Wetlands of Canada and Climate Change:

Observation Strategy and Baseline Data

Report of a Workshop

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Executive Summary

In 1999, a workshop on the Canadian component of the Global Climate Observing System took place. One of the recommendations was to address the observation requirements and existing data for wetlands, in view of their ubiquity in Canada and their important role in the global biogeochemical cycles involving greenhouse gases. Following the approval of a proposal to the Climate Change Impact Fund, a workshop was organised for January, 2000. It was attended by scientists from government, universities and non-government agencies. The objectives of the workshop were to:

1. Confirm objectives of an observation system for wetlands;
2. Identify critical observations for such a system (satellite and in situ);
3. Review currently available data, gaps, and options for improvement of the observations;
4. Define requirements and specifications for a baseline wetland data set, review current status of the data set assembly, and agree on next steps to be taken to complete the data set;
5. Prepare workshop report.

Presentations and discussions at the workshop provided a clear understanding of the rationale for, and the configuration of, an observation system for Canada's wetlands from the perspective of climate and climate change. It identified the key policy issues with scientific implications; the information required to address these issues; the characteristics and configuration of an observing system to provide such information; and the status of the national wetland data base and the next steps in its improvement.

The following recommendations are made.

1. Observations of Canada's wetlands and an assessment of their roles in the climate system should be an integral part of a system designed to address these issues for all Canadian ecosystems, and should be implemented as part of the Canadian Climate Observing System. Its components should include observations, data processing and analysis, and scientific use of the resulting information.

2. Improvements in the observing capabilities for wetlands are essential and urgent. The three critical areas are:
   - (i) sites instrumented for flux measurements (minimum of 3 stationary and 2 roving; 1 stationary (0 roving) in place);
   - (ii) their long-term operation (0 in place);
   - (iii) a well-structured, ongoing acquisition and processing of satellite data (now a R&D effort).

3. Supporting research program is necessary that will encompass three areas:
   - (i) The development, validation and maintenance of accurate models used in combination with the input data
   - (ii) Development of methods for the extraction of wetland information from satellite data, with emphasis on new variables and taking advantage of the new sensors and data available over the next 5 years;
   - (iii) Use of the observations to obtain new insights into the functioning of the wetlands and to provide inputs to policy discussions regarding the response to climate change and the management of the terrestrial carbon cycle.

4. The national wetlands data base should be further developed by:

   - i. Completing the first version of a self-contained digital database by March 2001 and developing a plan for further improvements of this database.

ii. In consultation with the user groups, decide which existing regional data sets should be incorporated into the first version of the database and, if necessary, modify the database structure to accommodate these additional sources.

iii. Ensure peer review of the database before publication in 2001.

1. Introduction and objectives

In response to the climate change issues identified through various scientific (World Climate Conferences, International Geosphere-Biosphere Program, World Climate Research Program) and policy (UN framework Convention on Climate Change, the Kyoto Protocol, ..) mechanisms, international organisations have agreed to initiate global observing systems for climate (GCOS), terrestrial environment (GTOS), and oceans (GOOS). These observing systems defined requirements and approaches for systematic, long-term global observations and also proposed implementation steps that emphasise building on existing capabilities and the key roles of national institutions. In Canada, a workshop on climate-related observations held in February, 1999 produced a report 'PLAN FOR CANADIAN PARTICIPATION IN THE GLOBAL CLIMATE OBSERVING SYSTEM' (Canadian Institute for Climate Studies, 1999). This report laid out initial steps to be taken in the preparation of a Canadian component of GCOS in five areas: atmosphere, oceans, cryosphere, hydrology, and terrestrial ecosystems.

One of the recommended initial activities identified in the Plan was the development of an improved data base and a strategy for assessing the interactions between climate and wetlands. This recognised the special role wetlands have in the boreal zone because of the large areas, the very large carbon pool they contain, and the cross-over of both carbon and hydrological cycles in this ecosystem. From a policy perspective, questions surrounding the response of wetlands to climate change have an added significance as a result of the provisions of the Kyoto Protocol which makes provision for the recognition of wetlands as a component in the management of terrestrial carbon. A thorough knowledge of their characteristics and behaviour is essential for this purpose.

As a step towards realisation of the recommendation of the February, 1999 workshop, a proposal to the Climate Change Action Fund was submitted in the fall of 1999 and was accepted, thus paving the way for the present workshop. The objectives of the workshop were:

1. Confirm objectives of an observation system for wetlands;
2. Identify critical observations for such a system (satellite and in situ);
3. Review currently available data, gaps, and options for improvement of the observations;
4. Define requirements and specifications for a baseline wetland data set, review current status of the data set assembly, and agree on next steps to be taken to complete the data set;
5. Prepare workshop report.

The workshop took place on 24-25 January, 2000 in Ottawa, ON (see agenda in Appendix 2) and was attended by scientists from government, universities and non-government agencies (Appendix 1). This report contains the outcome of the presentations and discussions. Recommendations are made in two areas: an observing strategy for Canada's wetlands, and the preparation of a consistent national wetlands data base. The main report and Appendix 4 capture information produced during the workshop, while Appendix 5 contains the summaries of the presentations.

2. Wetland observing system

2.1 Needs and rationale: policy driven science

Wetlands cover approximately 14% of the Canadian landscape (National Wetlands Working Group, 1988). Because of the northern climate, over 90% of Canadian wetlands are also peatlands. By definition, these are wetlands that contain at least 40 cm of organic soil are represented by bogs and fens. Since the area of Canada covered by wetlands is so large, the remaining 10% of wetlands, represented by non-peat accumulating systems also represent a significant actual area, and in some regions (e.g. prairies or coastal regions - prairie pot holes and slat marshes, respectively) they are the dominant wetland form.

From a policy perspective, wetlands are recognised for their ecological, hydrological, social and educational functions. Assessment of these functions is an important factor that is now considered in land-use planning both in provincial and federal guidelines and legislation. The societal functions are important, however, it has been recently recognised that wetlands play a significant role in climate science. Of primary importance in this respect is the production and sequestration of greenhouse gases (GHGs), particularly carbon dioxide (CO_2) and methane (CH_4). In addition, wetlands are now considered a distinct land cover type in global data sets and as a result there is a significant international effort to classified and determine their extent (IGBP, 1996). The Climate Research Network of Canada has developed the parameterisation for the inclusion of wetlands in the Canadian Land Surface Scheme (CLASS), the land surface component of the newest Canadian general climate model (CCCma – GCMiii).

Wetlands play an important role in the global carbon cycle because they are mostly sinks for atmospheric CO_2. While some wetlands do have a very high primary productivity, the sink in northern wetlands (peatlands) results more from the inhibition of decomposition due the their generally water-logged condition which limits oxygen diffusion into the soil. There are no published studies on the annual carbon exchange between wetlands and the atmosphere based on continuous measurements. Results from measurements over taken over a few weeks to a single growing season (Burton et al., 1996; Jarvis et al., 1997; Lafleur et al., 1997; Neuman et al., 1994; Shurpali et al., 1995; Suyker et al., 1997; Waddington and Roulet, 1996) indicate that the annual sink for CO_2 in peatlands is relatively small compared to that of re-growing forest ecosystems (Baldocchi et al.,1996; Goulden et al., 1996; Kurz et al., 1995; Wofsy et al., 1993). However, in contrast to mature forests (100 to 200 years old) which are no longer sinks and may even be a small CO_2 source (Goulden et al., 1998) the wetland sink for CO_2 is maintained for thousands of years (Clymo, 1984, 1993; Hilbert et al., 2000; Tolonen and Turunen, 1995). As a result, some peat accumulating wetlands contain well over 200 kg C m^{-2} compared to 10 to 30 kg C m^{-2} stored in forest ecosystems. The total amount of carbon stored in peatlands is estimated to be between 200 and 450 Gt C (Gorham, 1991, 1995), while the global estimates for all soil carbon and living phytomass, including peatlands, is estimated to be 1,500 and 600 Gt C, respectively (Schimel, 1995).

The estimates of carbon fluxes and carbon storage in peatlands are ill-constrained because of the very poor coverage statistics used to extrapolate the point measurements and a lack of data on the carbon exchange from individual wetland types. In the latter case, there have been almost no studies, even short-term, on the carbon exchange in non-peat accumulating wetlands of Canada. Unlike peatlands, which fix in situ most of the carbon they store, non-peat accumulating wetlands obtain a large portion of the carbon storage from adjacent terrestrial or aquatic ecosystems. In the case of salt marshes, much of the carbon store occurs as a result of net sedimentation (Chmura, per. comm.)

The large carbon storage, combined with the persistently water logged conditions in wetlands, results in a significant proportion of decomposition occurring through anaerobic pathways which results in the production of CH_4. There have been many studies of the flux of CH_4 from wetlands (see Bartlett and Harriss, 1992; Moore and Roulet, 1995 for reviews), but the extrapolation of fluxes to regional and global estimates is hampered, as it is for CO2, by the lack of good wetlands coverage data. Based on the published literature, Canadian wetlands emit somewhere between 4 and 10 Tg CH_4 yr^{-1} (Moore and Roulet, 1995). This represents about 2% of all global sources, and 6% of natural sources of CH_4 (Fung et al., 1991).

To place the exchange of GHGs into a climate perspective it is common to use a 'warming' potential (Isaksen et al., 1992). The warming potential for each GHG is based on its radiative properties and atmospheric lifetime in reference to those for CO_2. Since the lifetimes of GHGs vary, the warming potential for each gas depends on the time period under consideration. Very few studies have examined the exchange of GHGs from wetlands using this approach. In an assessment of Canadian wetlands as terrestrial sinks in the context of the Kyoto Protocol, Roulet (in press) concluded that peatlands were small net sources in the short term (e.g., 10 years), but switched to small sinks in the long term (> 100 years). Again, it must be stressed that uncertainties in excess of 100% can be attributed to this analysis because it relies on flux estimates extrapolated with poor coverage statistics. With respect to the Kyoto Protocol on forest and other terrestrial sinks and based on the preliminary draft of the IPCC Special Committee report on Land Use Change and Forestry, Canada would not be able to produce a 'transparent', 'effective', and 'verifiable' accounting of its carbon stores or exchanges for wetlands because of the lack coverage statistics. This and the effect of land-use change (see below) are the key issues in wetland science related directly to climate change policy.

From the perspective of climate change and GHG exchanges, the critical issues are not natural contemporary sink/source strengths, but rather (i) how secure is the large present store of carbon in wetlands and (ii) how the contemporary stores and fluxes are modified by land-use changes. Predictions based on the current understanding are very uncertain, one of the weakest elements being the link between climate and the atmospheric - biospheric exchange of GHGs. Studies of the effect of climate change on ecosystems, particularly on wetlands and their biogeochemistry, are in their infancy. It is difficult to determine the sign of the change with confidence, i.e. switches from sinks to sources of visa-versa, let alone estimating the magnitude of possible changes (Moore et al., 1998). This is an extremely important issue if terrestrial sinks are to be used as offsets for fossil fuel emissions. In this case, there should be assurance that carbon sequestered in ecosystems would remain sequestered, baring natural disturbance. The second area of uncertainty concerns how the store and exchanges of GHGs changes with land-use conversion. Assumed stores of carbon could be lost with changes in land-use practices. Roulet (in press) concluded that almost all land-use changes that involve wetlands result in large emissions of CO_2, CH_4 and nitrous oxide (N_2O) (see Roulet, in press for review).

Based on the above, the key policy - related science questions for climate science and wetlands are:

1. What are the contemporary, 'baseline' stores and exchanges of GHGs in Canadian wetlands?;
2. How have the C storage changed since the industrialisation, and what is the predicted exchange rate under future climate change over next 10-50 years?;
3. What is the effect of disturbance on the store and exchanges of GHGs in Canadian wetlands?

These basic questions imply the need for the following information:

- The current distribution of wetlands and the associated stores and fluxes;
- The understanding of the relationships between wetlands and the atmosphere regarding the exchange of GHGs, at various time scales;
- The understanding of the relationships between GHG exchange and disturbance;
- Evolution of climate and disturbances, permitting to assess the magnitude and distribution of GHG exchanges from wetlands at seasonal to decadal time scales.

2.2 Information and observation requirements

The questions and rationale given in section 2.1 can be restated as a requirement:

To observe and understand the role of Canada's wetlands in the exchange of GHGs, energy, and water between the wetlands and the atmosphere.

The following additional constraints can be put on this requirement:
GHG exchange: the most important GHGs are CH_4, CO_2, and to a lesser degree N_2O.
Energy exchange: the most important aspects are energy albedo, sensible and latent heat.
Spatial extent: Canada's wetlands, with emphasis on peatlands
Time frame: since the current climate change issues are mostly linked to the build-up of GHGs in the atmosphere and given the ecological time scales of wetland functions, the last 100 years and the next 100 years are of greatest interest. In this time frame, the area and land use of wetlands also change and have an effect on the interaction between wetlands and the atmosphere.

Thus an observing and assessment system for Canada's wetlands should provide information:

- on fluxes of GHGs and energy between wetlands and the atmosphere;
- for the past (-100 years), present and future (next 100 years);
- for the landmass of Canada, but with an adequate spatial detail to resolve processes at the regional and landscape level as required;
- with a temporal resolution of years (for past or future) or seasons (present); and
- the distribution of, and land use changes in, these wetlands.

2.3 The observation concept

The main types of wetlands in Canada are bogs and fens, but other types also occur and are important regionally or locally (swamps, marshes, shallow water). Wetlands are involved in many environmental processes. They are also important from the economic and social viewpoints, especially in more southerly regions of Canada where they may serve as source of peat, for recreation, or locations for other human activities. Thus, in general, a range of information requirements exists regarding wetlands and it would be difficult to design an observing system that meets all such needs.

A major ecological characteristic of wetlands is spatial heterogeneity. Wetland characteristics vary at spatial scales of 10^1-10^4 metres due to topography, substrate, hydrological regime, composition, and other factors. Most wetlands are also in remote regions and not readily accessible. Given in addition the temporal heterogeneity (e.g., a short growing season) and spatial variability, it is not feasible to design an observing system based on in situ measurements. Instead, it must rely primarily on remote observations such as can be provided by satellites. Satellite data are most effectively used as inputs into models that describe the processes of GHG and energy exchange between wetlands and the atmosphere, in addition to their use a source of information on land cover and land use change. These mechanistic process models in turn require field observations to quantify model coefficients for specific ecosystem functions and to check the realism of the models and the derived outputs.

Thus, an effective observing system should consist of data from orbiting satellites, in situ measurements from selected sites, and a data processing and analysis mechanism which converts the raw data into information on GHG and energy fluxes between the wetlands and the atmosphere.

Once successfully implemented, the above approach should provide information on the current conditions. With appropriate modifications of the mechanistic models and given assumptions regarding future climate and land use, projections of the impact on wetlands and their changing role in the climate system could also be made. For the past, additional efforts are required to obtain data on climate and land use changes over the historical period.

2.4 Observation requirements

Since current techniques cannot directly measure the carbon balance of terrestrial ecosystems at regional or global scales, process-based models, which up-scale biogeochemical functionality derived from site measurements to the regional or global scales using remote sensed data and geo-referenced ground observations, offers the best alternative. For example, Cao et al. (1996) calculated global CH_4 emission (mostly originating in wetlands) at a resolution of 1o latitude and 1o longitude, based-on modified version of TEM (Terrestrial Ecosystem Model) which simulates terrestrial ecosystem production and carbon cycling (McGuire et al., 1992). The modifications to represent wetlands and anaerobic decomposition included (1) layered soil temperature and water table depth (WTD) as a function of daily climate drivers, (2) CH_4 production as a function of WTD and decomposition rate, (3) CH_4 gaseous transport pathways as a function of WTD and ecosystem type. The input data included climate, vegetation, soil, and wetland distribution. With similar modifications made for CASA (Carnegie-Ames-Stanford Approach) model, a terrestrial carbon cycling model, Potter (1997) tested a CH_4 emission against measurements at wetland sites near Fairbanks, Alaska, and found an overall consistency. Present models are not capable to produce satisfactory representation of the nitrogen cycle in wetlands, and the following discussion therefore concentrates primarily on carbon GHGs (CO_2 and CH_4).

In Canada, the development of similar process-based terrestrial carbon cycle models for national-scale applications has been underway in the last few years. For example, Chen et al. (2000a) developed an Integrated Terrestrial Ecosystem C-budget model (InTEC) to estimate the national carbon balance of Canada's forests, based on the Farquhar's leaf photosynthesis model, the forestry inventory-based age-biomass relationships, and the Century model. It was calibrated against site measurements (e.g., Goulden et al., 1998; Chen et al., 1999), and then scaled up to Canada using remotely sensed data and ground observations of disturbances (i.e., fire, insect-induced mortality, and harvest), planting, climate, atmospheric CO_2 concentration, and nitrogen deposit. The simulation results show that during 1895-1910, Canada's forests were small sources of 30+/-15 Tg C y^{-1} due to large disturbances (forest fire, insect-induced mortality, and harvest) in late 19th century (Chen et al., 2000b). The forests became large sinks of 170+/-85 Tg C y^{-1} during 1930-1970, due to forest regrowth in previously disturbed areas and growth stimulation by non-disturbance factors such as climate, atmospheric CO2 concentration, and N deposition. In recent decades (1980-1996), Canada's forests have been moderate sinks of 50 to 25 Tg C y^{-1}, as a result of a trade-off between the negative effects of increased disturbances and positive effects of non-disturbance factors. With appropriate modifications and calibration against site measurements (e.g., Roulet et al., 1997), the terrestrial C-budget model can also be used for estimating the national carbon balance of Canada's wetlands.

Based on the experience of Cao et al. (1996) and Potter (1997), carbon cycling in wetlands involves the following processes: net primary productivity (NPP); soil carbon decomposition; methane production, oxidation, and emission rates; soil water table and water cycle; soil temperature and energy balance/heat transfer; nitrogen cycle; and land use change, fire, and other disturbances. NPP is the difference between gross photosynthesis and vegetation autotrophic respiration. Some site measurements are available. To estimate spatial distributions of wetland NPP, models are needed. Current terrestrial NPP models include TEM, CASA, and the Boreal Ecosystem Productivity Simulator (BEPS). Input data into these models include wetland type, leaf area index, leaf nitrogen content, atmospheric CO_2 concentration, air temperature, radiation, precipitation, humidity, soil moisture (water table). The soil carbon decomposition rate is governed by soil moisture, water table, soil temperature, thaw table, and soil carbon content and quality (C/N ratio). Most models, such as TEM, CASA and InTEC, are similar to the well-tested Century model (Parton et al., 1987; Schimel et al., 1994). Essential modifications are usually made for specific ecosystems under study.

In wetland ecosystems, the influence of water table is critically important. CH_4 is produced in the anaerobic soil layers. In the transportation process from the anaerobic soil layers to the atmosphere (through diffusion, ebullition, and, plant vascular transport), CH_4 oxidation occurs in the layers above the water table or in the rhizosphere. The final CH_4 emission rate is the difference between CH_4 production and oxidation. Methane production rate is proportional to soil carbon decomposition rate, and is also affected by water table and soil temperature. Methane oxidation rate is a function of CH_4 production, water table, and physiological activities. Various existing hydrological models can estimate water content profile near the surface. The processes considered in most models are precipitation, evapotranspiration, run-on and runoff, and soil storage/water table change. The inputs needed for estimating evapotranspiration are similar to those required by NPP calculation. Topographic information (elevation, slope, orientation, etc.) is essential for the determination of run- on and runoff. In principle, soil temperature regimes and thaw depth can be determined from energy balance at the soil surface, and heat transfer equations with the soil (including water and organic layers). Data needed for these calculations include vegetation type (both overstory and understory), leaf area index, solar radiation, temperature, humidity, soil moisture/water table, soil thermal conductivity and diffusivity. Soil nitrogen availability affect NPP significantly. Soil nitrogen (N) availability is determined by net N mineralization, N fixation, and N deposition. The net N mineralization rate is in turn determined by soil temperature, soil moisture, and C/N ratio of soil carbon components.

The synthesised observation requirements are given in Table 1. Table 1 also contains information on the spatial and temporal resolution of these observations needed by the models, reasons for the individual variables, and an indication of measurement methods.

Table 1. Data need for achieving a credible national carbon balance of Canada's wetlands

	Variable	Reason [a]	Type [b]	Arial extent [c]	Temporal extent [d]	Method [e]
Atmosphere	Temperature	1	1	1	1	1 & 2
Atmosphere	Precipitation	1	1	1	1	1 & 2
Atmosphere	Solar radiation	1	1	1	1	1 & 2
Atmosphere	N deposition	1	1	1	1	1 & 2
Vegetation	Wetland class	2	2	1	2	3 & 4
Vegetation	Biomass	2	2	1	2	1 & 3
Vegetation	Leaf area index	2	2	1	2	1 & 3
Vegetation	Leaf N content	2	2	2	2	1 & 3
Vegetation	C/N ratio	2	2	2	2	1
Vegetation	Maximum stomatal conductance	2	2	2	2	1
Soil	Temperature	2	2	2	4	1
		1	1	1	1	2
Soil	Maximum thaw depth	2	2	2	4	1
		1	1	1	1	2
Soil	Thermal conductance	2	2	2	4	1 & 2
Soil	Thermal diffusivity	2	2	2	4	1 &2
Soil	Moisture	2	2	2	4	1
		1	1	1	1	2
Soil	Water table	2	2	2	4	1
		1	1	1	1	2
Soil	C content	2	2	1	3	4
Soil	C/N ratio	2	2	2	3	4
Soil	Texture	2	2	1	3	4
Ecosystem	CO_2 flux (net and components)	2	3	2	4	1
Ecosystem	CH_4 flux	2	3	2	4	1
Ecosystem	Evapotranspiration	2	3	2	4	1
Ecosystem	Peat carbon accumulation rate	2	3	2	3	1
Ecosystem	Topography	2	2	1	3	3 & 4
Ecosystem	Fire history	1	1	1	1	3 & 4
Ecosystem	Land use history	1	1	1	1	3 & 4

[a] 1, driver; and 2, calibration and validation.
[b] 1, external forcing variable; 2, internal status variable; and 3, output.
[c] 1, girded with a spatial resolution of 1 Km or better; and 2, each for a wetland class.
[d] 1, since industrialisation with desirable frequency; 2, periodical measurement once every 5-10 years; 3, one time measurement; and 4, multiple-year continuous measurement.
[e] 1, site measurement; 2, modelling; 3, remote sensing; and 4, survey or inventory.

2.5 Existing observations, quality, gaps, and needed improvements

In general, data needed for the monitoring and assessment of Canada's wetlands are sparse, not comprehensive, and not systematically organised. In this section, information on existing data is provided, based on the knowledge of workshop participants. The data are reviewed with reference to the observation requirements (section 2.4, Table 1). It is realised that this list is incomplete and other sources should be added. However, the provision of systematic coverage for all wetlands of Canada will take substantial additional effort.

2.5.1 Atmospheric data

For the use of process models, the driving variables (Table 1) must be available for all pixels/locations where the model is to be applied. This means that meteorological observations from existing meteorological stations are not sufficient for use in such models. The only viable alternative is to use data produced through assimilation of observations through atmospheric models (typically using four dimensional data assimilation, 4DDA). Several such data sets have been produced for extended periods in a consistent manner. Table 2 describes the main potential sources available for Canada.

Table 2. Reanalysed atmospheric data sets

Data set name	**Agency**	**Variables of interest***	**Spatial coverage**	**Spatial resolution**	**Temporal coverage**	**Temporal resolution**	**Availability**	**Contact or reference**	**Comments**
NCEP/NCAR Global Reanalysis Products	NCAR, USA	R, T, H, P	Global	Various with parameters, mostly in 2.5 degrees	1948-present	6 hours & daily	Yes	NCAR	
The NCEP MRF Global Flux Archive	NCAR, USA	R, T, H, P, Snow	Global	~0.9 degree	1991-present	6 hours & daily	Yes	NCAR	Radiation overestimated. Yearly precipitation values generally agree with ground measurements. Daily values may disagree at some locations.
ECMWF Re-analysis basic global surface data & supplementary fields	ECMWF, UK	T, H, W, IR, P	Global	2.5 degrees	1979-1993	6 hours & daily	Yes	ECMWF/NCAR	

ECMWF Re-analysis advanced global surface data & supplementary fields	ECMWF, UK	T, H, W, IR, P	Global	~1.125 degrees	1979-1993	6 hours & daily	Yes	ECMWF/NCAR	
ECMWF TOGA Global Sfc Anals & supplementary fields	ECMWF, UK	T, H, W, R	Global	~1.125 degrees	1985-present	6 hours & daily	Yes	ECMWF/NCAR	
CRU05	University of East Anglia, UK	T, H, Cloud cover	Global	~0.5 degree	1901-1996	Monthly	Yes	CCRS	
Canadian Climate Normal	Environment Canada, Canada	R, T, P, W, Soil temperature	Canada	Station Data	1961-1990 normal	Monthly	Yes	CCRS	

R = radiation; T= air temperature; H = humidity; P = precipitation; Snow = snowpack; IR = infrared radiation; W = wind

2.5.2 Satellite data

Satellite data obtained in the optical part of the electromagnetic spectrum (~0.4-2.4 micrometres) are most suitable for understanding ecosystem functioning and interactions with the atmosphere. Among these, coarse resolution data have been most widely used because of the daily revisit period and low cost. Table 3 shows the characteristics of the main optical data sets available for Canada at the present time. It is important to note that the recently launched NASA Terra satellite will provide much improved data of this type, over the next 5 years or longer, both spectrally (with many new bands) and spatially (resolution down to 250 m).

Table 3. Existing key satellite data sets for biospheric studies

Data set name and agency	Variables of interest* contains (with reference to Table of observation requirements	Spatial coverage (e.g. global, Canada, ..)	Spatial resolution (e.g., 1degree, 1km,..)	Temporal coverage (e.g., 100 years, 1951-present, ..)	Temporal resolution (e.g., 1 month, 6 hours,..)	Availability (Yes, No)	Contact	Reference documents

NOAA AVHRR Pathfinder	Radiance, temperature, VI	Global landmass	8 km	1983 to present	Daily and 10/11 day composite	Yes	NASA	James and Kalluri (1994)
NOAA AVHRR HRPT	Radiance, temperature, VI	Global landmass	1 km	1992-1993	10/11 day composite	Yes	NASA	Eidenshink and Faundeen (1994)
NOAA AVHRR HRPT	Normalised reflectance, surface temperature, VI, LAI, cloud/snow masks	Canada's landmass	1 km	1993 to present (April to October)	10/11 day composite	Yes	CCRS	Cihlar et al. (1997)
VEGETATION	Radiance, Normalised reflectance, VI, LAI, cloud/snow mask	Global	1 km	1998 to present	10/11 days)	Yes	CNES, CCRS	Saint (1992)
Landsat MSS	Radiance	Canada's landmass	80 m	1973 to present	16 days (nominal)	Yes	CCRS	
SAR (Radarsat, JERS-1)	Baskscatter	Canada's landmass	~15-30 m	Variable	Variable, no systematic acquisition	Yes	CSA, NASDA	
Landsat TM	Radiance, emission	Canada's landmass	30 m	1984-present	16 days (nominal)	Yes	CCRS	

* LAI = leaf area index; VI = vegetation index

2.5.3 In situ data

To effectively use models as important components of a national observation system to assess the exchange of carbon between the atmosphere and wetlands a number of variables are required (section 2.4). The databases associated with an observation system needs to include continuous observations from wetlands recognised as “typical” examples for each of the five wetland classes according to National Wetlands Working Group (1988). To ensure that appropriate consideration is given to the range of climatic and landscape variability experienced by wetlands across Canada, the database should also contain growing season observations from additional sites in each wetland class. These additional sites should be selected so that they span an appropriate range of conditions for each variable required by the models.

Data for inclusion in the wetlands database, and required by the models (Table 1), are separated into three groups. The first group contains variables that can be considered constant or change slowly with time and thus need to be determined once for each site. Table 4 lists sites in Canada known to the workshop participants where these variables were measured. The second group contains variables that change with time on an inter-annual basis and therefore require periodic measurement. Revisiting sites and determining the listed variables every ten years would be sufficient to update the model. Workshop participants identified those sites listed in Table 5 where such data are available. Finally, some variables require continuous measurement at representative sites. These data are needed so that the models represent well the dynamic exchange processes between wetlands and the atmosphere. Over the years, various data sets have been obtained in research projects involving Canadian wetlands. Table 6 contains those data sets that may be available as identified by the workshop participants and correspondents.

Although much research and monitoring effort has occurred over many parts of Canada in the past (Tables 4, 5, 6) most of the results are short term and focused on only certain variables. Only the bog site at Mer Bleue has been monitored on a continuous basis throughout an annual cycle (about 1.5 years as of January, 2000) for a sufficiently broad set of variables. Long-term continuous measurements are urgently needed from four more Canadian wetlands considered as “type” examples - fen, bog, marsh, swamp and shallow open water. Candidates for these sites with recent, and in some cases ongoing, research are listed in Table 6. As well, candidate sites exist among those listed in the table which could satisfy the requirement for climatic and landscape variability. Encouragement for more combined flux and energy balance studies is due both for continuous study sites and for climatic gradient sites (growing season). This will be costly to do on a strictly monitoring basis, but if the costs are shared by partnering research organisations and funding sources, research studies (*e.g.* biogeochemical process studies, biodiversity studies, impact studies, etc.) could be conducted simultaneously at monitoring sites to obvious mutual advantage. In addition, serious consideration should be given to the concept of roving flux towers, where operations are conducted for shorter time periods but the effective time period is lengthened through quantitative relationships with stationary towers (i.e., operating continuously).

Limited information was available at the workshop regarding land-use history. Since impacts on wetlands from human manipulation can be profound, it is important to catalogue land use history for sites selected to provide data to the wetlands data base. Fire history is also important and should be gleaned from those sites that are studied continuously, on a 10 year basis and on a one time - only basis. Both land use history and fire history are important for the modelling. Land use change is the primary consideration at sites where peat mining, peatland forestry and agricultural drainage have occurred. Restoration efforts in these areas provide opportunities to study management options that could maximise sequestration and thus are potentially relevant to the Kyoto Protocol, but they also provide opportunities for realising collateral benefits. Such benefits include habitat creation and conservation, control of water quantity and quality on a local scale and providing educational and participatory opportunities for the local populace.

Table 4. Catalogue of data sets for variables identified as required for measurement one time - only

Site Name, Location & (Area)	Data Set Name and/or Contact Agency	Variables of Interest	Temporal Coverage	Wetland Class	Data Available From?	Active Site 2000	Comments and References
Thompson, MB Beaver Pd. Fen Old Blk. Spruce Prince Albert, SK Fen	BOREAS Roulet (McGill) LaFleur (Trent) Wofsy (Harvard) BOREAS Verma		 1994 1994, 96 1994	 Marsh (?) Fen (?) Fen	From BORIS	 No No Yes No	
Western Boreal Alb & Man	Vitt & Halsey (Alberta)						Vitt *et al.* (1996) Halsey *et al.* (1997)
Ont. + others (?)	Warner (Waterloo)						
St. Denis WCA SK, Prairie Pds.	Robarts (Env Cda)	Sediment C, N Sed. Texture	1999 (10 pds)	Shallow Open Water	Robarts	Yes	
Beverly Swamp S. Ontario	Waddington (McMaster) Bourbonniere (Env Cda)	Peat C profile Peat Structure Bulk Density	1998 -	Swamp: cedar and hardwood	Waddington	Yes	
Luther Bog S. Ont.	Bourbonniere (Env Cda)	Peat C, N profiles, stratigraphy,	1983	Bog	Bourbonniere	No	McAndrew (1984)
Mackenzie Valley, NWT	Robinson and Kettles (GSC)	Peat C, accumulation rates, stratigraphy	1993-1997	Sev classes (permafrost & unfrozen)	Robinson and Kettles	moderately	Data from many sites are being compiled for an overall look at carbon stocks and accumulation rates. As yet unpublished.
Fort Simpson, NWT region	Robinson (GSC)	Peat C, N, Caccum, strat, struct, permaf cond, fire hist	1995-1997	Bog Fen Peat plateau	Robinson	Awaiting further funding	Robinson and Moore (1999)
Western Canada, Subarctic & Arctic Canada	Zoltai	Vegetation, Stratigraphy, accumulation	1970-1989	All	NRCan	No	Zoltai *et al.* (2000)
Eastern/Central Transect (US and Canada)	Gorham (UMinn)	Stratigraphy, accumulation	1980's	Bogs and Fens		No	
Barrington Cty, NS	Bourbonniere (Env Cda)	Peat C, N, bulk den stratigraphy	1985	Bog	Bourbonniere	No	

Table 5. Catalogue of data sets for variables identified as required for measurements every ten years

Site Name, Location & Area (km^2)	Data Set Name and/or Contact Agency	Variables of Interest	Temporal Coverage (resolution)	Wetland Class	Data Available From?	Active Site 2000	Comments and References
	LaFleur (Trent)	Max. Stomatal Cond.					
	LaFleur (Trent)	Max. Stomatal Cond.					
	Moore (McGill)	Leaf N, C/N					
	CFS (S. Campbell)	Tot. Biomass					
	Moore (McGill)	Leaf N, C/N					
North America	Vitt and Halsey (Alberta)	NPP & Biomass lit review by species, layer, and total	1950's to 1990's	All northern types excl. coastal	Vitt & Halsey (Alberta)	No	Campbell et al. 2000
Western Canada	Vitt (Alberta)	NPP	Various	peatlands	Vitt (Alberta)	No	Vitt 1990
Western Canada	Vitt (Alberta)	NPP, decomposition	Various	peatlands	Vitt (Alberta)	No	Rochefort et al. 1990

Table 6. Catalogue of data sets for variables identified as required to be measured continuously

Site Name, Location & (Area)	Data Set Name and/or Contact Agency	Variables of Interest	Temporal Coverage	Wetland Class	Data Available From?	Active Site 2000	Comments and References
BOREAS NSA Beaver Pd. 55.9N 98.0W (5 ha)	Roulet (McGill) Crill (UNH)	Tower: Chamber:	1994 Growing Season	Shallow Open Water	Yes in BORIS	No	Roulet *et al.* (1997) Moosavi and Crill (1997)
BOREAS NSA Fen 55.9N 98.4W (50 ha)	LaFleur (Trent)	Tower: AirT, Prec, Solar, SoilT, WT, CO2flx, Evap.	1994 (May-Sep, 1996 (May-Oct)	Fen	Yes in BORIS	No	LaFleur *et al.* (1997)
BOREAS NSA Uplands	Moore (McGill) Crill (UNH) Bubier (Mt. Holyoke))	Chamber:	1994-96 (?) Growing Seasons		Yes in BORIS	No	Savage *et al.* (1997)
BOREAS NSA Old Blk. Spruce	Wofsey (Harvard)	Tower: Chamber:	1994 - Pres. 1994			Yes No	 Moosavi and Crill (1997)
BOREAS SSA Fen	Verma	Tower:	1994 Growing Season	Fen	Yes in BORIS	No	Suyker et al. (1997)
Mer Bleue 45.4N, 75.5W (35 km2)	Roulet (McGill) Lafleur (Trent)	Tower: AirT, Prec, Solar, SoilT, WT, CO2flx, Evap, DOC	May 1998 - Present	Bog	In Future	Yes	
Beverly Swamp S. Ontario	Waddington (McMaster) Bourbonniere (Env Cda)	Chamber:CO_2 Resp, CH_4 AirT, Wtable, DOC, Peat Temp, Solar, Prec	May 1998 - Present	Swamp: cedar and hardwood	After QC and Compilation	Yes	Beverly Swamp is a CLASS site for energy budget and vegetation 1980-1998 (S.Munro - U of T) Above canopy tower on site Needs instrumentation
Churchill 58.4N, 93.5W (5km2)	Lafleur (Trent)	Tower: (EdCor): AirT, Prec, Solar, SoilT, WT, CO2flx, Evap	1997-1999 (Jun-Aug)	Open Conifer Forest	In Future	Yes	

Table 6: cont'd							
Site Name, Location & (Area)	Data Set Name and/or Contact Agency	Variables of Interest	Temporal Coverage	Wetland Class	Data Available From?	Active Site 2000	Comments and References
Churchill 56.8N, 93.5W (2km2)	Rouse (McMaster)	Tower: (profile/Bowen Ratio): AirT, Prec, Solar, SoilT, WT, CO2Flx, Evap	1994-1999 (Jun - Aug)	Fen			
ELA (NW Ont)	Roulet (McGill)			Bog		No	
NOWES (James Bay Lowlands)	King (Guelph) Whiting	Tower: Chamber:				No	JGR Special Issue
Schefferville	Fitzjarrald (SUNY)	Tower: CH_4		Fen		No	JGR
Various (Churchill, NWT, Kejimkujik)	Moore (McGill)	Chambers:	Growing Seasons	Bog Fen		No	
Copetown S. Ontario	Waddington (McMaster)	Chambers: NEE, AirT, PeatT, Solar, WT	Growing Seasons	Bog		No	Vegetation Surveys 1966, 1999
St. Denis WCA SK, Prairie Pds.	Robarts (EnvCda)	Hydrology Climatology	19?? -	Shallow Open Water	Robarts	Yes	

2.6 Summary and recommendations

Presentations and discussions at the workshop provided a clear understanding of the rationale for, and configuratoin of, an observation system for Canada's wetlands from the perspective of climate and climate change. In summary:

a) The main policy-related issues are (section 2.1):

- What are the contemporary, 'baseline' stores and exchanges of GHGs in Canadian wetlands?; and
- What is the effect of disturbance on the store and exchanges of GHGs in Canadian wetlands?

b) The following information is required:

- The current distribution of wetlands and the associated stores and fluxes;
- The understanding of the relationships between wetlands and the atmosphere regarding the exchange of GHGs, at various time scales;
- The understanding of the relationships between GHG exchange and disturbance;
- Evolution of climate and disturbances, permitting to assess the magnitude and distribution of GHG exchanges from wetlands at seasonal to decadal time scales.

c) An observing system for Canada's wetlands from the climate perspective should yield the following outputs :

- fluxes of GHGs and energy between wetlands and the atmosphere;
- for the past (-100 years), present and future (next 100 years);
- for the landmass of Canada, but with an adequate spatial detail to resolve processes at the regional and landscape level as required;
- with a temporal resolution of years (for past or future) or seasons (present); and
- the distribution of, and land use changes in, these wetlands.

The following recommendations are made.

2. Observations of Canada's wetlands and an assessment of their roles in the climate system should be an integral part of a system designed to address these issues for all Canadian ecosystems, and should be implemented as part of the Canadian Climate Observing System. Its components should include observations, data processing and analysis, and scientific use of the resulting information.

2. Improvements in the observing capabilities for wetlands are essential and urgent. The three critical areas are:
   - (iv) sites instrumented for flux measurements (minimum of 3 stationary and 2 roving; 1 stationary (0 roving) in place);
   - (v) their long-term operation (0 in place);
   - (vi) well-structured, ongoing acquisition and processing of satellite data (now a R&D effort).

3. Supporting research program is necessary that will encompass three areas:
   - (iv) The development, validation and maintenance of accurate models used in combination with the input data
   - (v) Development of methods for the extraction of wetland information from satellite data, with

emphasis on new variables and taking advantage of the new sensors and data available over the next 5 years;

(vi) Use of the observations to obtain new insights into the functioning of the wetlands and to provide inputs to policy discussions regarding the response to climate change and the management of the terrestrial carbon cycle.

3. Wetland database for Canada

3.1 Needs and rationale

To apply the observation and modelling concept described in section 2.3 to Canada's wetlands, a spatially explicit database of numerous wetland attributes is required (Table 1). Many of these cannot be acquired from existing or forthcoming satellite data. Some of them have been obtained through mapping programs and fieldwork in various regions of Canada, as well as nationally. The limitations of these data are lack of completeness, consistency in methods, timing and coverage. Nevertheless, they potentially provide a rich source of data for national wetland studies, and a potentially unique one since the cost of field operations makes the repeat of many of these programs fiscally prohibitive. Thus, it is critically important to make the best possible use of these existing data. In this respect, the first step is to assemble such data sets and reconcile differences among them, so that a homogenous, consistent national data set is available for use in wetland studies. Such a step is urgent, in view of the serious danger of data sets being lost, either physically or by losing the knowledge (through retirements, program reductions) that must accompany each data set for its proper use.

An effort has been underway by some researchers to compile a national data base of wetlands. To advance and strengthen this process, additional funding has been obtained from the Climate Change Action Fund. At this workshop, the goal of preparing the 'Wetlands of Canada Database' was discussed. This section deals with the content, status and next steps in the preparation of the data base. In section 3.2, the characteristics of the national data base for wetlands that have been agreed upon by the participants are described, and the status of the current preparation of the data base is given. The potentially important data sets that exist but have not yet been considered for incorporation are described in Appendix 4. Recommendations for the next steps are made in section 3.5.

3.2 Spatial database for Canada's wetlands

Workshop participants discussed the content and format of the Wetlands of Canada Database, and have agreed to accept the following approach (Figure 1).

The database will consist of four major tables: POLYGON, COMPONENT, LAYER and SITE tables.

The POLYGON, COMPONENT, and LAYER are composed of generalised wetland data and are associated with the polygons of a 1:1 million scale digital soil landscape database.

The SITE table includes seven sub-tables which contains the site specific wetland information. This site information forms the basis of the interpretive information found in the POLYGON, COMPONENT and LAYER tables. The site ID in the COMPONENT table provides the link to the SITE table. However, the SITE table also has important value in its own right as it provides quantitative information on wetland characteristics at specific sites.

Additional information on the database is provided in Appendix 3.

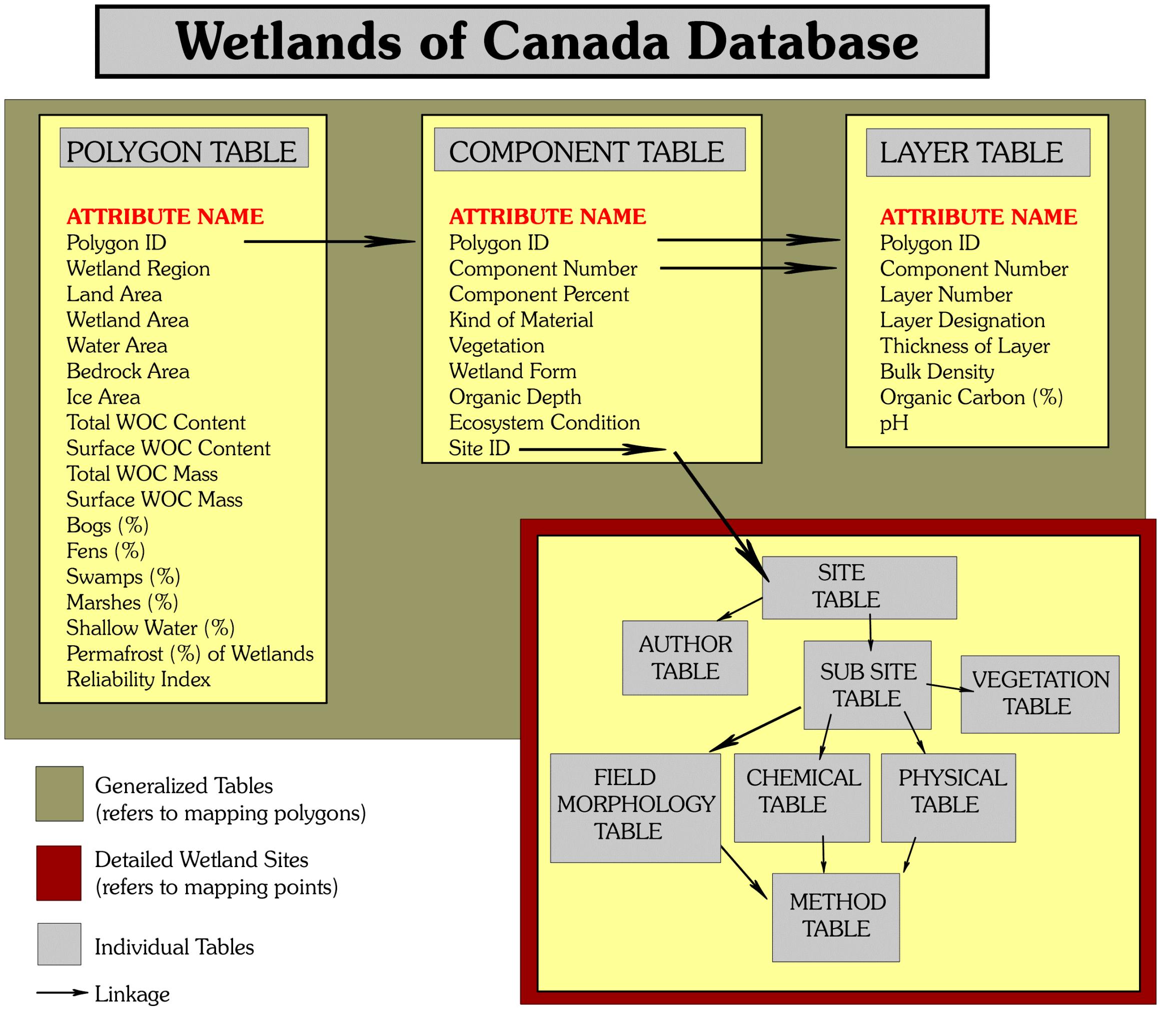

Figure 1. The structure of the Wetlands of Canada Database

3.3 Current status

The existing peatland database (Tarnocai *et al*., 1995) was upgraded by incorporating information from wetland studies carried out in the 1990s (Halsey and Vitt, 1997; Halsey *et al*., 1997; Vitt *et al*. 1995), some older studies (Geological Survey of Canada, B-series and Open File Maps. 1973–1980), and from an additional photo-interpretation, especially for the Northwest Territories and Nunavut. The resulting updated Canadian peatland database (Tarnocai *et al*., 2000) includes information on percent distribution and area of the four-peatland classes for each of the 6149 polygons in the database. The peatland data base will be incorporated into the Wetlands of Canada Database.

3.4 Additional data sources

A number of additional existing data sources that would add value to Wetlands of Canada Database were reviewed by the participants, and the characteristics of each of these are briefly described in Appendix 4. They are the main potential additions to the national database. However, the feasibility of incorporating them depends on the exact nomenclature and methodology used in the preparation of each data set, its current status and format, and the incremental costs involved in the incorporation. The recommendations in section 3.5 suggest a way forward.

3.5 Summary and Recommendations

A national database of wetlands that captures the present information on wetlands distribution and properties across the Canadian landmass is a pre-requisite for addressing the policy-driven questions regarding the role of wetlands in climate change. Compilation of such a data base from uncorrelated sources is a challenging but necessary task. It is made urgent by both the policy questions posed to the scientific community, but also by the danger of the loss of some data sets that were obtained at significant cost in the past.

Regarding the development of a national wetlands data base, workshop participants make the following recommendations:

1. Complete the first version of a self-contained digital database by March 2001 and develop a plan for further improvements of this database.
2. Set up a user group for the development of the database, in particular ensuring the representation of modellers.
3. Accept the modified database structure presented in section 3.2.
4. Analyse the characteristics of additional potential databases to determine the feasibility and problems involved in incorporating these data sources into the national database.
5. In consultation with the user groups, decide which regional data sets (Appendix 4) will be incorporated into the first version of the database and, if necessary, modify the database structure to accommodate these additional sources.
6. Ensure peer review of the database before publication in 2001.

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Appendix 1: Workshop Participants

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Wells, Doyle	Natural Resources Canada Canadian Forest Service	DWells@nrcan.gc.ca	P.O.Box 960 Corner Brook, NFLD, A2H 6J3

Appendix 2: Workshop Agenda

Venue: January 24–25, 2000
Harrison Hall, Room 177
601 Booth Street, Ottawa

SPONSOR: Canadian Climate Change Action Fund

ORGANIZING COMMITTEE: C. Tarnocai (AAFC), J. Cihlar (CCRS), N. Roulet (McGill U.), I. Kettles (GSC)

CONTACTS:
Workshop organisation: C. Tarnocai (tel. 613-759-1857), J. Cihlar (tel. 613-947-1265)
Local arrangements: L. Bloess (tel. 613-947-1256)

GOAL: To define an approach for observing and assessing Canadian wetlands and their role in the climate system, including completion of a baseline data set.

OBJECTIVES:

1. Confirm objectives of an observation system for wetlands
2. Identify critical observations (satellite and in situ)
3. Review currently available data, gaps, and options for improvement of the observations
4. Define requirements and specifications for a baseline wetland data set, review current status of the data set assembly, and agree on next steps to be taken to complete the data set
5. Prepare workshop report

AGENDA:

January 24

Chair: Charles Tarnocai

8:55–9:00	Charles Tarnocai – Welcome
9:00–9:20	Nigel Roulet and Josef Cihlar – Modelling and measuring the carbon and water dynamics of peatlands: critical climate change policy and science issues
9:20–9:50	Wenjun Chen and Nigel Roulet – Issues and questions regarding the role of wetlands from the perspective of climate change and Canadian Climate Observing System
9:50–10:15	Charles Tarnocai – Review of wetland databases, with emphasis on baseline data
10:15–10:30	Coffee
10:30–10:45	Inez Kettles and Steve Robinson – Distribution of peatlands in the Mackenzie Valley
10:45–11:00	Clay Rubec –Canadian wetland inventory: hard issues and realities
11:00–11:15	Hugo Veldhuis – Wetland data availability for Manitoba and northern Ontario
11:15–11:30	Linda Halsey and Dale Vitt – Wetland data available for continental western Canada
11:30–11:45	Doyle Wells and Bruce Pike– Wetland databases in Atlantic Provinces
11:45–12:00	Discussion
12:00–13:00	Lunch

Chair: Josef Cihlar

13:00–15:00	Charge and meeting of discussion groups *Discussion Group 1*: Objectives of wetland observation system (within the scope of a CCOS-Terre) *Discussion Group 2*: Definition of the wetland database: definition (content and format), current status, gaps/deficiencies and action plan
15:00–15:30	Coffee
15:30–16:30	Reports from discussion groups and discussion

January 25

Chair: Josef Cihlar

08:30–11:00 Charge and meeting of discussion groups (including coffee break)

Discussion Group 3: Design of the wetland observation and assessment component for the CCOS-Terre (also consider desirable and minimum observation sets, with spatial and temporal resolution and data transmission)

Discussion Group 4: Observation system for Canada's wetlands: implementation steps

11:00–12:00 Reports from discussion groups

12:00–12:45 Lunch

Chair: Charles Tarnocai

12:45-16:30 Concluding session and report writing

Appendix 3: Wetlands of Canada Database structure

(input to workshop discussions)

INTRODUCTION

The following is a proposal for the Wetlands of Canada Database. The following 3 tables, POLYGON, COMPONENT and LAYER, are composed of generalised wetland data and are associated with a polygons of a 1:1 million scale digital cover. The linework is composed of soil landscape polygons. In the COMPONENT table there is a link to the Wetland site information (described in the next section of this report). This site information forms the basis of the interpretive information found in the POLYGON, COMPONENT and LAYER tables.

Wetland Site Information

STRUCTURE

The following is the structure of the Site portion of the Wetlands of Canada Database. Eight modular, relational tables are presented, SITE, AUTHOR, SUBSITE, VEGETATION, FIELD MORPHOLOGY, CHEMICAL, PHYSICAL and METHOD. Each table is related to each other by a unique identification number SITE_ID which in turn is associated with a generalised wetland component listed in the COMPONENT table.

SITE TABLE (Describes General Wetland Site Area)

DESCRIPTION	***ITEM NAME***	***WIDTH***	***TYPE***	***N.DEC***
Site ID Number	SITE_ID	6	I	
Province	PROVINCE	2	C	-
Latitude - Degrees	LAT_DEG	2	I	-
Latitude - Minutes	LAT_MIN	2	I	-
Latitude - Seconds	LAT_SEC	2	I	-
Longitude - Degrees	LONG_DEG	2	I	-
Longitude - Minutes	LONG_MIN	2	I	-
Longitude - Seconds	LONG_SEC	2	I	-
Wetland Region	REGION	3	C	-
Wetland District	DISTRICT	3	C	-
Open Water (%)	OPENWATER	3	I	-
Climate Station	CLIM_STATION	16	C	-
Climate Relevance	CLIM_REL	5	C	-
Climate Mean Temp - Jan (^{O}C)	CLIM_JAN	5	N	1
Climate Mean Temp - July (^{O}C)	CLIM_JULY	5	N	1
Climate Precipitation (mm)	CLIM_PREC	4	I	-
Metadata - Collection Type 1	COLLECT1	10	C	-
Metadata - Collection Type 2	COLLECT2	10	C	-
Confidence level	CONFIDENCE	1	C	-
Author	AUTHOR	16	C	-
Transect ID	TRANSECT	6	I	-

AUTHOR TABLE (Describes Author Information - not completely defined)

DESCRIPTION	ITEM NAME	WIDTH	TYPE	N.DEC
Author	AUTHOR	16	C	-
Affiliation	AFFILIATION	40	C	-
City				
Province of Territory				
Phone				
etc.				

SUBSITE TABLE (Describes a specific Wetland Sub Site)

DESCRIPTION	ITEM NAME	WIDTH	TYPE	N.DEC
Site ID Number	SITE_ID	6	I	
Subsite Number	SUBSITE_ID	2	I	-
Date	YYYYMMDD	8	C	-
Site Position	POSITION	6	C	-
Wetland Class	CLASS	5	C	-
Wetland Form	FORM	17	C	-
Wetland Type	TYPE	13	C	-
Wetland Condition	CONDITION	10	C	-
Wetland Nutrient Status	NUTRIENT_STAT	4	C	-
Soil Classification	SOILCLASS	6	C	-
Soil Series Code	SOILCODE	3	C	-
Modifier	MODIFIER	3	C	-
Elevation (m)	ELEVATION	6	N	0
Slope (%)	SLOPE	4	N	1
Peat Depth (cm)	PEAT_DEPTH	6	I	-
Landform Height (cm)	LANDFORM_HEIGHT	6	I	-
Depth to Watertable (cm)	H2OTABLE_DEPTH	4	I	-
Active Layer Depth (cm)	ACTIVELYR_DEPTH	4	I	-
Vegetation Community 1	VEG_COMMUNITY1	16	C	-
Vegetation Community 2	VEG_COMMUNITY2	16	C	-
Vegetation - Area sampled (m^2)	VEG_AREA	3	I	-
Vegetation - Tree cover (%)	VEG_TREE	3	I	-
Vegetation - Shrub > 1.5 m (%)	VEG_SHRUBTALL	3	I	-
Vegetation - Shrub 0.5-1.5 m (%)	VEG_SHRUBMED	3	I	-
Vegetation - Shrub 0.1-0.5 m (%)	VEG_SHRUBSM	3	I	-
Vegetation - Shrub < 0.1 m (%)	VEG_SHRUBVSM	3	I	-
Vegetation - Herb cover (%)	VEG_HERB	3	I	-
Vegetation - Moss & Lichen (%)	VEG_MOSS	3	I	-
Vegetation - Submerge & Float (%)	VEG_SUB&FLOAT	3	I	-
Vegetation - Exposure	VEG_EXPOSURE	3	C	-
Vegetation - Homogeneity	VEG_HOMO	7	C	-
Old Identification Key	OLDKEY	13	C	-

VEGETATION TABLE (Describes Vegetation of Subsite)

DESCRIPTION	ITEM NAME	WIDTH	TYPE	N.DEC

Site ID Number	SITE_ID	6	I	-
Subsite Number	SUBSITE _ID	2	I	-
Vegetation Number	VEG_ID	2	I	-
Strata	STRATA	12	C	-
Genus	GENUS	16	C	-
Species	SPECIES	16	C	-
Ground Cover (%)	EXTENT	3	I	-
Height (m)	HEIGHT	2	I	-
Tree Diameter breast height (cm)	DIAMETER	3	I	-
Age (years)	AGE	3	I	-
Crown Class	CROWN	8	C	-

FIELD MORPHOLOGY TABLE (Morphological Characteristics)

DESCRIPTION	***ITEM NAME***	***WIDTH***	***TYPE***	***N.DEC***
Site ID Number	SITE_ID	6	I	-
Subsite Number	SUBSITE_ID	2	I	-
Layer Number	LAYERNO	2	I	-
Horizon Depth - Upper	UDEPTH	3	I	-
Horizon Depth - Lower	LDEPTH	3	I	-
Horizon Lithological Discontinuity	HOR_LD	1	C	-
Horizon Master Horizon	HOR_MAS	3	C	-
Horizon Suffixes	HOR_SUF	5	C	-
Horizon Modifier	HOR_MOD	1	C	-
Horizon Aspect	HOR_ASPECT	6	C	-
Munsell Colour	COLOR	12	C	-
Von Post Scale	VONPOST	2	C	-
pH - Field	PH	3	N	1
Rubbed Fibre - Field (%)	RFIBRE	2	I	-
Soil Temperature (^{0}C)	TEMP	2	I	-
Botanical Comp-Sphagnum (%)	SPHAGNUM	2	I	-
Botanical Comp-Sedge (%)	SEDGE	2	I	-
Botanical Comp-Moss (%)	MOSS	2	I	-
Botanical Comp-Br. Moss (%)	BR.MOSS	2	I	-
Botanical Comp-Wood (%)	WOOD	2	I	-
Botanical Comp-Other (%)	OTHER	2	I	-
Botanical Comp-Sed.peat (%)	SED.PEAT	2	I	-
Botanical Comp-Amorphous (%)	AMORPHOUS	2	I	-
Botanical Comp-Seeds (%)	SEEDS	2	I	-
Botanical Comp-Charcoal (%)	CHARCOAL	2	I	-
Wood-Diameter (cm)	WOOD_DIAM	2	I	-
Wood-Hardness	WOOD_HARD	5	C	-
Structure - Kind	STRUCT_KIND	8	C	-
Structure - Grade	STRUCT_GRADE	4	C	-
Horizon Boundary - Distinctness	HORBOUND_DISTNCT	7	C	-
Horizon Boundary - Form	HORBOUND_FORM	6	C	-
Consistence - Wet	CONSIS_WET	9	C	-
Consistence - Dry	CONSIS_DRY	7	C	-
Consistence - Moist	CONSIS_MST	8	C	-

Limnic Mat - Marl	LIMNIC_MARL	1	C	-
Limnic Mat - Coprogenous	LIMNIC_COPR	1	C	-
Limnic Mat - Diatomaceous	LIMNIC_DIAT	1	C	-
Root - Penetration Depth (cm)	ROOT_DEPTH	3	I	-
Root - Abundance	ROOT_ABUND	6	C	-
Root - Size	ROOT_SIZE	7	C	-
Root - Orientation	ROOT_ORIENT	10	C	-
Texture	TEXTURE	5	C	-
Volcanic Ash (%)	ASH_VOLCANIC	2	I	-
Wood Ash (%)	ASH_WOOD	2	I	-
Water (%)	H2O	2	I	-

CHEMICAL TABLE (Describes Chemical Characteristics)

DESCRIPTION	***ITEM NAME***	***WIDTH***	***TYPE***	***N.DEC***
Site ID Number	SITE_ID	6	I	-
Subsite Number	SUBSITE_ID	2	I	-
Layer Number	LAYERNO	2	I	-
Horizon Depth - Upper	UDEPTH	3	I	-
Horizon Depth - Lower	LDEPTH	3	I	-
pH - Value 1	PH1	4	N	1
pH - Value 2	PH2	4	N	1
Organic Carbon (%)	ORGCARB	5	N	2
Pyrophosphate Extractable C (%)	PYRO_XC	4	N	1
Total Nitrogen (%)	TOTAL_N	5	N	2
CEC-Total (me/100g)	CEC	5	N	1
CEC-Ca (me/100g)	CEC_BUFF_CA	5	N	1
CEC-Mg (me/100g)	CEC_BUFF_MG	4	N	1
CEC-Na (me/100g)	CEC_BUFF_NA	4	N	1
CEC-K (me/100g)	CEC_BUFF_K	4	N	1
CEC-Al (me/100g)	CEC_BUFF_Al	4	N	1
Electrical Conductivity(mmhos/cm)	EC	5	N	1
Carbon 14 - Value (Yrs. B.P.)	C14	5	I	-
Carbon 14 - Range (Yrs. B.P.)	C14_RANGE	3	I	-
Carbon 14 - Lab #	C14_LAB	12	C	-
Delta13 - Value (Yrs. B.P.)	D13	5	I	-
Delta13 - Interval (Yrs. B.P.)	D13_INT	3	I	-
Delta13 - Lab#	D13_LAB	12	C	-

PHYSICAL TABLE (Describes Physical Characteristics)

DESCRIPTION	***ITEM NAME***	***WIDTH***	***TYPE***	***N.DEC***
Site ID Number	SITE_ID	6	I	-
Subsite Number	SUBSITE_ID	2	I	-
Layer Number	LAYERNO	2	I	-
Horizon Depth - Upper	UDEPTH	3	I	-

Horizon Depth - Lower	LDEPTH	3	I	-
Rubbed Fibre (%)	RUB_FIBRE	3	I	-
Unrubbed Fibre (%)	UNRUB_FIBRE	3	I	-
Ash (%)	ASH	3	I	-
Part.Size-%samp-V.CoareSand(%)	PS_VCSAND	3	I	-
Part.Size-%samp-Coars Sand(%)	PS_CSAND	3	I	-
Part.Size-%samp-Med Sand(%)	PS_MSAND	3	I	-
Part.Size-%samp-Fine Sand(%)	PS_FSAND	3	I	-
Part.Size-%samp-V.Fine Snd(%)	PS_VFSAND	3	I	-
Part.Size-%samp-Total Sand(%)	PS_TSAND	3	I	-
Part.Size-%samp-Total Silt(%)	PS_TSILT	3	I	-
Part.Size-%samp-Total clay(%)	PS_TCLAY	3	I	-
Bulk Density (g/cc)	BD	5	N	2
Moisture status (%)	MOISTURE	5	N	1
Ice (%)	ICE	5	N	1

METHOD TABLE (Methodology of Analytical Data)

DESCRIPTION	***ITEM NAME***	***WIDTH***	***TYPE***	***N.DEC***
Site ID Number	SITE_ID	6	I	-
Property	PROPERTY	16	C	-
Method #1	METHOD1	16	C	-
Method #2	METHOD2	16	C	-
Method #3	METHOD3	16	C	-
Removal of carbonates	REMOVAL_CARB	3	C	-
Removal of organic matter	REMOVAL_ORG	3	C	-
Removal of iron	REMOVAL_FE	3	C	-
Removal of soluble salts	REMOVAL_SALT	3	C	-

Appendix 4: Additional data sources on Canada's wetlands

Note: This appendix contains information on existing wetland data sets as known to the workshop participants. It is not necessarily complete or accurate. The intent of including it in the workshop report was to provide a basis for further improvements of the national database, by making easier the location and identification of additional data sets.

1. Name, Agency:	NRVIS (Natural Resource Values Information System), OMNR
2. Level, Scale, Format:	10K, 20K vector
	(1) detailed, based on field work; classes: Wetland, permanent and Wetland, seasonal
	(2) based on interpretation of medium-scale aerial photography (OBM); classes: *Evaluated wetland* – Wetland, bog; Wetland, fen; Wetland, marsh; Wetland, open water; Wetland, swamp. *Unevaluated wetland*.
3. Area:	(1) OBM (Ontario Basic Mapping) coverage
	(2) Southern Ontario, up to the Shield; planned to have province-wide coverage
4. Status:	Mostly completed, still in progress
5. Recommend incorporation?	Yes
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Rob Parry, OMNR: tel. (705) 755-2158; fax. (705) 755-2168; e-mail rob.parry@mnr.gov.on.ca
9. Miscellaneous:	

1. Name, Agency:	Ontario Ministry of Natural Resources , Wildlife and Natural Heritage Science Section
2. Level, Scale, Format:	Point data, describing field stops in wetlands by listing location, date of visit, wetland type, sub-formation, physiognomic group, plant list with cover %, water temperature and depth, peat depth, substrate, depth of peat over ice. Verbal description of the wetland, links to small-scale aerial photography and 35 mm slides (ground and aerial) are also provided.
	The data is available in manuscript form and as an Access file, with references to scanned site descriptions in Word format.
3. Area:	Hudson Bay Lowlands, Ontario portion.
4. Status:	Approximately 129 bog sites, 109 fen sites and a few marsh sites were visited, the project is completed. The sites are well distributed in the HBL.
5. Recommend incorporation?	Yes
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Andrew Jano, Ontario Ministry of Natural Resources, Tel: 705 755-1552, Fax: 705 755-1569, e-mail: andrew.jano@mnr.gov.on.ca

9. Miscellaneous:	

1. Name, Agency:	Forest Resources Inventory, OMNR
2. Level, Scale, Format:	10k, 20k photointerpretation-based digital vector database; interpreted medium-scale B&W aerial photography (FRI); 3–17 classes (see Comments)
3. Area:	Managed forest area, approximately to 51.5° North
4. Status:	Completed
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Purpose: forest management, recently ELC classification is used 3 classes for all of the province except for most of the Northwest Region: Treed Muskeg, Open Muskeg, Alder; 17 classes for most of the Northwest Region (Ecosite-based classes): ES34 Treed Bog–Black Spruce, ES35 Poor Swamp–Black Spruce, E36 Intermediate Swamp–Black Spruce (Tamarack), ES37 Rich Swamp–Cedar (Other Conifer), ES38 Rich Swamp–Black Ash (Other Hardwood), ES39 Open Bog–, ES40 Treed Fen–Tamarack–Black Spruce, ES41 Open Poor Fen–Ericaceous Shrub, ES42 Open Moderately Rich Fen–, ES43 Open Extremely Rich Fen–Ericaceous Shrub, ES44 Thicket Swamp, ES45 Shore Fen, ES46 Meadow Marsh, ES47 Sheltered Marsh, ES48 Exposed Marsh, ES49 Open Water Marsh:Peat substrate, ES50 Open Water Marsh: Mineral substrate
8. Contact:	Joe Kapron, OMNR: tel. (705) 755-1616; fax. (705) 755-1640; e-mail joe.kapron@emnr.gov.on.ca
9. Miscellaneous:	

1. Name, Agency:	Ontario Great Lakes Basin Wetland Atlas; joint ownership Canadian Wildlife Service, Environment Canada and Ontario Ministry of Natural Resources and Natural Heritage Information Centre
2. Level, Scale, Format:	Point and polygon (NRVIS–link. See Rob Parry, OMNR re NRVIS) Evaluated wetlands in Ontario: 1983–1996 Vegetation communities within wetlands. Wetland type – swamp bog marsh fen 90/polygon open water Wetlands georeferenced VTM Site type + geomorphic
3. Area:	Great Lakes Basin
4. Status:	Point database – complete. Polygons NRVIS complete – in process of linking to point database Wetland Atlas
5. Recommend incorporation?	Yes
6. Needed for incorporation:	
7. Comments:	NRVIS may be more useful for this project.
8. Contact:	Laurie Maynard, Canadian Wildlife Service, Environment Canada Brian Potter, Ontario Ministry of Natural Resources, Peterborough

	Jarmo Jalava, Natural Heritage Information Centre, Peterborough
	NRVIS – Rob Parry, Ministry of Natural Resources, Peterborough
9. Miscellaneous:	

1. Name, Agency:	Lake Erie Basin Wetlands Database, Ontario Environment Canada
2. Level, Scale, Format:	Digital, 1:25 000
3. Area:	Lake Erie basin
4. Status:	Completed
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Wetlands derived from universal soil loss equation and topographic maps.
8. Contact:	
9. Miscellaneous:	

1. Name, Agency:	Provincial Landcover Database, OMNR
2. Level, Scale, Format:	LANDSAT-derived digital raster database; 10 wetland classes
3. Area:	All of Ontario
4. Status:	Completed
5. Recommend incorporation?	TBD
6. Needed for incorporation:	
7. Comments:	Source date: 1986–1992, mostly 1990–91. Disturbance updated: 1996.
8. Contact:	David White, OMNR (705) 755-1470
9. Miscellaneous:	

1. Name, Agency:	AAFC, BRC, Land Resource Unit
2. Level, Scale, Format:	Soil, soil–landscape maps, reports, data. Scale varying from 1:250 000 to 1:20 000; also includes biophysical maps.
3. Area:	Most of the south and central Manitoba
4. Status:	Most of the area is completed. However, in the central part some maps are draft or data only.
5. Recommend incorporation?	Y
6. Needed for incorporation:	The maps need to be digitised. Information needs to be decoded before it can be used
7. Comments:	Most of this information has already been used to generate SLC, which in turn provided data for the Canada map. There is still other data in other agencies that are not represented here. Most of this data is in papers, theses
8. Contact:	Hugo Veldhuis: (204) 474-6124; (204) 474-7633; veldhuish@em.agr.ca

9. Miscellaneous:	

1. Name, Agency:	Ontario Great Lakes Basin Wetland Atlas; joint ownership Canadian Wildlife Service, Environment Canada and Ontario Ministry of Natural Resources and Natural Heritage Information Centre
2. Level, Scale, Format:	Point and polygon (NRVIS–link. See Rob Parry MNR re NRVIS)
	Evaluated wetlands in Ontario: 1983–1996
	Vegetation communities within wetlands.
	Wetland type – swamp bog marsh fen 90/polygon open water
	Wetlands geo-referenced VTM
	Site type + geomorphic
3. Area:	Great Lakes Basin
4. Status:	Point database – complete.
	Polygons NRVIS complete – in process of linking to point database Wetland Atlas
5. Recommend incorporation?	? Yes
6. Needed for incorporation:	
7. Comments:	NRVIS may be more useful for this project.
8. Contact:	Laurie Maynard, Canadian Wildlife Service, Environment Canada
	Brian Potter, Ontario Ministry of Natural Resources, Peterborough
	Jarmo Jalava, Natural Heritage Information Centre, Peterborough
	NRVIS – Rob Parry, Ministry of Natural Resources, Peterborough
9. Miscellaneous:	

1. Name, Agency:	Lake Erie Basin Wetlands Database, Ontario Environment Canada
2. Level, Scale, Format:	Digital, 1:25 000
3. Area:	Lake Erie basin
4. Status:	Completed
5. Recommend incorporation?	TBD
6. Needed for incorporation:	
7. Comments:	Wetlands derived from universal soil loss equation and topographic maps.
8. Contact:	
9. Miscellaneous:	

1. Name, Agency:	Wetland Trends Through Time Database, Laurie Maynard, Canadian Wildlife Service, Environment Canada
2. Level, Scale, Format:	Digital, 1:10 000, ArcInfo, source data air photos – various scales, predominantly 1:8 000
3. Area:	Site Database Ontario; 8 coastal Great Lakes wetlands, 7 years mapping for each

	site 1954–1995, and adjacent land use.
4. Status:	8 sites completed
5. Recommend incorporation?	TBD
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Laurie Maynard , Environment Canada: tel. (519) 826-2093; fax. (519) 826-2113; e-mail laurie.maynard@ec.gc.ca
9. Miscellaneous:	

1. Name, Agency:	Québec Ministry of Natural Resources
2. Level, Scale, Format:	Raster, DBase format
3. Area:	Southern Québec
4. Status:	Completed 1990
5. Recommend incorporation?	Yes
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Pierre Bureau
9. Miscellaneous:	

1. Name, Agency:	EC–CWS
2. Level, Scale, Format:	Digital–vector (1 x 1 km^2)
	Land-use (26 classes) pixel = 30 x 30 m
3. Area:	Southern Québec – St. Lawrence Valley
4. Status:	Completed
5. Recommend incorporation?	Yes
6. Needed for incorporation:	Database transfer +
7. Comments:	
8. Contact:	luc.belanger@ec.gc.ca
9. Miscellaneous:	

1. Name, Agency:	Ducks Unlimited Canada
2. Level, Scale, Format:	Digital raster and tabular data derived from LANDSAT TM imagery (1984–96)
	Wetland cover classes: open water, deep marsh, shallow march, wet meadow
	Tabular data by basin, quarter section, township, 1:50k map sheet
3. Area:	150 million acres in Agro Prairie Canada (53 LANDSAT Scenes)
4. Status:	Completed, some slivers of missing data
5. Recommend incorporation?	

6. Needed for incorporation:	Wetland data to be aggregated to SLC polygons – done Some updating of databases by recent acquisitions – about 4 scenes
7. Comments:	Database was already acquired by Polestar Geomatics for Environment Canada as part of “National Wetland Dataset.”
8. Contact:	Brian Kazmerik: (204) 467-3247, b_kazmeik@ducks.ca
9. Miscellaneous:	

1. Name, Agency:	Linda Halsey, University of Alberta
2. Level, Scale, Format:	1:250 000 scale wetland maps for west Canada
3. Area:	Alberta–Grassland region, Saskatchewan–Grassland region, Manitoba (all)
4. Status:	Completed
5. Recommend incorporation?	Yes [within 1 year]
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Linda Halsey: lhalsey@gpu.srv.ualberta.ca
9. Miscellaneous:	

1. Name, Agency:	Marty Siltanen, Northern Forestry Center
2. Level, Scale, Format:	dBase
3. Area:	Western Canada
4. Status:	in press @ March [2000]
5. Recommend incorporation?	Yes [within 1 year]
6. Needed for incorporation:	
7. Comments:	Site specific data that closely follows your site specific data
8. Contact:	Marty Siltanen: msiltane@NRCan.gc.ca
9. Reference:	Zoltai, S.C., Siltanen, R.M., and Johnson, J.D., 2000. A wetland data base for the western boreal, subarctic, and arctic regions of Canada. Natural Resource Canada, Northern Forestry Canada. Edmonton, AB. Information report NOR–X–368.

1. Name, Agency:	Québec Wetland Database, Québec Ministry of Natural Resources
2. Level, Scale, Format:	Ground and aerial photos
3. Area:	Peatland (>40 ha located in southern Québec)
4. Status:	1990
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	size, peat depth, etc.
8. Contact:	Pierre Bureau (to be confirmed)

9. Miscellaneous:

1. Name, Agency:	Québec Wetland Database, Environment Canada, St. Lawrence Centre
2. Level, Scale, Format:	Airborne satellite images, 1989
3. Area:	Wetland (St. Lawrence River)
4. Status:	1989–1990
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Type, acreage, plants, etc.
8. Contact:	Guy Letourneau: guy.letourneau@ec.gc.ca
9. Miscellaneous:	

1. Name, Agency:	Québec Wetland Database, Environment Canada, Canadian Wildlife Service
2. Level, Scale, Format:	LANDSAT–TM satellite images, 1989–93–94
3. Area:	Wetland (St. Lawrence Valley – southern Québec),
4. Status:	1993–94
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	type, size and other land-use type
8. Contact:	Luc Belanger: luc.belanger@ec.gc.ca
9. Miscellaneous:	

1. Name, Agency:	Québec Wetland Database, EC, DU, WHC, U de Mtl, etc.
2. Level, Scale, Format:	RADARSAT satellite images, 1999
3. Area:	Wetland (St. Lawrence Valley – southern Québec)
4. Status:	In progress
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	type, size (in development)
8. Contact:	Luc Belanger: luc.belanger@ec.gc.ca
9. Miscellaneous:	

1. Name, Agency:	Québec Wetland Database
2. Level, Scale, Format:	
3. Area:	
4. Status:	
5. Recommend incorporation?	

6. Needed for incorporation:	
7. Comments:	+ many, many studies by HQ [Hydro Québec] and consultants for the James Bay–Hudson coastal areas. – in addition to the previous four entries
8. Contact:	
9. Miscellaneous:	

1. Name, Agency:	Peatland Index, DNRE, New Brunswick
2. Level, Scale, Format:	Scale of digital base maps: 1:250 000; format unknown
3. Area:	New Brunswick
4. Status:	Available in digital form
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Pascal Giassom: (506) 453-2440
9. Miscellaneous:	

1. Name, Agency:	Wetland Inventory, DNRE, New Brunswick
2. Level, Scale, Format:	Scale of digital base maps: 1:10 000 and others (not specified); minimum mapping unit 0.25 ha; various aerial photography used; Arc/Info and Caris formats
3. Area:	New Brunswick
4. Status:	Ongoing; to be completed in the next few years
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Mapping simultaneous to Forest Inventory Mapping
8. Contact:	Jacques Thibault: (506) 547-7429
9. Miscellaneous:	

1. Name, Agency:	Peatland Inventory, Department of Natural Resources, Wildlife Division, NS
2. Level, Scale, Format:	Digital base maps: 1:250 000 scale; minimum mapping unit 25.0 ha (to be confirmed); Arc/Info format
3. Area:	Nova Scotia
4. Status:	Available in digital form
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Centroids linked to Wetland Inventory
8. Contact:	[None given]
9. Miscellaneous:	

1. Name, Agency:	Wetland Inventory, Department of Natural Resources, Wildlife Division, NS
2. Level, Scale, Format:	Digital base maps: 1:10 000 scale (NSTDB), MTM Projection, ATS77 Datum; minimum mapping unit 0.5 ha; 1:10 000 scale colour aerial photos used (various years 1988–1995)
3. Area:	Nova Scotia
4. Status:	Digitization completed for 14 counties (4 remaining); will be completed 2001/2002
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Integrated with Forestry, Cross-Linked with Sig. Habit., Cross-linked with Species Database
8. Contact:	Randy Milton: (902) 679-6224
9. Miscellaneous:	

1. Name, Agency:	Wetland Inventory, PEI
2. Level, Scale, Format:	Digital base maps: 1:10 000 scale; Caris, MapInfo formats; minimum mapping unit 1.0 ha; aerial photography used: 1:17 500 scale colour infrared (1990)
3. Area:	Prince Edward Island
4. Status:	Available in digital form
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Randy Dibble
9. Miscellaneous:	

1. Name, Agency:	Peatland Inventory, Department of Mines and Energy, Newfoundland
2. Level, Scale, Format:	Digital base maps: 1:12 500 scale; minimum mapping unit 1.0 ha; 1:12500 scale colour aerial photos used (to be confirmed)
3. Area:	Newfoundland
4. Status:	Building partnership, seeking funding
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	
8. Contact:	Fred Kirby
9. Miscellaneous:	

1. Name, Agency:	Forest Inventory, Department of For. Res. & Agrifoods, Newfoundland
2. Level, Scale, Format:	Digital base maps: 1:12 500 scale, MTM Projection, NAD27 Datum; minimum mapping unit 4.0 ha; 1:12 500 colour aerial photos used; Arc/Info format

3. Area:	Newfoundland
4. Status:	First round of inventory nearing completion
5. Recommend incorporation?	
6. Needed for incorporation:	
7. Comments:	Integrated in Forest Inventory
8. Contact:	[not given]
9. Miscellaneous:	

Appendix 5: Summaries of presentations

Issues and questions regarding the role of wetlands from the perspective of climate change and Canadian Climate Observing System

Wenjun Chen[1], Josef Cihlar[1] and Nigel Roulet[2]
1) Canada Centre for Remote Sensing, Ottawa, ON
2) McGill University, Montreal, QUE

The Sinks Table Options Paper (Climate Change Secretariat, 2000, http://www.nccp.ca) stated that "the current state of scientific knowledge does not warrant pushing for a inclusion of wetlands as a sinks, according to the Table". Indeed, there is no national carbon (C) balance estimations for Canada's wetlands at present. In comparison, more information is available for Canada's agricultural lands and forests in terms of national C balance (Smith et al., 1997; Kurz et al., 1995; Chen et al., 2000 a&b) and corresponding management options (Smith et al., 1997; Chen et al., 2000c). Therefore, there is an urgent need to provide credible estimates of national C balance of Canada's wetlands.

Since current techniques can not directly measure the C balance of terrestrial ecosystems at regional or global scales, process-based models, which up-scale biogeochemical functionality derived from site measurements to the regional or global scales using remote sensed data and geo-referenced ground observations, offers the best alternative. For example, Cao et al. (1996) calculated global CH_4 emission at a resolution of 1^o latitude and 1^o longitude, based-on modified version of TEM (Terrestrial Ecosystem Model) which simulates terrestrial ecosystem production and C cycling (McGuire et al., 1992). The modifications to represent wetlands and anaerobic decomposition included (1) layered soil temperature and water table depth (WTD) as a function of daily climate drivers, (2) CH_4 production as a function of WTD and decomposition rate, (3) CH_4 gaseous transport pathways as a function of WTD and ecosystem type. The input data included climate, vegetation, soil, and wetland distribution. With similar modifications made for CASA (Carnegie-Ames-Stanford Approach) model, a terrestrial C cycling model, Potter (1997) tested a CH_4 emission against measurements at wetland sites near Fairbanks, Alaska, and found an overall consistency.

In Canada, we also have leading-edge research on terrestrial C cycle modelling at the national scale. For example, Chen et al. (2000a) developed an Integrated Terrestrial Ecosystem C-budget model (InTEC) to estimate the national C balance of Canada's forests, based on the Farquhar's leaf photosynthesis model, the forestry inventory-based age-biomass relationships, and the Century model. It was calibrated against site measurements (e.g., Goulden et al., 1998; Chen et al., 1999), and then up-scaled to national scale using remote sensed data and ground measured data of disturbances (i.e., fire, insect-induced mortality, and harvest), planting, climate, atmospheric CO_2 concentration, and nitrogen deposit. The simulation results show that during 1895-1910, Canada's forests were small sources of 30 ± 15 Tg C y^{-1} due to large disturbances (forest fire, insect-induced mortality, and harvest) in late 19th century. The forests became large sinks of 170 ± 85 Tg C y^{-1} during 1930-1970, due to forest regrowth in previously disturbed areas and growth stimulation by non-disturbance factors such as climate, atmospheric CO_2 concentration, and N deposition. In recent decades (1980-1996), Canada's forests have been moderate sinks of 50 ± 25 Tg C y^{-1}, as a result of a trade-off between the negative effects of increased disturbances and positive effects of non-disturbance factors. With appropriate modifications and calibration against site measurements (e.g., Roulet et al., 1997), the terrestrial C-budget model can be used for estimating the national C balance of Canada's wetlands.

Based on the experiences of Cao et al. (1996) and Potter (1997), the C cycling of wetlands involve the following processes: net primary productivity (NPP), soil carbon decomposition rate, methane production, oxidation, and emission rates, soil water table and water cycle, soil temperature and energy balance/heat transfer, nitrogen cycle, and land use change, fire, and others. NPP is the difference between gross photosynthesis and vegetation autotrophic respiration. Some site measurements are available. To estimate spatial distributions of wetland NPP, models are needed. Current terrestrial NPP models include TEM, CASA, and BEPS. Input data into these models include wetland type, leaf area index, leaf nitrogen content, atmospheric CO_2 concentration, air temperature, radiation, precipitation, humidity, soil moisture (water table). The soil carbon decomposition rate is determined by soil moisture, water table, soil temperature, thaw table, and soil carbon content and quality (C/N ratio). Most models, such as TEM, CASA, InTEC, are similar to the well-tested Century model. Essential modifications are usually made for specific ecosystems under study. For wetland ecosystems, the influence of water table is critically important.

Methane is produced in the anaerobic soil layers. In the transportation process from the anaerobic soil layers to the atmosphere (through diffusion, ebullition, and, plant vascular transport), CH_4 oxidation occurs in the above-water-table layers or in the rhizosphere. The final methane emission rate is the difference between CH_4 production and oxidation. Methane production rate is proportional to soil carbon decomposition rate, and is also affected by water table and soil temperature. Methane oxidation rate is a function of CH_4 production, water table, and physiological activities. Various hydrological cycle models exist. The processes considered in most models are precipitation, evapotranspiration, run-on and runoff, and soil storage/water table change. The inputs needed for estimating evapotranspiration are similar to that required by NPP calculation. Topography (elevation, slope, orientation, etc.) data are essential for the determination of run- on and runoff. In principle, soil temperature regimes and thaw depth can be determined from energy balance at the soil surface, and heat transfer equations with the soil (including water and organic layers). Data needed for these determinations include vegetation type (both overstory and understory), leaf area index, solar radiation, temperature, humidity, soil moisture/water table, soil thermal conductivity and diffusivity. Soil nitrogen availability affect NPP significantly. Soil N availability is determined by net N mineralization, N fixation, and N deposition. The net N mineralization rate is in turn determined by soil temperature, soil moisture, and C/N ratio of soil C components. The

References

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Potter, C.S., 1997. An ecosystem simulation model for methane production and emission from wetlands, *Global Biogeochem. Cycles*, *11*, 495-506.

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Review of wetland databases with emphasis on baseline data

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Background

One of the earliest wetland databases was developed in 1983. This computerised database, which included information (morphological descriptions, analytical data from core samples and vegetation data) for more than 200 wetland sites, was based on the uniform wetland data collected for the Canadian Wetland Registry. Although this data was unfortunately discarded during downsizing of the federal government, hard copies of the original data forms do still exist.

Baseline data for representative wetland sites were also collected during preparation of the Wetlands of Canada book (National Wetlands Working Group, 1988). These data, although not in database form, were incorporated in this publication.

Some wetland-related data (for wet organic and mineral soils) are stored in the Soil Landscapes of Canada (SLC) database (Centre for Land and Biological Resources Research, 1996), a spatial database that covers all of Canada. Wetland data, especially peat core data, are also stored in regional soil and peatland databases held by various federal and provincial resource units.

Recent wetland databases

The Canadian Soil Carbon Database (Tarnocai and Lacelle, 1996a) developed during the early 1990s includes wetland-related information. This database contains such data as peat depth, carbon percent and bulk densities of various peat layers. Since the depth criterion in the definitions of peatlands (>40 cm peat) and organic soils are the same, carbon contents and carbon masses calculated for organic soils also yield information for peatlands. These calculations indicate that Canadian peatlands contain approximately 154 Gt of carbon, or 59% of the total organic carbon stored in all Canadian soils (Tables 1 and 2). The calculated carbon data were also spatially linked to the SLC polygons in order to generate various map products (Tarnocai and Lacelle, 1996b).

The Geological Survey of Canada initiated a project aimed at developing a peatland database for Canada and generating a peatland distribution map for the entire country (Tarnocai et al., 1995). The primary purpose for creating this database was to evaluate the effect of climate change on peat deposits.

This peatland database (Tarnocai et al., 1995) was upgraded by utilising wetland studies carried out in the 1990s (Halsey and Vitt, 1997; Halsey et al., 1997; Vitt et al. 1995), some older studies (Geological Survey of Canada, B-series and Open File Maps. 1973–1980) and additional photo-interpretation, especially for the Northwest Territories and Nunavut. The resulting updated Canadian Peatland Database (Tarnocai et al., 2000) includes information on percent distribution and area of the four wetland classes for each of the 6149 polygons in the database.

Future plans: the Canadian Wetland Database

The "Wetland Distribution and Carbon Cycle" project, supported by the Climate Change Action Fund, will provide an opportunity to develop a more robust wetland database for Canada. The Canadian Wetland Database will include both spatial information and additional data such as depth of peat, carbon percent and bulk density. This information is needed to calculate carbon concentrations and masses for various wetland classes and ecoclimatic regions. In addition, a site-specific (point) database associated with the Canadian Wetland Database will also be developed. This site-specific database will contain data from core samples that have been collected from wetlands.

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Tarnocai, C., I.M. Kettles and B. Lacelle. 2000. Peatlands of Canada. Geological Survey of Canada, Ottawa, Open File 3834. (map)

Vitt, D.H., L.A. Halsey, M.N. Thormann and T. Martin. 1995. Peatland inventory of Alberta. Prepared for the Alberta Task Force and Alberta Environmental Protection Agency.

Table 1. Carbon masses in various ecolimatic provinces (Tarnocai and Lacelle, 1996a).

Ecoclimatic Province	Total Organic Soil Carbon Mass (Gt)		
	Unfrozen soils	Perennially frozen soils	All Canadian soils
Arctic	0	4.2	4.2
Subarctic	22.9	30.3	53.2
Boreal	76.5	12.5	89.0
Cordilleran	3.6	0.4	4.0
Temperate	3.2	0	3.2
Grasslands	0.1	0	0.1
TOTAL	106.3	47.4	153.7

1 Gt = 10^9 tonnes = 10^{12} kilograms = 10^{15} grams

Table 2. The area and the amounts of carbon stored in organic soils in the various provinces and territories (Tarnocai and Lacelle, 1996a).

Organic Soils	Soil Area (km^2)											
	B.C.	**Alta.**	**Sask.**	**Man.**	**Ont.**	**Que.**	**N.S.**	**N.B.**	**P.E.I.**	**Nfld.**	**Yukon**	**N.W.T.***	**Canada**
Unfrozen	46.0	122.2	63.0	82.1	280.3	107.4	5.7	3.4	0	58.5	1.1	25.9	795.6
Perennially frozen	14.6	28.3	1.0	108.1	67.1	7.1	0	0	0	0	8.4	208.0	442.6
All	60.6	150.5	64.0	190.2	347.4	114.5	5.7	3.4	0	58.5	9.5	233.9	1238.2

Organic Soils	Total Organic Carbon (Gt)											
	B.C.	**Alta.**	**Sask.**	**Man.**	**Ont.**	**Que.**	**N.S.**	**N.B.**	**P.E.I.**	**Nfld.**	**Yukon**	**N.W.T.***	**Canada**
Unfrozen	3.1	9.6	11.3	8.7	37.2	14.0	1.7	0.2	0	16.7	0.1	3.7	106.3
Perennially frozen	1.1	1.8	0.1	6.5	6.8	0.8	0	0	0	0	0.7	29.6	47.4
All	4.2	11.4	11.4	15.2	44.0	14.8	1.7	0.2	0	16.7	0.8	33.3	153.7

* Includes Nunavut

1 Gt = 10^9 tonnes = 10^{12} kilograms = 10^{15} grams

Peatland and Related Maps and Data Sets for the
Mackenzie Valley area, Northwest Territories, Canada

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The Mackenzie Valley is the lowland area that lies parallel to the Mackenzie River along its course from Great Slave Lake to the Beaufort Sea (Fig. 1). Except where the river flows between the Mackenzie and Franklin Mountains in its central section, the valley floor is broad and it rises gradually away from the Mackenzie River. Five wetland regions are represented - Low Arctic, High Subarctic, Low Subarctic, High Boreal, and Rocky Mountain (Fig. 1; National Wetlands Working Group, 1988). Although the river basin encompasses part of northern Alberta and northern Saskatchewan, this review is limited to the part of the valley between 60^o and 71^o N. The first part of this document describes the surficial materials and peatland mapping and climate change research efforts undertaken in the Mackenzie Valley. The second part provides reference to some site-specific studies, concerning palaeo-ecological reconstructions, morphology, and carbon storage in peatlands.

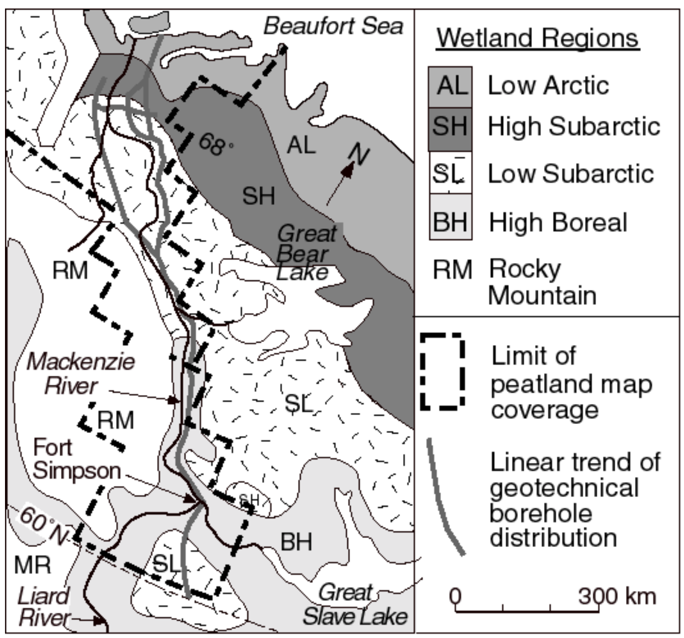

Figure 1. Map of the Mackenzie Valley region. Also shown are peatland coverage (Tarnocai and Kettles, in prep.), geotechnical borehole distribution (Lawrence and Proudfoot, 1976), and wetlands regions (National Wetlands Working Group, 1988).

Mapping Efforts

The first major surficial and soil mapping work was carried out in the early 1970's as part of the environmental assessment studies along the Mackenzie River corridor for the proposed Mackenzie Valley pipeline. A series of Geological Survey of Canada Open File and B-series maps (1: 125 000 or 1: 250 000 scale) (see references) were generated, on which major areas of organic terrain were delineated. In the early 1990's, another series of surficial maps for the northern part of the Mackenzie valley, based on a continuation of the pipeline work, were released. In addition, detailed work on peatlands, characterizing unfrozen and perennially frozen peat landforms, was also accomplished (Zoltai and Tarnocai, 1975; Zoltai et al., 1988a; 1988b; Tarnocai and Zoltai, 1988).

As part of the same pipeline assessment initiative, the Mackenzie Geotechnical Borehole Database (Lawrence and Proudfoot, 1976) was developed by Natural Resources Canada. The database contains geotechnical information for over 12 000 boreholes drilled along the Mackenzie Valley between 60°N and the Beaufort Sea (Fig. 1). Surface organic deposits with thicknesses of at least 0.46 m were recorded for 2708 holes, approximately 23% of the database.

Agriculture and Agri-Foods Canada generated soil and carbon storage data for peatlands and other components of the landscape as part of its Soil Landscape of Canada and Soil Carbon Storage databases (National Soil Database, 1996; Soil Carbon Data Base Working Group, 1993). These databases were based on satellite mosaic coverages backed up with information from the 1970's pipeline work.

Derived Peatland Coverages

None of the surficial materials mapping work undertaken in the Mackenzie Valley was directed specifically at peatlands. Hence, the available peatland coverages are based on information gleaned from surficial materials maps and the Soil Landscapes of Canada map and database.

Aylsworth and Kettles (in press) produced a peatland distribution map for the area between 60° and 68° N (1: 1000 000 scale), based on information from the 1970's and 1990's surficial materials maps. In this compilation, areas are delineated where peatlands make up 10% or more of the surficial cover. More recently, Tarnocai and Kettles (in preparation) generated another map and database (1: 250 000 scale) for the area between 60° and 72° N (see Figure 2). This compilation is based on the 1970's surficial maps and on some new air photo interpretation. The new database was used as baseline data to generate the Mackenzie Valley portion of the Peatlands of Canada map and database (1: 6 500 000 scale) (Tarnocai et al., 2000).

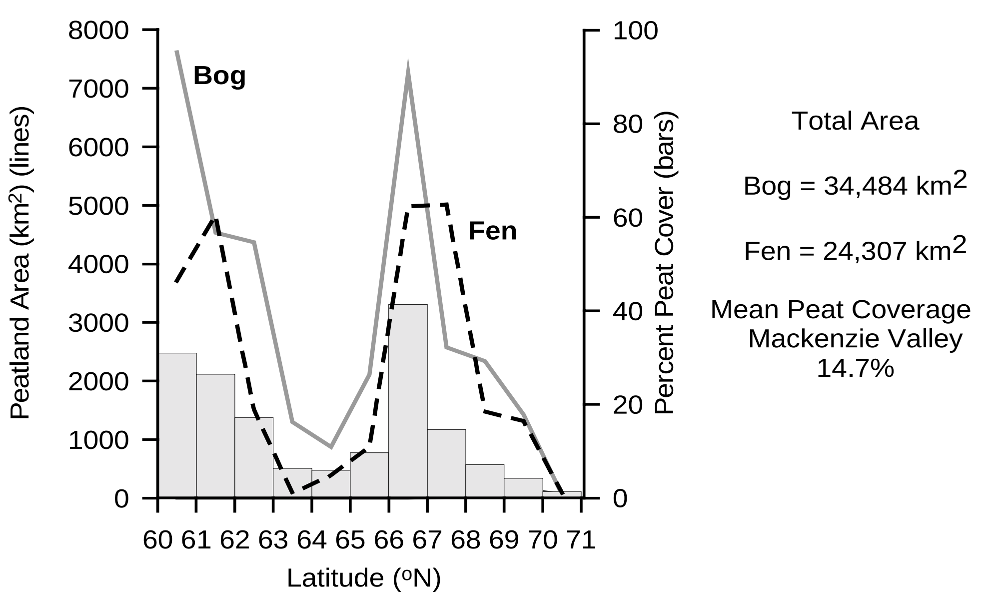

Figure 2. Distribution of bog and fen in the Mackenzie Valley. Data derived from Tarnocai et al., 2000.

A map of the distribution of organic soils over Canada (Tarnocai, 1998), including the Mackenzie Valley, was generated, based on the Agriculture and Agri-Food Canada Soil Carbon Database (Soil Carbon Database Working Group, 1993).

Other Mackenzie Valley Studies and Data Sets

The Mackenzie Basin Impact Study (MBIS) was a six-year collaborative effort, to assess the potential impact of climate change on the Mackenzie basin (Cohen, 1997). Many aspects of the landscape, including water, snow cover, permafrost, vegetation, wildlife, and human activities were considered. As part of this project, Nicholson et al. (1997) modelled the relationships between various climatic and environmental gradients that underlie the abundance and distribution of peatland bryophytes.

The Mackenzie Valley, with its extensive permafrost areas, was one of the three areas chosen in 1988 as the Geological Survey of Canada's Integrated Research Monitoring Areas (IRMA). The main objective was to address the relationship between climate, permafrost, and landscape-forming processes as a baseline for assessment of environmental change. Existing and new information on surficial materials, climate, past-climate indicators, permafrost, ground temperatures, landslides, and fluvial processes were synthesized and presented in a final report (Dyke and Brooks, in press). The Aylsworth and Kettles (in press) peatland distribution map forms part of this report.

More recently, the Geological Survey of Canada carried out peat coring and other detailed work (macrofossil analysis, ground penetrating radar, bulk density analysis, and radiocarbon dating) on samples from 14 peatlands between Inuvik and Fort Simpson. Trace and minor element data have been generated for more than 840 peat samples. The Geological Survey of Canada and Agriculture and Agri-Foods Canada have also been conducting ongoing soil and ground temperature monitoring at sites along the Zama-Norman Wells pipeline, some of which is documented in Dyke and Brooks (in press).

A number of post-graduate thesis projects have been carried out in the Mackenzie Valley. Chatwin (1981) examined permafrost aggradation and degradation in a subartic peatland near Fort Simpson. Paleoenvironmental reconstructions and carbon accumulation studies were undertaken in peatlands near Inuvik and Tuktoyaktuk (Vardy, 1997; Vardy et al., 1997). Liblik et al. (1997) measured methane emissions from different peatland forms near Fort Simpson. Robinson (in preparation) determined carbon accumulation in discontinuously frozen peatlands near Fort Simpson (Robinson and Moore, 1999). Efforts to summarize carbon and peat accumulation are ongoing for the Mackenzie Valley (Figure 3).

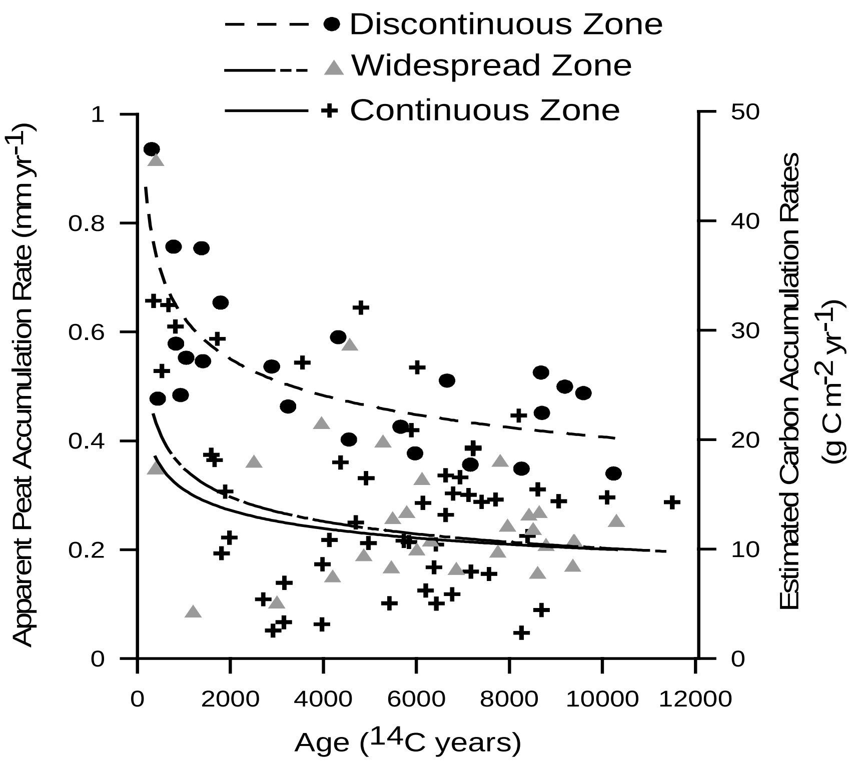

Figure 3. Vertical peat and carbon accumulation rates for the Mackenzie Valley (preliminary). Moderately good fit is found with the data from the discontinuous permafrost zone ($r^2 = 0.58$), and poor fit for both the widespread ($r^2 = 0.07$) and continuous zones ($r^2 = 0.08$). Carbon accumulation rates are estimated based upon assumed carbon content and bulk density values. The apparent recent rise in both vertical growth and carbon accumulation may be owing to the measurement of relatively fresh, undecomposed peat.

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Canadian wetland inventory: hard issues and realities

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Abstract

Canada is one of the few industrialised nations in the OECD with virtually no national capacity to track or report on the status of wetland resources. While such a program existed in the 1980-1985 period (i.e. the Canada Land Use Monitoring Program of Environment Canada), no federal agency now claims any mandate in this sector. It is easy to identify a forestry, water, oceans, or agricultural federal agency, but not so with wetlands. Even in the provinces, only Saskatchewan has a specific wetland department, the Saskatchewan Wetland Conservation Corporation (SWCC). Responsibility for wetlands is clearly defined by constitutional authorities for natural resources management. The federal government owns about 29% of Canada's wetlands, the rest are under the authority of provincial governments.

While the federal government, in cooperation with the National Wetlands Working Group, published a synthesis of then current inventory information with the book *Wetlands of Canada* in 1988, no national review of this kind has been published in the past 12 years. Since 1988 there have many new wetland inventories or synthesis studies, in some cases covering entire provinces (Nova Scotia, New Brunswick, Prince Edward Island, British Columbia, Alberta). Table 1 compares National Wetlands Working Group (1988) wetland distribution information province by province noting that the area of wetlands in some provinces is likely significantly greater than assessed in the 1988 overview. None of these new inventories use a standardized wetland classification system and continue with different mapping conventions and objectives. A revised Second Edition of *The Canadian Wetland Classification System* (National Wetlands Working Group) was published in 1997 but remains poorly accepted by any agency nationally.

It has been observed (not only in Canada but globally by Wetlands International and the Ramsar Convention) that wetland inventories have almost totally ignored the marine wetland components. When these are properly assessed and "mapped", we are now seeing very large increases in wetland area being reported. In Table 1 for example, the wetland area in Nova Scotia is 280% higher than reported by the National Wetlands Working Group in 1988, and in Prince Edward Island 800% higher. Surprisingly, the wetland area in New Brunswick is reported now as 24% less. In other provinces, increases from 5% to 40% are reported in comparison to the 1988 assessment. No new province-wide statistics are available from Ontario, Newfoundland and Labrador, Quebec and all three of the northern territories. As these provinces and territories account for about 60% of the national wetland distribution, there is quite a void of "new and improved" wetland information.

The Sustaining Wetlands Forum in 1990 recommended that Environment Canada lead development of a synthesis of known information on wetland inventory and reestablish a nationwide monitoring capability. With the creation of the North American Wetlands Conservation Council (Canada) in 1991, this recommendation was pursued. A National Workshop on Data Integration in 1993 identified a series of initiatives that the group of experts felt was a path forward. The Workshop in particular recommended a "minimum data set" on wetlands for inventories: wetland location, size, ecological health, ecological type, ownership, protection status, stresses and threats to the site, and changes occurring.

Three major research studies were funded.

(a) The first study, by Geomatics International Inc., focused on an looking at a potentially inexpensive method to create a wetland data base for areas North of the settled zone of Canada. The study, regrettably, firmly established that surrogate wetland data from the National Topographic Digital Data Base does not overlap well with digital data on wetland type and occurrence developed from LANDSAT Thematic Mapper information at 1:250 000 scale (two study regions in the Queen Maud Gulf area of the NWT and the Sprit Lake area of northwestern Ontario were examined). The overlap in mapping polygons was less than 7-11%.

(b) The second study, again by Geomatics International Inc., reviewed the potential to integrate existing wetland survey information across Southern Canada starting with existing digital data sets. It was recognised that at least 25 wetland inventories exist for pieces of Canada many in digital format. However, mapping scales, wetland classification systems, significantly different digital data parameters, and different inventory objectives as well as other factors precluded any cost effective way to integrate such information into a southern Canada data base. It was recommended that partner agencies undertake remapping all of Canada from scratch at a predicted, minimum cost of $2 million.

(c) A third study conducted by Consulting and Audit Canada surveyed wetland data users identifying their priorities for information in a national or regionalized wetland data base. Users supported creation of an integrated data base (s), wanted detailed management information, and continued to be frustrated by a lack of accuracy, detail and standardization. They wanted both hard copy and digital access and products.

The Geological Survey of Canada, Agriculture Canada and Environment Canada have been partners with PoleStar Geomatics Inc. to establish a National Wetland and Peatland Data Base. This project drew together over a four-year period (1995-1999) synthesis of wetland information from almost all existing digital and non-digital wetland inventories. Information is extracted by wetland class (fen, bog, marsh, swamp, shallow water wetlands) at the soil landscape or ecodistrict level nationally. Table 2 presents one summary of this data, reported by Canada's 15 Ecozones by wetland class. Overall this project indicated that the total wetland area is at least 147.9 million ha (15.9% of Canada), about 16% greater in area than published in 1988 by the National Wetlands Working Group (they proposed this area to be 127.2 million ha or 14% of Canada). Sadly, PoleStar Geomatics has gone out of business and the status of this national wetland data base is uncertain. The peatland components now seem to be housed with the Geological Survey of Canada.

Conclusions

Overall at the start of the new Millennium, Canada is in sad shape with regard to wetland data management.

(a) There is no existing capacity for a national status and trends data base or survey.

(b) Major programs such as agricultural crop subsidy programs and the North American Waterfowl Management Plan continue to fail to launch habitat monitoring initiatives despite widespread support and recognition these are essential to these programs.

(c) No federal agency acknowledges it has a legislative mandate for wetlands. Resources for the North American Wetlands Conservation Council (Canada) are likely to be consumed by other priorities for the North American Bird Conservation Initiative (NABCI) and endangered species legislation delivery (Species At Risk Act).

(d) Canada is not able to report nationally on the status of wetland resources to OECD, the Convention on Biological Diversity, the Convention on Wetlands and appears poorly positioned to manage wetlands for carbon conservation under the UNFCC Kyoto Protocol

(e) No standardized national wetland classification system is in use despite it having being published in 1987 and in second edition in 1997.

(f) Existing wetland inventories old and new exist for much of Canada done with different scales, mapping conventions and digital systems; varying objectives; and inconsistent classification systems.

UPDATED WETLAND STATISTICS FOR CANADA

In 1988, the National Wetlands Working Group in the book Wetlands of Canada estimated that the total wetland area of Canada is 127 199 000 ha (14% of Canada) (Table 1), of which 90% is peatland. Since then, numerous regional and provincial wetland and peatland surveys have been published. How well have the 1988 National Wetlands Working Group estimates stood up to the test of time? The estimated areas of 1988 are compared to more recent survey data, presented west to east by province, followed by the territories.

Table 1: Comparison of National Wetlands Working Group (1988) statistics and more recent sources across Canada

Province or Territory	Total Wetland Area (National Wetlands Working Group 1988) (ha)	Total (1995-1999) Revised Estimated Wetland Area (ha)	Percentage Change
British Columbia	3 120 000	5 288 000 (van. Ryswyk et al. 1992)	+40%
Alberta	13 704 000	18 690 000 (Strong et al. 1993; Vitt 1994)	+35%
Saskatchewan	9 687 000	Integration in progress (Vitt et al. 1997)	N/A
Manitoba	22 470 000	23 334 000 (Vitt et al. 1997)	+5%
Ontario	29 241 000	No new data	--
Quebec	12 151 000	No new data	--
New Brunswick	544 000	306 195 ha of freshwater wetlands and 105 071 ha of coastal wetlands. The total is 411 266 ha (Hanson and Calkin 1996).	-24%
Nova Scotia	177 000	223 427 ha of freshwater wetlands plus 275 812 ha of coastal wetlands. Total is 499 239 ha (Hanson and Calkin 1996).	+280%
Prince Edward Island	9 000	Freshwater wetlands 15 675 ha plus 56 913 ha of coastal wetlands. The total is 72 588 ha (Hanson and Calkin 1996)	+800%
Newfoundland and Labrador	6 792 000	New surveys in Labrador underway 1996-1998	--
Northwest Territories	27 794 000	Some inventory of areas such as Queen Maud Gulf MBS and Dewy Soper MBS (CWS, Saskatoon)	--
Yukon	1 510 000	No new data	--
CANADA TOTAL	127 199 000	139 832 000 peatlands only (Tarnocai et al. 1995) 147,880,046 (all wetlands PoleStar Geomatics 1998)	+ 9%, + 16%

Table 2: Wetland Area by Ecozone (June 1998 Pole Star Geomatics)

Ecozone	Area (%)					
	Total Wetland Area (ha)	Bog (%)	Fen (%)	Marsh (%)	Swamp (%)	Total (%)
Arctic Cordillera	27,680	0.06	--	0.06	--	0.12
Northern Arctic	3,657,660	1.85	0.12	0.56	--	2.5
Southern Arctic	4,801,470	5.46	0.44	0.13	--	6.03
Taiga Plain	22,700,240	28.50	9.58	0.21	0.20	38.49
Taiga Shield	15,711,890	7.55	4.83	0.17	0.01	12.41
Boreal Shield	32,722,870	12.88	5.18	0.31	0.35	18.72
Atlantic Maritime	1,016,210	4.11	0.75	0.12	0.12	5.10
Mixed Wood Plain	839,090	1.93	0.97	2.26	2.45	7.55
Boreal Plain	28,169,900	13.87	22.38	4.41	0.15	41.48
Prairie	5,210,150	0.01	3.67	7.08	0.67	11.42
Taiga Cordillera	750,420	1.93	0.90	--	--	2.83
Boreal Cordillera	686,390	1.20	0.28	--	--	1.48
Pacific Maritime	378,630	1.66	0.14	0.03	0.01	1.84
Montane Cordillera	1,271,870	0.64	1.99	0.02	0.01	2.65
Hudson Plain	29,935,990	45.27	35.68	0.07	--	81.01
Canada Total	147,880,046 hectares					15.91%

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Wetland Data Availability for Manitoba and Northern Ontario

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Over the years many different types of projects have been carried out to inventory and describe the landscape. Agriculture and Agri-Food Canada (AAFC), the Manitoba Department of Agriculture (MDA) and the Ontario Ministry of Agriculture (OMA) conducted soil surveys and, in cooperation with other agencies, carried out biophysical land inventories. Surficial deposits inventories have been carried out by the Geological Surveys of Canada (GSC), Manitoba (MNR) and Ontario (NR), habitat inventories have been conducted by Ducks Unlimited (DU), and land capability inventories have been carried out under the auspices of the Canada Land Inventory (CLI) project. Although most of these surveys or inventories were not specifically designed to collect comprehensive data on wetlands, a large amount of data was gathered with respect to wetland soils, drainage, vegetation and ecology. Some dedicated wetland inventories have generated additional data on wetland distribution. Although the data collected during these inventories is not necessarily different with respect to properties or characteristics recorded compared to other inventories, there is generally more data, and as a result more information on hydrology, peat depth, and relationships between the physical and biological components.

During the last decade, there have been projects in which existing data was reviewed, additional new field data collected, and remotely sensed imagery interpreted to produce Soil Landscapes of Canada Maps (SLC) or to compile maps and reports specifically dealing with wetlands (Halsey et al. 1997).
Research specific to wetland ecosystems has also been carried out in Manitoba and Northern Ontario by universities, AAFC, museums and conservation agencies like DU, which have generated data on physical and biological characteristics and interactions for a number of wetlands.

Not all the information that has been gathered is very available or easily accessible. Large amounts of data are in a form that requires a translation or decoding effort to unlock the information desired. Some of the information is available in digital form as maps and databases, but most of the data is only available as hard-copy line maps, photo base maps, and hard-copy databases. The quantity and quality of the data collected and its presentation has improved over the years, and the data on wetlands has become more comprehensive as a result. Detail and scale of mapping in soil and biophysical surveys varies much between project areas, but the quality and detail of the point data is often comparable.

In the table, some of the information on distribution of wetlands that is available for Manitoba and Northern Ontario is listed for the agency(ies) that generated the data and the type of information that was collected. The list is not complete and it doesn't provide a rating on the quality and quantity of the data available.

As most of the data that has been collected during surveys, inventories, and studies has already been used to compile wetland maps or other generalised maps, this information will not enhance any new product at a general scale significantly. The information will be of value if wetland maps are to be produced at a less generalised scale. However, archived data like field notes, pedon descriptions, and chemical and physical analyses would be very valuable if transferred to an electronic database, which can be used for characterization of wetland types and modelling studies.

Wetland Data Availability by Agency and Inventory Type

AGENCY	CATEGORY	DATA	SCALE	COVERAGE	STATUS OF INFO
AAFC, MDA	Soil survey	Reconnaissance and detailed. Map symbol soil codes link to info in legends and reports (landforms, drainage, vegetation, physical and chemical data). It also links to data in the Soil Layer File (SLF). Pedon data.	1:125K, 1:50K and 1:20K	Southern half of Manitoba. Southern parts of Manitoba and limited areas elsewhere.	Published maps and reports. Some northern project area maps are preliminary maps and/ or reports or are data only. Only a limited coverage is digitised
AAFC, OMA	Soil survey	Reconnaissance to semi detailed. (see above).	1:125K and 1:50K	Selected maps sheets in N. Ontario	Some published, others data only.
AAFC, MDA, MNR, Forestry Canada	Biophysical inventory	Reconnaissance. Various projects. Data presentation and map symbology unique to each project. Map symbol contains some connotative info on peatland type, otherwise as above.	1:250K, 1:125K and 1:50K	East side of Lake Winnipeg. North-central Manitoba.	Most map sheets covered under the NRIP are published, but copies are very scarce. Some areas have preliminary map or data only. Limited coverage digitised, but a project has been initiated to digitize and update several map sheets.
AAFC, MDA	Soil landscapes (SLC)	Generalised map and database compiled from published soil maps and other sources at varying scales. Map polygons are large and info on peatlands is very general; link to SLF through soil code.	1:1M	Manitoba and Northern Ontario.	Published Digital maps and data bases available; also info on the Web.
Geological Surveys Canada, Manitoba and Ontario	Surficial deposits	Varying in survey intensity. Most info stored in notes and on topo maps. Extensive data collected during peat inventory, and other surveys in Ontario.	1:1M to 1:250K	1:M for all of Manitoba and N. Ontario. 1:250K for parts of Manitoba and most of Northern Ontario.	Published, or available as open file. Extensive data in field notes and on topo maps in hard copy archived at OCRS.

CLI	Capability classification	Reconnaissance (to detailed). Difficult to reconstitute the info that led to the capability rating. Original field sheets and notes contain useful info, but may be lost as well.	1:250K	South of the ARDA boundary in Manitoba (to 55°N and west of East shore of Lake Winnipeg). Limited area for N. Ontario.	Published. Map info at 1:50K was generated in Manitoba, but may be lost.
AAFC, MDA, Universities, Forestry Centres	Dedicated inventories/ point data/ transect data/ pedon data	Reconnaissance to very detailed. The amount of data varies, but some of the point and pedon data is the most extensive and detailed collected.	1:100K to, 1:1K or larger. 1:1M	Selected areas in Manitoba. Manitoba	Some studies are published, others are data only. Some are in the form of a thesis, scientific paper or "in house" report. Published map & paper (Halsey et al).
DU	Inventory	Detailed; distribution per 1/4 section.	Varying	Southern Manitoba	Open file?
Manitoba Heritage Corporation				Southern Manitoba	Data
BOREAS	Soils, ecosystems	Semi detailed and detailed. Point and transect data, pedon data and data on ecosystem function.	1:5K to 1:100K	Limited areas in North-Central Manitoba	Limited distribution of hard copy and digital data inventory data. Extensive data in the form of scientific papers on a wide range of peatland related topics. Extensive data available on the Web.
Industry	Inventory	Reconnaissance to detailed.			

Wetland data available for continental western Canada

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Wetland data currently available for continental western Canada can be subdivided into two types: spatial cover data and site-specific physical and biological data.

Spatial Data

Wetlands and wetland complexes in continental western Canada have been inventoried using a hierarchical system grounded in wetland form and function from 1;40,000 to 1:60,000 aerial photographs following the classification of Halsey and Vitt (1996), and transferred to 1:250,000 base maps. Wetlands were first subdivided into 1) class (bog, fen, marsh, swamp, and shallow open water; 2) forest cover (wooded, shrubby, or open); 3) regional landform modifier; and 4) local landform modifier. At the scale of mapping used, individual wetlands were rarely identified, with most polygons composed of wetland complexes, with components identified to the nearest 10% cover. Wetland distributions were determined from 1:250,00 base maps through digitizing onto provincial base maps for Alberta and Saskatchewan, and rasterized manually for Manitoba. Published summaries have been completed for Alberta (Vitt et al. 1996) and Manitoba (Halsey et al. 1997), and digital ARC/INFO covers for Alberta and Saskatchewan are available.

In addition to provincial reconnaissance mapping, more detailed wetland inventories have been and are being conducted in selected areas of Alberta, Saskatchewan, and Manitoba by both the peat and forest industries following the methods outlined above, but utilising 1;15,000 to 1:20,000 aerial photograph. At this more detailed level, polygons generally represent individual stands, and thus individual wetlands or wetland components are identified. As the classification system of Halsey and Vitt (1996) has been sanctioned by both the Alberta and Saskatchewan governments, large tracts of the boreal forest in these provinces are currently being coherently subjected to detailed inventories by the Alberta Peat Task Force and individual Forest Management Agreement holders. All data is being placed into digital form.

Site-Specific Data

Currently there are two databases that pertain to site specific data that have been collected from across western Canada. The first represents a dataset targeted at generating species response surfaces and contains vegetation cover collected from 611 sites located within 10 km of a permanent weather station in mountainous areas and within 50 km in more topographically homogeneous areas from across western Canada (British Columbia, Alberta, Saskatchewan, Manitoba, Yukon, and Northwest Territories). Associated with each site are climatic, physical and chemical parameters that can then be linked to species cover values, thus generating species responses.

Steve Zoltai compiled a database and accompanying report on methodology of 629 wetland components that he examined during his career from 1970 to 1989 (Zoltai et al. 2000). The database files include information on site and subsite, vegetation, and stratigraphy (chemical and physical). Following this effort we have been slowly expanding this database to include available macrofossil and radiocarbon stratigraphy of Steve's sites as well as to include information from additional sites generated by other individuals both published and unpublished. Due to the multiple sources of information an additional table referring to source has also been added to the database in addition to macrofossil and radiocarbon tables. Currently this database contains eleven linked tables with 118 unique fields and is very much a work in progress.

Data Utilization

We have been and will continue to couple and expand these datasets to examine how wetlands respond at both the site specific and landscape scale to disturbances that include climate change, fire, logging, and peat harvesting. Recently we have combined our spatial and site specific datasets to generate spatial and temporal trends in carbon storage for peatlands of continental western Canada (Vitt et al. 2000). Currently we are comparing and contrasting these continental trends to those found in oceanic regions (B.C. coast). We will also be using response surfaces to model present (Gignac et al. 2000), past (Gajewski et al. 2000) and future changes in peatland distributions across North America. Past distributions will be validated from distributions generated from spore (Halsey et al. 2000) and macrofossil records.

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