SCM0007 – Methodology for the treatment of Harmful Algae Blooms

Document Prepared by the Social Carbon Foundation

Title	Methodology for the treatment of Harmful Algae Blooms
Version	V1.0

Date of Issue	20/03/2023
Type	Methodology
Sectoral Scope	Scope 17 - Water
Prepared By	Social Carbon Foundation
Contact	128 City Road, London, United Kingdom, EC1V 2NX

Acknowledgements

We thank the following individuals for their contribution towards the development of this methodology: Michael Davies, Professor Aaron Kaplan, Dr Moshe Harel, Dr Oori Weisshaus, Yossi Klar, Dr. Gad Weiss, Dr. Pravin Jeba Dev, Gabriel Rozman (BlueGreen Water Technologies Ltd.).

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Methodology Details

1. Sources

Multiple sources have been used to develop this methodology. A full list of the academic literature supporting this methodology can be found in section 10. References.

2. Summary description of the Methodology

This methodology provides a means to quantify net GHG removals through the treatment of harmful Algae Blooms in freshwater bodies. Harmful algal blooms are the rapid growth of algae or cyanobacteria that can cause harm to people, animals, or the local ecology. This methodology outlines the procedures required to quantify the carbon removals achieved through the initiation of Programmed Cell Death (PCD) and subsequent sedimentation of the algae bloom's biomass. Studies on freshwater bodies demonstrate the permanence of this carbon storage mechanism[1].

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

The prevalence of harmful algae blooms is increasing globally, posing a risk to humans and biodiversity. If unmanaged, the algae blooms not only produce methane emissions, but also produce toxins that can kill fish, mammals and birds, and may cause human illness or even death in extreme cases. This poses a significant risk to human health, local biodiversity, freshwater and food supplies. The purpose of this methodology is to support areas that typically lack the funding required to treat their local freshwater bodies and manage harmful algae blooms.

[1] Clayer et al. (2020) demonstrate high rates of sediment from algae cell death and stable organic carbon concentrations across various sediment depths. Several studies demonstrate the biomineralization of cyanobacterium cells, resulting in the $CaCO^3$ and $MgCO^3$ and a permanent carbon store; Benzerara et al., (2014); Lamérand et al., (2022); Mehta et al., (2022); Morse et al., (2007); Klump et al., (2020).

3. Definitions

In addition to the definitions set out in the latest version of the SOCIALCARBON Standard Definitions, the following definitions apply to this methodology:

Burial Efficiency

The ratio between buried and deposited organic carbon in a given water body.

Cyanotoxins

Toxins produced by cyanobacteria that are harmful to humans and other organisms.

Harmful Algae Bloom

Harmful algal blooms are the rapid growth of cyanobacteria (i.e. blue-green algae) that can cause harm to people, animals, or the local ecology.

Mineralization

Mineralization is the process by which ammonium is released by soil micro-organisms as they utilise soil organic materials as an energy source.[2]

Photic Zone

The area of the water body in which enough light penetrates the water for the photosynthesis of algae and other photosynthetic plants to occur. Below 1% of the surface incident light, the photic zone ends and the aphotic zone begins.

Programmed Cell Death (PCD)

Form of cell death, in which a 'suicide' program is activated within the cell, leading to fragmentation of the DNA, shrinkage of the cytoplasm, membrane changes and cell death without lysis or damage to neighboring cells.

Sedimentation

Sedimentation involves settling of solid particles in liquid suspensions mainly due to gravity.

Surface area

The total area of the water surface where Harmful Algae Bloom concentrates.

Treatment Event

The act of treating Harmful Algae Blooms to trigger PCD.

[2] Benzerara et al., (2014); Lamérand et al., (2022); Mehta et al., (2022); Morse et al., (2007)

Treatment Solution
The solution used to treat Harmful Algae Blooms.

Waterbody
Under this methodology, the following waterbodies are eligible: natural and man-made lakes, ponds, and reservoirs of fresh and brackish water.

4. Applicability Conditions

This methodology is applicable under the following conditions:

- The treatment solution is at a minimum approved by the United States Environmental Protection Agency (EPA) or an equivalent authority, and is also NSF/ANSI/CAN 60 certified for drinking water;
- The treatment solution has been piloted and proven effective in treating harmful algae blooms, with evidence documenting the results;
- The water body being treated has a mean depth of at least 1 meter;
- The treatment induces Programmed Cell Death (PCD) and results in significant cell death[3];
- The treatment improves water turbidity;
- The treatment increases phytoplankton biodiversity in the water within 5 days of treatment by at least one standard deviation;
- The treatment reduces cyanotoxins levels below 6 ppb[4].

[3] At least 99.9% of the HAB cells die (but are not lysed) following the treatment. Braun & Harel (2013); Berman-Frank et al., (2004); Zhou et al., (2018); Hu & Rzymski, (2019); Zhou et al., (2020).

[4] 6 ppb (Parts per Billion) is considered safe for human health (Koreivienė et al., (2014); WHO (2020); EPA)

5. Project Boundary

Table 1 below identifies the carbon pools included or excluded from the project boundary.

Table 1: Selected Carbon Pools under the Baseline and Project Activity

Carbon Pools	Included?	Explanation
Aboveground woody biomass	No	Not applicable.
Aboveground non-woody biomass	No	Not applicable.
Belowground biomass	No	Not applicable.
Deadwood	No	Not applicable.
Litter	No	Not applicable.
Soil Organic Carbon (SOC)	No	Not applicable.
Water-surface biomass	Yes	This the primary carbon pool – the biomass of the Harmful Algae Bloom (HAB).

Table 2 presents the GHG sources included or excluded from the Project Boundary in this methodology.

Table 2: GHG Sources included in or excluded from the Project Boundary

Source		Gas	Included?	Explanation
Project	Project implementation partners Scope 1 and 2 emissions	CO_2	Yes	Primary source of implementation emissions
		CH_4	Yes	Included to ensure full scope 1 and 2 emissions are deducted
		N_2O	Yes	Included to ensure full scope 1 and 2 emissions are deducted

This methodology takes into account biomass degradation and evolution of Carbon Dioxide (CO_2) Methane (CH_4) and Nitrous Oxide (N_2O)[5] during the sedimentation process.

[5] Mengis et al., (1997); Wunderlin et al., (2012); Lin et al., (2022); Gruber et al., (2022); Vasilaki et al., (2019).

6. Baseline Scenario

The baseline scenario is the non-treatment of the HAB, resulting HAB oscillations during the seasonality of the year.

Projects must demonstrate historical trends of Harmful Algae Bloom growth in the water body. Project proponents must obtain at least 3 years of historical data (remote sensing imagery) prior to the project start date. The resolution of the historical data must be at least weekly, and with no less than 52 images per year to ensure a trend can be accurately determined.

The project must demonstrate that in the past three years, HABs have been present in the water body and their volumes, or observed growth rates over the time period, have or will increasingly pose a risk to human and environmental health.

The data source and evidence of the baseline analysis must be documented in the Project Description Document.

7. Additionality

This methodology uses a project method for the demonstration of additionality.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the SOCIALCARBON Methodology Requirements.

Step 2a: Pro Bono Deployment

If the treatment solution is deployed pro bono, the project is considered additional. If true, projects do not need to proceed to step 2b.

Step 2b: Project Method

In the event that the treatment is not being deployed pro-bono, the project activity shall apply the additionality analysis method set out in the latest version of the *SOCIALCARBON Tool for the Demonstration and Assessment of Additionality for AFOLU[6] project activities (SCT0001)* to determine that the proposed project activity is additional. As an exception for this methodology and due to the nature of the project activity, project proponents are permitted to skip Step 1 of the additionality assessment (Identification of alternative land use scenarios to the proposed AFOLU project activity) and move to either Step 2 (Investment Analysis) or Step 3 (Barrier Analysis) of the additionality assessment.

[6] AFOLU – Agriculture, Forestry and Other Land Use

8. Quantification of GHG Emission Removals

To generate GHG Emission Removals projects must align with and complete all the steps outlined in Appendix 2: Methodology Flowchart.

8.1 Baseline Removals

In the baseline scenario there are no net baseline removals[7]. For waterbodies with high infestation rate, where >95% of the phytoplankton populations consist of cyanobacterial species, it is assumed that the cyanobacterial biomass does not change significantly during the year – as their pelagic–benthic life cycle helps them survive periods of adverse conditions which contributes greatly to their ecological success.

In addition, this methodology does not account for the methane emissions that were avoided as a result of the HAB treatment, that would have otherwise occurred in the baseline scenario (Bižić et al., (2018); Bižić et al., (2020); Fazi et al., (2021)).

8.2 Project Removals

Project proponents should use the following equations to quantify the project removals achieved.

$$TER_t = \Delta HAB_t \times 0.48 \times \frac{44}{12} \times d \times a \qquad \text{(Equation 1)}$$

Where:

TER_t	=	Total Emission Removals in monitoring period t; tCO_2e (metric tonnes)
ΔHAB_t	=	The total change in dry biomass of the Harmful Algae Bloom following treatment in the monitoring period t; tonnes
0.48	=	The conversion of dry biomass to carbon for Algae[8]
$\frac{44}{12}$	=	Equation to convert carbon (tC) to carbon dioxide equivalent (tCO_2e)

[7] Ma et al., (2016); Suikkanen et al., (2010); Tan et al., (2008); Tian et al., (2021).

[8] Huntley et al., (2015)

d	=	Burial efficiency[9]
a	=	Correlation constant of remote sensing estimates; decimal fraction

The total dry biomass of the Harmful Algae Blooms shall be calculated as follows:

$$\Delta HAB_{\mathrm{t}} = \sum_{0}^{n} \mathrm{FB}_{n}^{t^{i}}[R_{rs}(\lambda)_{n}] - \sum_{0}^{n} \mathrm{FB}_{n}^{t^{i-1}}[R_{rs}(\lambda)_{n}]$$

(Equation 2)

Where:

ΔHAB_{t}	=	The total change in dry biomass of the Harmful Algae Bloom following treatment in the monitoring period t; metric tonnes
$\mathrm{FB}_{n}^{t^{i}}$	=	Calibrated biomass model of the HAB post-treatment determined as described in equation 3, below..
$\mathrm{FB}_{n}^{t^{i-1}}$	=	Calibrated biomass model of the HAB pre-treatment determined as described in equation 3, below.
$R_{rs}(\lambda)$	=	Remote sensing reflectance; unitless
n	=	Specific image pixels; unitless

$$FB_{n} = F_{cal}[R_{rs}(\lambda)_{n}]$$

(Equation 3)

Where:

FB_{n}	=	Biomass model of the HAB based on the calibration coefficients derived from the Remote Sensing ("RS") Biomass values combined with the Dry Biomass values that were measured on-site.
F_{cal}	=	Calibration coefficients
$R_{rs}(\lambda)$	=	Remote sensing reflectance; unitless

The biomass calibration coefficients must be determined as a result of the $CB_n \leftrightarrow DB_n$ correlation. The mandatory condition for Calculated Biomass (CB_n) from RS and Dry Biomass (DB_n) correlation is 0.7.

$$r^{2}\left(CB_{1,\ldots,n}, DB_{1,\ldots,n}\right) > 0.7$$

[9] Clayer et al., (2020); Klump et al., (2020); Reynolds et al., (1981); Nelson (1954); Ozdemir & Palabiyik (2019); Walters (2006).

The calculated biomass (CB) is given as:

$$CB_n = f[Rrs(\lambda)_n] \quad \text{(Equation 4)}$$

Dry biomass (DB) is calculated using the actual cyanobacterial biomass collection from the water *(see* Appendix 2 for more details on the procedures to be followed).

8.3 Project Emissions

Project proponents are required to conduct an analysis of their scope 1 and 2 emissions associated with the deployment of the treatment. The emissions should be calculated in compliance with internationally recognized GHG protocols, such as the Greenhouse Gas Protocol. These emissions can be calculated by the project proponent or by a professionally qualified third party.

Emissions to be considered:

- Transport emissions to access the site, deploy the treatment and monitor the results.
- Energy usage for the implementation and monitoring of the project during the monitoring period.
- Emissions generated in the production of the formulation used (per tonne of compound used).

Organic biomass degradation and the evolution of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) during the carbon sedimentation process are detailed in paragraph 9.1, under the “burial efficiency” section.

8.4 Leakage

There is no leakage risk from this project activity.

8.5 Uncertainty

Uncertainty is discounted for in the calculated change in HAB biomass following treatment. Project proponents must submit an accurate and calibrated HAB Biomass model and prove its accuracy through a correlation assay.

The model must be calculated using remote sensing (“RS”) tools and images obtained on the same day as the field samplings were conducted.

For each sampling point, biomass concentration will be calculated using the RS model based on the relevant image.

A correlation test shall be conducted between the samples and the model's calculations. Based on the r^2 value calculate a constant must be applied to Equation 1 to discount for any uncertainty.

- For r^2>0.800, define Constant a=1;
- For r^2 that is between 0.750 to 0.799, define Constant a=0.90;
- For r^2 that is between 0.700 to 0.749, define Constant a=0.85;
- For r^2<0.700 – the sampling processes must be run again, and the project proponent must re-evaluate the algorithm and measuring procedure.

8.6 Net GHG Emission Removals

$$NER_t = TER_t - PE_t \quad \text{(Equation 5)}$$

Where:

NER_t = Net emission removals during monitoring period t; tCO_2e (metric tonnes)

TER_t = Total emission removals during monitoring period t; tCO_2e (metric tonnes)

PE_t = Total project emissions during monitoring period t; tCO_2e (metric tonnes)

9. Monitoring

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied (as described in Section 2.3 of the SOCIALCARBON Standard, v6.0).

9.1 Data and Parameters at Validation

Data / Parameter	$Area$
Data unit	km^2
Description	Total area of the project area
Equations	N/A
Source of data	Delineation of the project area may use a combination of GIS coverages, ground survey data, remote imagery (satellite or aerial photographs), or other appropriate data. Any imagery or GIS datasets used must be geo-registered referencing corner points, clear landmarks or other intersection points.

Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at validation.
Purpose of Data	Outline the size of the water body being treated.
Comments	N/A

Data / Parameter	Water body depth
Data unit	Meters
Description	The mean depth of the water body
Equations	N/A
Source of data	Either from reputable published sources or measured onsite.
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at validation.
Purpose of Data	Demonstrate compliance with the eligibility criteria for water body depth.
Comments	

Data / Parameter	Burial efficiency
Data unit	unitless
Description	Determination of the potential quantity of the organic material buried. Its subtrahend parameter includes all other forms of degradation, including CO_2, Methane and/or N_2O released back into the ecological water system. Although this process can take years, this methodology takes a conservative approach and reduces this outcome instantly.

Equations	1
Source of data	Measured onsite
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be determined at validation and remain fixed for the duration of the crediting period (and not over than 1 year from initial determination).
Purpose of Data	Calculation of organic material burial rate
Comments	See Appendix 2, section Sediment Characterization

Data / Parameter	Historical HAB occurrence
Data unit	unitless
Description	Demonstration of historical HAB occurrences within the waterbody in at least the past 3 years prior to the project implementation.
Equations	NA
Source of data	Remote sensing
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	This parameter shall be used to demonstrate the historical trends of HAB occurrence in the waterbody. See section 6. Baseline Scenario At a minimum, timestamped satellite imagery must be documented in the Project Description Document.
Purpose of Data	This parameter shall be used to demonstrate the historical trends of HAB occurrence in the waterbody.
Comments	See section 6. Baseline Scenario

Data / Parameter	Sampling sites

Data unit	unitless
Description	Sampling points for the collection of sediment cores and wet biomass
Equations	NA
Source of data	NA
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The locations of the sampling sites shall align Chapter 9.3.1 and was adapted from US EPA Manuals.[10] All sampling sites shall be recorded, and GPS tagged.
Purpose of Data	Determination of burial efficiency and dry biomass.
Comments	See section 9.3 and Appendix 2

9.2 Data and Parameters at Verification

Data / Parameter:	$HAB_{\text{Area,t}}$
Data unit:	km^2
Description:	The surface area of the HAB pre-treatment.
Equations	2
Source of data:	Measured through remote sensing, either unmanned vehicle (e.g. drone) or using satellite imagery depending on the size of the water body.
Description of measurement methods	See section 9.3

[10] WVDEP (West Virginia Department of Environmental Protection). 2018. Watershed Assessment Branch 2018 Field Sampling Standard Operating Procedures. Division of Water and Waste Management, Watershed Assessment Branch, Charleston, WV; Sampling and Consideration of Variability (Temporal and Spatial) For Monitoring of Recreational Waters. U.S. Environmental Protection Agency Office of Water. EPA-823-R-10-005. 2010; National Rivers and Streams Assessment 2013/14. Field Operations Manual Wadeable. Version 1.0, May 2013. The United States Environmental Protection Agency, Office of Water. Office of Environmental Information. Washington, DC. EPA-841-B-12-009b.

and procedures to be applied:	
Frequency of monitoring/recording:	Every monitoring period (pre-treatment for monitoring period).
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculate of HAB biomass pre-treatment.
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	$HAB_{\text{Depth,n}}$
Data unit:	meters
Description:	The average depth of the Harmful Algae Bloom at pixel *n* in monitoring
Equations	NA
Source of data:	Collected through on-site measurements
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Every monitoring period. At t_0 only (pre-treatment for monitoring period).
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculate of HAB biomass pre-treatment. For RS (remote sensing) ground truthing purposing
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	Biodiversity index pre-treatment
Data unit:	Shannon Index, ratio
Description:	The phytoplankton biodiversity index pre-treatment.
Equations	7
Source of data:	Calculated through on-site measurements.
Description of measurement methods and procedures to be applied:	See section 9.3 and Appendix 2: Methodology Flowchart.
Frequency of monitoring/recording:	Every monitoring period (pre-treatment for monitoring period).
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of weighted score for treatment effectiveness. See Appendix 2, section See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details. Treatment phase.
Calculation method:	See section 9.3
Comments:	The Shannon Index shall be the biodiversity index utilized by projects. The biodiversity index value pre-treatment and post-treatment shall be calculated based on water samples that were analyzed and processed by an independent agency for eDNA or Flow Cytometry procedures. The project proponent must demonstrate that no conflicts of interests exist between themselves and the agency. The biodiversity assessment must be completed pre-treatment (see Appendix 2).

Data / Parameter:	Biodiversity index post-treatment
Data unit:	NA
Description:	The phytoplankton biodiversity index pre-treatment.

Equations	7
Source of data:	Calculated through on-site measurements.
Description of measurement methods and procedures to be applied:	See section 9.3 and Appendix 2: Methodology Flowchart.
Frequency of monitoring/recording:	Every monitoring period (pre-treatment for monitoring period).
QA/QC procedures to be applied:	See section 9.3 and Appendix 2: Methodology Flowchart
Purpose of data:	Calculation of weighted score for treatment effectiveness. See Appendix 2, section See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details. Treatment phase.
Calculation method:	See section 9.3
Comments:	The Shannon Index shall be the biodiversity index utilized by projects. The biodiversity index value pre and post-treatment shall be calculated based on water samples that were analyzed and processed by an independent agency for eDNA or Flow Cytometry procedures. The project proponent must demonstrate that no conflicts of interests exist between themselves and the agency. Assessment must be completed post treatment (see Appendix 2).

Data / Parameter:	Cyanotoxin levels post-treatment
Data unit:	ppb
Description:	The Cyanotoxin levels pre-treatment.
Equations	7
Source of data:	Collected either through on-site measurements.
Description of measurement methods	See section 9.3

and procedures to be applied:	
Frequency of monitoring/recording:	Every monitoring period (pre-treatment for monitoring period).
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of weighted score for treatment effectiveness. See Appendix 2, section See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details. Treatment phase.
Calculation method:	See section 9.3 (either via a third-party laboratory or approved kits, done on-site by Field Auditor)
Comments:	N/A

Data / Parameter:	Water turbidity pre-treatment
Data unit:	cm
Description:	Measurement of water turbidity at the sample sites.
Equations	7
Source of data:	Collected either through on-site measurements.
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of weighted score for treatment effectiveness. See Appendix 2, section

	See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details. Treatment phase
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	Water turbidity post-treatment
Data unit:	Meters (Secchi Depth)
Description:	Measurement of water turbidity at the sample sites.
Equations	7
Source of data:	Collected either through on-site measurements.
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Calculation of weighted score for treatment effectiveness. See Appendix 2, section See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details. Treatment phase
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	Dead fish numbers pre-treatment
Data unit:	Integer
Description:	Measurement of dead fish prior to treatment
Equations	NA
Source of data:	Number of dead fish will be counted in each sampling point, on-site, by Field Auditor.
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Demonstrate compliance with the eligibility criteria of zero treatment-induced fish deaths.
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	Dead fish numbers post-treatment
Data unit:	Integer
Description:	Measurement of dead fish prior to treatment
Equations	NA
Source of data:	Number of dead fish will be counted in each sampling point, on-site, by Field Auditor.
Description of measurement methods and procedures to be applied:	See section 9.3

Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Demonstrate compliance with the eligibility criteria of zero treatment-induced fish deaths.
Calculation method:	See section 9.3
Comments:	Measured up to 48 hours post treatment.

Data / Parameter:	Weighted score for treatment effectiveness
Data unit:	Integer
Description:	Weighted score of four variables required for project eligibility.
Equations	7
Source of data:	10.5
Description of measurement methods and procedures to be applied:	See section 9.3
Frequency of monitoring/recording:	At t_1 only (post-treatment)
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Demonstrate compliance with methodology requirements for water treatment effectiveness and no net harm.
Calculation method:	Calculated using four variables used in equation 7.
Comments:	Minimum accepted score is 75

Data / Parameter:	$R_{rs}(\lambda)$

Data unit:	unitless
Description:	Remote sensing reflectance.
Equations	2, 3, 4
Source of data:	Measured using remote sensing.
Description of measurement methods and procedures to be applied:	See section 8.2 Project Removals
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Measurement of HAB surface area.
Calculation method:	See Section 9.3
Comments:	N/A

Data / Parameter:	F_{cal}
Data unit:	unitless
Description:	Calibration coefficient must be determined as a result of the calculated Biomass per pixel and the measured dry biomass correlation
Equations	3
Source of data:	Measured using remote sensing.
Description of measurement methods and procedures to be applied:	See section 8.2 Project Removals
Frequency of monitoring/recording:	Every monitoring period.

QA/QC procedures to be applied:	See Appendix 2
Purpose of data:	Measurement of HAB surface area.
Calculation method:	See Appendix 2
Comments:	N/A

Data / Parameter:	FB_n
Data unit:	unitless
Description:	Biomass model of the HAB based on the calibration coefficients derived from the Remote Sensing ("RS") Biomass values combined with the Dry Biomass values that were measured on-site
Equations	2, 3
Source of data:	Calculated
Description of measurement methods and procedures to be applied:	See section 8.2 Project Removals
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	See section 9.3
Purpose of data:	Measurement of HAB surface area.
Calculation method:	See Section 9.3
Comments:	N/A

Data / Parameter:	NER_t
Data unit:	tCO_2e (metric tonnes)

Description:	Net emission removals during monitoring period t
Equations	6
Source of data:	Calculated
Description of measurement methods and procedures to be applied:	See Equation 6
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of Net Emission Removals
Calculation method:	See section 9.3
Comments:	N/A

Data / Parameter:	PE_t
Data unit:	tCO_2e (metric tonnes)
Description:	Total project emissions during monitoring period t
Equations	6
Source of data:	Calculated used internationally recognized GHG protocol
Description of measurement methods and procedures to be applied:	Project proponents are required to conduct an analysis of their scope 1 and 2 emissions associated with the deployment of the treatment. The emissions should be calculated in compliance with internationally recognized GHG protocols, such as the Greenhouse Gas Protocol.
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	The emissions should be calculated in compliance with internationally recognized GHG protocols, such as the Greenhouse Gas Protocol.

	These emissions can be calculated by the project proponent or by a professionally qualified third party. All data, parameters and models / spreadsheets shall be documented and made available to the VVB on request.
Purpose of data:	Calculation of Net Emission Removals
Calculation method:	The emissions should be calculated in compliance with internationally recognized GHG protocols, such as the Greenhouse Gas Protocol. These emissions can be calculated by the project proponent or by a professionally qualified third party.
Comments:	N/A

Data / Parameter:	TER_t
Data unit:	tCO_2e (metric tonnes)
Description:	Total emission removals during monitoring period t
Equations	6
Source of data:	Equation 2
Description of measurement methods and procedures to be applied:	See equation 2
Frequency of monitoring/recording:	Every monitoring period.
QA/QC procedures to be applied:	N/A
Purpose of data:	Calculation of Net Emission Removals
Calculation method:	See section 8
Comments:	N/A

9.3 Description of the Monitoring Plan

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 9.2. The monitoring plan must contain at least the following information:

- A description of each task to be undertaken, and the technical requirements therein;
- Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches;
- Parameters to be measured;
- Data to be collected and data collection techniques and sample designs for directly-sampled parameters;
- Anticipated frequency of monitoring, including anticipated definition of “year”;
- Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection and screen for, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate;
- Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of the monitoring process, including QA/QC data, must be archived electronically and be kept at least for two years after the end of the last project crediting period; and
- Roles, responsibilities and capacity of monitoring team and management;
- Details on the Field Auditors used in the monitoring period;
- During monitoring periods, projects must also provide timestamped satellite images of the HAB before treatment and up to 5 days post treatment.

9.3.1 Water Sampling Procedure

Projects are permitted to measure the HAB biomass per the entire water-column using Remote Sensing (“RS”) techniques only (e.g. Unmanned Aerial Vehicles or Satellite Imagery). In addition, physical sampling will be used to calibrate the RS model and validate its accuracy. Failing to address a correlation curve above $r^2>0.800$ between the physical water sampling data to the RS readings will result in a discount of the confirmed carbon removals. Failing to confirm $r^2>0.700$ will require the Project Proponent to re-evaluate either the algorithm/RS program or the in-situ water collection procedure.

When measuring the HAB surface area, measurements must be taken at the same time of day. This must be documented alongside timestamped images of the waterbody before treatment and no less than 5 days post the last mitigation step.

The sampling methodology detailed below was adapted from US EPA Manuals.[11]

The most important aspect of sampling is careful documentation including GPS location tagging, date, and time. All samples must comply with the protocol details below. Project Proponents are encouraged to take more sampling points (spatial and depth) in order to rectify the HAB biomass quantification. In any event, all sampling points must be presented, even when extra sampling points were taken.

Field sampling points must be pre-approved by the Specialist Verifier. Actual sampling must be conducted by a Field Auditor only. A field crew should consist of at least two individuals of which (at least) one is the Field Auditor, and one is the boat's skipper.

Due to the ever-changing nature of HABs in water (e.g., HAB's growth rate, spatial/depth change due to wind pattern or solar radiation), sampling must take no longer than five (5) hours and must be conducted between 7-12 am. The number of field crews must comply with the 5-hours' time frame. In cases where a large number of sampling points are being taken, Project Proponents must consider hiring additional crews. Alternatively, collect water data in the next days (between the above time frame). For each sampling day, data should be aligned/calibrated against remote sensing data collected on the same day.

The Field Auditor will be the stakeholder responsible for collecting the water/sediment samples. Navigation to the locations must be done with a GPS device using decimal degrees with a resolution of 5 decimal places.

Once in the location, the boat should be moored using an anchor. A ±25 m deviation from the approved location is allowed. Samples must be taken in the same sequence for both, t_0 and t_1. The entire route shall be recorded and kept as proof of compliance.

Target sites are defined as natural and man-made lakes, ponds, and reservoirs of fresh and brackish water. This Methodology is not approved for salt waters. The number of sites per waterbody will follow this schedule:

Size (km^2)	Minimum number of Sites
Area ≤ 0.5	3
0.5 < Area ≤ 10	5
10 < Area ≤ 100	10
100 < Area	15

[11] WVDEP (West Virginia Department of Environmental Protection). 2018. Watershed Assessment Branch 2018 Field Sampling Standard Operating Procedures. Division of Water and Waste Management, Watershed Assessment Branch, Charleston, WV; Sampling and Consideration of Variability (Temporal and Spatial) For Monitoring of Recreational Waters. U.S. Environmental Protection Agency Office of Water. EPA-823-R-10-005. 2010; National Rivers and Streams Assessment 2013/14. Field Operations Manual Wadeable. Version 1.0, May 2013. The United States Environmental Protection Agency, Office of Water. Office of Environmental Information. Washington, DC. EPA-841-B-12-009b.

Under this schedule, sample points will be used to collect water for the following measurements:

1. HAB biomass calibration,
2. Biodiversity assessment,
3. Cyanotoxin evaluation,
4. Water turbidity,
5. Quantification of fish-kill

In waterbodies greater than 1.0 km^2, water must be sampled from at least 4 corners and another point from the middle. When the waterbody consists of arms or branches, each branch shall be sampled according to the table above.

Project Proponents are encouraged to use more than the above data points and use them to improve his accuracy. There is no need to pre-approve additional data points (or additional depth samples) as long as all the data is being collected in compliance with the above protocol.

At each sampling point water must be collected from the water surface. At least 4 liters must be collected using a wide-mouth sterile sample opaque bottle. Samples must be stored on ice during the course of the sampling campaign. Samples must be processed following the instructions in the Table below:

Analysis	Process time	Location
HAB biomass analysis	Up to two months prior to t_0	By the Field Auditor in the field or a 3rd party laboratory (academia or similar)
Biodiversity assessment	Within 21 days	By the Field Auditor in the field (microscopy) or by a 3rd party laboratory (academia or similar)
Cyanotoxin evaluation	Within 21 days	By the Field Auditor in the field (off the shelf kits) or by a 3rd party laboratory (academia or similar).
Water turbidity	Immediately	At the sampling point
Quantification of fish-kill	Immediately	At the sampling point

9.3.2 HAB Biomass Analysis

Water Collection

Water must be collected from the surface. A volume of 4 liters must be collected using a wide-opened and clean container/s. Water collection must not take more than 30 seconds per sample. Depth profile can also be collected from additional depth points. Each sample point shall be GPS tagged. If more depths are to be taken per each sample point, then the volume for each depth should be 2 liters per each sampling depth and GPS tagged in accordance.

Depth profiles should be taken at the same remote sensing calibration locations where total biomass can also include a depth axis. Dry biomass at each depth can be determined and integrated according to the following equation:

$$Total\ column\ biomass\ (grams) = \int_{surface}^{depth} f(b)db$$

Water samples will be kept under dark conditions at 4C until retrieved to the lab. All samples must be processed within 72 hours post collection.

Project Proponents are encouraged to use more than the above data points and use them to improve his accuracy. There is no need to pre-approve additional data points (or additional depth samples) as long as all the data is being collected in compliance with the above protocol.

There are different options to assess algal and cyanobacterial biomass, one of the below protocols should be applied for algal biomass weight enumeration:

1. **Filtration**

Water will be concentrated on a filter (>0.7µm).

The tare weight of each filter will be recorded before filtration. The final volume of filtered water will be recorded as well.

2. **Centrifugation**

Centrifuge at >5,000g for >20 minutes and discard the supernatant. One can add 1gr flocculant per 200 ml of water to enhance sedimentation. Examples of flocculants are aluminum sulfate, calcium chloride, or potassium iodide. When applied, mixed thoroughly and left to settle for 1 hour.

3. Drying-oven

Samples of >100 ml are placed in a drying oven (capable of 40°C or higher). Before drying, the aluminum foil disposable trays are weighted and adequately labeled. Samples are placed in the dryer rays and dried at >40°C until completely dried for <24 hours. Each tray is then weighed, and the net weight of dry biomass is recorded (see paragraph below).

When either of the first two options is used (either filtration or centrifugation) then a dehydration stage should be used: The filter or the vial with the wet biomass will be weighted on a clean plastic dish, using an analytical scale that displays the results of at least three decimal points (for example, 0.001 grams). The scale should be calibrated on the same day by the Field Auditor according to the manufacturer's guide. Each sample weight should be recorded in an appropriate log sheet. Weight will be recorded, and samples will be transferred into a drying oven for <24 hours at >40°C. When complete, samples will be weighed, and the new weight will be recorded on the log sheet. Net mass of dry biomass should be retrieved for each data point.

$$Net\ dry\ biomass\ =\ weight\ of\ filter\ after\ dehydration\ stage\ -\ filter\ tare\ weight$$

9.3.3 Biodiversity assessment

Project Proponents are required to measure the phytoplankton biodiversity in the water before and after treatment. Water shall be collected at the same sample locations used for the dry biomass measurements.

All samples must be sent to an independent agency for eDNA or Flow Cytometry procedures to calculate a phytoplankton biodiversity value using the Shannon Diversity Index. Samples should be sent in accordance with the third-party requirements.

Alternatively, a microscopical analysis can be performed in the field by a trained Field Auditor following the Manual for Standard Operating Procedure for Phytoplankton Analysis (US EPA, Version 7, March 2021, Chapter 6).[12]

9.3.4 Sampling Cyanotoxin levels

Project Proponents are required to measure the cyanotoxin levels only after the treatment (at t_1) and to confirm that cyanotoxin levels are below 6 ppb. Water shall be collected at the same sample locations used for the dry biomass measurements. The water samples should be sent to a third laboratory (academia etc.) according to the local lab's written instructions.

[12] https://www.epa.gov/system/files/documents/2021-12/lg401.v07-phytoplankton-analysis_rfa.pdf

Alternatively, the Field Auditor can perform the cyanotoxin analysis using off-the shelf kits, within 7 days from t_1. During this period, water samples shall be kept in the dark and at 4 degrees the whole time.

9.3.5 Sampling Water Turbidity

Water turbidity should be calculated using a Secchi Disk (measured in cm). All samples must be documented with a time of sample, measured value and GPS location.

9.3.6 Quantification of fish-kill

Field Auditors shall record the number of visible dead fish in a circumference of ~20 m around the sampling point. The total number shall be calculated, and the percentage mortality shall be calculated for t_0 and t_1.

If the average number of dead fish is greater than 50 fish per square kilometer of surface water, then and $t_1 / t_0 < 2$. If the dead-fish count is greater than 50 per square km and $t_1 / t_0 > 2$ than the campaign must be aborted, and no carbon credits can be received for the treatment.

9.3.7 Sampling Sediment Cores[13]

Sediment cores shall be analysed to define the biomass degradation rate in the lake.

Sediment Corers are used to sample the waterbody's floor (the benthos). Sediment Corers work by boring a large tube into the benthos and then bringing up a column, or core, of sediment intact within the tube. Caps can seal off the ends of the core after it has pulled up a sample, protecting the sample and keeping it intact.

For conservativeness, samples shall be taken only from the waterbody's circumference in a depth that is not greater than 1.5 meters. At least 4 sediment cores must be taken from four corners of the waterbody, no matter how big it is. In case there is no access to one corner (such as may be the case in dams), then a different spot will be located, as close as possible to the requested place. When the waterbody consists of arms or branches, an additional sediment core will be taken from branches that are greater than 1km^2.

Sediment cores will be collected using a standard corer with a diameter greater than 4 cm. The sample will be divided to two phases:

[13] Sampling protocol was adapted from Haney, R. L., et al. "Soil carbon and nitrogen mineralization: Influence of drying temperature." Soil Science Society of America Journal 68.2 (2004): 489-492; Sampling and Consideration of Variability (Temporal and Spatial) For Monitoring of Recreational Waters. U.S. Environmental Protection Agency Office of Water. EPA-823-R-10-005. 2010; National Rivers and Streams Assessment 2013/14. Field Operations Manual Wadeable. Version 1.0, May 2013. The United States Environmental Protection Agency, Office of Water. Office of Environmental Information. Washington, DC. EPA-841-B-12-009b.

- Water and loose benthic substance at the upper 5 cm above waterbody's floor; and
- The sediment core (>10 cm in length).

After retrieving the corer to the lab, the upper 5 cm of water and loose benthic substance shall be collected in a clean container and stored at 4C, under dark conditions, for up to 3 months before processing.

The sediment cores should be released from the corer and kept in a Ziploc plastic bag under dark conditions and at 4C until being processed (up to 3 months).

Sample Analysis of Total Organic Carbon (TOC)

Sample preparation:

To calculate TOC in sediment cores, a *Loss on Ignition* procedure will be used: where samples will be heated and loss mass. From the difference in mass, the amount of carbon can be than accurately determined.

Dehydration stage:

For each phase (water and loose benthic substance or the sediment-core), 10-100 g of wet biomass will be collected from the homogeneous sample. The sample shall be weighted on a clean plastic dish, using an analytical balance that displays results of at least four decimal points (for example, 0.0001 grams). The balance shall be calibrated at the same day by the Field Auditor according to the manufacturer's guide. Each sample weight shall be recorded in an appropriate log sheet. Weight will be recorded, and samples will be transferred into a drying oven for <24 hours at >40°C. When complete, samples will be weighed, and the new balance will be recorded on the log sheet.

Combustion stage:

Samples, 1-2 grams, shall be transferred into crucible caps, and tare weight will be retrieved. Following a combustion stage at 900°C for 2 hours[14] samples will be weighed and the new balance will be recorded on the log sheet.

[14] Heiri et al., (2001). Loss on ignition as a method for estimating organic and carbonate content in sediments: reproducibility and comparability of results. Journal of paleolimnology, 25, 101-110.

Analysis stage:

Tare weights will be calculated for pre- vs. post combustion stage and the TOC will be calculated.

Per each sampling point, the TOC value of the Sediment Core will be normalized to the TOC value of the Water Phase. The percent of TOC decline from Water Phase to Sediment will be calculated and the Burial Efficiency will be retrieved:

$$Burial\ efficiency\ (d)\ =\ \frac{TOC\ of\ Sediment\ Core}{TOC\ of\ Water\ Phase}$$

The averaged Burial Efficiency rate will be calculated from all 4 or more samples and the Burial efficiency parameter (d) will be calculated per the specific lake (see paragraph 8.2, Equation 1).

Determination of sediment degradation rate using Isotopic dating analysis:

Simultaneous to calculating TOC of core samples, an analysis of the sediment decomposition rate should be carried out using Lead 210 analysis method in a qualified lab.[15] The purpose of this analysis is to establish geological dating for the core sample and confirm the TOC burial state in the sediment. The determination of sediment degradation rate using Isotopic dating analysis will be performed by a third party laboratory within 3 months from sampling and according to the local lab's official protocol.

[15] Edgington et al., (1991); Klump et al., (2020); Clow et al., (2015); Sobek, et al., (2009); Sobek et al., (2014).

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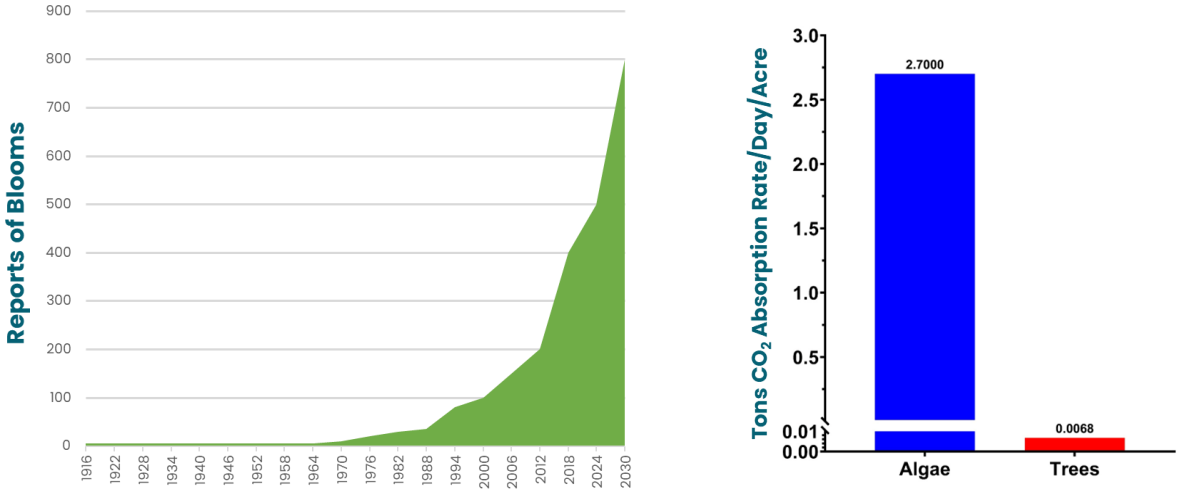
Appendix 1: Carbon Removals from HAB treatment

The increase in nutrient run-off into water bodies has caused an increased occurrence of hypoxic areas (see Diagram 1). The effective treatment of HAB ensures that harmful cyanobacteria is kept at bay due to natural competition, protecting biodiversity and reducing hypoxia of freshwater sources.

Diagram 1: increase in frequency of HABs over time[16]

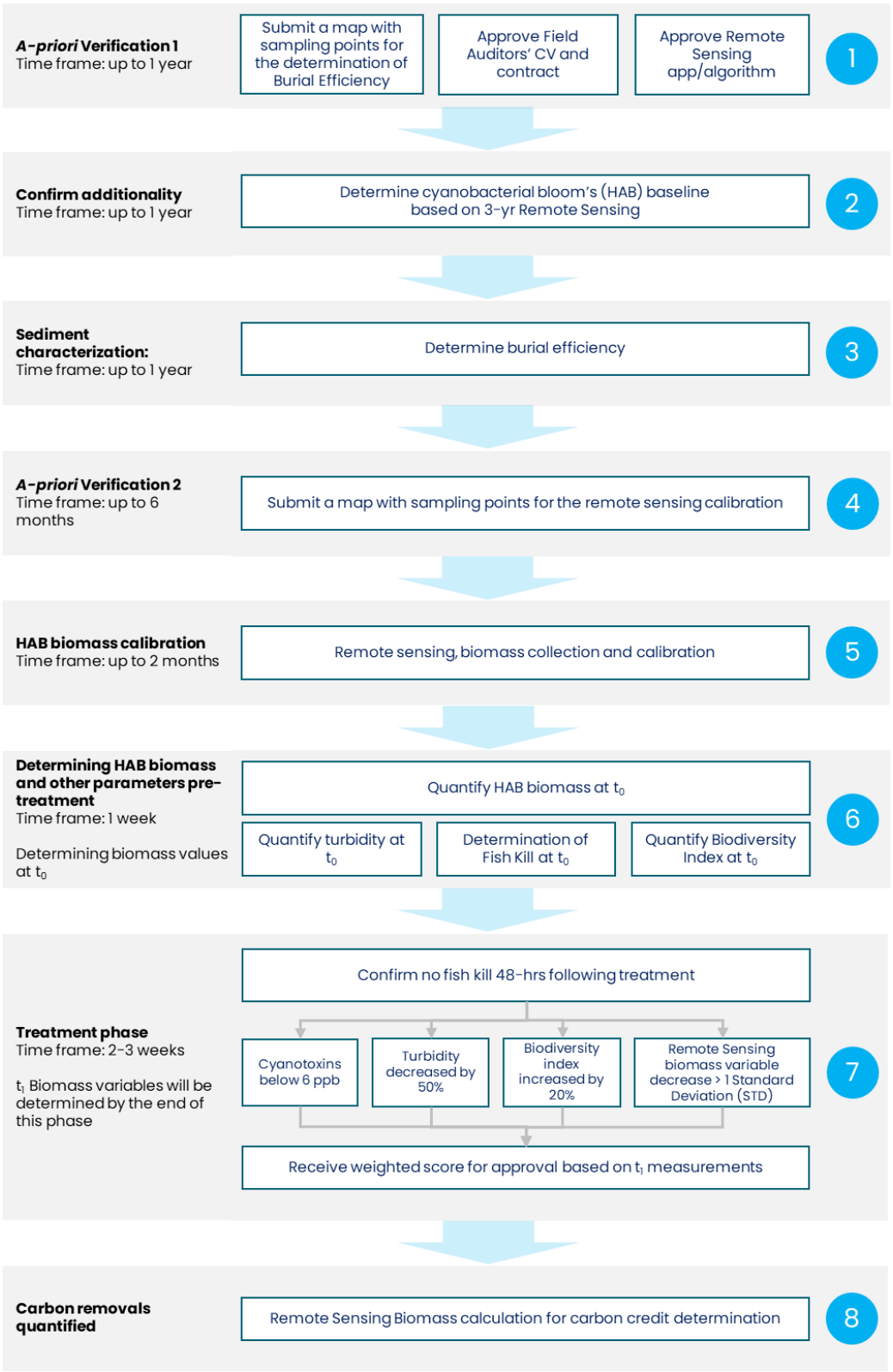


The treatment of the HAB will result in rapid sedimentation and burial of the HAB's biomass at rates greater than seen in nature. Burial efficiency is calculated for the biomass that will be buried within this process and remain sedimented for >1000 years.[17]

[16] Adapted from: Vaquer-Sunyer & Duarte (2008); Keeling, et al., (2010); Breitburg et al., (2018); Field *et al.*, (1998); Raven & Falkowski (1999); Ducklow & Doney (2013); Coffield et al., (2022).

[17] Clow, et al., (2015); Sobek, et al., (2009); Hobbs, et al., (2013); Heathcote & Downing (2012); Ward, et al., (2017); Marcé et al., (2019); Mendonça et al., (2017); Butman et al., (2016).

Appendix 2: Methodology Flowchart



1. A-priori Verification 1

Purpose:

Ensure that the sampling points for burial efficiency, Field Auditors and Remote Sensing app/algorithm meet the requirements of the methodology accordance with Methodology prior to implementation.

Timeframe:

Up to one year prior to the monitoring period's HAB treatment.

Materials & Methods:

1) Submit a map with sampling points for approval by the Specialist Verifier.
    a. For core sample: 4-7 different points at least depending on lake size and along the lake periphery.
2) Approve Field Auditors' CV and Contract and ensure they meet the requirements outlined in Appendix 3: Methodology Specific Roles
3) Approve Remote Sensing App/Algorithm
    a. The remote sensing algorithm must be presented on an online platform which the Specialist Verifier and VVB can access. The data sources and parameters applied in the app/algorithm must be documented in the monitoring report.

See 9.3 Description of the Monitoring Plan for more details.

2. Confirm additionality

The project must demonstrate compliance with the applicability conditions, Section 6. Baseline Scenario and Section 7. Additionality.

Timeframe:

Up to one year prior to the monitoring period's HAB treatment.

3. Sediment Characterization

Purpose:

- Determination of the quantity and the date of the organic material sedimented
- Calculating factor "d"

Timeframe:

Up to one year prior to the monitoring period's HAB treatment.

Materials & Methods:

See 9.3 Description of the Monitoring Plan, section 9.3.7

4. A-priori Verification 2

Purpose:

A priori verification that the biomass sampling points are in accordance with Methodology prior to implementation.

Timeframe:

Up to 6 months prior to the monitoring period's HAB treatment.

Materials & Methods:

Submit a map with HAB biomass sampling points for approval by the Specialist Verifier. See 9.3 Description of the Monitoring Plan, section 9.3.1 for more details.

5. HAB biomass calibration

Purpose:

- Calibration of the remote sensing model pre-treatment

Timeframe:

Data collection and verification must not exceed two months.

Materials and Methods:

See 8.5 Uncertainty and 9.3 Description of the Monitoring Plan sections 9.3.1 and 9.3.2 for more details.

6. Determining HAB biomass and other parameters pre-treatment.

Purpose:

Quantification of the HAB biomass, water turbidity, phytoplankton biodiversity index and fish kill prior to treatment.

Timeframe:

Data collection and verification must not exceed seven days before treatment.

Materials and Methods:

See 9.3 Description of the Monitoring Plan, sections 9.3.3, 9.3.5 and 9.3.6 for more details.

7. Treatment phase

Purpose:

Verify the effectiveness of the treatment and ensuring the impacts meet the minimum accepted threshold of the methodology.

Timeframe:

Data collection and verification must not exceed three weeks post treatment.

Materials and Methods:

7.1 Confirm no fish kill.

1. A Field Auditor must inspect the lake within the time frame of the treatment and validate that no fish kill accrues during the mitigation phase and up to 48 hours after the last day of treatment.
2. If treatment was held for more than one day – up to 48 hours post-treatment.
3. Treatment mitigation protocol should be confirmed by Field Auditor and submitted to the Specialist Verifier at the end of the procedure. The Specialist Verifier must confirm that the treatment's protocol, including dosage, location and time between treatments, was done in accordance with the approved product label.

See 9.3 Description of the Monitoring Plan, section 9.3.6 for more details.

7.2 Determination of Weighted Score

A weighted score must be calculated to determine the effectiveness of the treatment. All four variables must be assessed and given a score (as outlined below). The minimum accepted score is 75, with a maximum of 100. Projects that do not meet this threshold are not permitted to issue carbon credits for the treatment in the monitoring period.

$$Weighted\ Score = V_1 + V_2 + (V_3 \times 2 \times 0.1) + (V_4 \times 5 \times 0.1) \quad \text{(Equation 7)}$$

- *Variable 1 (V_1) - Cyanotoxins below 6 ppb*

  V_1 is binary (yes = 60, no=0).

- *Variable 2 (V_2) – Remote Sensing biomass variable decrease > 1 Standard Deviation (STD)*

  V_2 is binary (yes = 20, no = 0)

- *Variable 3 (V_3) – Turbidity decreases by 50%*

  Variable 3 must be the measured percentage (in integer format) decrease yields. If turbidity has decreased by more than 50% a value of 50 shall be applied.

- *Variable 4 (V_4) – The biodiversity index increased by 20%*

  Variable 4 must be the measured percentage (in integer format) increase in biodiversity index. If the biodiversity index has increased by more than 20% a value of 20 shall be applied.

8. Carbon removals quantified.

See section 8.2 Project Removals.

Appendix 3: Methodology Specific Roles

Due to the novelty and the sophistication of this methodology, specific roles are required to ensure robustness and professionalism to achieve accurate results. HAB grow at rapid pace, therefore a new approach to verification is required to ensure that procedures and data collection aligns with the requirements of this methodology.

The following table outlines the methodology specific role (beyond standard procedures) required by the methodology.

Role	Responsibility	Requirements	Involvement on project
VVB	As stated in the SOCIALCARBON Standard.	-	Review and audit the project as per the SOCIALCARBON Standard. With regards to methodology applicability and GHG Quantification, they shall receive project data from the Field Auditors and a report from Specialist Verifiers to confirm compliance with the methodology.
Specialist Verifier	The Specialist Verifier is responsible for approving technical implementation of the treatment and the results achieved. These findings will then be reported back to the selected VVB so they can complete their validation / verification.	The Specialist Verifier should be led by an accredited scholar that has completed a Ph.D. in one of the following fields: Environmental Studies, Biology, Hydrology, Chemistry, Geology, or related. Has at least three publications as a leading author on phytoplankton. **The Specialist Verifier must be working on behalf of a SOCIALCARBON Approved VVB** (this may be sub-contracted)	A priori –approvals: 1. Data collection points 2. Field Auditors Proofing: 1. Verify the correlation of satellite analysis with ground truthing. 2. Approve quantity of harvested credits

Field Auditor	Collect all field data and conduct measurements.	A professional with a degree in one of the following scientific fields: Environmental Studies, Biology, Chemistry, Geology, or an Engineering degree in Water-related field, etc. The Field Auditors must have expertise in, and at least one year's experience in field data collection (water/sediment/biological samples).	Water sampling at t_0, t_1

The Field Auditor must sign a contract with the project developer in English to confirm the following:

- The Field Auditors have a degree in one of the following scientific fields: Environmental Studies, Biology, Chemistry, Geology, or an Engineering degree in Water-related field, etc;
- Field Auditors have the relevant expertise and at least one year's experience in field data collection (water/sediment/biological samples); and
- No conflict of interest with the Project Developer.

CVs of the Field Auditors and their contracts with the Project Developer must be made available to both the VVB and Specialist Verifier on request.