Verified Carbon Standard

VCS Module

VMD0051

METHODS FOR MONITORING OF CARBON STOCK CHANGES AND GREENHOUSE GAS EMISSIONS AND REMOVALS IN TIDAL WETLAND RESTORATION AND CONSERVATION PROJECT ACTIVITIES (M-TW)

Version 1.1

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Sectoral Scope 14

CONTENTS

1 SOURCES

This module is one of numerous modules that constitute the VCS approved methodology *VM0007 REDD+ Methodology Framework (REDD+ MF).*

This module is based on the following methodology:

- *VM0033 Methodology for Tidal Wetland and Seagrass Restoration*

This module uses the latest version of following modules:

- *Module BL-TW VMD0050 Estimation of baseline carbon stock changes and greenhouse gas emissions in tidal wetland restoration and conservation project activities*
- *Module E-BPB VMD0013 Estimation of greenhouse gas emissions from biomass and peat burning*
- *Module X-STR VMD0016 Methods for stratification of the project area*
- *Module VMD0019 Methods to Project Future Conditions*
- *Module M-ARR VMD0045 Methods for monitoring greenhouse gas emissions and removals in ARR project activities*
- *Module E-FFC VMD0014 Estimation of emissions from fossil fuel combustion*
- *Module CP-AB VMD0001 Estimation of carbon stocks in the above- and belowground biomass in live tree and non-tree pools*
- *Module M-REDD VMD0015 Methods for monitoring of greenhouse gas emissions and removals in REDD project activities*

2 SUMMARY DESCRIPTION OF THE MODULE

This module provides procedures to estimate soil emission reductions and removals generated by WRC project activities implemented on tidal wetlands, i.e. Restoration of Wetland Ecosystems (RWE) and Conservation of Intact Wetlands (CIW) project activities.

It also provides procedures for the accounting of the effect of submergence and erosion on the biomass and tidal wetland SOC pool.

3 DEFINITIONS

In addition to the definitions set out in the VCS Program document *Program Definitions* and VCS methodology *VM0007 REDD+ MF*, the following definitions apply to this module:

Aerobic Environment
An aerobic environment – in the context of this module – is defined as an ecosystem that does not meet the definition of a wetland.

Allochthonous Soil Organic Carbon
Soil organic carbon originating outside the project area deposited within the project area (compare to *unreactive allochthonous soil organic carbon*, below).

Autochthonous Soil Organic Carbon
Soil organic carbon originating or forming in the project area (e.g., from vegetation)

Carbon Preservation Depositional Environment (CPDE)
Type of subaquatic sediment deposition environment that impacts the amount of deposited organic carbon that is preserved. Carbon preservation is affected by mineral grain size, sediment accumulation and burial rates, O_2 availability in the overlying water column and sediment hydraulic conductivity.

Deltaic Fluidized Mud
A Carbon Preservation Depositional Environment (CPDE) type. This subaquatic depositional environment is characterized by sediment accumulation rates generally greater than 0.4 g per cm^2 per year in deltaic settings, consisting primarily of fluidized (unconsolidated) fine-grain materials. Surface sediments may be re-suspended by waves and tides, but deposited organic matter will be buried. Examples of these can be found in the Amazon and Mississippi deltas.

Extreme Accumulation Rate
A Carbon Preservation Depositional Environment (CPDE) type. This subaquatic depositional environment is characterized by accumulation rates generally greater than 1 g per cm^2 per year resulting in rapid and long-term burial of deposited sediments. Examples of these systems can be found in the Ganges-Brahmaputra and Rhone river deltas.

Impounded Water
A pool of water formed by a dam or pit

Mangrove
A subset of wetlands dominated by mangrove plant species, which are shrubs or trees that grow in coastal saline or brackish water

Marsh
A subset of wetlands characterized by emergent soft-stemmed vegetation and shrubs adapted to saturated soil conditions[1]

Mineral Soil
A soil that does not meet the definition of an organic soil

[1] There are many different kinds of marshes, ranging from the prairie potholes to the Everglades, coastal to inland, freshwater to saltwater, but the scope of this methodology is limited to tidal marshes. Salt marshes consist of salt-tolerant and dwarf brushwood vegetation overlying mineral or organic soils.

Mudflat

A subset of tidal wetlands consisting of soft substrate and a near absence of emergent vegetation

Normal marine

A Carbon Preservation Depositional Environment (CPDE) type. This is a depositional environment that does not meet the definition of the other four defined conditions (i.e., *deltaic fluidized mud*, *extreme accumulation rate*, *oxygen depletion zone*, or *small mountainous river*). Normal marine environments typically have low sedimentation rates and high O_2 availability in overlying sediments.

Open Water

An area in which water levels do not fall to an elevation that exposes the underlying substrate

Organic Soil

Soil with a surface layer of material that has a sufficient depth and percentage of organic carbon to meet an internationally accepted threshold (e.g., host-country, FAO or IPCC) of organic soil. Where used in this methodology, the term *peat* is used to refer to organic soil.

Oxygen (O_2) Depletion Zone

A Carbon Preservation Depositional Environment (CPDE) type. This is a depositional environment with low O_2 levels in water overlying sediments due to restricted hydrologic circulation or impaired water quality that leads to hypoxic or anaerobic conditions (including euxinic and semi-euxinic).

Salinity Average

The average water salinity value of a wetland ecosystem used to represent variation in salinity during periods of peak CH_4 emissions (e.g., during the growing season in temperate ecosystems)

Salinity Low Point

The minimum water salinity value of a wetland ecosystem used to represent variation in salinity during periods of peak CH_4 emissions (e.g., during the growing season in temperate ecosystems)

Seagrass Meadow

An accumulation of seagrass plants over a mappable area. This definition includes both the biotic community and the geographic area where the biotic community occurs. Note that the vast majority of seagrass meadows are sub-tidal, but a percentage are intertidal.

Small Mountainous River (SMR)

A Carbon Preservation Depositional Environment (CPDE) type. This is a depositional environment from which the sediment is supplied from small mountainous rivers, most commonly found in tectonically active margins and small steep gradients. Sediment accumulation rates are generally greater than 0.27 g per cm^2 per year. Examples of these systems can be found in the rivers flowing from the island of Taiwan and the Eel river of California.

Tidal Wetland
A subset of wetlands under the influence of the wetting and drying cycles of the tides (e.g., marshes, seagrass meadows, tidal forested wetlands and mangroves). Subtidal seagrass meadows are not subject to drying cycles, but are still included in this definition.

Tidal Wetland Restoration
Re-establishing or improving the hydrology, salinity, water quality, sediment supply and/or vegetation in degraded or converted tidal wetlands. For the purpose of this methodology, this definition also includes activities that create wetland ecological conditions on uplands under the influence of sea level rise or activities that convert one wetland type to another or activities that convert open water to wetland.

Unreactive Allochthonous Soil Organic Carbon
The portion of soil organic carbon originating outside the project area deposited within the project boundary that is stable over the project period regardless of depositional environment. In practice, it is the portion of allochthonous soil organic carbon associated with and stabilized by soil minerals.

Water Table Depth
Depth of sub-soil or above-soil surface of free water, relative to the soil surface

Acronyms	
ARR	Afforestation, Reforestation and Revegetation
CIW	Conservation of Intact Wetlands
CPDE	Carbon Preservation Depositional Environment
GHG	Greenhouse Gas
REDD	Reducing Emissions from Deforestation and forest Degradation
RWE	Restoration of Wetlands Ecosystems
SOC	Soil Organic Carbon
VCS	Verified Carbon Standard
WRC	Wetlands Restoration and Conservation

For definitions of VCS AFOLU project categories, refer to the *VCS Standard*.

4 APPLICABILITY CONDITIONS

This module applies to tidal wetland restoration and conservation project activities, as defined in *REDD+ MF*. This module is applicable under the same applicability conditions outlined in *REDD+ MF* for WRC project activities.

5 PROCEDURES

5.1 General Procedures

Emissions in the project scenario of WRC project activities in tidal wetlands are attributed to carbon stock changes in biomass carbon pools, soil processes, or a combination of these. In addition, where relevant, emissions from fossil fuel use and prescribed burning of biomass may be quantified.

For REDD-CIW and stand-alone CIW project activities, procedures for biomass, fossil fuel use and biomass burning are provided in Module *M-REDD*, in combination with Modules *CP-AB*, *E-FFC* and *E-BPB*. When using Module *CP-AB*, for non-tree biomass, project proponents may apply default values for carbon stocks in herbal biomass in tidal wetlands provided in Module *M-ARR*.

For ARR-RWE project activities, procedures for biomass and biomass burning are provided in Module *M-ARR*. For *ARR-RWE* and stand-alone RWE project activities, procedures for fossil fuel use are provided in Module *E-FFC*. The net GHG emissions from fossil fuel use in the project scenario is then calculated as:

$$GHG_{WPS-fuel} = \sum_{i}^{M_{WPS}} \sum_{t}^{t*} E_{FC,i,t} \tag{1}$$

Where:

$GHG_{WPS-fuel}$	=	Net CO_2e emissions from fossil fuel use in the project scenario up to year $t*$; t CO_2e
$E_{FC,i,t}$	=	Net CO_2e emissions from fossil fuel combustion in stratum *i* in year *t* (from Module *E-FFC*); t CO_2e
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … $t*$ years elapsed since the project start date

When referred to use procedures in Module *BL-TW*, for all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Net GHG emissions in the project scenario on tidal wetland are estimated as:

$$GHG_{WPS-TW} = \sum_{t=1}^{t^*} \sum_{i=1}^{M_{WPS}} (A_{WPS,i,t} \times GHG_{WPS-TW,i,t}) \tag{2}$$

Where:

GHG_{WPS-TW}	=	Net GHG emissions in the WRC project scenario on tidal wetland up to year $t*$; t CO_2e

$GHG_{WPS-TW,i,t}$	=	GHG emissions in the WRC project scenario on tidal wetland in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$A_{WPS,i,t}$	=	Area of stratum *i* in year *t* in the project scenario; ha
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … $t*$ years elapsed since the project start date

Estimation of GHG emissions and removals from the tidal wetland SOC pool is based on either various proxies (e.g., carbon stock change, water table depth) or through the use of literature, data, default factors or models. Procedures are provided in Module *BL-TW*. When referred to use procedures in Module *BL-TW*, for all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Ex-ante estimates of GHG_{WPS-TW} must be based on a project scenario that is defined *ex ante*, and must be projected using the latest version of VCS module *VMD0019 Methods to Project Future Conditions*.

Ex-post estimates of GHG_{WPS-TW} must be based on monitoring results.

This module provides accounting procedures for mineral wetland soils. Accounting procedures for organic soils (also those existing in tidal wetlands) are provided in Module *M-PEAT*.

5.2 Accounting for Submergence and Erosion

5.2.1 Carbon Loss in Biomass and Soil

The consequences of submergence and/or erosion of a given stratum due to sea level rise or other factors (e.g., wave action due to boats) are:

1. Carbon stocks from aboveground biomass are lost to oxidation, and
2. Depending upon the geomorphic setting, soil carbon stocks may be submerged and held intact or be eroded and transported beyond the project area.

If it can be demonstrated that the submergence or erosion of carbon stocks is due to sea level rise, then projects will account for this loss using the *VCS AFOLU Non-Permanence Risk Tool (NPRT)*. The tool provides procedures to determine contributions to the AFOLU pooled buffer account. Where a loss event occurs, projects must conform with the rules set out in the latest version of the *VCS Registration and Issuance Process*.

For carbon loss due to other factors, follow the procedures below.

Regarding (1) above, where biomass is submerged, it is assumed that this carbon is immediately and entirely returned to the atmosphere. For the year of submergence, the aboveground carbon stock in biomass is set to zero. Therefore, for the year of submergence in a REDD-WRC project activity, the following applies:

$C_{AB\_tree,i}$=0

$C_{AB\_non-tree,i}$=0

Where:

$C_{AB\_tree,i}$ = Carbon stock in aboveground tree biomass in stratum *i*; t CO_2e ha^{-1}

$C_{AB\_non-tree,i}$ = Carbon stock in aboveground non-tree vegetation in stratum *i*; t CO_2e ha^{-1}

Follow procedures provided for areas undergoing natural disturbance in Module *M-REDD*, where the carbon stock in post-natural disturbance can be set to zero.

For the year of submergence in an ARR-RWE project activity, the following applies:

$C_{AB,TREE\_PROJ,t}$=0

$C_{AB,SHRUB\_PROJ,t}$=0

Aboveground biomass carbon stocks can be obtained from CDM tool *AR-Tool14* (see Module *M-ARR*). Since CDM tool *AR-Tool14* quantifies biomass carbon stocks $C_{TREE\_PROJ,t}$ and $C_{SHRUB\_PROJS,t}$ and does not provide separate terms for above-ground and below-ground carbon stocks in trees and shrubs, calculate the portion of belowground biomass that remains in the soil using root-shoot ratios, as follows.

$$C_{AB,TREE\_PROJ,t} = \frac{C_{TREE\_PROJ,t}}{(1 + R_{TREE})} \quad (3)$$

$$C_{AB,SHRUB\_PROJS,t} = \frac{C_{SHRUB\_PROJ,t}}{(1 + R_S)} \quad (4)$$

Where:

$C_{AB,TREE\_PROJ,t}$ = Above-ground carbon stock in tree biomass in the project scenario in year *t*; t CO_2e

$C_{TREE\_PROJ,t}$ = Carbon stock in tree biomass in the project scenario within the project boundary at a given point of time in year *t* (from CDM tool *AR-Tool14*); t CO2e

R_{TREE} = Root-shoot ratio for trees (from CDM tool *AR-Tool14*); dimensionless

$C_{AB,SHRUB\_PROJ,t}$= Above-ground carbon stock in shrub biomass in the project scenario in year *t*; t CO_2e

$C_{SHRUB\_PROJ,t}$ = Carbon stock in shrubs in the project scenario within the project boundary at a given point of time in year *t* (from CDM tool *AR-Tool14*); t CO_2e

R_S = Root-shoot ratio for shrubs (from CDM tool *AR-Tool14*); dimensionless

Note that for stand-alone WRC project activities, as per *REDD+ MF*, accounting for tree and shrub biomass is omitted.

The gradual loss of vegetation in the project area due to submergence may be captured by detailed stratification into areas with and without vegetation.

For strata where conversion to open water is expected before *t* = 100, the long-term average of $C_{TREE\_PROJ,t}$ and $C_{SHRUB\_PROJ,t}$ in CDM tool *AR-Tool14* must be calculated as defined in Module *M-ARR*.

For soil carbon, see Section 5.2 in Module *BL-TW* for procedures for accounting for submergence and erosion. For all equations, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

In areas with wave action, there may be a net loss of soil material in cases where erosion exceeds deposition, which would lead to carbon removal. In the project scenario, assuming that all carbon is oxidized and returned to the atmosphere is conservative. However, in most cases a portion of this carbon will not return to the atmosphere. Procedures are provided in Section 5.3.3 in Module *BL-TW* to estimate this quantity.

5.2.2 Long-term Average GHG Benefit in ARR-WRC Project Activities

Biomass may be lost due to submergence following sea level rise. For strata where conversion to open water occurs during the crediting period, the maximum number of GHG credits generated over the crediting period by the ARR project activity must not exceed the long-term average GHG benefit, as in the case of harvesting, as calculated in Module *M-ARR*. For strata where conversion to open water is expected after the crediting period but before *t* = 100, to account for the associated loss of tree and shrub biomass, the maximum stock in tree and shrub biomass used in *AR-Tool14* ($C_{TREE\_PROJ,t}$ and $C_{SHRUB\_PROJ,i,t}$, respectively in Module *M-ARR*) is limited to $C_{AVG-TREE,i}$ as calculated in Equation (5) and $C_{AVG-SHRUB,i}$ as calculated in Equation (6), where *n* = 100.

$$C_{AVG-TREE\_PROJ,i} = \frac{\sum_{t=1}^{n} C_{TREE\_PROJ,i,t}}{n} \tag{5}$$

Where:

$C_{AVG-TREE\_PROJ,i}$	=	Long-term average carbon stock in project tree biomass within the project area (in stratum *i*) in time period *n*; t CO_2-e
$C_{TREE\_PROJ,i,t}$	=	Carbon stock in project tree biomass within the project area (in stratum *i*) in year *t* (derived from application of *AR-Tool14*); t CO_2-e yr^{-1}
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … *n* years elapsed since the project start date
n	=	Total number of years in the established time period

$$C_{AVG-SHRUB\_PROJ,i} = \frac{\sum_{t=1}^{n} C_{SHRUB\_PROJ,i,t}}{n} \tag{6}$$

Where:

$C_{AVG-SHRUB\_PROJ,i}$ = Long-term average carbon stock in project shrub biomass within the project area (in stratum *i*) in time period *n*; t CO_2-e

$C_{SHRUB\_PROJ,i,t}$ = Carbon stock in project shrub biomass within the project area (in stratum *i*) in year *t* (derived from application of *AR-Tool14*); t CO_2-e yr^{-1}

i = 1, 2, 3, … M_{WPS} strata in the project scenario

t = 1, 2, 3, … *n* years elapsed since the project start date

n = Total number of years in the established time period

Restoration projects which include afforestation or reforestation components may account for long-term carbon storage in wood products (see procedures in Module *M-ARR*) in case trees are harvested before dieback. In this case, the parameter $\mathrm{C_{TREE\_PROJ,t}}$ in Equation (5) must be read as $C_{TREE\_PROJ,i,t}$ + $C_{WP\_PROJ,i,t}$.

5.3 Assessing Soil GHG Emissions in the Project Scenario

5.3.1 General

Net GHG emissions from tidal wetland soil in the project scenario are estimated as:

$$GHG_{WPS-TW,i,t} = GHG_{WPS-soil-CO2,i,t} - Deduction_{alloch} + GHG_{WPS-soil-CH4,i,t} + GHG_{WPS-soil-N2O,i,t} \quad (7)$$

CO_2 emissions from the tidal wetland SOC pool in the project scenario may occur *in situ* or indirectly following soil erosion (see Equation (8)). For strata with *in-situ* emissions, follow the procedures set out in Section 5.3.2 below. For strata where soil erosion occurs, the procedures in Section 5.3.3 must be used. For strata where soil is exposed to an aerobic environment through excavation prior to the project start date, procedures in Section 5.3.4 must be used. For strata with *in-situ* emissions, CH_4 and N_2O emissions must be estimated using the procedures in Sections 5.3.5 and 5.3.6, respectively.

$$GHG_{WPS-soil-CO2,i,t} = GHG_{WPS-insitu-CO2,i,t} + GHG_{WPS-eroded-CO2,i,t} + GHG_{WPS-excav-CO2,i,t} \quad (8)$$

Where:

$\mathrm{GHG_{WPS-TW,i,t}}$ = GHG emissions in the WRC project scenario on tidal wetland in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}

$\mathrm{GHG_{WPS-soil-CO2,i,t}}$ = CO_2 emissions from the tidal wetland SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}

$\mathrm{Deduction_{alloch}}$ = Deduction from CO_2 emissions from the tidal wetland SOC pool to account for the percentage of the carbon stock that is derived from allochthonous soil organic carbon; t CO_2e ha^{-1} yr^{-1}

$GHG_{WPS-soil-CH4,i,t}$	=	CH_4 emissions from the tidal wetland SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-soil-N2O,i,t}$	=	N_2O emissions from the tidal wetland SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-insitu-CO2,i,t}$	=	CO_2 emissions from the tidal wetland SOC pool of *in-situ* soils in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-eroded-CO2,i,t}$	=	CO_2 emissions from the eroded tidal wetland SOC pool in the project scenario in stratum *i* in year *t* ; t CO_2e ha^{-1} yr^{-1}
$GHG_{WPS-excav-CO2,i,t}$	=	CO_2 emissions in the project scenario from the tidal wetland SOC pool of soil exposed to an aerobic environment through excavation in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … *n* years elapsed since the project start date

5.3.2 CO_2 Emissions from Soil – *in situ*

CO_2 emissions from *in-situ* soil exposed to an aerobic environment ($GHG_{WPS-insitu-CO2,i,t}$) may be calculated directly or may be calculated from estimates of the initial amount of carbon that is exposed ($C_{WPS-soil-CO2,i,t}$) and the percentage of the exposed carbon that is returned to the atmosphere ($C\%_{WPS-emitted,i,t}$) as defined in Equation (9).

Estimates of $C_{WPS-soil,i,t}$ or $C\%_{WPS-emitted,i,t}$ following aerobic exposure must account for tendency of organic carbon concentrations to approach steady-state equilibrium in mineral soils. For this reason, a complete loss of soil organic carbon may not occur in mineral soils. Likewise, $C\%_{WPS-emitted,i,t}$ may not reach 100%. This steady-state equilibrium must be determined conservatively, e.g. by assuming that $C_{WPS-soil,i,t}$ at steady state will be zero or that $C\%_{WPS-emitted,i,t}$ will be 100%. In case of alternating mineral and organic horizons that are exposed, CO_2 emissions must be determined for all individual horizons.

$$GHG_{WPS-insitu-CO2,i,t} = \frac{44}{12} \times \frac{C_{WPS-soil,i,t} \times C\%_{WPS-emitted,i,t}}{100} \quad (9)$$

$$C_{WPS-soil,i,t} = C\%_{WPS-soil,i,t} \times BD \times Depth\_i_{i,t} \times 10 \quad (10)$$

Where:

$GHG_{WPS-insitu-CO2,i,t}$	=	CO_2 emissions from the *in-situ* tidal wetland SOC pool in the project scenario in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$C_{WPS-soil,i,t}$	=	C mass present in in-situ tidal wetland soil material in the project scenario in stratum *i* in year *t*; t C ha^{-1}
$C\%_{WPS-emitted,i,t}$	=	Organic carbon loss due to oxidation, as a percentage of C mass present in *in-situ* tidal wetland soil material in the project scenario in stratum *i* in year *t*; %
$C_{WPS-soil,i,t}$	=	Percentage of carbon of *in-situ* tidal wetland soil material in stratum *i* in year *t*; %

BD = Soil bulk density; kg m^{-3}

$Depth\_i_{i,t}$ = Depth of the *in-situ* exposed soil in stratum *i* in year *t*; m

Project proponents can use any combination of the following methods to calculate these terms:

1) Proxies
2) Published values
3) Default factors and emission factors
4) Models
5) Field-collected data, or
6) Historical or chronosequence-derived data

In certain cases, allochthonous soil organic carbon may accumulate in the project area, and such carbon must be accounted for in the project scenario. Procedures for the estimation of a compensation factor for allochthonous soil organic carbon are specified in Section 5.3.2.2.

5.3.2.1 Approaches for Estimating $GHG_{WPS\text{-}insitu\text{-}CO2,i,t}$

$GHG_{WPS-insitu-CO2,i,t}$ must be calculated using the same procedures set out in Section 5.3.2. in Module *BL-TW*. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

Note that linear interpolation of the default factor may not be used for areas with a crown cover between 15% and 50%.

5.3.2.2 Deduction for Allochthonous Carbon

A deduction must be applied to account for allochthonous carbon using the procedures set out in Section 5.3.2.7 of Module *BL-TW*. The project proponent must also follow the additional guidance below.

The determination of the deduction for allochthonous carbon is mandatory for the project scenario unless the project proponent is able to demonstrate that the allochthonous carbon would have been returned to the atmosphere in the form of carbon dioxide in the absence of the project.

The deduction for allochthonous carbon must only be applied to soil layers deposited or accumulated after the project start date (such as materials formed above a feldspar marker horizon).

If the organic surface layer exceeds 10 cm, the soil is deemed organic and no deduction is required. If an organic surface layer of up to 10 cm is present, $Deduction_{alloch}$ must be determined only in such cases where the project experiences mineral sedimentation events sufficient to create mineral soil layers. In practice, the project area may show mineral sedimentation in places. If this is observed it is assumed that at some point during the project crediting period mineral sediment can be deposited on top of organic surface layers, unless the project proponent can justify that strata with an organic surface layer of less than 10 cm will not experience mineral sedimentation during the project crediting period.

5.3.3 CO_2 Emissions from Eroded Soil

For each stratum *i* at time *t* the project proponent must determine if soil erosion occurs. If it can be demonstrated that CO_2 emissions due to erosion are the result of sea level rise, projects do not need to account for this emission source, as it is included in the *VCS AFOLU Non-Permanence Risk Tool*. If the erosion is caused by another factor, follow the procedures below.

CO_2 emissions from eroded soil material ($GHG_{WPS-eroded-CO2,i,t}$) may be calculated directly or may be calculated from estimates of the amount of carbon that is eroded ($C_{WPS-eroded,i,t}$) and the percentage of the eroded carbon that is returned to the atmosphere ($C\%_{WPS-emitted-CO2,i,t}$) as defined in Equation (11).

$$GHG_{WPS-eroded-CO2,i,t} = \frac{44}{12} \times \frac{C_{WPS-eroded,i,t} \times C\%_{WPS-emitted,i,t}}{100} \tag{11}$$

Where:

$GHG_{WPS-eroded-CO2,i,t}$	=	CO_2 emissions from the eroded tidal wetland SOC pool in the project scenario; t CO_2e ha^{-1} yr^{-1}
$C_{WPS-eroded,i,t}$	=	C mass present in eroded tidal wetland soil material in the project scenario; t C ha^{-1} yr^{-1}
$C\%_{WPS-emitted,i,t}$	=	Organic carbon loss due to oxidation, as a percentage of C mass present in eroded tidal wetland soil material in the project scenario[2]; %

$$C_{WPS-eroded,i,t} = C\%_{WPS-eroded,i,t} \times BD \times Depth\_e_{i,t} \tag{12}$$

Where:

$C\%_{WPS-eroded,i,t}$	=	Percentage of carbon of tidal wetland soil material eroded in stratum *i* in year *t*; %
BD	=	Soil bulk density; kg m^{-3}
$Depth\_e_{i,t}$	=	Depth of the eroded area from the surface to the surface prior to erosion in stratum *i* in year *t*; m

Project proponents can use any combination of the following methods to calculate these terms:

1. Proxies
2. Published values

[2] To ensure a conservative outcome, emissions must be estimated for a 1-year time period following the initial year of erosion.

3. Default factors
4. Models
5. Field-collected data, or
6. Historical or chronosequence-derived data

5.3.3.1 Approaches for Estimating $GHG_{WPS-eroded-CO2,i,t}$

$GHG_{WPS-eroded-CO2,i,t}$ must be calculated using the same procedures set out in Sections 5.3.3.1 – 5.3.3.6 in Module *BL-TW*. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario. If it can be demonstrated that $GHG_{WPS-eroded-CO2,i,t}$ is the result of sea level rise, projects do not need to account for this emission source, as it is included in the *VCS AFOLU Non-Permanence Risk Tool*.

5.3.4 CO_2 Emissions from Soil Exposed to an Aerobic Environment Through Excavation

For each stratum *i* at time *t* the project proponent must determine if piled-up soil[3] exposed to an aerobic environment exists within the project boundary.

CO_2 emissions from soil exposed to an aerobic environment through excavation ($GHG_{WPS-excav-CO2,i,t}$) may be calculated directly or may be calculated from estimates of the initial amount of carbon that is exposed ($C_{WPS-excav,i,t}$) and the percentage of the exposed carbon that is returned to the atmosphere ($C\%_{WPS-emitted,i,t}$) as defined in Equation (13). For ex-ante calculations, estimates of $C_{WPS-excav,i,t}$ following the aerobic exposure event must account for tendency of organic carbon concentrations to approach steady-state equilibrium in mineral soils. For this reason, a complete loss of soil organic carbon may not occur in mineral soils. This steady-state equilibrium must be determined conservatively, e.g. by assuming that $C_{WPS-soil,i,t}$ at steady state will be zero.

$$GHG_{WPS-excav-CO2,i,t} = \frac{44}{12} \times \frac{C_{WPS-excav,i,t} \times C\%_{WPS-emitted,i,t}}{100} \quad (13)$$

$$C_{WPS-excav,i,t} = C\%_{WPS-excav,i,t} \times BD \times Depth\_ex_{i,t} \times 10 \quad (14)$$

Where:

$GHG_{WPS-excav-CO2,i,t}$	=	CO_2 emissions in the project scenario from the tidal wetland SOC pool of tidal wetland soil exposed to an aerobic environment through excavation in stratum *i* in year *t*; t CO_2e ha^{-1} yr^{-1}
$C_{WPS-excav,i,t}$	=	C mass present in the project scenario in tidal wetland soil exposed to an aerobic environment through excavation in stratum *i* in year *t*; t C ha^{-1}

[3] "Piled up soil" refers to a body of soil material accumulated in piles or layers as a result of excavation.

$\mathrm{C\%_{WPS-emitted,i,t}}$	=	Organic carbon loss due to oxidation in the project scenario, as a percentage of C mass present in excavated tidal wetland soil material in stratum *i* in year *t*; %
$C\%_{BSL-excav,i,t}$	=	Percentage of carbon of tidal wetland soil material excavated in stratum *i* in year *t*; %
BD	=	Soil bulk density; kg m^{-3}
$Depth\_ex_{i,t}$	=	Depth of the piled-up soil material due to excavation in stratum *i* in year *t*; m

Project proponents can use any combination of the following methods to calculate these terms:

1) Proxies
2) Published values
3) Default factors
4) Models
5) Field-collected data, or
6) Historical or chronosequence-derived data

5.3.4.1 Approaches for Estimating $GHG_{WPS-excav-CO2,i,t}$

$GHG_{WPS-excav-CO2,i,t}$ must be calculated using the same procedures set out in Sections 5.3.4.1 – 5.3.4.6 in Module *BL-TW*. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

5.3.5 CH_4 Emissions from Soil – *in situ*

The estimation of CH_4 emissions in the project scenario must follow one of the approaches provided in Section 5.3.5 in Module *BL-TW*. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

5.3.6 N_2O Emissions from Soil – *in situ*

Where the project proponent is able to demonstrate (e.g., by referring to peer-reviewed literature based on similar project circumstances[4]) that N_2O emissions do not increase in the project scenario compared to the baseline scenario, N_2O emissions may be excluded.

N_2O emissions must be accounted for in the project scenario in strata where water levels were lowered as a result of project activities[5]. Seagrass restoration projects do not require N_2O emission accounting. The estimation of N_2O emissions in the project scenario may follow one

[4] Project circumstances are defined by pre-project land use (e.g., forestry, agriculture, abandonment after such activities) and its intensity (especially related to N-fertilization), climatic zone, water table depths, and soil type.

[5] See applicability conditions.

of the approaches provided in Section 5.3.6 in Module *BL-TW*. For all equations in these sections, the subscript *BSL* must be substituted by *WPS* to make clear that the relevant values are being quantified for the project scenario.

In addition, where the project proponent is able to demonstrate (e.g., by referring to peer-reviewed literature) that N_2O emissions in the project scenario are *de minimis*, N_2O emissions may be excluded. To demonstrate that N_2O emissions are *de minimis* in the project scenario, the project proponent must use CDM tool *Tool for testing significance of GHG emissions in A/R CDM project activities*, or refer to peer-reviewed literature.

5.4 Monitoring Procedures

5.4.1 Soil Coring Approach for Estimating Soil Organic Carbon

Soil organic carbon stock ($C_{WPS-soil,i,t}$) may be estimated by determining the organic carbon present above a consistent reference plane. The reference plane must be established using a marker horizon (most commonly using feldspar)[6], a strongly contrasting soil layer (such as the boundary between organic and mineral soil materials), an installed reference plane (such as the shallow marker in a surface elevation table)[7], a layer identified biogeochemically (such as through radionuclide, heavy metal, or biological tracers)[8], a layer with soil organic carbon indistinguishable from the baseline SOC concentration (as determined in Module *BL-TW* Section 5.3.2.5)[9] or other accepted technologies. Note that feldspar marker horizons may not be used in systems where they are unstable, such as some sandy soils and systems with significant bioturbation. The material below the reference plane may be conservatively assumed to have zero change due to project activities.

The material located above the reference plane must be analyzed for total carbon and bulk density. Sediment samples may be collected for the estimation of $\%C_{depsed}$ (see Section 5.3.2.7 of Module *BL-TW*) using sediment tiles,[10] through collection of suspended sediments in tidal channels during a period of high suspended sediment concentration or by collecting cores of sediment deposits in tidal flats. Total organic carbon must be analyzed directly using CHN elemental analysis or the Walkley-Black chromic acid wet oxidation method or determined from loss-on-ignition (LOI) data using the following equation:

$$\%C_{soil} = 0.04 \times \%OM_{soil} + 0.0025 \times \%OM_{soil}{}^{2} \quad \text{(only for marsh soils)}^{11} \tag{15}$$

[6] Cahoon and Turner 1989

[7] Cahoon *et al.* 2002

[8] DeLaune et al. 1978

[9] Greinier et al. 2013

[10] Pasternack and Brush 1998

[11] Craft *et al.* 1991

$$\%C_{soil} = 0.415 \times \%OM_{soil} + 2.8857 \text{ (only for mangrove soils)}^{12} \tag{16}$$

$$\%C_{soil} = 0.21 + 0.40\,(\%OM_{soil}) \text{ (only for seagrass soils with } \%OM_{soil} < 20 \text{ percent)}^{13} \tag{17}$$

$$\%C_{soil} = 0.33 + 0.43\,(\%OM_{soil}) \text{ (only for seagrass soils with } \%OM_{soil} > 20 \text{ percent)}^{14} \tag{18}$$

Alternatively, an equation developed using site-specific data may be used or an equation from peer-reviewed literature may be used if the equation represents soils from the same or similar systems as those in the project area.

Inorganic carbon must be removed from samples if present in significant quantities, usually through acid treatment (such as sulfurous or hydrochloric acid). Live coarse below-ground tree biomass must be removed from soil samples prior to analysis. Additional live below-ground biomass may be removed or included. Soil samples collected may be aggregated to reduce the variability.

The mass of carbon per unit area is calculated as follows:

$$C_{WPS-soil,i,t} = \sum_{i=1}^{Ndepth} \left(CF_{SOC,sample} \times BD \times Thickness \times 100 \right) \tag{19}$$

Where:

$C_{WPS-soil,i,t}$	=	Carbon stock in the project scenario in stratum *i* in year *t*; (t C ha^{-1})
$Ndepth$	=	Number for soil horizons, based on subdivisions of soil cores
$CF_{SOC,sample}$	=	Carbon fraction of the sample, as determined in laboratory (dimensionless)
BD	=	Soil bulk density; kg m^{-3}
$Thickness$	=	Thickness of soil horizon (cm)
100	=	Conversion factor of g cm^{-3} to Mg ha^{-1}

5.4.2 Monitoring CH_4 and N_2O Emissions

Direct measurement of CH_4 and/or N_2O emissions may be made with either a closed chamber technique or a chamber-less technique such as eddy covariance flux. For eddy covariance methods, the guidelines presented in VCS methodology *VM0024 Methodology for Coastal Wetland Creation* must be followed, taking into account the additional guidance below.

[12] Kauffman *et al*. 2011, Howard *et al*. 2014

[13] Fourqurean *et al*. 2012 as summarized in Howard *et al*. 2014

[14] Fourqurean *et al*. 2012 as summarized in Howard *et al*. 2014

Flux measurements are expected to conform to standard best practices used in the scientific community[15]. The basic design of the closed chamber for wetlands requires a base that extends into the soil (5 cm minimum), and a chamber that is placed over the plants and sealed to the base. To prevent the measurement from disturbing CH_4 emissions, the base must be placed at least one day in advance, and the plot must be approached on an elevated ramp or boardwalk when taking samples, although failure to do so is conservative because it will cause higher fluxes. CH_4 flux is calculated as the difference in initial and final headspace CH_4 concentration, without removing non-linear increases caused by bubble (ebullition) fluxes that may have occurred. Initial and final concentrations will be determined as the average of duplicate determinations. Because CH_4 and N_2O emissions can be low from tidal wetlands, it may be necessary to enclose large areas ($\geq 0.25\ m^2$) or lengthen the measurement period to improve sensitivity.

Methane emissions from strata lacking vegetation (<25 percent cover), such as open water, hollows or ponds, can be dominated by episodic bubble emissions (i.e., ebullition). Chambers for open water emissions are typically a single piece that floats such that the bottom extends under the water surface (5 cm minimum). Floating chambers must be deployed for a minimum of 4 days.

Eddy covariance techniques sense total CH_4 and N_2O emissions (diffusive and ebullition) at high temporal resolution; such systems must be deployed for a minimum of 48 hours of useable data.

CH_4 and N_2O emission estimates must be either accurate or conservative. Accurate estimates must account for variation in time caused by changes in plant activity, temperature, water table depth, salinity and other sources of variation, and in space caused by factors such as topography (e.g., hummocks versus hollows) or plant cover. A conservative estimate may be based on direct measurements taken at times and places in which CH_4 or N_2O emissions are expected to be the highest based on expert judgment, datasets or literature.

Fluxes must be measured in the stratum with the highest emissions. For CH_4, these are likely to be strata in the wettest strata that support emergent vegetation, but may include stagnant pools of water. Eddy flux towers must be placed so that the footprint lies in the stratum with the highest CH_4 or N_2O emissions for 50 percent of the time. CH_4 fluxes must be measured when the water table is <10 cm from the soil surface, during times of year when emissions are highest, such as the warmest month and/or wettest month. When CH_4 emission rates incorporate measurements from periods of time outside the peak, they must be made at approximately monthly intervals.

In addition to the conservative principles above, the project proponent must consider other factors that are specific to the method applied. In particular, closed chambers must be transparent and deployed in daylight unless it is can be shown that CH_4 emissions are not sensitive to light.

[15] Oremland 1975

Regardless of method, emissions must be averaged and expressed as daily (24 hour) rates and converted to annual estimates using the following equations:

$$GHG_{WPS-soil-CH4,i,t} = GHG_{CH4-daily,i,t} \times 365 \times CH4 - GWP \times 100 \quad (20)$$

Where:

$GHG_{WPS-soil-CH4,i,t}$	=	CH_4 emissions from the tidal wetland SOC pool in the project scenario in stratum *i* in year *t* (t CO_2e ha^{-1} yr^{-1})
$GHG_{CH4-daily,i,t}$	=	Average daily CH_4 emissions in the project scenario based on direct measurements of stratum *i* in year *t* (mg CH_4 m^{-2} d^{-1})
$CH4 - GWP$	=	Global warming potential of CH_4 (dimensionless)
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … $t*$ years elapsed since the project start date
100	=	Conversion factor of g cm^{-3} to Mg ha^{-1}

$$GHG_{WPS-soil-N2O,i,t} = GHG_{N2O-daily,i,t} \times 365 \times N2O - GWP \times 100 \quad (21)$$

Where:

$GHG_{WPS-soil-N2O,i,t}$	=	N_2O emissions from the tidal wetland SOC pool in the project scenario in stratum *i* in year *t* (t CO_2e ha^{-1} yr^{-1})
$GHG_{N2O-daily,i,t}$	=	Average daily N_2O emissions in the project scenario based on direct measurements of stratum *i* in year *t* (mg N_2O m^{-2} d^{-1})
$N2O - GWP$	=	Global warming potential of N_2O (dimensionless)
i	=	1, 2, 3, … M_{WPS} strata in the project scenario
t	=	1, 2, 3, … $t*$ years elapsed since the project start date
100	=	Conversion factor of g cm^{-3} to Mg ha^{-1}

Where the default factor approach is used for CH_4 emissions (see Section 5.3.4), the salinity average or salinity low point will be measured on shallow pore water (within 30 cm from soil surface) using a handheld salinity refractometer or other accepted technology. The salinity average must be calculated from observations that represent variation in salinity during periods of peak CH_4 emissions (e.g., during the growing season in temperate ecosystems or the wet season in tropical ecosystems). When the number of observations during this period is small (fewer than one per month for one year), the salinity low point from these data must be used. The salinity of the floodwater source (e.g., an adjacent tidal creek) during this period may be used as a proxy for salinity in pore water provided there is regular hydrologic exchange between the source and the wetland (i.e., the source floods the wetland at least on 20 percent of high tides).

5.4.3 Estimation of Eroded Soil Depth and Depth of Soil Exposed to Aerobic Conditions

Soil carbon loss may occur through three mechanisms: 1) vertical edge erosion at a wetland edge or channel bank, generally occurring at the seaward margin of wetlands exposed to wave energy, 2) horizontal surface soil erosion; and/or 3) soil exposure to aerobic conditions.

1) Vertical edge erosion at a wetland edge or channel bank: The depth of eroded soil may be measured in the field directly from the difference in elevation between the emergent wetland surface at the wetland edge to the surface of an adjacent mudflat, or sediments below adjacent waters. The adjacent point must be chosen conservatively, and must represent the shallowest point of the transition from the wetland to mudflat or adjacent subaquatic sediment surface. Determination of the surface elevation of mudflat slope must be based upon the projected amount of emergent wetland retreat. Internal loss of sediment through channel enlargement and or channel network expansion occurs in wetlands with insufficient sediment supply to build at a pace matching sea level rise in settings with a tidal range greater than 1 m. Change in channel volume can be calculated using hydraulic geometry equations and approaches.[16]
2) Horizontal surface soil erosion: Soil depth may be calculated by direct measurement at a reference site with reference to a datum that can be justified as not having shifted vertically relative to the original soil surface. This datum may be depth to a mineral soil horizon that has not shifted due to compaction or a bedrock soil horizon, a point on mangrove stumps held in place vertically (generally due to soils composed of coarse silt or sand), or through radiometric analysis to identify the age of exposed soil surfaces.
3) Soil exposure to aerobic conditions: The depth of soil exposed to aerobic conditions through drainage is intended to identify the depth at which anaerobic conditions no longer suppress organic matter decomposition as they do in wetland soils. In wetland science, these anaerobic conditions are generally understood to correspond to the conditions in which iron is reduced. The depth to which the soil is reducing with respect to iron may be identified using platinum electrodes, IRIS (Indicator of Reduction in Soils) Tubes,[17] the presence of reduced iron in pore water or on soil ped surfaces (indicated with Alpha-alpha-Dipyridyl or other laboratory analysis), or other accepted technologies. These methods must be used during the time of year with the peak height of anaerobic conditions (i.e., peak sustained water table and sufficient temperature for microbial activity[18]).

5.4.4 Monitoring Water Table

If water table is used as a proxy for carbon loss and GHG emissions, monitoring of water tables in the project or proxy area must be based on measurements in appropriate strata (see module

[16] e.g., Allen 2000; Williams and Orr 2002

[17] Rabenhorst *et.al*. 2013

[18] Vaughan *et.al*. 2009

X-STR). Water table depth measurements can be continuous with data loggers and using min-max devices (eg, Bragg et al., 1994) or simple water level gauges (dipwells consisting of e.g., perforated PVC tubes), Applied techniques must follow international standards of application or local standards as laid out in pertinent scientific literature or handbooks.

Water table depth measurements must be carried out at least every two months. At least 10 replicate dipwells must be evenly distributed per stratum, to ensure data consistency also when dipwells are lost. In peat swamp forest, dipwells must be placed in surface depressions between tree mounds. Visual inspection of the multiple records within a single stratum allows for identification of outlier values at single locations, indicating measurement errors that should be excluded from analysis. For remote and inaccessible areas, project proponents may rely on vegetation cover as an indicator for water table depth as supported by data or literature references in a conservative way.

6 DATA AND PARAMETERS

6.1 Data and Parameters Available at Validation

Data / Parameter	$CH4 - GWP$
Data unit	Dimensionless
Description	Global Warming Potential of CH_4
Equations	20
Source of data	IPCC Fourth Assessment Report 2007, available at www.ipcc.ch
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	Calculation of project emissions
Comments	$CH4 - GWP$ may change over time as new scientific data becomes available; the appropriate source is available from the latest version of the VCS Standard

Data / Parameter	$N2O - GWP$
Data unit	dimensionless
Description	Global warming potential for N_2O
Equations	21

Source of data	IPCC Fourth Assessment Report 2007, available at www.ipcc.ch
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	N/A
Purpose of Data	Calculation of project emissions
Comments	$N2O - GWP$ may change over time as new scientific data becomes available; the appropriate source is available from the latest version of the VCS Standard

6.2 Data and Parameters Monitored

Data / Parameter:	$E_{FC,i,t}$
Data unit:	t CO_2e
Description:	Net CO_2e emissions from fossil fuel combustion in stratum *i* in year *t*
Equations	1
Source of data:	Module *E-FFC*
Description of measurement methods and procedures to be applied:	See Module *E-FFC*
Frequency of monitoring/recording:	See Module *E-FFC*
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$A_{WPS,i,t}$
Data unit:	ha
Description:	Area of stratum *i* in year *t* in the project scenario
Equations	2
Source of data:	Module *X-STR*
Description of measurement methods	See Module *X-STR*

and procedures to be applied:	
Frequency of monitoring/recording:	See Module *X-STR*
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C_{TREE\_PROJ,t}$
Data unit:	t CO_2e
Description:	Carbon stock in tree biomass in the project scenario within the project boundary at a given point of time in year *t*
Equations	3
Source of data:	CDM tool *AR-Tool14*
Description of measurement methods and procedures to be applied:	See CDM tool *AR-Tool14*
Frequency of monitoring/recording:	See CDM tool *AR-Tool14*
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	R_{TREE}
Data unit:	dimensionless
Description:	Root-shoot ratio for the trees in the project
Equations	3
Source of data:	CDM tool *AR-Tool14*
Description of measurement methods and procedures to be applied:	See CDM tool *AR-Tool14*
Frequency of monitoring/recording:	See CDM tool *AR-Tool14*

QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C_{SHRUB\_PROJ,t}$
Data unit:	t CO_2e
Description:	Carbon stock in shrubs in the project scenario within the project boundary at a given point of time in year *t*
Equations	4
Source of data:	CDM tool *AR-Tool14*
Description of measurement methods and procedures to be applied:	See CDM tool *AR-Tool14*
Frequency of monitoring/recording:	See CDM tool *AR-Tool14*
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	R_s
Data unit:	dimensionless
Description:	Root-shoot ratio for shrubs
Equations	4
Source of data:	CDM tool *AR-Tool14*
Description of measurement methods and procedures to be applied:	See CDM tool *AR-Tool14*
Frequency of monitoring/recording:	See CDM tool *AR-Tool14*
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions

Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C_{WPS-soil,i,t}$
Data unit:	t C ha^{-1}
Description:	Carbon stock in the project scenario in stratum *i* in year *t*
Equations	9, 10, 19
Source of data:	Own measurements
Description of measurement methods and procedures to be applied:	See Section 5.4.1
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	BD
Data unit:	kg m^{-3}
Description:	Soil bulk density
Equations	19, 12, 13, 19
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$Depth\_i_{i,t}$
Data unit:	m
Description:	Depth of *in-situ* exposed soil in stratum *i* in year *t*
Equations	10
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$C\%_{WPS-soil,i,t}$
Data unit:	%
Description:	Percentage of carbon of *in-situ* tidal wetland soil material in stratum *i* in year *t*
Equations	10
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$\%OM_{soil}$

Data unit:	%
Description:	Percentage of soil organic matter
Equations	15 - 18
Source of data:	Direct measurements or may be derived from direct measurements of soil organic matter. These measurements may be made using samples collected in Section 5.4.1 or indirectly from the soil organic matter percentage determined through loss- on-ignition as described in Section 5.4.1.
Description of measurement methods and procedures to be applied:	The equations provided were developed for tidal marsh soils by Craft *et al.* 1991 and for mangrove soils by Kauffman *et al.* 2011, as summarized in Howard *et al.* 2014.
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	N/A

Data / Parameter:	$C\%_{WPS-eroded,i,t}$
Data unit:	%
Description:	Percentage of carbon of tidal wetland soil material eroded in stratum *i* in year *t*
Equations	12
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$C\%_{WPS-emitted,i,t}$

Data unit:	%
Description:	Organic carbon loss due to oxidation, as a percentage of C mass present in eroded tidal wetland soil material in the project scenario in stratum *i* in year *t*
Equations	9, 11, 13, 14
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$Depth\_e_{i,t}$
Data unit:	m
Description:	Depth of the eroded area from the surface to the surface prior to erosion in stratum *i* in year *t*
Equations	12
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

Data / Parameter:	$Depth\_ex_{i,t}$
Data unit:	m

Description:	Depth of piled-up soil material due to excavation in stratum *i* in year *t*
Equations	14
Source of data:	See Module *BL-TW*
Description of measurement methods and procedures to be applied:	See Module *BL-TW*
Frequency of monitoring/recording:	At each monitoring period
QA/QC procedures to be applied:	See Section 9.3 of *REDD+ MF* or other VCS methodology that uses this module
Purpose of data:	Calculation of project emissions
Calculation method:	N/A
Comments:	Refer to procedures set out in Module *BL-TW*. The subscript *BSL* must be substituted by *WPS*.

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DOCUMENT HISTORY

Version	Date	Comment
v1.0	8 Sep 2020	Initial version
v1.1	18 Dec 2023	• Updated to latest VCS methodology template • Updated to align with the *AFOLU Non-Permanence Risk Tool*, *v2.1*