Field guide for estimating carbon stocks in wetlands

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Acknowledgements

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 is 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 fighting climate change. Wetlands play a vital role in **greenhouse gas (GHG)** dynamics by storing large quantities of carbon in their soils and vegetation. Indeed, some wetlands, particularly **peatlands**, have been accumulating carbon for millennia and have a cooling effect on the climate. It is therefore essential to prioritize the conservation of wetlands.

Action *1.11.1.1 Equip government and municipalities with the tools to conserve priority carbon reservoirs* [Translation] of the PGE 2030 addresses this important nature-based solution to fight climate change. Considering that many important reservoirs are found in wetlands, it has become necessary to develop a method for quantifying the carbon stocks in these environments in Québec. Existing methods for quantifying wetland carbon stocks involve intensive field sampling and laboratory analysis, considerably limiting large-scale data collection across Québec. The proposed simple field method allows for better quantification of **carbon stocks** in order to support land-use planning decisions in the context of climate change mitigation.

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 approach is essential to prioritize wetlands for conservation. This approach can also be used to document carbon losses associated with the destruction or alteration of these ecosystems (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 to fight climate change. Although peatlands are already recognized as important carbon reservoirs (Garneau and van Bellen, 2016), currently there are only fragmented databases on carbon stock values in the various wetlands in Québec.

The aim of this guide is to enable the quantification of carbon stocks in wetlands using simple field measurements. The method was developed specifically for non-permafrost wetlands in temperate and boreal regions. It will be useful for 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 is intended to be used on a voluntary basis, in the context of land-use planning, climate change mitigation, or according to specific contexts requiring this type of detailed data, for example, for knowledge acquisition purposes.

The inventories performed using this method will make it possible 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 of carbon stocks over time 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 their soils or vegetation. These include **open peatlands**, **forested 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).
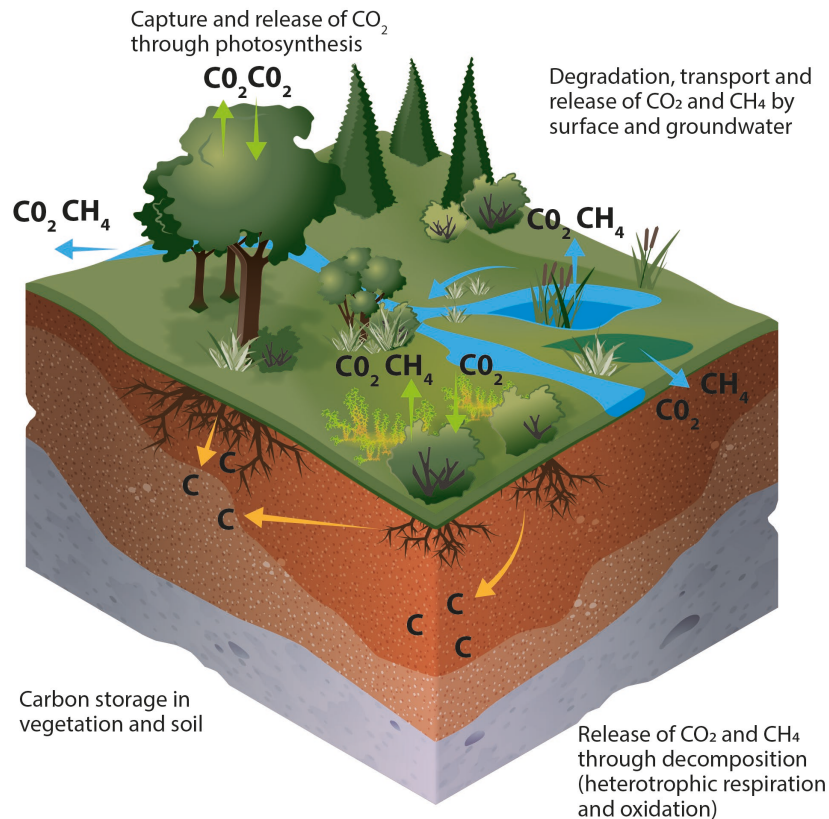
Figure 1. Carbon dynamics in wetlands. The arrows show the direction of exchanges, but do not quantify fluxes.

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 wetland types (Figure 2). Peatlands store the highest amounts 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 exceed decomposition, due to the acidic and **anaerobic conditions** and low biological activity in soils permanently saturated with water. Forested 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 faster 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 SOC mass similar to that of upland forests (non-**hydromorphic** soils) (Figure 2).
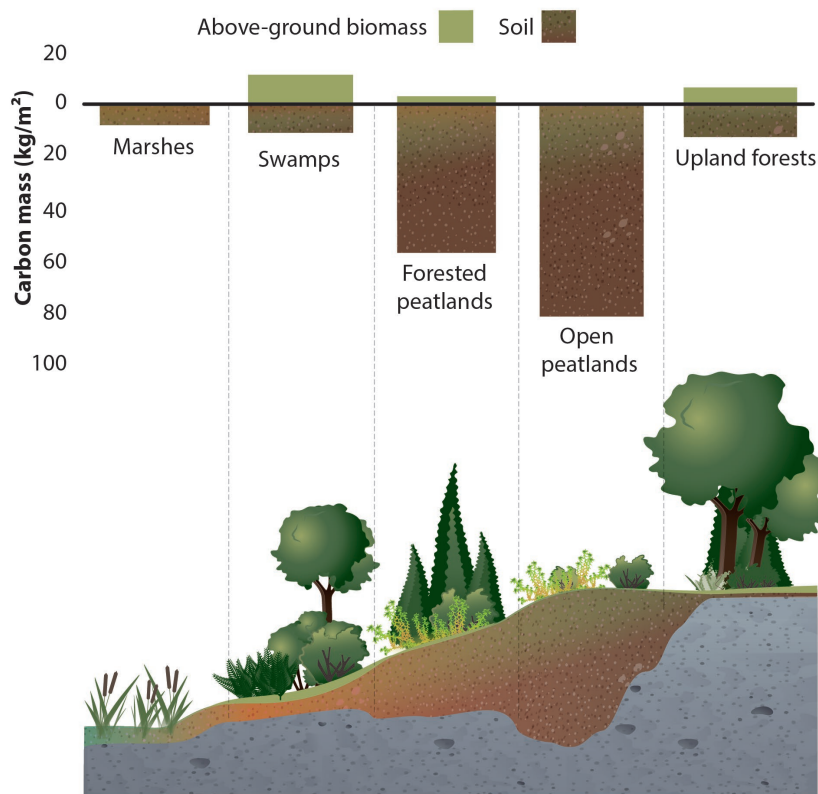
Figure 2. Carbon distribution in soils and above-ground biomass of different types of wetlands compared with upland forests (Source: C-PALEO Laboratory). The wetland classification used to synthesize the data is the one presented in Lachance et al. (2021).

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) mass** and **woody biomass carbon (WBC) mass** at different inventory stations. SOC mass is calculated using a synthesis of carbon density data (Magnan et al., 2023). WBC mass is calculated using **allometric equations** adapted to the different tree and shrub species (e.g., Lambert et al., 2005). Carbon mass 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 planning
2. Field inventory
3. Calculating carbon masses and stocks

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

Calculating carbon mass and stock

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

SOC mass (kg/m²): Average carbon density (kg/m^3) multiplied by the organic deposit thickness (m).

WBC mass (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 an entire or partial ecosystem (e.g., peatland) — average mass of SOC and WBC (kg/m^2) from multiple inventory stations multiplied by the wetland surface area.

WBC mass (kg/m^2)
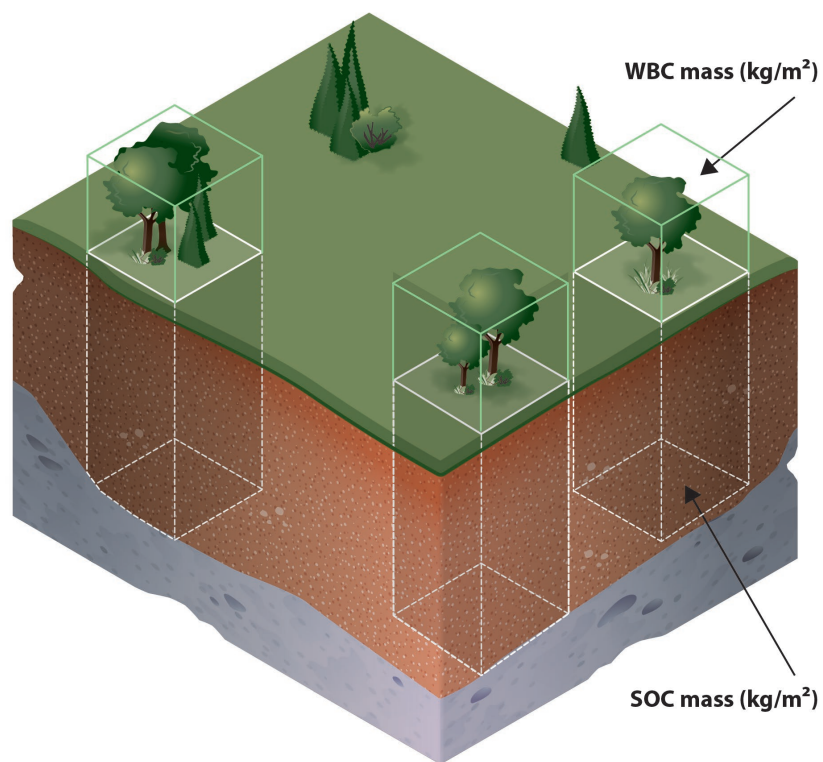
SOC mass (kg/m^2)

Carbon stock (kg) = average carbon mass (kg/m^2) × surface area (m^2)

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

Carbon stock inventory procedure

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

Inventory strategy

To obtain a representative value of a wetland's carbon stock, the following inventory effort is suggested based on the analyses carried out by the research team at the C-PALEO Laboratory (Geotop Centre-UQAM). The effort depends 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 quantifying the carbon stock of a large wetland complex with numerous HVUs (of varying types, shapes and surface areas), the inventory effort can be reduced by combining 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 geographic information systems (GIS) tools (Figure 4).

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

Figure 4. Examples of carbon mass 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 during 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 the field campaigns, 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 HVUs should be relocated.

Inventory to quantify soil organic carbon (SOC) mass

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Materials required

- Shovel

- Soil auger

- Tape measure

- Oakfield probe with extension rods (a minimum of 7 metres is recommended)

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Inventories are carried out in a 100-m^2 (10 m × 10 m) plot and four 25-m^2 (5 m × 5 m) subplots. The plot and subplots must be well delineated to ensure that their surface area is as accurate as possible, to avoid errors in the calculation of carbon mass per unit area in kg/m^2 (Figure 5).

To calculate the SOC mass, three measurements of organic deposit thickness must be taken randomly within three 25-m^2 subplots, ensuring that a minimum distance of 5 meters is left between the three measurement points (Figure 5).
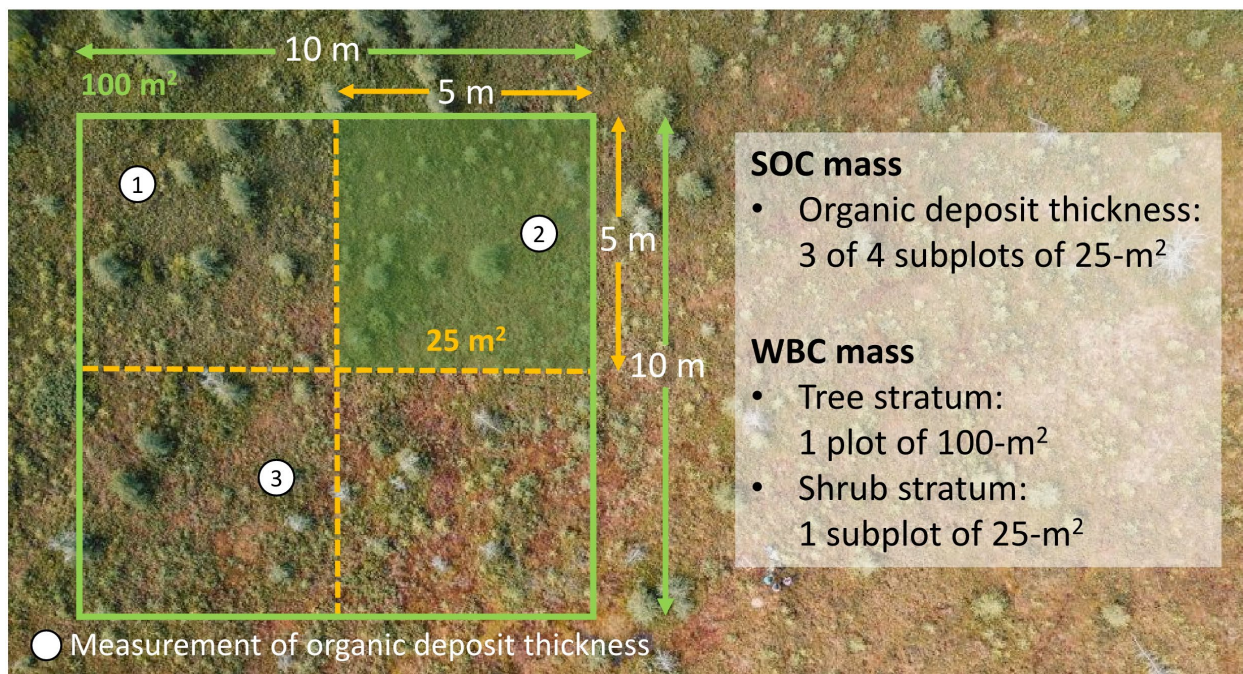
Figure 5. Summary diagram of SOC and WBC measurements to be carried out at an inventory station.

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, related to the 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 Dutch 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 has been reached **(definite mineral refusal)**. It is generally much easier to penetrate the organic deposit with the probe than the underlying mineral deposit. The total length of the inserted probe to where it makes contact with the mineral deposit is then measured. To facilitate measurements, the Oakfield probe rods can be graduated at 50 cm intervals. After removing the probe from the soil, the content of the tube must be identified to confirm contact between the organic deposit and the mineral deposit (Figure 6). The Oakfield probe tube must be emptied and cleaned between each measurement.

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

Measuring organic deposits: particular cases

Mineral deposit composed of fine particles

Extra precautions must be taken when the mineral deposit is composed 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 mass. If the probe seems to have penetrated too deeply, for example when the tube is filled with fine sand or clay, another measurement should be taken at a shallower depth in order to clearly identify the organic/mineral transition in the tube.

Obstruction by woody material

The presence of woody material (e.g. stumps or roots) in the organic deposit may prevent the probe from reaching the mineral deposit (see example of obstruction in figure 7). When such an obstruction occurs, 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 actual thickness of the organic deposit, as an obstruction can result in a substantial underestimation of the SOC mass of an inventory station.

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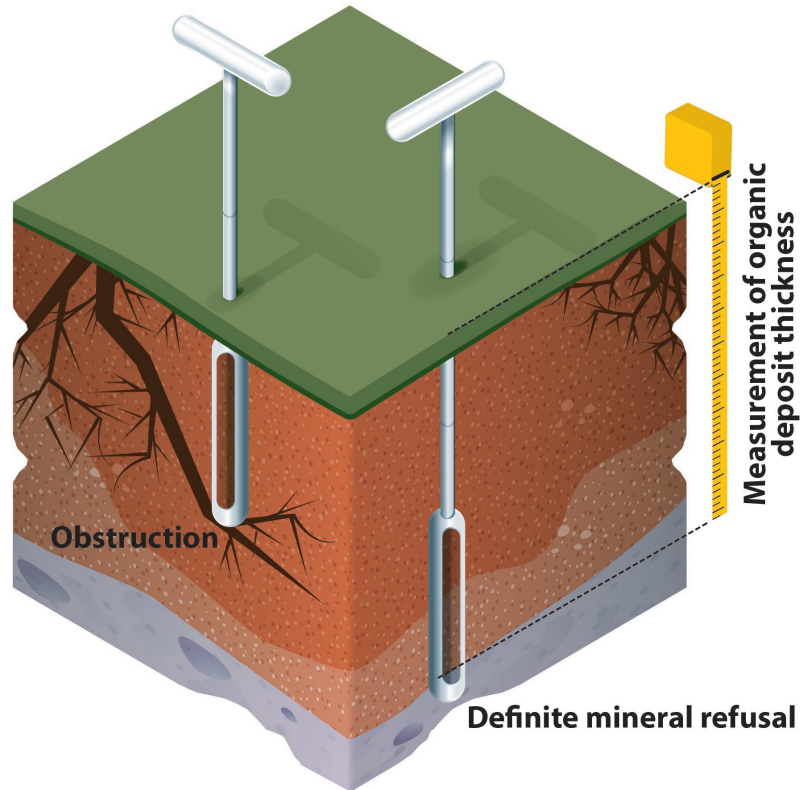
Figure 7. Examples of an obstruction when inserting the probe into the organic deposit (left) and a definite mineral refusal when the underlying mineral deposit is reached (right).

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 the 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 mass 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. Degree of organic matter decomposition: fibric, mesic and humic. (See von Post scale in Appendix 1.)

Inventory to quantify woody biomass carbon (WBC) mass

To calculate WBC mass, the above-ground woody biomass must be estimated within the 100 m^2 plot for the tree stratum (stem heights >4 m) and in a 25 m^2 subplot for the shrub stratum (stem heights between 1.3 m and 4 m) (Figure 5). Only stems 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 mass. Furthermore, the stems of dead trees and shrubs are excluded from the inventories.

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

DBH and DSH are measured using a diameter tape or tree caliper (Figure 9). It is also possible to measure the stem 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 stem is measured as a distinct individual (D'Eon et al., 1994). The DSH should be measured at the base of the stem, 15 cm above the ground surface. If a shrub grows in clusters from the **root collar** (e.g. alder), each stem is measured individually. Conversely, when stems separate above the 15 cm mark, only the main stem 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 masses.

Figure 9. Location of the measurements of A) DBH and B) DSH according to different growth patterns for trees and shrubs.

Calculating carbon masses and stocks

The detailed procedure for calculating carbon mass and stock values (SOC and WBC) for wetlands from field measurements is available on the [MELCCFP website](#). It is important to follow this procedure to standardize data for analysis and comparison purposes. An overview of the main calculation steps is provided below.

SOC mass per inventory station

To be able to calculate the SOC mass, it is necessary to identify the wetland type using the criteria presented 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 mass 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 analyses of soil cores in laboratory (Magnan et al., 2023). The SOC mass (kg/m²) is calculated using these data, by multiplying the average organic deposit thickness (m) by the average SOC density value (kg/m³), or by using the equation of the linear relationship between organic deposit thickness and SOC mass.

The accuracy of the calculations is higher for peatlands than for swamps and marshes, as SOC density and mass are not as well documented in the latter wetland types. If the objective of the inventory is to obtain precise SOC mass values, it is recommended to sample soil cores and perform carbon density analyses in 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 mass 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 distinct equation is used for each tree or shrub species (or group of species) present at the inventory station. The WBC mass (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 (m²) 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 mass (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.

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Glossary

Above-ground biomass	Dry weight of above-ground plant matter, including stems, 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 stem diameter (breast or stump height).
Anaerobic condition	Absence of oxygen in an environment.
Carbon storage	Long-term carbon accumulation 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	Area within which the wetland type and vegetation are uniform. Multiple homogeneous vegetation units (HVU) may be present within a wetland complex. For more details, consult the guide *Identification and delineation of wetlands in southern Québec* ([Lachance et al., 2021](#)) (French).
Hydromorphic	Characteristic of a soil whose development is influenced 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 soils, and the tree and shrub stratum covers less than 25% of its surface area.
Mineral deposit	Surface deposit on which a wetland has developed (e.g. clay, sand, gravel). Contact between the organic and mineral deposits is confirmed by a definite mineral refusal when a probe is inserted.
Open peatland	Non-forested peatland in which trees over 4 m high 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 decomposition (e.g. fibric, mesic, humic).

Peat   Accumulation of partially decomposed organic matter derived from plant remains (e.g. *Sphagnum* mosses, brown mosses, wood) under water-saturated conditions. Peat corresponds to a thick organic deposit (>30 cm) and excludes the living plant cover.

Peatland   Type of wetland in which the accumulation of organic matter prevails over decomposition processes, resulting in the formation of an organic deposit of 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.

Forested peatland   Peatland in which trees over 4 m high cover 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 common species in wetlands of southern Québec for which 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 masses (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*
	Forested 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]	Hardwood swamp	Ferns (e.g. *Onoclea sensibilis*, *Osmunda regalis*), horsetails (*Equisetum* spp.)	*Acer saccharinum*, *Acer rubrum*, *Salix* spp., *Ulmus* spp., *Fraxinus nigra*, *Fraxinus americana*
	Coniferous 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 distinguish swamps and forested peatlands. In the field, the criterion of the average organic deposit thickness (>30 cm for peatlands) is used to distinguish these two wetland types.

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