California Air Resources Board

Quantification Methodology

California Department of Fish and Wildlife
Wetlands Restoration for Greenhouse Gas Reduction Program
California Climate Investments

June 25, 2019
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Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as “priority populations.” Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the net GHG benefit and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project types for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cc/cci-expenditurerecords.

For the California Department of Fish and Wildlife (CDFW) Wetlands Restoration for Greenhouse Gas Reduction Program (Wetlands Program), CARB staff developed this Wetlands Quantification Methodology to provide guidance for estimating the net GHG benefit and selected co-benefits of each proposed project type. This methodology uses calculations to estimate carbon sequestration in soil from wetland restoration or enhancement and in biomass from tree planting, and GHG emission changes from wetland restoration or enhancement.

The Wetlands Program Benefits Calculator Tool (Wetlands Benefits Tool) automates methods described in this document, provides a link to a step-by-step user guide with project examples, and outlines documentation requirements. Projects will report the total project GHG benefit and co-benefits estimated using the Wetlands Benefits Tool as well as the total project GHG benefit per dollar of GGRF funds requested. The Wetlands Benefits Tool is available for download at: http://www.arb.ca.gov/cc/cci-resources.

Using many of the same inputs required to estimate net GHG benefit, the Wetlands Benefits Tool estimates the following co-benefits and key variables from Wetlands Program projects:

- Nitrous Oxide (NO\textsubscript{x}) Emission Absorption (in lbs)
- Reactive Organic Gases (ROG) Emission Absorption (in lbs)
- PM2.5 Emission Absorption (in lbs)
- Lands Restored/Treated (in acres)
- Trees Planted
Key variables are project characteristics that contribute to a project’s net GHG benefit and signal an additional benefit. Additional co-benefits for which CARB assessment methodologies were not incorporated into the Wetlands Benefits Tool may also be applicable to the project. Applicants should consult the Wetlands Program Guidelines, Proposal Solicitation Notice materials, and/or website to ensure they are meeting Wetlands Program requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

**Methodology Development**

CARB and CDFW developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability\(^1\). CARB and CDFW developed this Wetlands Program Quantification Methodology for estimating the outcomes of proposed projects, informing project selection, and tracking results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing and proven tools and methods;
- Use project-level data, where available and appropriate; and
- Result in net GHG benefit estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the Wetlands Program project types. CARB also consulted with CDFW to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

CARB released the Draft Wetlands Program Quantification Methodology and Draft Wetlands Benefits Tool for public comment in May 2019. This Final Wetlands Program Quantification Methodology and accompanying Wetlands Benefit Tool have been updated to address public comments, where appropriate, and for consistency with updates to the Wetlands Program Guidelines.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

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\(^1\) California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines
Tools

The Wetlands Benefits Tool relies on project-specific outputs from the following tools:

SoilWeb is used to determine the dominant soil order at the project site. SoilWeb was developed by the California Soil Resource Lab at University of California, Davis (UCD) and University of California Agriculture and Natural Resources (UCANR) in collaboration with the US Department of Agriculture Natural Resources Conservation Service (NRCS). Applicants use SoilWeb to explore soil survey areas using an interactive Google map and view detailed information about soils on the project site. SoilWeb runs in any web browser and is compatible with desktop computers, tablets, and smartphones. SoilWeb is available at: https://casoilresource.lawr.ucdavis.edu/gmap/.

The US Forest Service (USFS) i-Tree Planting web based tool provides quantitative data for an individual or population of trees to be planted as part of the project including the amount of carbon stored and the estimated effects of tree shade on building energy use based on project characteristics such as the climate zone, tree species, tree age, and tree diameter at breast height (DBH). i-Tree Planting is available at: https://planting.itreetools.org/. A description about the tool is available at: https://planting.itreetools.org/help/.

SoilWeb and i-Tree Planting are used statewide, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

In addition to the tools above, the Wetlands Benefits Tool relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Applicants must use the Wetlands Benefits Tool to estimate the net GHG benefit and co-benefits of the proposed project. The Wetlands Benefits Tool is available at: http://www.arb.ca.gov/cci-resources.
Updates

CARB staff periodically review each quantification methodology and benefits calculator tool to evaluate their effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB updated the Wetlands Program Quantification Methodology from the previous version\(^2\) to enhance the analysis and provide additional clarity. The changes include:

- Addition of Seasonal Inland Wetlands as a project type;
- Addition of a link to a step-by-step User Guide with project examples;
- Adoption of SoilWeb and i-Tree Planting as methodology tools; and
- Addition of new outputs in the Wetlands Benefits Tool that summarizes co-benefits and key variables the same inputs used to estimate the net GHG benefit.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the Wetlands Benefits Tool.

Project Types

CDFW developed four project types that meet the objectives of the Wetlands Program and for which there are methods to quantify a net GHG benefit.\(^3\) Other project features may be eligible for funding under the Wetlands Program; however, each project requesting GGRF funding must include at least one of the following:

- Coastal Tidal Wetlands Restoration
- Sacramento-San Joaquin Delta Wetlands Restoration
- Mountain Meadows Restoration
- Seasonal Inland Wetlands Restoration

General Approach

Methods used in the Wetlands Benefits Tool for estimating the net GHG benefit and air pollutant emission co-benefits by activity type are provided in this section. The Database Documentation explains how emission factors used in CARB benefit calculator tools are developed and updated.

These methods account for carbon sequestration in restored soil and planted trees, and for changes in carbon dioxide and methane emissions due to wetland restoration. In general, the Wetlands Benefits Tool estimates the net GHG benefit using the approaches in Table 1. The Wetlands Benefits Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate the net GHG benefit.

\(^3\) https://www.wildlife.ca.gov/Conservation/Watersheds/Greenhouse-Gas-Reduction
Table 1. General Approach to Quantification by Project Type

<table>
<thead>
<tr>
<th>Coastal Tidal Wetland and Uplands Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Net GHG Benefit} = \textit{Soil Carbon Sequestration from Wetland Restoration} + \textit{Soil Carbon Sequestration from Grassland Restoration} + \textit{Biomass Carbon Sequestration from Tree Planting} + \textit{Avoided Carbon Dioxide Emissions from Drained Farmland} + \textit{Avoided Nitrous Oxide Emissions from Drained Farmland} + \textit{Avoided Nitrous Oxide Emissions from Fertilizer Application} – \textit{Methane Emissions from Fresh Water Wetland Restoration}.</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Sacramento-San Joaquin Delta Wetlands Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Net GHG Benefit} = \textit{Soil Carbon Sequestration from Wetland Restoration} + \textit{Biomass Carbon Sequestration from Tree Planting} + \textit{Avoided Carbon Dioxide Emissions from Drained Farmland} + \textit{Avoided Nitrous Oxide Emissions from Drained Farmland} + \textit{Avoided Nitrous Oxide Emissions from Fertilizer Application} – \textit{Methane Emissions from Fresh Water Wetland Restoration}.</td>
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<table>
<thead>
<tr>
<th>Mountain Meadows Restoration</th>
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</thead>
<tbody>
<tr>
<td>\textit{Net GHG Benefit} = \textit{Soil Carbon Sequestration from Wetland Restoration} + \textit{Biomass Carbon Sequestration from Tree Planting}</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seasonal Inland Wetlands Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Net GHG Benefit} = \textit{Soil Carbon Sequestration from Wetland Restoration} + \textit{Soil Carbon Sequestration from Grassland Restoration} + \textit{Biomass Carbon Sequestration from Tree Planting} + \textit{Avoided Nitrous Oxide Emissions from Fertilizer Application} – \textit{Methane Emissions from Seasonal Mineral Soil Fresh Water Wetland Restoration}.</td>
</tr>
</tbody>
</table>
A. GHG Benefit from Coastal Tidal Wetlands Restoration

Equation 1 estimates the GHG benefit from conversion of farmland and degraded grassland to restored wetland and improved grassland. Equation 1 relies on 6 other equations. Equation 2 estimates the value for the difference in carbon loss rates ($\Delta CLR_{dos}$) from land-use change from drained organic soil on farmland that will be restored to coastal wetland. Equation 3 estimates increased methane emissions ($\Delta CH_{4,CTW}$) from wetland restoration. Equation 4 estimates the avoided N$_2$O emissions ($\Delta N_2O_{dos}$) from restoration of drained organic soil in farmland. Equation 5 estimates the avoided N$_2$O emissions ($\Delta N_2O_{fert}$) associated with fertilizer application. Equation 6 estimates the carbon sequestration benefit ($Cseq_{CTW}$) from coastal tidal wetland restoration. Equation 7 estimates the carbon sequestration benefit ($Cseq_G$) from grassland restoration.

**Equation 1: GHG Benefit from Coastal Tidal Wetlands Restoration**

$$GHG_{CTW} = (\Delta CLR_{dos} - \Delta CH_{4,CTW} \times 25 + (\Delta N_2O_{dos} + \Delta N_2O_{fert}) \times 298) \times 50 + Cseq_{CTW} + Cseq_G$$

*Where,*

- $GHG_{CTW}$ = GHG benefit of restoring coastal tidal wetlands and grassland [MT CO$_2$e]
- $\Delta CLR_{dos}$ = Avoided carbon loss rate of farmland on drained organic soil to be restored to coastal tidal wetlands (from Equation 2) [MT CO$_2$e/Year]
- $\Delta CH_{4,CTW}$ = Increase in methane emissions from restoring coastal tidal wetlands (from Equation 3) [MT CH$_4$/Year]
- 25 = Methane global warming potential [MT CH$_4$/MT CO$_2$e]
- $\Delta N_2O_{dos}$ = Avoided nitrous oxide emissions from farmland on drained organic soil to be restored to coastal tidal wetlands (from Equation 4) [MT N$_2$O/Year]
- $\Delta N_2O_{fert}$ = Avoided nitrous oxide emissions from farmland due to avoided nitrogen fertilizer application (from Equation 5) [MT N$_2$O/Year]
- 298 = Nitrous oxide global warming potential [MT N$_2$O/MT CO$_2$e]
- 50 = Number of years of project life [Years]
- $Cseq_{CTW}$ = Carbon sequestration increase from coastal tidal wetlands restoration (Equation 6) [MT CO$_2$e]
- $Cseq_G$ = Carbon sequestration increase from grassland restoration (Equation 7) [MT CO$_2$e]
Equation 2: Avoided Carbon Loss Rate of Farmland on Drained Organic Soil to be restored to Wetlands

\[ \Delta CLR_{dos} = \left( 0.05 \times \frac{40,468,564}{1,000,000} \times \frac{44}{12} \right) \times A_{dos} \]

Where,

\[ \Delta CLR_{dos} \] = Avoided carbon loss rate of farmland on drained organic soil to be restored to wetlands

\[ 0.05 \] = Drained organic soil carbon loss rate

\[ 40,468,564 \] = Conversion from acres to square centimeters

\[ 1,000,000 \] = Conversion from metric tons to grams

\[ 44 \] = Molecular weight ratio of carbon dioxide to carbon

\[ 12 \] = Months per year

\[ A_{dos} \] = Area of farmland on drained organic soil to be restored to wetlands.

Units

\[ \text{MT CO}_2\text{e} \] per Year

\[ \text{g} \] per cm² Year

\[ \text{cm}^2 \] per Acre

\[ \text{g} \] per MT

\[ \text{MT CO}_2 \] per MT C

Equation 3: Increased Methane Emissions from Coastal Tidal Wetland Restoration

\[ \Delta CH_{4,CTW} = 193.7 \times A_{CTW} \times \left( \frac{Freq_{Fresh} - Freq_{FreshWet}}{12} \right) \times 0.4047 \div 1,000 \]

Where,

\[ \Delta CH_{4,CTW} \] = Change in methane emissions from coastal tidal wetlands restoration

\[ 193.7 \] = Methane emission factor for wetlands with salinity less than 18 ppt

\[ A_{CTW} \] = Area restored to coastal tidal wetlands

\[ Freq_{Fresh} \] = Number of months per year restored permanent wetland has salinity less than 18 ppt

\[ Freq_{FreshWet} \] = Number of months per year the project area existed as a seasonal wetland with salinity less than 18 ppt before conversion or restoration to permanent tidal wetland, equal to the smaller of \( Freq_{Fresh} \) and \( Freq_{Wet} \).

\[ 12 \] = Months per year

\[ 0.4047 \] = Conversion from acres to hectares

\[ 1,000 \] = Conversion from metric tons to kilograms

Units

\[ \text{MT CH}_4 \] per Year

\[ \text{kg CH}_4 \] per Hectare Year

\[ \text{Acres} \]

\[ \text{Months} \]

\[ \text{Hectares per Acres} \]

\[ \text{kg per MT} \]
### Equation 4: Avoided Nitrous Oxide Emissions from Drained Organic Soils

\[
\Delta N_2O_{dos} = 0.008 \times A_{dos} \times 0.4047 \times \frac{44}{28}
\]

**Where,**

- \(\Delta N_2O_{dos}\) = Avoided nitrous oxide emissions from farmland on drained organic soil to be restored to wetlands
- 0.008 = Nitrous oxide emission rate for cropped wetlands soils
- \(A_{dos}\) = Area of farmland on drained organic soil to be restored to wetlands
- 0.4047 = Conversion from acres to hectares
- \(\frac{44}{28}\) = Molecular weight ratio of nitrous oxide to nitrogen

**Units**

- \(\Delta N_2O_{dos}\) = MT N\(_2\)O Year
- 0.008 = MT N\(_2\)O – N Hectare
- \(A_{dos}\) = Acres
- 0.4047 = Hectares
- \(\frac{44}{28}\) = MT N

### Equation 5: Avoided Nitrous Oxide Emissions from Nitrogen Application

\[
\Delta N_2O_{fert} = 0.01 \times N_{fert} \times A_{fert} \div 2204.62 \times \frac{44}{28}
\]

**Where,**

- \(\Delta N_2O_{fert}\) = Avoided nitrous oxide emissions from farmland due to avoided nitrogen fertilizer application
- 0.01 = Nitrous oxide emission rate for nitrogen fertilizer application
- \(N_{fert}\) = Former nitrogen fertilizer application rate
- \(A_{fert}\) = Area of farmland previously fertilized
- 2204.62 = Conversion from metric tons to pounds
- \(\frac{44}{28}\) = Molecular weight ratio of nitrous oxide to nitrogen

**Units**

- \(\Delta N_2O_{fert}\) = MT N\(_2\)O Year
- 0.01 = lb N\(_2\)O – N
- \(N_{fert}\) = lb N
- \(A_{fert}\) = Acre
- 2204.62 = lb
- \(\frac{44}{28}\) = MT N
Equation 6: Carbon Sequestration from Coastal Tidal Wetland Restoration

\[ C_{seq}^{CTW} = 79 \times A_{CTW} \times \left( 1 - \frac{Freq_{wet}}{12} \right) \times 4,046.86 \div 1,000,000 \times \frac{44}{12} \times 50 \]

Where,

- \( C_{seq}^{CTW} \) = Total carbon sequestration from coastal tidal wetlands restoration [MT CO₂e]
- \( 79 \) = Annual carbon sequestration coefficient for coastal tidal wetland restoration [g C/m² Year]
- \( A_{CTW} \) = Area restored to permanent coastal tidal wetlands [Acres]
- \( Freq_{wet} \) = Number of months project area existed as a seasonal wetlands before conversion or restoration to permanent wetlands [Months]
- \( 12 \) = Conversion from years to months [Year/Months]
- \( 4,046.86 \) = Conversion from acres to square meters [m²/Acre]
- \( 1,000,000 \) = Conversion from metric tons to grams [g/MT]
- \( 44 \) = Molecular weight ratio of carbon dioxide to carbon [MT CO₂e/MT C]
- \( 12 \) = Conversion from years to months [Year/Months]
- \( 50 \) = Number of years of project life [Years]
Equation 7: Carbon Sequestration from Grassland Restoration

\[ C_{seq_G} = \left( C_{\text{ref}} \times F_{LU,G} \times F_{GM,I} \times A_{IG} - C_{\text{ref}} \times F_{LU,G} \times F_{GM,MD} \times A_{MDG} \right) \times 0.4047 \times \frac{44}{12} \]

Where,

- \( C_{seq_G} \) = Total carbon sequestration from grassland restoration (MT CO\textsubscript{2}e)
- \( C_{\text{ref}} \) = Reference carbon stock for grassland IPCC soil type
  - Sandy (16) MT C
  - Wetland (48) Hectare
  - Volcanic (124) MT C
  - Spodic (86) Hectare
  - High Activity Clay Soil (37) MT C
  - Low Activity Clay Soil (25) Hectare
- \( F_{LU,G} \) = Land use factor, grassland for warm temperate dry climate (1.37) Unitless
- \( F_{GM,I} \) = Grassland management factor, improved (1.14) Unitless
- \( A_{IG} \) = Area restored to improved grassland Acres
- \( F_{GM,MD} \) = Grassland management factor, moderately degraded (0.95) Unitless
- \( A_{MDG} \) = Area restored from moderately degraded grassland Acres
- \( F_{CM,FT} \) = Cropland management factor, Full Till (1) Unitless
- \( A_{F,G} \) = Area restored from farmland to grassland Acres
- 0.4047 = Conversion from acres to hectares Hectares
- \( \frac{44}{12} \) = Molecular weight ratio of carbon dioxide to carbon MT C
- \( \frac{44}{12} \) = MT CO\textsubscript{2}e
B. GHG Benefit from Sacramento-San Joaquin Delta Wetlands Restoration

Equation 8 estimates the GHG benefit from Sacramento-San Joaquin Delta Wetlands Restoration (GHG_DW). Equation 8 relies on 2 other equations. Equation 4 is used to determine the avoided N_2O emissions (ΔN_2O_{dos}) from restoration of drained organic soil in farmland. Equation 5 is used to determine the avoided N_2O emissions (ΔN_2O_{fert}) associated with fertilizer application.

Equation 8: GHG Benefit from Sacramento-San Joaquin Delta Wetlands Restoration

\[
GHG_{DW} = \left( 0.05 \times \frac{40,468,564}{1,000,000} \times \frac{44}{12} - 2.60 \times 0.4047 \right) \times A_{RDW} + (\Delta N_2O_{dos} + \Delta N_2O_{fert}) \times 298 \times 50
\]

Where,

- GHG_DW = GHG benefit of restored Delta wetlands (MT CO_2e)
- 0.05 = Drained organic soil carbon loss rate (g C/cm^2 Year)
- 40,468,564 = Conversion from acres to square centimeters (cm^2)
- 1,000,000 = Conversion from metric tons to grams (g)
- 44/12 = Molecular weight ratio of carbon dioxide to carbon (MT CO_2e/MT C)
- 2.60 = Restored Delta wetland CO_2 and CH_4 emission rate (MT CO_2e/Hectare Year)
- 0.4047 = Conversion from acres to hectares (Hectares/Acre)
- A_{RDW} = Area of restored Delta wetlands (Acres)
- ΔN_2O_{dos} = Avoided nitrous oxide emissions from farmland on drained organic soil to be restored to wetland (from Equation 4) (MT N_2O/Year)
- ΔN_2O_{fert} = Avoided nitrous oxide emissions from farmland due to avoided nitrogen fertilizer application (from Equation 5) (MT N_2O/Year)
- 298 = Nitrous oxide global warming potential (MT CO_2e)
- 50 = Number of years of project life (Years)
C. GHG Benefit from Mountain Meadows Restoration

Equation 9 estimates the GHG benefit from Mountain Meadows Restoration (GHG_{MM}).

**Equation 9: GHG Benefit from Mountain Meadows Restoration**

\[ GHG_{MM} = C_{seq_{MM}} = 95.40 \times A_{MM} \times \frac{4046.86}{1,000,000} \times \frac{44}{12} \times 50 \]

Where,

- \( GHG_{MM} \) = GHG benefit of restored mountain meadows (MT CO\textsubscript{2}e)
- \( C_{seq_{MM}} \) = Total carbon sequestration from mountain meadows restoration (MT CO\textsubscript{2}e)
- 95.40 = Annual carbon sequestered in restored mountain meadows, 50 Year timescale (g C/m² Year)
- \( A_{MM} \) = Area of land restored to mountain meadows (Acres)
- 4046.86 = Conversion from acres to square meters (m²/Acres)
- 1,000,000 = Conversion from metric tons to grams (g/MT)
- 44/12 = Molecular Weight Ratio of carbon dioxide to carbon (MT CO\textsubscript{2}e/MT C)
- 50 = Number of years of project life (Years)
D. GHG Benefit from Seasonal Inland Wetlands Restoration

Equation 10 estimates the GHG benefit from Seasonal Inland Wetland Restoration (GHG\textsubscript{SIW}). Equation 10 relies on 4 other equations. Equation 11 estimates the carbon sequestration (Cseq\textsubscript{SIW}) from restoring seasonal inland wetlands. Equation 5 estimates the avoided N\textsubscript{2}O emissions (\Delta N\textsubscript{2}O\textsubscript{fert}) associated with fertilizer application. Equation 12 estimates the increase in CH\textsubscript{4} emissions (\Delta CH\textsubscript{4,SIW}) from restored seasonal inland wetlands.

**Equation 10: GHG Benefit from Seasonal Inland Wetland Restoration**

\[
GHG_{SIW} = Cseq_{SIW} + (\Delta N_2O_{fert} \times 298 - \Delta CH_4_{SIW} \times 25) \times 50
\]

<table>
<thead>
<tr>
<th>Where</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>GHG\textsubscript{SIW}</td>
<td>GHG benefit of restored seasonal inland wetlands project (MT CO\textsubscript{2}e)</td>
</tr>
<tr>
<td>Cseq\textsubscript{SIW}</td>
<td>Carbon sequestered in project site (from Equation 11) (MT CO\textsubscript{2}e)</td>
</tr>
<tr>
<td>\Delta N_2O_{fert}</td>
<td>Avoided nitrous oxide emissions from farmland due to avoided nitrogen fertilizer application (Equation 5) (MT N\textsubscript{2}O Year)</td>
</tr>
<tr>
<td>298</td>
<td>Nitrous oxide global warming potential (MT CO\textsubscript{2}e)</td>
</tr>
<tr>
<td>\Delta CH_4_{SIW}</td>
<td>Increase in methane emissions from restored seasonal inland wetlands (Equation 12) (MT CH\textsubscript{4} Year)</td>
</tr>
<tr>
<td>25</td>
<td>Methane global warming potential (MT CO\textsubscript{2}e)</td>
</tr>
<tr>
<td>50</td>
<td>Number of years of project life (Years)</td>
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Equation 11: Carbon Sequestration from Seasonal Inland Wetland and Grassland Restoration

\[
C_{seq_{SIW}} = \left( C_{seq} \times F_{LU,G} \times F_{GM,I} \times A_{SIW} + C_{ref} \times F_{LU,G} \times F_{GM,I} \times A_{IG} \right) \times 0.4047 \times \frac{44}{12}
\]

Where,

- **\(C_{seq_{SIW}}\)** = Carbon sequestered in restored seasonal inland wetlands (MT CO\(_2\)e)
- **\(C_{seq}\)** = Reference carbon stock for Wetland IPCC mineral soil (MT C/Hectare)
- **\(F_{LU,G}\)** = Land use factor, grassland for warm temperate dry climate (1.37) (Unitless)
- **\(F_{GM,I}\)** = Grassland management factor, improved (1.14) (Unitless)
- **\(F_{GIH}\)** = Grassland input factor, high (1.11) (Unitless)
- **\(A_{SIW}\)** = Area restored to seasonal inland wetlands (Acres)
- **\(C_{ref}\)** = Reference carbon stock for current IPCC soil type
  - Sandy (16) (MT C/Hectare)
  - Wetland (48) (MT C/Hectare)
  - Volcanic (124) (MT C/Hectare)
  - Spodic (86) (MT C/Hectare)
  - High Activity Clay Soil (37) (MT C/Hectare)
  - Low Activity Clay Soil (25) (MT C/Hectare)
- **\(A_{IG}\)** = Area restored to improved grassland (Acres)
- **\(F_{GM,MD}\)** = Grassland management factor, moderately degraded (0.95) (Unitless)
- **\(A_{MDG}\)** = Area restored from moderately degraded grassland (Acres)
- **\(F_{GM,SD}\)** = Grassland management factor, severely degraded (0.7) (Unitless)
- **\(A_{SDG}\)** = Area restored from severely degraded grassland (Acres)
- **\(F_{CM,FT}\)** = Cropland management factor, Full Till (1) (Unitless)
- **\(A_{farm}\)** = Area restored from farmland (Acres)
- **0.4047** = Conversion from acres to hectares (Hectares/Acres)
- **\(\frac{44}{12}\)** = Molecular weight ratio of carbon dioxide to carbon (MT CO\(_2\)e/MT C)
Equation 12: Increased Methane Emissions from Seasonal Inland Wetlands Restoration

\[ \Delta CH_{4,SIW} = 126 \times 0.4047 \div 1,000 \times A_{SIW} \]

Where,

- \( \Delta CH_{4,SIW} \): Increase in methane emissions from restored seasonal inland wetlands
- 126: Methane emission rate for intermittent (seasonal) wetlands
- 0.4047: Conversion from acres to hectares
- 1,000: Conversion from metric tons to kg
- \( A_{SIW} \): Area restored to seasonal inland wetlands

Units:
- MT CH\(_4\) Year
- kg CH\(_4\) Hectare Year
- Hectares
- Acres
- kg
- MT

E. GHG Benefit from Planting Trees

Trees may be planted as part of any Wetlands project. Refer to Wetlands Guidelines for guidance on tree selection and planting. Equation 13 estimates the GHG benefit from tree planting, based on the i-Tree Planting tool.

Equation 13: GHG Benefit from Tree Planting

\[ GHG_{IT} = \frac{1}{2204.62} \sum f_{GHG_{IT}}(location, species_i, number_i, 50, 10\%, DBH) \]

Where,

- \( GHG_{IT} \): The GHG benefit from carbon sequestration from planting trees, as calculated by i-Tree Planting
- 2204.62: Conversion from pounds to metric tons
- \( f_{GHG_{IT}} \): GHG benefit as calculated by i-Tree Planting based on location, species, number of trees by species, lifetime, mortality, and DBH of trees at planting.
- \( location \): The state, county, and closest city to the project site.
- \( species \): The species of planted trees for each species group i.
- \( number \): The number of planted trees for each species group i.
- 50: Project lifetime
- 10\%: Tree mortality over project lifetime
- DBH: Diameter Breast Height (DBH) of trees at planting (default is 1)

Units:
- MT CO\(_2\)
- MT lbs
- lbs CO\(_2\)
- unitless
- unitless
- unitless
- years
- n/a
- inches
F. PM2.5 Emissions Co-benefit from Tree Absorption

Equation 14 estimates the PM2.5 emissions from the project based on the i-Tree Planting tool.

**Equation 14: PM2.5 Emissions Co-benefit from Tree Absorption**

\[
PM_{2.5_{IT}} = \sum_{i} f_{PM_{2.5_{IT}}} (\text{location}, \text{species}_i, \text{number}_i, 50, 10\%, \text{DBH})
\]

Where,

- \(PM_{2.5_{IT}}\) = The particulate matter less than 2.5 microns captured by planted trees, as calculated by i-Tree Planting
- \(f_{PM_{2.5_{IT}}}\) = PM2.5 co-benefit as calculated by i-Tree Planting based on location, species, number of trees by species, lifetime, mortality, and DBH of trees at planting.
- \(\text{location}\) = The state, county, and closest city to the project site.
- \(\text{species}\) = The species of planted trees for each species group \(i\).
- \(\text{number}\) = The number of planted trees for each species group \(i\).
- \(50\) = Project lifetime
- \(10\%\) = Tree mortality over project lifetime
- \(\text{DBH}\) = Diameter Breast Height (DBH) of trees at planting (default is 1)

**Units**

- \(\text{lbs PM2.5}\)

G. NO\(_x\) Emissions Co-benefit from Tree Absorption

Equation 14 estimates the NO\(_x\) emissions from the project based on the i-Tree Planting tool.

**Equation 15: NO\(_x\) Emissions Co-benefit from Tree Absorption**

\[
NO_{x_{IT}} = \sum_{i} f_{NO_{x_{IT}}} (\text{location}, \text{species}_i, \text{number}_i, 50, 10\%, \text{DBH})
\]

Where,

- \(NO_{x}\) = The nitrogen oxides captured by planted trees, as calculated by i-Tree Planting
- \(f_{NO_{x_{IT}}}\) = NO\(_x\) co-benefit as calculated by i-Tree Planting based on location, species, number of trees by species, lifetime, mortality, and DBH of trees at planting.
- \(\text{location}\) = The state, county, and closest city to the project site.
- \(\text{species}\) = The species of planted trees for each species group \(i\).
- \(\text{number}\) = The number of planted trees for each species group \(i\).
- \(50\) = Project lifetime
- \(10\%\) = Tree mortality over project lifetime
- \(\text{DBH}\) = Diameter Breast Height (DBH) of trees at planting (default is 1)

**Units**

- \(\text{lbs NO}_x\)
- \(\text{n/a}\)
- \(\text{inches}\)
Section C. References

The following references were used in the development of this Quantification Methodology and the Wetlands Benefits Tool.


Deverel, S.J., Leighton, D.A. (2010) Historic, Recent and Future Subsidence, Sacramento-San Joaquin Delta, California, USA. *San Francisco Estuary and Watershed Science, 8*(2). [https://escholarship.org/uc/item/7xd4x0xw](https://escholarship.org/uc/item/7xd4x0xw).


