently being measured, not necessarily in relation to climatic trends over time. It focuses on agencies and projects that cover larger scales and concentrates on actual protocols and manuals that are used in the various projects.

The Climate section of this report is organized as a list with brief description of involved agencies first, followed by specific climatic parameters that are monitored. Detailed protocols or links to protocols are provided in Appendix IX (Table IX-1) and in the summaries provided below.

3.9.2 Monitoring Agencies

Environment Canada

Weatheroffice 2008

http://www.weatheroffice.gc.ca/forecast/canada/summary_e.html?NT

Climatic parameters such as air temperature, humidity and precipitation are monitored daily at more than 30 weather stations across the NWT, typically located at community airports. Data are reported to EC's Weatheroffice (CIMP 2007; Weatheroffice 2008). Weather balloons released twice daily since 1948 have gathered upper air information at Fort Smith, Norman Wells and Inuvik such as atmospheric pressure, temperature, moisture and winds (CIMP 2007). The NWT weather stations do not generally follow standardized protocols for the collection of their data (C. Dixon, MSC, pers. comm. January 2008). At stations where climate data have been collected for more than 15 years between 1971 and 2000, climate normals are available (EC 2008a).

Canadian Centre for Climate Modelling and Analysis

Canadian Centre for Climate Modelling and Analysis 2006

http://www.cccma.bc.ec.gc.ca/eng_index.shtml

Climate data as they relate to climate change have been compiled and incorporated into models by EC's MSC at the Canadian Centre for Climate Modelling and Analysis (CCCma 2006). More information about these models and their monitoring roles in assessing such topics as atmospheric climate modelling, sea-ice modelling in northern Canada and the carbon cycle is available for review.

Northern Climate Exchange Centre

Northern Climate Exchange Centre 2008

<http://yukon.taiga.net/nce/researchneeds/>

A centre based in the Yukon is focusing on climate change in the north. The Northern Climate Exchange Centre (NCE) integrates information from diverse sources such as western science and TK and integrates the information into a database to identify knowledge gaps. Various monitoring protocols may be found in the documents retrieved from a search of NWT-related reports found on the NCE's searchable database (2008).

World Meteorological Organization

Weatheroffice 2007

http://www.climate.weatheroffice.ec.gc.ca/climate_normals/climate_info_e.html

Fifteen sites in the NWT have sufficient data to assess "climate normals" (Weatheroffice 2007). Stations located in Fort Simpson, Fort Smith, Hay River, Inuvik, Norman Wells and Yellowknife have the capacity to meet the United Nation's World Meteorological Organization (WMO) standards. The protocols followed in the NWT to meet these standards are described including how to determine if data qualifies for definition as "climate normals" as well as details for measuring and recording individual climatic variables.

Monitoring Climate Change in Northern National Parks

Golder Associates 2005

To monitor climate and climate change impacts in northern Canada, including in the NWT, PC developed a report assessing climate change monitoring indicators / measures. Changes in temperature and precipitation were identified as the most appropriate indicators to develop a climate change index. General methodologies are provided for using temperature, precipitation (i.e., rain) and snow (i.e., snow water equivalent, depth, density and cover) as direct indicators / measures of climate change in northern national parks (Golder 2005).

Canadian Mackenzie Global Energy and Water Cycle Experiment Study

Mackenzie Global Energy and Water Cycle Experiment Study 2004

http://www.usask.ca/geography/MAGS/index_e.htm

The Canadian MAGS is attempting to assess the water and energy cycles of the Mackenzie Basin in relation to hydrological and atmospheric systems (2004). Protocols for data documentation and protocols for data management systems are provided.

Ice-Atmospheric Interactions and Biological Linkages

Langlois *et al.* 2004

Appendix IX

http://www.umanitoba.ca/CEOS/files/cases_data_report_2004.pdf

The Canadian Arctic Shelf Exchange Study (CASES) involved 5-year field experiments incorporating many different projects. One study led by the Centre for Earth Observation Science (CEOS) concentrated on the Beaufort Sea (specifically the Mackenzie Continental Shelf), Amundsen Gulf and Franklin Bay in the NWT and focussed on assessing ice-atmosphere interactions and biological linkages (Langlois *et al.* 2004). The report outlines how a baseline data set for western Arctic sea-ice was developed during the winter of 2003-2005.

Extensive methodologies are described for gathering data. Protocols are provided for collecting micrometeorological and microclimatological data (e.g., relative humidity, air temperature, wind speed and direction, solar and long-wave radiation). Cloud observations (e.g., visual observations, height and precipitation occurrences), atmospheric profiles (e.g., pressure), snow and sea ice geophysical, optical and microwave measurements (i.e., passive and active) and remotely sensed data (e.g., satellite imagery, aerial surveys and surface-based radiometry) are also discussed.

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

Detailed protocols are provided for collecting climate data at the stations in the ITEX manual (1996). Instructions are also provided on setting up Level 1 (entirely manual stations; discouraged) and Level 2 stations (either entirely automated or a combination of manual and automated; encouraged) including the parameters to be measured, the

instruments required, detailed construction and installation processes and measurement procedures such as frequency of data collection.

3.9.3 Air Temperature

Canadian Climate Data

Environment Canada 2008a

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Climate stations across the NWT monitor air temperatures on an hourly, daily and / or monthly basis and report their measurements to EC (2008a). Air temperature parameters are available for review for different stations that have more than 15 years of temperature measurements. This allows for the assessment of "climate normals" that show the station averages over time including the daily average, maximum and minimum temperatures, the year and date of the extreme maximum and minimum temperatures for a given month, and the yearly average temperature (i.e., MAAT) (EC 2008a). The protocols for gathering this data are diverse, with instruments, collection intervals and measurement techniques varying at the different monitoring stations across the NWT (C. Dixon, MSC, pers. comm. January 2008).

Thermometers and Thermistors

Environment Canada 2007a

Appendix IX

http://www.on.ec.gc.ca/skywatchers/ontario/wx_office_tour/compound/thermometers_e.html

Although not specifically referring to stations within the NWT, EC's Skywatchers website (EC 2007a) contains comprehensive descriptions of different temperature monitoring instruments used across Canada such as thermometers and thermistors. These measure parameters including maximum and minimum temperatures, extreme temperatures and the moisture content of the air. Detailed descriptions are provided on the monitoring equipment used for recording air temperatures as well as an explanation for determining air moisture content (EC 2007a).

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

The ITEX manual (1996) describes the instruments used in measuring air temperatures at its stations and methods for data recording. It also details methods for calculating daily heat accumulation and degree days, including formulas for calculating mean daily temperatures when the daily maximum is above 0°C and the daily minimum is below 0°C.

3.9.4 Wind

Canadian Climate Data

Environment Canada 2008a

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Wind energy information gathered at stations across the NWT is submitted to EC and compiled in its database. Wind speed, its most frequent direction, and gust events are recorded, with daily, monthly and yearly averages available for stations with more than 15 years data (EC 2008a). The protocols for collecting wind energy information are not consistent across the NWT (C. Dixon, MSC, pers. comm. January 2008).

Methodology for Measuring Canadian Wind Energy

Canadian Wind Energy Atlas 2005

Appendix IX

<http://www.windatlas.ca/en/methodology.php>

Wind energy speeds calculated for three heights across Canada (including the NWT) are available on-line at the Canadian Wind Energy Atlas (CWEA). Detailed methods are provided for deriving those wind speeds. Descriptions of the climatic modelling procedures used to assess atmospheric motion are presented, following protocols outlined for the following (CWEA 2005):

- wind climate classification;
- mesoscale simulations;
- statistical post-processing; and
- microscale modelling.

Wind Chill

Environment Canada 2002

Appendix IX

http://www.msc-smc.ec.gc.ca/education/windchill/windchill_fact_sheet_aug_10_e.cfm

In 2000, Canada led the development of a new international standard for assessing wind chill. Weather reports indicating wind chill factors are now consistent across Canada and the US (reported in degrees Celsius and Fahrenheit, respectively). A description of why a standard protocol was required and the development of the new wind chill index are provided (EC 2002).

Rainfall Measurements

Metcalfe *et al.* 1997

Appendix IX

<http://ams.allenpress.com/archive/1520-0442/10/1/pdf/i1520-0442-10-1-92.pdf>

Recorded precipitation amounts in rain gauges can be erroneous due to the effects of wind (e.g., from disturbed airflow around the gauge). Factors are provided for adjusting errors in rain gauge measurements due to wind in Metcalfe *et al.*'s 1997 report.

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

The ITEX Manual (1996) provides protocols for measuring wind energy. It includes detailed descriptions of the height at which wind should be measured and the accuracy with which wind speeds should be recorded.

A Corrected Precipitation Archive for the Northwest Territories

Metcalfe *et al.* 1994

Appendix IX

http://www.usask.ca/geography/MAGS/Data/Public_Data/precip_corr/pcpncor_e.htm

Wind is typically a major cause of error for measurements of precipitation amounts, with increasing wind speeds causing gauge catches to decreasingly represent "true precipitation." As wind breaks around an obstacle such as a precipitation gauge, the wind flow becomes disturbed and the trajectory of the precipitation particles changed, usually resulting in an under-catch of precipitation in the gauge (Metcalfe *et al.* 1997). In 1994, Metcalfe *et al.* presented a formula for calculating wind speed at 1.5 m above the ground surface from measurements taken at 10 m height at weather stations in the NWT. The purpose of the formula is to estimate the wind speed at the height of the stations' snow gauge instruments and be able to apply a correction to the recorded snowfall amounts.

3.9.5 Solar Radiation

The Canadian Ozone and Ultraviolet Measurement Program

Environment Canada 2008b

Appendix IX

<http://exp-studies.tor.ec.gc.ca/e/ozone/ozonecanada.htm>

Of the 13 spectral ultra-violet (UV) monitoring sites established in Canada, none are located in the NWT. In Nunavut, UV research is ongoing with UV monitoring instruments located in Resolute, Eureka and Alert (EC 2008b). Information about the monitoring network including historical data and images is available for review on the EC website.

Estimating UV Index Climatology over Canada

Fioletov *et al.* 2002

Appendix IX

http://woudc.ec.gc.ca/paper_data/UVI_climatology_Canada_0204/climat_uv_2002092_3.pdf (paper); and

http://exp-studies.tor.ec.gc.ca/e/paper_data/UVI_climatology_Canada_0204.html (including maps)

A report from 2002 (Fioletov *et al.*) describes techniques for establishing the UV Index climatology at over 45 sites in Canada, four of which occur in the NWT. The report discusses protocols for ground-based and total ozone measurements in connection with global solar radiation measurements, snow cover and dew point temperatures.

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

ITEX stations measure global solar radiation in watts (W) per square metre (W/m^2). From this, the manual produced by ITEX (1996) provides instructions on calculating integrated solar radiation at its climate stations and appropriate monitoring intervals.

Evaporation

Canadian Climate Weather Data

Environment Canada 2008a

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Climate Monitoring Program

Environment Canada 2006

Appendix IX

http://www.atl.ec.gc.ca/msc/em/land_climate.html

Some weather stations in the NWT record evaporation rates (e.g., monthly lake evaporation information is available in the summer months for the Yellowknife A station; EC 2008a). Stations obtaining evaporation information in Canada typically follow the *Class A Evaporation Plan* recommended by the WMO. The protocol describes how to observe the change of the free water surface level determined by using a Fixed Point Gauge. After each recorded measurement, the water level is returned to a fixed point using a calibrated container (EC 2006).

Evaporation Calculations at the Salmita-Tundra Mine Site

Reid 2004

Appendix IX

http://nwt-tno.inac-ainc.gc.ca/pdf/wr/Evaporation_Calculations_at_the_Salmita-Tundra_Mine_Site-1993-2004.pdf

Examples of protocols designed to measure evaporation rates are available from mines that conduct such monitoring for their water management facilities (Reid 2004). The Water Resources Division of INAC has been monitoring evaporation at mines in the NWT and Nunavut since 1993. Data collected from the Giant, Salmita, Colomac, Lupin, Silver Bear and Discovery mine sites contributes to daily and seasonal calculations of evaporation rates (CIMP 2007). Detailed protocols on collecting data and calculating evaporation rates are provided in Reid's (2004) report in Appendix IX.

Evaporation and Ice Growth in the Mackenzie Delta Lakes

Marsh 1991

Appendix IX

http://www.cig.ensmp.fr/~iahs/redbooks/a206/iahs_206_0257.pdf

Evaporation rates are considered in lake water balances in the NWT. In the Mackenzie Delta, Marsh (1991) considers this evaporation and its relation with ice development on delta lakes. Included in this report are protocols and formulas for

calculating lake water balances, the Priestley-Taylor model for evaporation and how to correlate evaporation information with climate data.

3.9.6 Precipitation

Canadian Climate Data

Environment Canada 2008a

http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html

Depending on the station, hourly, daily and monthly precipitation events are recorded across the NWT and compiled on the EC database. For stations with more than 15 years of data, climate normals and averages can be reviewed. Precipitation parameters available for the NWT stations over time include rainfall, snowfall, total precipitation, average snow depth, median snow depth and snow depth at the month's end, as well as the years and dates for the extremes of each parameter. Yearly averages for each station are also available (EC 2008a). There is no standard protocol for collecting precipitation data at the various stations across the NWT (C. Dixon, MSC, pers. comm. January 2008).

All-Weather Precipitation Gauge

Environment Canada 2007b

http://www.on.ec.gc.ca/skywatchers/ontario/wx_office_tour/compound/geonor_e.html

Automatic weather stations have the ability to measure both rainfall and snowfall. A description of the precipitation gauges used, including their most appropriate applications, is provided (EC 2007b).

Mackenzie Basin GEWEX Study on Precipitation

Louie 2003

Appendix IX

http://acsys.npolar.no/reports/archive/solidprecip/3_Ext_Abstracts/Louie_exabs.pdf

The recording of precipitation events in Canada has historically been erroneous, particularly for snowfall measurements which typically underestimate precipitation amounts. This is usually mostly due to wind affecting the trajectory of precipitation particles and the retention of a film of water in gauges after tipping (Metcalf *et al.* 1994 and 1997). The most common precipitation measurement equipment currently used in Canada are the Type B rain gauge, the Canadian Nipher Shielded Snow Gauge System and the ruler (metre-stick) as well as automatic weighted gauges. Examples of how these instrument measurements can be corrected for the NWT are provided in a report on the Mackenzie Basin (Louie 2003).

Rainfall

Rain Gauges

Environment Canada 2007c

http://www.on.ec.gc.ca/skywatchers/ontario/wx_office_tour/compound/rain_e.html

A description of commonly used manual and automatic rain gauges is provided on EC's Skywatcher website. Although it does not include specific sampling protocols, it provides general installation and operational information for the different gauges (EC 2007c).

Management of Agricultural Landscapes with Wetlands and Riparian Zones

Ducks Unlimited Canada and Agriculture and Agri-Food Canada 2006

Appendix IX

<http://friendsofoakhammockmarsh.com/consERVE/research/projects/climate/pdf/ducacaaf.pdf>

A field sampling manual produced by DUCS and Agriculture and Agri-Food Canada (ACAAF) in 2006 describes protocols for a series of wetland and riparian monitoring projects in agricultural landscapes within Canada. It gives the protocols for weather station sites where a Hobo rain gauge with a tipping bucket design is used as well as procedures for replacing the temperature and moisture sensors (DUC and ACAAf 2006).

Rainfall Measurement in Canada over Time

Metcalf *et al.* 1997

Appendix IX

<http://ams.allenpress.com/archive/1520-0442/10/1/pdf/i1520-0442-10-1-92.pdf>

In a report by Metcalf *et al.* (1997) methods of gathering rainfall data for all of Canada over the past century were considered. It was assessed that station rain gauges have been under-catching "true" precipitation amounts but that this bias has decreased over time with the installation of more accurate rain gauge equipment. The report describes methods for identifying and quantifying these systematic errors (e.g., adjustments due to wetting loss, wind-induced error and unrecorded trace precipitation) as well as methods for adjusting archived rainfall data.

Both of Metcalf *et al.*'s 1994 and 1997 reports provide protocols to adjust rainfall data gathered in the NWT and Canada in general to produce more reliable estimates of absolute rainfall amounts over time.

A Corrected Precipitation Archive for the Northwest Territories

Metcalf *et al.* 1994

Appendix IX

http://www.usask.ca/geography/MAGS/Data/Public_Data/precip_corr/pcpncor_e.htm

Methods of measuring rainfall have changed since the 1920's in the NWT. Metcalf *et al.* (1994) describe these changes and the protocols in place for measuring rainfall at Atmospheric Environment Service (AES) stations across the NWT as of 1994. Protocols are described for both the use of the old style of rain gauge as well as the new style. General methods for installing and recording data from these rain gauges are provided, as well as estimated error values for data measurements over time due to wetting losses (e.g., under-measurements due to water evaporation or water film remaining inside rain gauges). Correction methods for analyzing wetting losses and losses due to mixed precipitation measurements (i.e., for rain and snow) are provided.

International Tundra Experiment Manual

International Tundra Experiment 1996

Appendix II

<http://www.geog.ubc.ca/itex/library/manual/ITEXmanual.pdf>

The ITEX manual (1996) recommends using manual, non-recording rain gauges at its climate stations. The automated styles are susceptible to damage in the Arctic when precipitation freezes in them. It recommends that precipitation measurements for the past 24 hours be measured each morning and then the gauge reset.

Snowfall

Nipher Snow Gauge

Environment Canada 2007d

Appendix IX

http://www.on.ec.gc.ca/skywatchers/ontario/wx_office_tour/compound/snow_e.html

The Nipher Snow Gauge, commonly used in Canada and the NWT, is described, including brief protocols for its setup and operations (EC 2007d).

Ground Based Measurements of the Arctic Snow Cover

Woo 1997

Appendix IX

<http://www.socc.ca/snow/atlas/Woo.pdf>

Woo (1997) reviews snow measurement procedures carried out in northern Canada based on field work conducted in the Arctic. Detailed protocols for the different methods of measuring snow cover are described (see Section 3.2.1, Snow, for more details).

A Corrected Precipitation Archive for the Northwest Territories

Metcalf *et al.* 1994

Appendix IX

http://www.usask.ca/geography/MAGS/Data/Public_Data/precip_corr/pcpncor_e.htm

Metcalf *et al.*'s 1994 report considers snowfall data gathered in the NWT's AES stations. It describes methods for recording snowfall (e.g., different calibrations on measuring rulers, how to record observations) as well general information about calculating water equivalents from fresh snowfall. Snow gauges are described and their accuracy considered. Wetting loss potentials are described for the gauges as are methods for correcting inaccurate measurements due to errors in recording trace snowfall events. The report also describes how to correct data records for mean snowfall densities reported in five different regions of the NWT (i.e., the High Arctic, NWT barrens [east and west of longitude 110], the Mackenzie Delta area and the Mackenzie Norman Wells / Great Slave Lake area) as well as one area previously located within the NWT (i.e., Baffin Island).

Note - Section 3.2 of this report (*Snow, Permafrost and Ground Ice*) provides additional information on snow monitoring protocols.

3.9.7 Lightning

The Canadian Lightning Detection Network

Network Pinpointing Lightning Strikes

The Science & the Environment Bulletin 2000

1) http://www.ec.gc.ca/science/sandesept00/article6_e.html (description);

Lightning Hot Spots in Canada

Environment Canada 2003

2) http://www.msc-smc.ec.gc.ca/education/lightning/hot_e.html (map);

The Canadian Lightning Detection Network

Dockendorff and Spring 2005

Appendix IX

3) [http://www.wmo.ch/pages/prog/www/IMOP/publications/IOM-82-TECO_2005/Papers/1\(04\)_Canada_2_Dockendorff.pdf](http://www.wmo.ch/pages/prog/www/IMOP/publications/IOM-82-TECO_2005/Papers/1(04)_Canada_2_Dockendorff.pdf); and

Lightning

Vaisala 2007

4) <http://www.vaisala.com/weather/applications/severeweather/lightning>

1 and 2) Lightning strikes are monitored by the Canadian Lightning Detection Network (CLDN) through ground-based sensors operating on a continuous basis to detect lightning discharged to the ground. Of the more than 80 lightning sensors established by the CLDN in the country, few exist above the treeline, but a review of a lightning strike intensity map indicates that lightning is comparatively rare in the NWT, with the northern half of the territory not even shown on the map (EC 2003; The Science & the Environment Bulletin 2000).

3) The CLDN stations in the NWT are located in Fort Smith, Yellowknife and Fort Simpson (CIMP 2007). The network has a detection efficiency of 85-90% and a median spatial accuracy of approximately 500m (CIMP 2007). Protocols related to performance measurement and network management for CLDN information is provided by Dockendorff and Spring (2005).

4) The lightning sensors used for the CLDN (as well as the US National Lightning Detection Network; US NLDN) are produced by Vaisala (2007). Detailed protocols for the installation and operation of one popular sensor, the Vaisala Thunderstorm Local Lightning Sensor TSS928, can be found at the link above. All lightning activities recorded at the CLDN sites are transmitted to Vaisala's Tucson Operations for recording and analysis together with the US NLDN information.

Fourteen lightning detection stations in the NWT are monitored by the GNWT from May through September (CIMP 2007). Information gathered from these and other sources has indicated that lightning strike intensity can be high in the NWT, particularly during the summer months. Lightning intensity is largely dependent on topography and local moisture sources and strikes are a common source of forest fires in the NWT (Kochtubajda *et al.* 2006). Information on the type of specific lightning sensors used in the GNWT system or lightning-related protocols used in the NWT is not readily available.

3.9.8 Ice Phenology

Refer to Section 3.1.3, Ice Phenology, for a detailed description of ice phenology monitoring studies and protocols.

3.10 Air Quality

3.10.1 Introduction to Air Quality

For the purpose of this report, air quality monitoring involves the measurements of indicators for air pollution and contamination, such as nitrogen oxides (NO_x), sulphur dioxide (SO₂), particulate matter (PM, PM₁₀), total suspended particulates (TSP), fine particulate matter (PM_{2.5}), coarse particulate matter (PM_{2.5}- PM₁₀), carbon monoxide (CO), volatile organic compounds (VOC's), ground level ozone (O₃), hydrogen sulphide (H₂S) and others. Most federal monitoring networks across Canada are managed by EC, but several monitoring stations are operated by the GNWT as well (ENR 2005).

There are many organizations and agencies that monitor air quality in the NWT. Each has its own set of protocols; some protocols are used by more than one agency. However, the way in which the data is collected (i.e., through automated or manned stations) can be different at each monitoring site. Automated monitoring stations are the most common method to collect air quality data in the NWT. Additionally, each air pollutant has a different interval for which it is monitored, with some components being more closely monitored than others.

Today, air quality is being monitored rigorously by various agencies because there is more of a perceived need for it now than there was in the past. Since monitoring started in the urban areas of Canada, some of the air quality monitoring programs are fairly new to the NWT and may still have errors that need to be corrected in the future.

This section is organized so that information for monitoring air quality within the NWT is presented first, followed by descriptions of monitoring protocols used across Canada and in other provinces. Further information is provided in Appendix X (Table X-1).

3.10.2 Monitoring in the Northwest Territories

Snap Lake Mine Air Quality and Emissions Management Plan

De Beers Canada Mining Inc. 2007

[http://www.slema.ca/documents/De%20Beers/2007/Air%20Quality%20and%20Emissions%20Management%20Plan%20October%202007%20\(PDF\).pdf](http://www.slema.ca/documents/De%20Beers/2007/Air%20Quality%20and%20Emissions%20Management%20Plan%20October%202007%20(PDF).pdf)

De Beers' *Emissions Monitoring Program* includes three methods used to estimate project emissions (De Beers Canada Mining Inc. [De Beers] 2007):

- mass balance;
- published / calculated emission factors; and
- source stack testing.

The first method uses a breakdown of the total amount of component parts that are used by the industry and assumes their ultimate release. Total chemical emissions will

be the same as total chemical use. Supplier documentation is used to confirm chemical content.

The second method attempts to estimate the emissions produced by using an industry factor. Industry factors are available for different industry types and are calculated based on source tests. Level of source activity can be used with the industry factor to arrive at an approximation of contaminant output.

A stack test is a source test that directly measures the amount of specific contaminants present in stack exhaust gas.

De Beers uses different methods to calculate different contaminants' emission. Levels of SO₂ are calculated using the mass balance approach. The amounts of released NO_x, particulates, and greenhouse gases such as CO₂, methane (CH₄) and nitrous oxide (N₂O) are estimated using the emission factor method. Factors and calculations for specific compounds are found in the *Air Quality and Emissions Management Plan*. Dioxins, furans, and mercury emissions are found using source stack testing.

National Air Pollution Surveillance Network

Department of Environment and Natural Resources 2005

<http://lisin.rwed-hq.gov.nt.ca/NWTAQ/effects.aspx>; and

<http://lisin.rwed-hq.gov.nt.ca/NWTAQ/NetworkSummary.aspx>

Quality Assurance and Control Guidelines

National Air Pollution Surveillance Network 2004

Appendix X

<http://www.etc-cte.ec.gc.ca/publications/naps/NAPSQAQC.pdf>

The National Air Pollution Surveillance Network (NAPS) was established in 1970 and is a joint venture between the federal, provincial, territorial and some regional governments across Canada. The main goal of this monitoring program is to ensure long term data collection is standardized throughout Canada and is designed to protect human health and the environment. In 2004, a *Memorandum of Understanding* was signed which formalized the responsibilities of each federal, provincial and territory jurisdiction (NAPS 2004).

The only NAPS station in the NWT is located in Yellowknife and is operated in partnership with ENR. The station was established in 1974. The other stations operated by ENR are located in Inuvik, Fort Liard and Norman Wells; these have been recent monitoring additions, all established within the last five years (ENR 2005). In 2003 and 2004 there was also a spring-summer sampling in Fort Simpson conducted by ENR to monitor TSP concentrations by sampling every six days for 24 hr (ENR 2005). Since NAPS developed such comprehensive air quality protocols and the Yellowknife station participates in the program, ENR also adheres to these standards at its other stations. The territorial stations were set up to monitor the possible associations between amplified development and increased emissions and their affect on air quality in different areas.

Ground level ozone (O₃)

Four stations in the NWT monitor O₃ concentrations (i.e., at Yellowknife, Inuvik, Fort Liard and Norman Wells) (ENR 2005; NAPS 2004). O₃ is registered by a continuous O₃ analyzer that detects the concentrations of O₃ in the surrounding environment. The results are sent to ENR headquarters in Yellowknife via telephone lines and the government's intranet. O₃ is detected primarily by UV absorption and has a minimum detection range of 0.002 parts per million (ppm) (NAPS 2004)

Sulphur Dioxide (SO₂)

SO₂ is continuously monitored in the NWT. In Yellowknife this has occurred since 1992, while the other stations participated within the last five years (ENR 2005). SO₂ is generated through the emissions of burning fossil fuels. Additionally, metal ore smelting can also be a large contributor. Monitoring is conducted primarily by UV fluorescence analysis and has a minimum detection of 0.002 ppm. SO₂ is monitored at all four NWT sites (ENR 2005)

Nitrogen Oxides (NO_x)

NO_x's accumulate in the air through combustion of fuel from different sources (NAPS 2004). Commercial, industrial, residential heating or vehicle use all contribute to this contamination. The NO_x of highest concern is nitrogen dioxide (NO₂), because of associated health concerns, although all possible NO_x's are monitored continuously. Especially during times of the highest winter inversions, NO_x levels are high. The NWT stations except Ford Liard monitor all nitrogen oxides; Fort Liard only monitors NO₂ (ENR 2005).

Carbon Monoxide (CO)

Carbon monoxide (CO) is only monitored at Yellowknife station. It is analyzed by using infrared gas filtration correlations and has a minimum detection limit of 0.1 ppm. This air pollutant is usually caused by the burning of various fuels (NAPS 2004)

Total Suspended Particulates (TSP) and Particulate Matter (PM)

In the NWT, different types of particulates are monitored at the different stations (ENR 2005). In Yellowknife, total suspended particulates (TSP), and fine and coarse particulates (PM_{2.5}, PM₁₀) are monitored. In the other three communities only fine particulates (PM_{2.5}) are monitored as these tend to be the most harmful type causing various types of heart and respiratory problems and diseases (ENR 2005)

Particulates are used to describe the mixture of airborne solid and liquid particles. TSP refers to particles in size from the smallest to the largest (dust) with PM_{2.5} referring to the smallest PM with a diameter less than 2.5 microns, and PM₁₀ particles with a diameter of less than 10 microns. TSP levels in Yellowknife are monitored on a predetermined 6 day schedule where TSP samples are collected over a 24 hr period using a High Volume Air Sampler. The sampler is able to draw a measured volume of

air into a filter to collect the PM. The filters are then sent to the NAPS lab in Ottawa for analysis (NAPS 2004).

There are two methods used for sampling PM₁₀ and PM_{2.5}. One uses a filter-based Partisol dichotomous sampler and the other uses a beta attenuation mass monitor (BAM). The Partisol is able to collect at the same time for both PM₁₀ and PM_{2.5}. The BAM method provides almost continuous samples on an hourly basis every day, while the Partisol samples every 6 days for a 24 hour period. Both filters require laboratory analysis to determine the particulate concentrations. The two methods work cooperatively in that the Partisol is able to detect metals as well as particulates and BAM can also identify PM. Thus they can overlap so that no parameter is missed. An hourly sample is also obtainable. The overlap method is only done in Yellowknife; the other communities only use BAM to sample for PM (NAPS 2004; ENR 2005).

Arsenic

The Partisol filters used for TSP analysis can also be used to determine arsenic concentrations. This analysis is only conducted in Yellowknife, and not at the other NWT stations (ENR 2005; NAPS 2004).

The Canadian National Atmospheric Chemistry Database and Analysis System

Environment Canada 2002

http://www.msc-smc.ec.gc.ca/natchem/particles/n_capmon_e.html

CAPMoN is a non-urban air quality monitoring network operating under EC. It has passive sampling stations across Canada including one station in the NWT at Snare Lake. Each day, at 08:00 am, air and precipitation samples are collected using open-faced, 3-stage filter packs mounted at a height of 10 m above ground level. The filters are exposed for 24 hours at a flow rate of 25 l/min. Exposed filter samples are sent to the CAPMoN National Laboratory for analysis. The data are quality controlled and stored at AES in Downsview, Ontario.

The filter pack uses a Teflon filter to collect particulate species, a nylon filter for nitric acid and a base-impregnated cellulose (Whatman) filter for SO₂. The Teflon filter samples are analyzed for ions of sulphite (SO₄⁻), nitrate (NO₃⁻), ammonium (NH₄⁺), chlorine (Cl⁻), sodium (Na⁺), calcium (Ca⁺⁺), magnesium (Mg⁺⁺) and potassium (K⁺). The nylon filter sample is analyzed for SO₄⁼ and NO₃⁻. The Whatman filter is analyzed for SO₄⁼, NO₃⁻. The NO₃⁻ in the nylon filter extract is interpreted HNO₃. The sum of SO₄⁼ in the nylon and cellulose filter extracts is interpreted as SO₂ gas.

3.10.3 Monitoring in Canada

Canadian Tundra Ecosystem Carbon Study

Trent University 2005

Appendix X

http://www.trentu.ca/academic/bluelab/research_daringlake.html

In summers of 2002 to 2006 a short term particulate study was conducted at Daring Lake, NWT. Monitoring conducted for PM_{2.5} used a battery-operated mini Partisol

particulate sampler and a solar panel. These were set up to gather information on background concentrations of particulates in barren lands under the Canadian Tundra Ecosystem Carbon Study (CTECS) (Trent University 2005). The objective was to assess carbon dioxide (CO₂) sinks and sources in representative tundra ecosystems, determine seasonal and annual variations in CO₂ exchanges, and examine biological influences on carbon exchange in those ecosystems.

Canadian Air and Precipitation Monitoring Network

Canadian Air and Precipitation Monitoring Network 2002
http://www.msc-smc.ec.gc.ca/capmon/index_e.cfm

The Canadian Air and Precipitation Monitoring Network (CAPMoN) is managed by EC and in consultation with provinces and territories (CAPMoN 2002). In 1989, ENR and the NTPC started to collect rain and snow samples on a daily basis to monitor primarily acid precipitation and smog. The samples are sent to Toronto to the CAPMoN laboratory (operated by EC) for analysis. The samples are analyzed for pH and inorganic ions within the precipitation such as nitric acid (HNO₃) and ammonia (NH₃) (CAPMoN 2002). The site is located at Snare Rapids approximately 150 km northwest of Yellowknife.

Canadian Atmospheric Mercury Measurement Network

Canadian Atmospheric Mercury Measurement Network 2002
Appendix X
http://www.msc.ec.gc.ca/arqp/camnet_e.cfm

The Canadian Atmospheric Mercury Measurement Network (CAMNet) is managed by EC to monitor the spatial and temporal variations in gaseous mercury, mercury in precipitation and the relative contributions of mercury depositions. Currently the only station in Canada's north is located in Alert, Nunavut (CAMNet 2002). CAMNet is part of EC MSC's Air Quality Processes Research Division (ARQP) where the environmental concentrations of contaminants are monitored. ARQP conducts research into the environmental processes responsible for chemicals changing over time and space in response to different human activities and / or environmental occurrences. CAMNet is also a part of Northern Contaminants Program (NCP) of INAC which monitors contaminants of air quality in the north.

The CORE Network Database

CORE Network 2002
Appendix X
http://www.msc.ec.gc.ca/natchem/core/index_e.html
http://www.msc-smc.ec.gc.ca/natchem/core/measurement_e.html

The CORE Network Database (CORE is not an acronym) is managed by EC. The network takes measurements of greenhouse gases, smog-related gases, aerosols, O₃, VOCs, aldehydes, precipitation, temperature, relative humidity, and PM(2.5, 10) (CORE Network 2002). These substances are monitored in response to the common knowledge that human activities are having an impact on the environment, more specifically the chemical compositions and radiation balance of the atmosphere (CORE Network 2002). Currently, the only station in the north that monitors all of these parameters as part of the CORE Network is located in Alert, Nunavut. The MSC

has identified the combination of these parameters to be of interest when observing changes in air quality or general climate (CORE Network 2002).

Alberta

Alberta Source Emission Monitoring

Alberta Environment 2007

<http://environment.alberta.ca/616.html>

Alberta Environment (2007) recognizes two types of in-stack source emissions monitoring: short-term and continuous. Periodic, short-term in-stack monitoring must be in accordance with the *Alberta Stack Sampling Code* and continuous emissions in-stack monitoring must be in accordance with the *Alberta Continuous Emission Monitoring System Code*.

Particulate Matter

Clean Air Strategic Alliance 2006

http://www.casadata.org/pollutants/part_matter.asp

The Clean Air Strategic Alliance (CASA) is an Alberta organization that represents industry, government and non-government organizations and researches and promotes strategies to assess and improve air quality.

H₂S is measured by pulsed fluorescence. First, all SO₂ in the air sample is eliminated. The H₂S in the sample is then converted to SO₂. The sample is then drawn through a sample chamber and irradiated with pulses of UV light. SO₂ in the sample is excited to a higher energy level and so when it returns to its previous state, light or fluorescence is released. The amount of fluorescence measured is proportional to the SO₂ (converted from H₂S or Total Reduced Sulphur) concentration (CASA 2006).

Particulate matter is monitored using the Tapered Element Oscillating Microbalance (TEOM). This machine aerodynamically separates particles of a specified diameter (e.g. 2.5 µm to find PM_{2.5} levels or 10 µm to find PM₁₀ levels) from an air sample. The air sample is filtered in a tapered element in the mass transducer which vibrates. As particles are deposited onto the filter the oscillating frequency changes in proportion to the amount of mass deposited. The sampler can separate the particles into fine particles (< 2.5 µm) and coarse particles (2.5 to 10 µm). Fine and coarse particles are collected by drawing a known volume of air through two individual pre-weighed filters for a 24-hour period. The total particulate concentration in the two size ranges may then be calculated for the 24-hour period (CASA 2006).

British Columbia

BC Water and Air Monitoring and Reporting

British Columbia Ministry of Water, Land and Air Protection 2003

http://www.env.gov.bc.ca/air/wamr/labsys/field_man_03.html

BC's Ministry of Water, Land and Air Protection (2003) has a manual that specifies field methods for emission monitoring. The *British Columbia Field Sampling Manual: For Continuous Monitoring and the Collection of Air, Air-Emission, Water, Wastewater,*

Soil, Sediment, and Biological Samples contains forms to standardize calibration procedures and data collection forms. It lays out guidelines for sampling procedures including specific considerations for in-stack sampling, high volume particulate sampling, and gaseous constant rate sampling. Some of these regulations are as simple as sample history data collection and specify that method, time, location, sampler, preservative agents, and storage conditions must be labelled on samples. The manual also mandates sampling program design considerations such as field and trip blanks, duplicate and split sample use.

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5 CLOSURE

We trust the above meets your present requirements. If you have any questions or require additional details, please contact the undersigned.

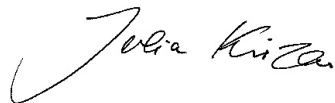
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Appendices