Inventory guide for estimating carbon stocks in wetlands

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Coordination and drafting

This publication was developed by Michelle Garneau's research team at the Université du Québec à Montréal Research Centre in Earth System Dynamics (Geotop-UQAM), in partnership with the Direction des milieux humides of the Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs (MELCCFP).

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Acknowledgements

This inventory guide for estimating carbon stocks was developed by Professor Michelle Garneau's research team (C-PALEO laboratory) at the Université du Québec à Montréal (UQAM) Research Centre in Earth System Dynamics (Geotop), under the direction of Gabriel Magnan and Michelle Garneau, in collaboration with the Direction des milieux humides and the Direction de la prospective climatique et de l'adaptation. The research work was funded by the Plan for a Green Economy 2030, under [Translation] *measure 1.11.1 Conserving priority natural environments*. More specifically, they are in line with [Translation] *action 1.11.1.1 To equip government and municipalities to conserve priority carbon reservoirs*.

Grande Plée Bleue peatland in Lévis. Photo credit: MELCCFP.

Foreword

The 2030 Plan for a Green Economy (PGE) is Québec's first electrification and climate change policy framework. It commits us to an ambitious project laying the foundations for a low-carbon, more prosperous economy that is resilient to climate change by 2030.

The PGE 2030 recognizes the role of natural environments in the fight against climate change. Wetlands play a vital role in **greenhouse gas (GHG)** levels by storing large quantities of carbon in their soil and vegetation. Indeed, some wetlands, particularly **peatlands**, have been accumulating carbon for millennia and have had a cooling effect on the climate. It is therefore essential to prioritize the conservation of wetlands.

[Translation] Action *1.11.1.1 Tools for government and municipalities to conserve the priority carbon reservoirs* of the PGE 2030 addresses this need for conservation. Considering that many priority reservoirs are found in wetlands, it has become necessary to develop a method for quantifying the carbon reserves of these environments in Québec. Existing methods for quantifying wetland carbon stocks involve a considerable amount of field sampling and laboratory analysis, severely limiting large-scale data collection across Québec. The proposed simple field method enables us to better quantify **carbon stocks** in order to support land-use planning decisions in the context of the fight against climate change.

Introduction

The modernization of the Environment Quality Act (EQA) and the adoption of the Act respecting the conservation of wetlands and bodies of water (ARCWBW) have laid the foundations for a new environmental authorization regime in Québec. Among the legislative changes introduced in 2017, the Act to affirm the collective nature of water resources and to promote better governance of water and associated environments (chapter C-6.2, commonly referred to as the Water Act) recognized the fundamental role of wetlands in carbon storage and mitigating the impacts of climate change (section 13.1). The presence of wetlands offers benefits that deserve to be better known and promoted.

As part of the application of the ARCWBW and the implementation of the 2030 Plan for a Green Economy (PGE), it has become necessary to rigorously and systematically estimate carbon stocks in the various types of wetlands, using a simple and effective method. This data is essential for identifying priority wetlands for conservation. This data could also be used to document carbon losses associated with the destruction or alteration of these environments (e.g., drainage or residential development)). The loss of terrestrial carbon stocks is irrecoverable in the short term, in addition to causing greenhouse gas (GHG) emissions, which undermines efforts in the fight against climate change. Although peatlands are already recognized as huge carbon reservoirs (Garneau and van Bellen, 2016), currently there are only fragmented databases on stored carbon stocks in the various wetlands in Québec.

The aim of this guide is to enable the quantification of carbon stocks stored in wetlands using simple field measurements. The method was developed for non-permafrost wetlands in temperate and boreal regions. It will be useful for the various stakeholders who wish to document wetland carbon stocks (government and municipal stakeholders, non-profit organizations, consultants, etc.). It will allow for data collection on wetland carbon stocks to be standardized. The methodology presented in this guide can be used on a voluntary basis, in the context of land use planning and the fight against climate change, or according to specific contexts requiring this type of detailed data, for example, for knowledge acquisition purposes.

The inventories created using this method will enable us to achieve the following objectives:

- Developing an accessible, centralized database on carbon stocks;
- Mapping carbon stocks in different types of wetlands;
- Developing decision-making tools for land use planning and wetland conservation;
- Tracking the change over time of carbon stocks in Québec.

Theoretical notions

Wetlands and the terrestrial carbon cycle

Wetlands include many types of ecosystems that are saturated with water or flooded for long enough for the water to have an impact on the soil or vegetation found there. These include **open peatlands**, **wooded peatlands**, **swamps** and **marshes** (Lachance et al., 2021). Wetlands are some of the most important terrestrial reservoirs of carbon (C). Their conservation is recognized as one of the best nature-based solutions to fight against climate change (Drever et al., 2021; Taillardat et al., 2020). The alteration and destruction of these natural environments can disrupt their carbon cycle and cause significant emissions of GHGs, including carbon dioxide (CO_2) and methane (CH_4).

In wetlands, carbon is exchanged between soil, vegetation and the atmosphere (terrestrial carbon fluxes) (Figure 1). CO_2 is assimilated by plants during photosynthesis. CO_2 and CH_4 are the main GHGs released into the atmosphere through vegetation respiration or the **decomposition** of **organic matter**. **Dissolved organic carbon (DOC)** is also produced and transported by surface and groundwater (aquatic carbon fluxes). Wetlands generally have a negative carbon balance on an annual scale, meaning they absorb more carbon than they emit, making them important terrestrial carbon sinks (Shukla et al., 2019, Taillardat et al., 2020).

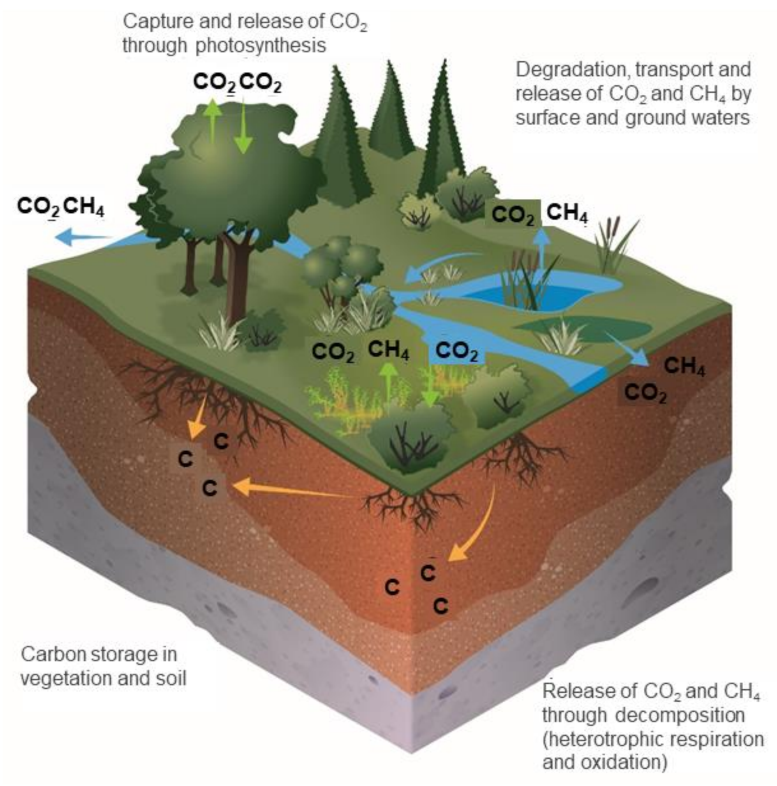

Figure 1. Carbon dynamics in wetlands. The arrows show the direction of exchanges, but do not quantify fluxes.

Carbon storage in wetlands

In wetlands, carbon accumulates annually in vegetation and soil, where it can be stored for tens or even thousands of years (FAO, 2017). The **soil organic carbon (SOC) storage** process is mainly controlled by hydrological and physicochemical conditions that influence organic matter decomposition rates (Rydin and Jeglum, 2013).

There are significant differences in carbon distribution among types of wetlands (Figure 2). Peatlands store the greatest quantities of carbon, most of which is found in the thick **organic deposits** of their soil **(peat)**. In these environments, the production and accumulation of organic matter exceeds decomposition, due to the **anaerobic** and acidic **conditions** and low biological activity in soils permanently saturated with water. Wooded peatlands, which are characterized by more decomposed organic deposits, generally have lower amounts of SOC than open peatlands, but have a higher **above-ground biomass**.

In marshes and swamps, organic matter is less abundant in soils due to greater hydrological variability and increased decomposition of vegetation under **aerobic conditions**. In marshes, the amount of carbon in the vegetation is relatively low, and the amount of SOC is generally lower than in other types of wetlands. In swamps, a significant portion of the carbon is stored in woody vegetation and these environments have a COS concentration similar to that of forests on **non-hydromorphic** soils (Figure 2).

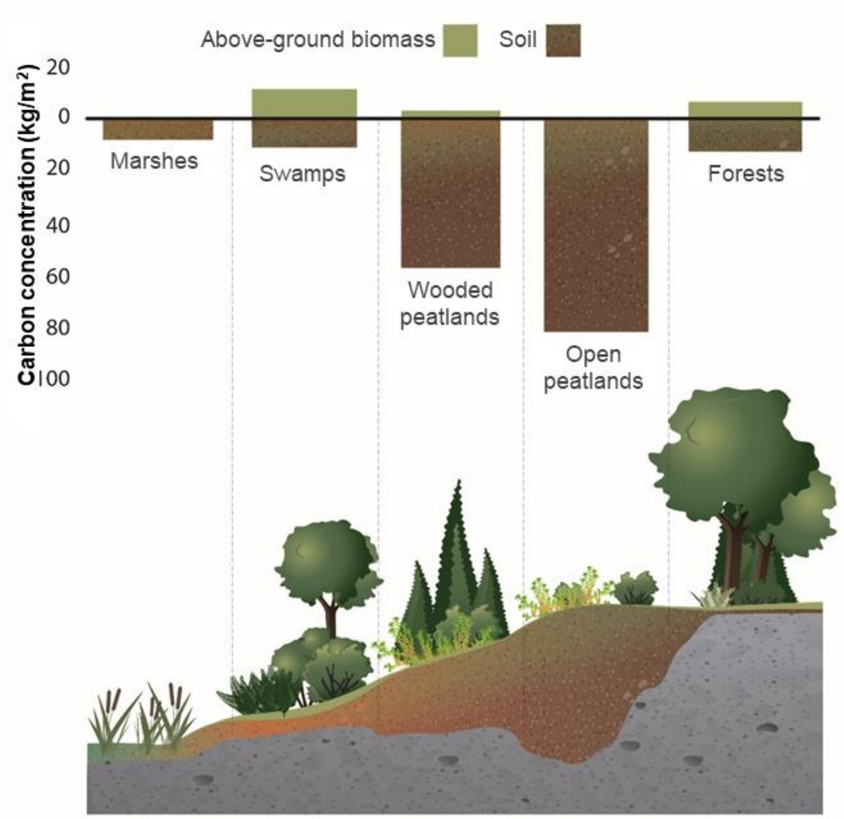

Figure 2. Carbon distribution in soils and above-ground biomass of different types of wetlands compared with forests on non-hydromorphic soils (Source: C-PALEO Laboratory). The wetlands classification used to synthesize the data is that presented in Lachance et al. (2021).

Quantifying carbon stocks in wetlands

The method presented in this guide aims to collect data to quantify the carbon stored in soils and above-ground woody biomass in peatlands, swamps and marshes. This method does not apply to ponds, which have distinct organic carbon storage dynamics in shallow water, nor to permafrost wetlands.

Carbon stocks are estimated from measurements of **soil organic carbon (SOC) concentration** and **woody biomass carbon (WBC) stocks** at different inventory stations. SOC concentration is calculated using a synthesis of carbon density data (Magnan et al., 2023). WBC stock is calculated using **allometric equations** adapted to the different tree and shrub species (e.g., Lambert et al., 2005). Carbon concentration values calculated at different inventory stations can then be extrapolated to the entire wetland surface area to obtain a carbon stock value (figure 3).

The method consists of three steps:

1. Inventory strategy development
2. Field inventory
3. Calculating carbon concentration and stocks

This guide describes the first two steps in detail. The third step is briefly presented in this guide, and the detailed process is available on the MELCCFP website (French).

Calculating carbon concentration and stocks

SOC density (kg/m³): Quantity of soil organic carbon per unit of volume.

SOC concentration (kg/m²): Average carbon density (kg/m³) multiplied by the thickness (m) of the organic deposit.

WBC stock (kg/m²): Sum of the quantities of carbon stored in trees and large shrubs (above-ground components) for a given surface area.

Carbon stock (kg or t): For a whole or partial ecosystem (e.g., peatland) — average SOC concentration and WBC stock (kg/m²) from several inventory stations multiplied by the wetland surface area.

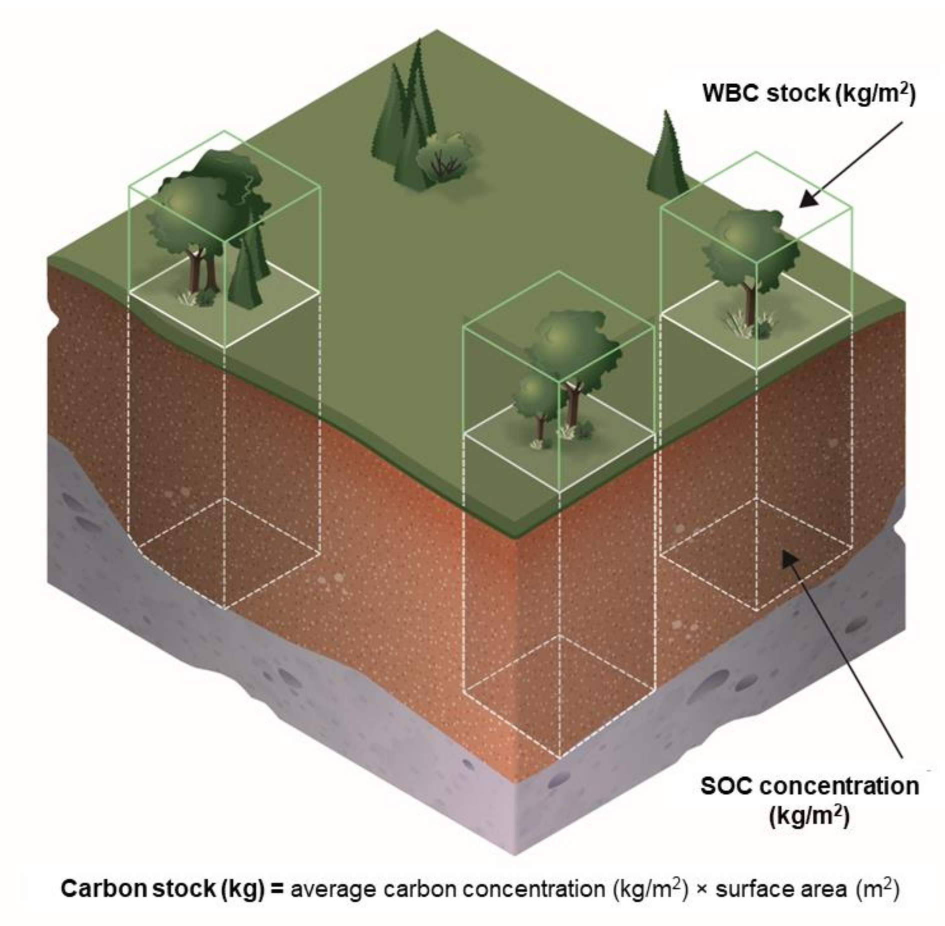

Figure 3. Diagram showing the calculation of carbon stock in a peatlands, based on carbon concentration measurements (SOC and WBC) at several inventory stations.

Carbon inventory process

Useful documents related to this guide, including a paper form for inventories, are available on the MELCCFP website (French).

Inventory strategy

To obtain a representative value of a wetland's carbon stock, the research team at the C-PALEO Laboratory (Geotop Centre-UQAM) suggests ,based on the analyses carried out, the following inventory effort based on the surface area of the **homogeneous vegetation unit (HVU)**[1]:

- <1 hectare: 3 stations per hectare;
- 1-10 hectares: 1 station per hectare;
- 10-100 hectares: 1 station per 3 hectares;
- >100 hectares: 1 station per 10 hectares.

These recommendations apply to HVUs with relatively homogeneous organic deposits and woody plant cover (trees and shrubs). A higher inventory effort may be required to obtain a more accurate carbon stock value, especially when organic deposit thicknesses vary widely within the same HVU. It is also possible to reduce the inventory effort, particularly for a large HVU (>100 hectares), when it is fairly homogeneous.

When inventories aim to quantify carbon stock at the scale of a large wetland complex with numerous HVUs (of varying types, shapes and surface areas), it is possible to reduce the inventory effort by adding up the areas of similar HVUs of the same wetland type, rather than considering each HVU as distinct.

The inventory stations, which correspond to 100 m^2 plots, must be positioned to optimally cover the entire HVU, using a grid of points to properly characterize the variability of the topography and thickness of the organic deposit. This step can be carried out using geomatics tools (figure 4).

[1] For more details on HVUs, refer to the guide *Identification et délimitation des milieux humides du Québec méridional* (Lachance et al., 2021).

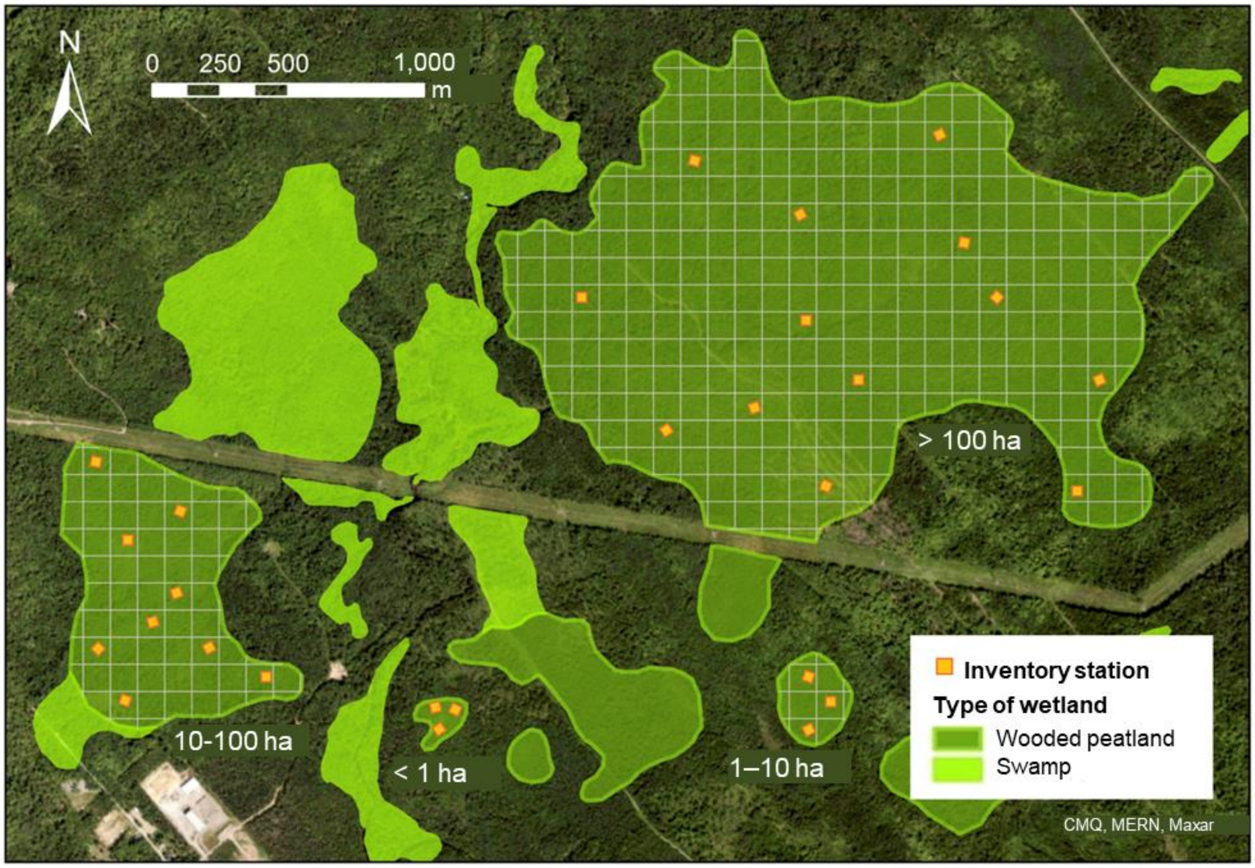

Figure 4. Examples of carbon concentration inventory strategies to quantify carbon stock in wetlands of different surface areas. Stations are placed randomly within each grid square.

Inventories must be carried out at a time of year when reliable data can be acquired. Wetlands are often flooded in spring, which can hamper the measurement of organic deposit thickness. The best time to carry out an inventory of the woody biomass is when trees and shrubs have foliage, making them easier to identify.

During field visits, stations can be moved if the initial position is inaccessible or if disturbances are observed. As this method applies to natural wetlands, stations should be located far enough away from disturbances that could affect site hydrology and woody vegetation cover (ditches, drains, embankments, power lines, trails, logging, etc.). In addition, stations located too close to wetland boundaries or an ecotone between two HUVs should be relocated.

Inventory to quantify soil organic carbon (SOC) concentration

Materials required

- Shovel
- Soil auger
- Measuring tape
- Oakfield probe with extension rods (a minimum of 7 metres is recommended)

Inventories were carried out in a 100-m^2 (10 m × 10 m) plot and four 25-m^2 (5 m × 5 m) subplots. It is important to define the plot and subplots to ensure that their surface area is as accurate as possible, to avoid errors in calculating the carbon concentration per unit of surface area in kg/m^2 (figure 5).

To calculate the SOC concentration, three measurements of organic deposit thickness must be taken randomly within three 25-m^2 subplots, ensuring that a minimum distance of 5 metres is left between the three measurement points (Figure 5).

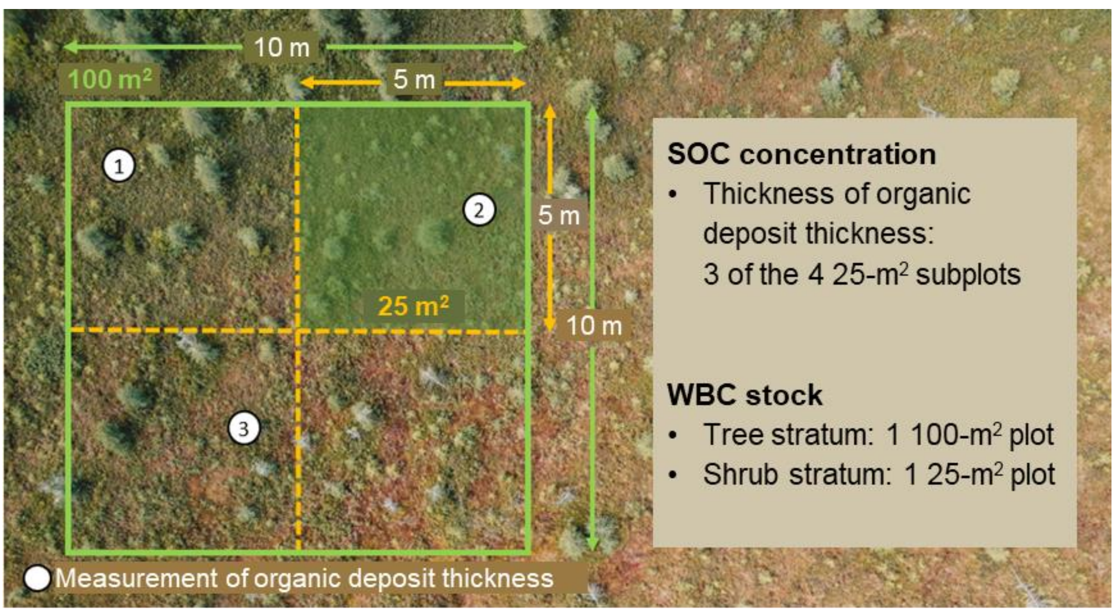

Figure 5. Summary diagram of SOC and WBC measurements to be carried out at an inventory station.

Techniques for measuring organic deposit thickness

The measurement of organic deposit thickness must include the litter and the deposit dominated by organic matter (>50%), which is distinguished by its dark colour, generally brown or black, characteristic of an abundance of organic matter (figure 6).

Swamps and marshes

In swamps and marshes, where there is a thin organic deposit (< 30 cm), the deposit thickness should ideally be measured on a **soil profile** using a shovel. A soil auger or Oakfield probe can also be used. In the hydromorphic mineral soils of swamps and marshes, it is sometimes difficult to distinguish the transition between the organic deposit and the underlying **mineral deposit**. A lack of organic deposit is also common in coastal swamps and marshes.

Peatlands

In a peatland, organic deposit thickness is measured using an Oakfield probe with extension rods (figures 6 and 7). The probe should be inserted into the organic deposit until a strong resistance is felt, indicating that the mineral deposit or bedrock at the base has been reached **(definite mineral refusal)**. It is generally much easier to penetrate the organic deposit with the probe than the underlying mineral deposit. Measure the total length of the inserted probe to where it makes contact with the deposit. To facilitate measuring, Oakfield probe rods can be graduated at 50 cm intervals. After removing the probe from the soil, the contents of the ejector spoon must be identified to confirm contact between the organic deposit and the mineral deposit (figure 6). The Oakfield probe ejector spoon must be emptied and cleaned between each measurement.

Figure 6. Measuring the thickness of an organic deposit in different types of wetlands. The orange dashed lines represent the contact zone between the organic deposit and the mineral deposit.

Measuring organic deposits: special cases

Mineral deposit containing fine particles

Extra precautions must be taken when the mineral deposit is made up of fine particles (e.g. clay or fine sand). The refusal in these cases can be less definite than in the case of a coarse mineral deposit (e.g. gravel), as the probe may penetrate too deeply into the mineral deposit, leading to an overestimation of the SOC concentration. If the probe seems to have penetrated too deeply, for example when the ejector spoon is filled with fine sand or clay, another measurement should be taken at a shallower depth in order for the organic/mineral transition to be clearly identified in the spoon.

Obstruction by woody material

The presence of woody material (e.g. stumps or roots) in the organic deposit may prevent the probe from penetrating up to the mineral deposit (see example of obstruction in figure 7). When such an obstruction occurs before reaching the mineral deposit, a second measurement attempt must be made at another location within the 25 m^2 subplot. Attempts should be made to reach the underlying mineral deposit to confirm the true thickness of the organic deposit, as an obstruction can result in a substantial underestimation of an inventory station's SOC concentration.

Very hard mineral deposit or bedrock

If the probe hits a very hard surface that appears to correspond to the mineral deposit or bedrock, but it is impossible to harvest the mineral deposit, this measurement should still be considered a definite mineral refusal and not an obstruction. In this case, the depth reached by the probe corresponds to the actual thickness of the organic deposit.

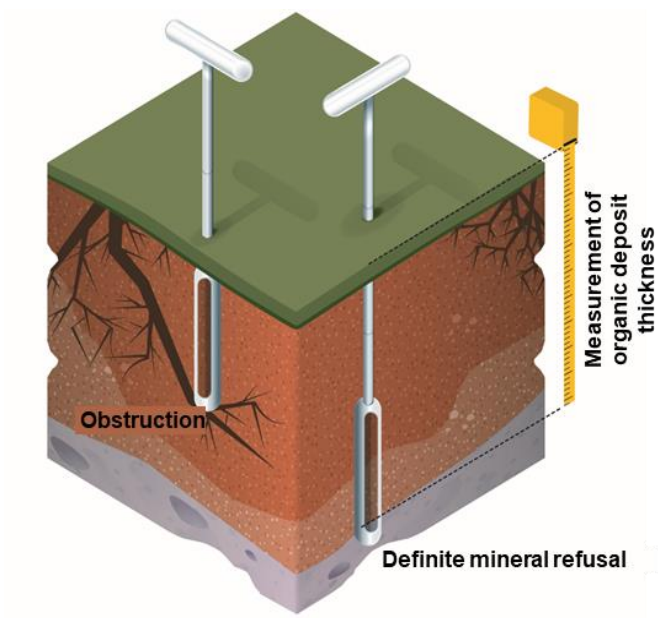

Figure 7. Examples of an obstruction when inserting the probe into the organic deposit (left) and a definite mineral refusal when the underlying mineral deposit is reached (right).

The degree of decomposition (fibric/mesic/humic) must also be determined when the thickness of the organic deposit exceeds 30 cm (figure 8). Only one measurement of degree of decomposition is required per station. This measurement should be carried out in the middle tier of the organic deposit (50–100 cm deep) using a soil auger. If the thickness of the organic deposit is less than 50 cm, the average decomposition level of the entire deposit should be noted. As carbon density increases with the degree of decomposition of organic matter, this information can improve the accuracy of SOC concentration calculations (Magnan et al., 2023). A description of the method for visually estimating the degree of decomposition of organic matter using the von Post scale is provided in Appendix 1.

It is recommended to take photos of the samples collected with the auger or Oakfield probe. The photos should show 1) the sample of organic material taken to determine the von Post degree of decomposition and 2) the contact zone between the organic deposit and the mineral deposit.

Figure 8. Degrees of organic matter decomposition: fibric, mesic and humic. (See von Post scale in Appendix 1.)

Inventory to quantify woody biomass carbon (WBC) stocks

To calculate WBC stocks, the above-ground woody biomass must be estimated within the 100 m^2 plot for the tree stratum (trunks >4 m tall) and in a 25 m^2 subplot for the shrub stratum (trunks between 1.3 m and 4 m tall) (figure 5). Only trunks with a minimum diameter at breast height (DBH) of 1 cm should be measured. Small shrubs (height <1.3 m or DBH <1 cm) are excluded from the estimates, as they represent only a negligible proportion (<1%) of a station's total carbon stock. Furthermore, the trunks of dead trees and shrubs are excluded from the inventories.

Each living tree or large shrub must be identified by species and its DBH measured to be able to estimate the WBC stocks using allometric equations. For most shrub species, measurement of the diameter at stump height (DSH) is also required to estimate WBC stocks (see taxa list in Appendix 2).

DBH and DSH are measured using a circumference tape measure or tree caliper (figure 9). It is also possible to measure the trunk circumference using a conventional tape measure and dividing the result by π (3.1416) to obtain the diameter. DBH is measured perpendicular to the trunk axis at a height of 1.3 m above the ground. If the trunk has an irregularity (e.g. burl, knot or scar) at this height, the DBH should be measured above or below the defect, as close as possible to the reference height (figure 9). If there is a fork at breast height, the DBH is measured below the trunk division. If the fork is below the reference height of 1.3 m, the DBH of each trunk is measured as an individual (D'Eon et al., 1994). The DSH should be measured at the base of the trunk, 15 cm above the ground surface. If a shrub grows in clusters from the **root collar** (e.g. alder), each trunk is measured individually. Conversely, when trunks separate above the 15 cm mark, only the main trunk is measured (figure 9).

At each station, it is recommended to take photos of (1) the overall view, (2) the lower strata <1.3 m (muscinal and herbaceous), (3) the shrub stratum (1.3 m to 4 m) and (4) the tree stratum >4 m. Taking such photos is essential, particularly for validating the wetland types inventoried after the fieldwork, as this information is required when calculating SOC concentrations.

Figure 9. Location of A) DBH and B) DSH measurements, according to different growth scenarios for tree and shrub trunks.

Calculating carbon concentration and stocks

The detailed procedure for calculating carbon concentration and carbon stock (SOC and WBC) values for wetlands based on field measurements is available on the MELCCFP website (French). It is important to follow this procedure in order to standardize data for analysis and comparison. An overview of the main calculation steps is provided below.

SOC concentration per inventory station

To be able to calculate the SOC concentration, it is necessary to identify the wetland type based on criteria set out in the guide *Identification et délimitation des milieux humides du Québec méridional* (Lachance et al., 2021). The wetland classes used for the calculations are presented in Appendix 3 of this guide.

The SOC concentration of an inventory station is calculated using the average thickness of the three organic deposit measurements. Calculations were developed for each wetland type using a database of SOC densities from laboratory soil core analyses (Magnan et al., 2023). The SOC concentration (kg/m²) is calculated using this data, by multiplying the average organic deposit thickness (m) by the average SOC density value (kg/m³), or by using the equation for the linear relationship between organic deposit thickness and SOC concentration.

The accuracy of the calculations is higher for bogs than for swamps and marshes, as SOC density and concentration are not as well documented in the latter wetland types. If the objective of the inventory is to obtain precise SOC concentration values, it is recommended to sample soil cores and perform carbon density analyses in the laboratory (see Magnan et al., 2023), particularly for swamps and marshes where it may be more difficult to visually estimate the organic deposit thickness.

WBC stock per inventory station

Allometric equations can be used to convert DBH (or DSH) measurements into total above-ground woody biomass (kg) for an inventory station. A separate equation is used for each tree or shrub species (or group of species) present at the inventory station. The WBC stock (kg/m²) is then calculated by multiplying the biomass value obtained (kg) by the standard value of 50% carbon content (IPCC, 2006), then dividing by the area (m^2) of the station.

Carbon stock

The carbon stock (kg or t) of an HVU is calculated by multiplying the average value of the total carbon stock (SOC + WBC) of all inventoried stations by the surface area of this HVU. The carbon stocks of the various HVUs can then be added together to obtain a value for the wetland complex as a whole.

For more information...

If you have any questions about the data collection or calculation methods, please contact the Direction des milieux humides of the MELCCFP at milieuxhumides@environnement.gouv.qc.ca.

References

D'EON, S.P., MAGASI, L.P., LACHANCE, D., DESROCHERS, P. (1994). Canada's National Forest Health Monitoring Plot Network Manual on Plot Establishment and Monitoring (Revised). *Petawawa National Forestry Institute: Ontario, CA, USA*.

DREVER, C.R., COOK-PATTON, S.C., AKHTER, F. et al. (2021). "Natural climate solutions for Canada". *Science Advances*, 7: 1-13. [https://www.science.org/doi/epdf/10.1126/sciadv.abd6034].

FAO (2017). *Carbone Organique du Sol: une richesse invisible*, Organisation des Nations Unies pour l'alimentation et l'agriculture, Rome, Italie. [https://www.fao.org/3/I6937FR/i6937fr.pdf].

GARNEAU, M., VAN BELLEN, S. (2016) Synthèse de la valeur et de la répartition du stock de carbone terrestre au Québec, Rapport final présenté au Ministère du développement durable, de l'Environnement et de la Lutte contre les changements climatiques, Chaire DÉCLIQUE, Centre Géotop et Département de géographie, Université du Québec à Montréal, 36 pages and appendices, [https://www.environnement.gouv.qc.ca/changementsclimatiques/rapport_final.pdf]

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 4: Agriculture, Forestry and Other Land Use, Chapter 8: Settlements. [https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_08_Ch8_Settlements.pdf].

LACHANCE, D., FORTIN, G., DUFOUR TREMBLAY, G. (2021) Identification et délimitation des milieux humides du Québec méridional - version décembre 2021, Ministère de l'Environnement et de la Lutte contre les changements climatiques, Direction adjointe de la conservation des milieux humides, Québec, 70 pp. + appendices, [https://www.environnement.gouv.qc.ca/eau/rives/guide-identif-dellimit-milieux-humides.pdf].

LAMBERT, M.C., UNG, C.H., RAULIER, F. (2005) Canadian national tree aboveground biomass equations. Canadian Journal of Forest Research, 35: 1996-2018.

MAGNAN, G., GARNEAU, M., BEAULNE, J., LAVOIE, M., PELLERIN, S., PERRIER, L., RICHARD, P.J.H., SANDERSON, N. (2023) A simple field method for estimating the mass of organic carbon stored in undisturbed wetland soils. Mires and Peat, 29: 1-13.

RYDIN, H., J.K. JEGLUM (2013). *The biology of peatlands*, Second Edition, Oxford University Press, 382 pages.

SAUCIER, J.P., BERGER, J.-P., D'AVIGNON, H., RACINE, P. (1994). Le point d'observation écologique (pp. 1-126). Gouvernement du Québec, Ministère des ressources naturelles.

SHUKLA, P.R., SKEA, J., CALVO BUENDIA, E. et al. (2019). IPCC, 2019: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

TAILLARDAT, P., THOMPSON, B.S., GARNEAU, M, TROTTIER, K, FRIESS, D.A. (2020). “Climate change mitigation potential of wetlands and the cost-effectiveness of their restoration”. *Interface Focus*, 10, 20190129 [https://royalsocietypublishing.org/doi/pdf/10.1098/rsfs.2019.0129].

Glossary

Above-ground biomass	Dry weight of above-ground plant matter, including trunks, stumps, branches, bark and foliage.
Aerobic condition	Environment in which oxygen is available, enabling the oxidation of organic matter and the transformation of carbon into carbon dioxide (CO_2).
Allometric equation	Equation for estimating the biomass of a woody species (tree or shrub) using field measurements such as trunk diameter (breast or stump height).
Anaerobic condition	The absence of oxygen in an environment.
Carbon storage	Long-term carbon storage in wetland soils and plant biomass. Stored carbon is removed from the atmosphere, helping to reduce GHGs and thus mitigate global warming.
Decomposition	The process in which organic matter decays into simple organic and inorganic compounds. Organic matter decomposes much more slowly under anaerobic conditions than under aerobic conditions.
Definite mineral refusal	Strong resistance encountered when inserting a probe into an organic deposit, indicating that the mineral deposit or bedrock at the base has been reached.
Dissolved organic carbon (DOC)	All the carbon contained in organic molecules that is found in dissolved form, i.e. mobile in water.
Greenhouse gases (GHG)	Gases in the earth's atmosphere that absorb infrared radiation emitted by the earth's surface, thereby contributing to global warming. The most prevalent GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).
Homogeneous vegetation unit	A wetland in which the environment type and vegetation are uniform. Several different homogeneous vegetation units (HVU) may be present within a wetland complex. For more details, consult the guide titled *Identification and delineation of wetlands in southern Québec* (Lachance et al., 2021) (French).
Hydromorphic	Characteristic of a soil whose features are largely caused by temporary or permanent water saturation.
Marsh	Wetland that is permanently, semi-permanently or temporarily flooded. A marsh is dominated by herbaceous vegetation (emergent, graminoid or latifoliate) growing on mineral or organic soil, and the tree and shrub stratum covers less than 25% of its surface area.
Mineral deposit	Loose deposit on which a wetland has developed (e.g. clay, sand, gravel). Contact between the organic deposit and the mineral deposit is confirmed by a definite mineral refusal when a probe is inserted.
Open peatland	Non-wooded peatland in which trees exceeding 4 m in height cover less than 25% of the surface area.

Organic deposit	Accumulation of organic matter in the soil.
Organic matter	Carbonaceous matter produced by living organisms (animals, plants or micro-organisms) that decomposes and can accumulate in the soil. Soil organic matter is the fraction of the soil that consists of plant debris in various stages of breakdown (decomposition).
Peat	Accumulation of partially decomposed organic matter derived from plant remains (e.g. sphagnum mosses, brown mosses, wood) under water-saturated conditions. Peat is a thick organic deposit (>30 cm) and excludes the living plant cover.
Peatland	Moist environment where the accumulation of organic matter prevails over decomposition processes, resulting in the formation of an organic deposit at least 30 cm thick (peat).
Root collar	Transition point between the roots and the trunk.
Soil organic carbon (SOC)	Portion of carbon that remains in the soil following partial decomposition of plant biomass.
Soil profile	Vertical section showing all soil horizons, including organic and mineral fractions.
Swamp	Wetland dominated by woody vegetation (shrubs or trees) covering more than 25% of the surface area, growing on mineral soil with poor or very poor drainage. The swamp may be subject to seasonal flooding or be characterized by permanently or temporarily water-saturated soil.
Wooded peatland	Peatland comprising trees exceeding 4 m in height covering at least 25% of the surface area.

List of abbreviations and symbols

C	Carbon
CH_4	Methane
CO_2	Carbon dioxide
DBH	Diameter at breast height
DOC	Dissolved organic carbon
DSH	Diameter at stump height
GHG	Greenhouse gas
HVU	Homogeneous vegetation unit
MELCCFP	Ministère de l'Environnement, de la Lutte contre les changements climatiques, de la Faune et des Parcs
PGE	Plan for a Green Economy
SOC	Soil organic carbon
UQAM	Université du Québec à Montréal
WBC	Woody biomass carbon

Appendix 1 – von Post decomposition scale

CLASS	DESCRIPTION
Fibric	
1	Layer of living moss, which cannot be considered peat.
2	Dead peat, with complete plant structure. Yellowish, clear water. The sample is spongy and elastic, returning to its original shape after being squeezed.
3	Very easily distinguishable plant material. Yellow water containing some plant debris. Somewhat darker colour, good elasticity.
4	Plant material disintegrating. Light brown water containing plant debris. After being squeezed, the sample retains a perfect imprint of the fingers and no peat escapes the hand.
Mesic	
5	Amorphous, unstructured plant material. Water definitely brown. When the sample is squeezed, a small amount escapes the hand.
6	More than half the sample is decomposed. Dark brown water. When the sample is squeezed, about a third escapes the hand.
Humic	
7	Impossible to distinguish the original plant material. When the sample is squeezed lightly, a small amount of very dark water is emitted, and when squeezed harder, more than half escapes the hand.
8	If the sample is squeezed gently, no more than two-thirds escapes the hand.
9	Very homogeneous, amorphous sample containing no roots or fibres. When squeezed, no water is emitted and almost all of the sample escapes the hand.
0	Homogeneous material, jelly-like consistency. When squeezed, the sample escapes the hand. These very rare soils are found mainly in sedimentary peat.

Source: Le point d’observation écologique (Saucier et al., 1994)

Appendix 2 – List of species common to southern Québec wetlands whose DSH must be measured

Taxon – common name	Taxon – scientific name
Serviceberry	*Amelanchier spp.*
Black chokeberry	*Aronia melanocarpa*
Hawthorn	*Crataegus* spp.
Dwarf birch	*Betula pumila*
Chokecherry	*Prunus virginiana*
Pin cherry	*Prunus pensylvanica*
Honeysuckle	*Lonicera* spp.
Dogwood	*Cornus* spp.
Leatherwood	*Dirca palustris*
Northern bush honeysuckle	*Diervilla lonicera*
Common winterberry	*Ilex verticillata*
Canadian yew	*Taxus canadensis*
Sweet gale	*Myrica gale*
Mountain holly	*Nemopanthus mucronatus*
Buckthorn	*Rhamnus* spp.
Beaked hazelnut	*Corylus cornuta*
Common ninebark	*Physocarpus opulifolius*
Mountain ash	*Sorbus* spp.
Spirea	*Spiraea* spp.
Staghorn sumac	*Rhus typhina*
Elderberry	*Sambucus* spp.
Viburnum	*Viburnum* spp.

Appendix 3 – Wetland types used to calculate SOC concentrations (Magnan et al., 2023).

Wetland classes	Wetland subclasses	Common non-woody vegetation	Common woody vegetation
Peatlands	Open bog	Sphagnum mosses (e.g. *Sphagnum fuscum*, *S. magellanicum*)	*Vaccinum* spp., *Rhododendron* spp., *Picea mariana*, *Larix laricina*
	Open fen	Cyperaceae, brown mosses (e.g. *Scorpidium* spp., *Straminergon* spp., *Warnstorfia* spp.)	*Andromeda polifolia*, *Larix laricina*, *Myrica gale*
	Wooded peatland	Sphagnum mosses*(Sphagnum capillifolium*, *S. girgensohnii*), feather mosses (e.g. *Dicranum* spp., *Pleurozium schreberi*)	*Picea mariana*, *Larix laricina*, *Abies balsamea*, *Thuja occidentalis*, *Acer rubrum*, *Tsuga canadensis*, *Kalmia angustifolia*, *Rhododendron groenlandicum*
Swamps[1]	Deciduous tree swamp	Ferns (e.g. *Onoclea sensibilis*, *Osmunda regalis*), horsetails*(Equisetum* spp.)	*Acer saccharinum*, *Acer rubrum*, *Salix* spp., *Ulmus* spp., *Fraxinus nigra*, *Fraxinus americana*
	Coniferous tree swamp	Feather mosses (e.g. *Dicranum* spp., *Pleurozium schreberi*)	*Picea mariana*, *Abies balsamea*, *Alnus* spp.
Marshes[2]	Freshwater marsh	*Typha latifolia*, *Sagittaria latifolia*, *Pontederia cordata*, *Scirpus* spp., *Sparganium* spp., *Calamagrostis canadensis*	*Salix* spp., *Alnus incana* subsp. *rugosa*
	Saltwater marsh	Cordgrasses (e.g. *Sporobolus alterniflorus*, *S. pumilus*), *Salicornia* spp.	*Myrica gale*, *Spiraea alba* var. *latifolia*

[1] It is sometimes difficult to tell the difference between treed swamps and wooded peatlands. In the field, the criterion of average organic deposit thickness (>30 cm for peatlands) is used to distinguish them.

[2] Wet meadows are included in the freshwater marsh category. This category includes both lotic and lentic ecosystems.

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