California Department of Fish and Wildlife and
California Air Resources Board

Greenhouse Gas Interim Quantification Methodology for the California Department of Fish and Wildlife Wetlands Restoration for Greenhouse Gas Reduction Grant Program

Greenhouse Gas Reduction Fund

Fiscal Year 2014-15

A. Introduction

The California Air Resources Board (ARB) is required to develop quantification methods for agencies receiving Greenhouse Gas Reduction Fund (GGRF) appropriations per SB 862 (Senate Budget and Fiscal Review Committee, Chapter 36, statutes of 2014).

Some administering agencies receiving appropriations of Fiscal Year (FY) 2014-15 GGRF funds developed interim quantification methodologies in consultation with ARB. For FY 2015-16 and future years, ARB will continue to develop or update quantification methodologies for GGRF funded programs.

B. Quantification Methodology

The California Department of Fish and Wildlife (CDFW) developed the Wetlands Restoration for Greenhouse Gas Reduction Grant Program to reduce greenhouse gas (GHG) emissions and provide co-benefits through restoration or enhancement of the Sacramento-San Joaquin Delta and coastal wetlands and mountain meadow ecosystems. ARB in consultation with CDFW, developed the following interim quantification methodology for use in estimating the net GHG benefit from wetland restoration or enhancement projects proposed for funding with FY 2014-2015 GGRF monies.

There are three wetland restoration project types for FY 2014-15:

- Sacramento-San Joaquin Delta Wetlands
- Coastal Wetlands
- Mountain Meadow Ecosystems

Wetlands sequester carbon through plant material via photosynthesis and store this carbon in both biomass and in soil organic matter. However, as part of the natural respiration of vegetation and underwater microbial activity, wetlands also emit carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). When considering all emission sources and sinks, wetlands restoration or enhancement projects provide a net GHG benefit. This interim quantification methodology estimates the net GHG benefit of wetland restoration or enhancement projects taking into account both the carbon sequestered and project GHG emissions. ARB recommends the use of the quantification methods below to estimate the net GHG benefit of wetland restoration projects. Where applicable, applicants should follow the appropriate project-type specific instructions provided.

This methodology uses the best available science that is supported by peer-reviewed research demonstrating net GHG benefits from wetland restoration. The specific methods described in this document are a representative approach to quantifying net GHG emission reductions from a wetland restoration project; however, applicants may use alternative methods for estimating net GHG emission reductions where appropriate.

Where available, data obtained at project sites in comparable locations with similar characteristics may be used as proxies to estimate the net GHG benefit. When proxy sites are used, applicants should include a description of the proposed project, the source of the representative data, as well as a description of the characteristics of the proxy site. Estimates may also be derived from existing peer-reviewed literature or, for mountain meadow ecosystem projects, conceptual models. The following list represents the preferred hierarchy of data sources for GHG estimates:

1. Onsite monitoring data for GHG fluxes from existing projects and land uses with similar characteristics.
2. If the above option is not available, modeled estimates that incorporate soil conditions and local vegetation based on peer-reviewed literature.
3. If the above options are not available, mountain meadow projects may use the most applicable conceptual model of the behavior of the system. The conceptual model should map the hypothetical behavior of the meadow using assumptions based on supported science. Onsite monitoring will be required to validate the assumptions and conceptual model.

Using the sources listed above, it is recommended applicants estimate GHG fluxes and net GHG benefit from land use change, aboveground and belowground biomass, and soil organic carbon. This methodology contains equations to estimate the annual net GHG benefit from these areas. Alternatively, applicants may present the net GHG benefit over the project life. The following is a summary of the steps to estimate the net GHG benefit from wetland restoration projects proposed for funding with FY 14-15 GGRF monies. Detailed instructions for each step are provided on subsequent pages.

Step 1 Estimate GHG emission reductions and carbon sequestration potential at maturity. The wetland is expected to reach maturity prior to the end of project life.

Step 2 Estimate GHG emissions.

Step 3 Estimate the net GHG benefit.

Step 1: Estimate GHG emission reductions and carbon sequestration potential at maturity

GHG emission reductions can result from land use change, while carbon sequestration results from increased vegetative biomass and increased soil carbon storage capacity. Estimate (1) GHG emissions reductions and (2) carbon sequestration from the following categories separately:

(1) Land use change
(2a) Biomass
(2b) Soil organic carbon[1]

[1] "Soil organic carbon" refers to the carbon present in the soil; a component of total organic constituents known as "soil organic matter".

The carbon sequestration potential should be estimated at project maturity, when vegetation has been fully established and the rate of carbon sequestration is no longer increasing. Carbon sequestration can either be presented as a one-time increase in capacity (weight per acre) or rate of carbon sequestration (weight per acre per year).

(1) GHG Emission Reductions from Land Use Change

Emission reductions can result from land use change such as converting agricultural land to a wetland ecosystem or restoring degraded wetlands. When land use change is accounted for, applicants must demonstrate that the land use emissions are not displaced. For example, switching from agricultural operations does not result in new land being converted to agricultural uses elsewhere. To account for land use change, baseline GHG emission data should be collected for at least one year at a site with similar characteristics including crop, irrigation method, nitrogen management (fertilizer type and amount), climate (temperature and precipitation), and soil type (texture, organic matter). Absent accounting for land use change, this methodology assumes that emissions from the land are zero, thus not accounting for any avoided emissions. This approach is considered conservative as typical pre-project land use, agricultural or severely degraded wetlands, is a net source of emissions where measured. Applicants can estimate emission reductions from land use change as shown in Equation 1.

Equation 1: Estimated Emissions Avoided from Land Use Change

$$\boldsymbol{ER_{landuse} = (E_{CO2} + [E_{CH4} \times 25] + [E_{N2O} \times 298]) \times PA}$$

Where,

$ER_{land\ use}$	=	GHG emissions avoided from the existing land use (MT CO_2e per year)
E_{CO2}	=	Measured emissions of CO_2 (MT CO_2 per acre per year)
E_{CH4}	=	Measured emissions of CH_4 (MT CH_4 per acre per year)
25	=	Global warming potential of CH_4[2]
E_{N2O}	=	Measured emissions of N_2O (MT N_2O per acre per year)
298	=	Global warming potential of N_2O[1]
PA	=	Project area (acres)

(2) Carbon Sequestration

Applicants may use Equation 2 to estimate carbon sequestration rates from both biomass and soil carbon. For systems where biomass or soil carbon sequestration capacity is estimated as a one-time storage increase, applicants can annualize sequestration rates over the expected project life using Equation 3.

[2] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Equation 2: Carbon Sequestration from Annual Rates

$$C_{seq,i} = \left(C_{seq,post-project} - C_{seq,pre-project}\right) \times PA \times 3.67$$

Where,

$C_{seq,i}$	=	Carbon sequestration rate for carbon pool i (MT CO_2e per year)
i	=	Carbon pool (biomass or soil organic carbon)
$C_{seq,post-project}$	=	Carbon sequestration rate from post-project (i.e., mature wetland) conditions (MT C per acre per year)
$C_{seq,pre-project}$	=	Carbon sequestration rate from pre-project (i.e., baseline) conditions (MT C per acre per year)
PA	=	Project area (acres)
3.67	=	Conversion from C to CO_2e

Equation 3: Carbon Sequestration from Capacity

$$C_{seq,i} = \frac{\left(C_{seq,post-project} - C_{seq,pre-project}\right) \times PA \times 3.67}{Project\ Life}$$

Where,

$C_{seq,i}$	=	Carbon sequestration rate for carbon pool i (MT CO_2e per year)
i	=	Carbon pool (biomass or soil organic carbon)
$C_{seq,post-project}$	=	Carbon storage capacity from post-project (i.e., mature wetland) conditions (MT C per acre)
$C_{seq,pre-project}$	=	Carbon storage capacity from pre-project (i.e., baseline) conditions (MT C per acre)
PA	=	Project area (acres)
3.67	=	Conversion from C to CO_2e
Project Life	=	Time expected for the increase in capacity to be realized (years). If such data is not available, the applicant may include an estimate based on best available science and provide a justification or use a default of 25 years.

Annual Carbon Sequestration and Emission Reductions

Applicants can sum the total carbon sequestration and emission reductions as shown in Equation 4.

Equation 4: Annual GHG Emission Reductions

$$GHG_{reductions} = ER_{land\ use} + \sum_{i} C_{seq,i}$$

Where,

$GHG_{reductions}$	=	Annual carbon sequestration and emission reductions (MT CO_2e per year)
$ER_{land\ use}$	=	GHG emissions avoided from the existing land use (MT CO_2e per year) (Eq. 1)
$C_{seq,i}$	=	Carbon sequestration rate for carbon pool i (MT CO_2e per year) (Eq.2, Eq. 3)
i	=	Carbon pool (biomass or soil organic carbon)

Step 2: Estimate GHG emissions

GHG emissions of CO_2, CH_4, and N_2O can result from the natural respiration of vegetation and underwater microbial activity. CO_2 emissions can also result from restoration equipment activities. Estimate the CO_2 and CH_4 emissions from the ecosystem separately from on-site restoration equipment emissions. If N_2O emission information is available, also include these emissions in the calculations below.

Wetland Ecosystem Emissions

CO_2 emissions from vegetation can be estimated by empirically modeling ecosystem respiration. If it is infeasible to characterize the magnitude of CH_4 emissions from the wetland ecosystem, applicants should provide justification for the infeasibility. For coastal wetland ecosystems with salinity greater than 18 ppm, it can be assumed that CH_4 generation is zero.[3,4] N_2O emissions have not been well monitored in restored and constructed wetlands, therefore, absent data, N_2O emissions can be conservatively ignored in permanently flooded wetland conditions.[5] Applicants can use Equation 5 to estimate the wetland ecosystem emissions.

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[3] Poffenbarger, H.J., B.A. Needelman, and J.P. Megonigal. 2011. Salinity influence on methane emissions from tidal marshes. Wetlands, 31:831–842 ;
Chmura, G. L., L. Kellman, and G. R. Guntenspergen. 2011. The greenhouse gas flux and potential global warming feedbacks of a northern macrotidal and microtidal salt marsh. Environmental Research Letters 6:044016; and Weston, N. B., S. C. Neubauer, D. J. Velinsky, and M. A. Vile. 2014. Net ecosystem carbon exchange and the greenhouse gas balance of tidal marshes along an estuarine salinity gradient. Biogeochemistry:1-27.

[4] Keller, Jason K.; Takagi, Kimberly K.; Brown, Morgan E.; Stump, Kellie N.; Takahashi, Chelsea G.; Joo, Woojin; Au, Kimberlee L.; Calhoun, Caitlin C.; Chundu, Rajesh K.; Hokutan, Kanani; Mosolf, Jessica M.; and Roy, Kylle (2012) "Soil Organic Carbon Storage in Restored Salt Marshes in Huntington Beach, California," Bulletin of the Southern California Academy of Sciences: Vol. 111: Iss. 2. Available at: http://scholar.oxy.edu/scas/vol111/iss2/5

[5] Butterbach-Bahl, K., Baggs, E. M., Dannenmann, M., Kiese, R., and Zechmeister-Boltenstern, S.: Nitrous oxide emissions from soils: how well do we understand the processes and their controls?, Philos. Trans. Roy. Soc. B, 368, 20130122, 2013.

Equation 5: Wetland GHG Emissions

$$GHG_{wetlands} = (E_{CO2} + [E_{CH4} \times 25] + [E_{N2O} \times 298]) \times PA$$

Where,

$GHG_{wetlands}$	=	GHG emission rate for mature wetland ecosystem (MT CO_2e per year)
E_{CO2}	=	Measured or modeled emissions of CO_2 (MT CO_2 per acre per year)
E_{CH4}	=	Measured or modeled emissions of CH_4 (MT CH_4 per acre per year)
25	=	Global warming potential of CH_4[1]
E_{N2O}	=	Measured or modeled emissions of N_2O (MT N_2O per acre per year)
298	=	Global warming potential of N_2O[1]
PA	=	Project area (acres)

Restoration Equipment Emissions

Restoration equipment emissions are those associated with the vehicles and equipment used on-site during restoration activities. Restoration equipment emission estimates should cover the length of project construction until restoration activities and on-site equipment use is complete. Applicants can base estimates of CO_2 emissions from vehicles and equipment on the volume of fuel consumed and fuel-specific emission factors. Volume of fuel consumed can be estimated from expected hours of operation using equipment manufacturer's specified fuel use rate. Restoration equipment related CO_2 emissions from all vehicles and equipment used are summed using Equation 6 and Table 1.

Equation 6: Restoration equipment GHG Emissions

$$GHG_{equipment} = \sum_i \frac{Fuel_i \times EF_i}{1000}$$

Where,

$GHG_{equipment}$	=	GHG emissions from restoration equipment (MT CO_2)
$Fuel_i$	=	Estimated fuel use for vehicle or equipment i (gallons)
EF_i	=	Emission factor from Table 1 for fuel type used by vehicle or equipment i (kg CO_2/gallon)
1000	=	Conversion from kg to MT

Table 1. CO_2 Emission Factors for Fuels[6]

Fuel	CO_2 Emission Factor (kg CO_2/gallon)
Aviation Gasoline	8.31
Biodiesel (B100)	9.45
Crude Oil	10.28
Diesel 1 Diesel 2 Diesel 4	10.18 10.21 10.96
Ethane	6.01
Ethanol (E100)	5.75
Isobutane	6.29
Jet Fuel (Jet A or A-1)	9.75
Kerosene	10.15
Liquefied Petroleum Gas (LPG)	5.79
Methanol	4.15
Motor Gasoline	8.78
n-Butane	6.58
Propane	5.59
Residual Fuel Oil (#5,6)	10.21, 11.27
	(kg CO_2/therm)
Natural Gas	5.30

Project Emissions

Applicants can sum the total project emissions from the mature wetland as shown in Equation 7. The restoration equipment emissions will be annualized over the project life for comparison.

Equation 7: Total Annual GHG Emissions

$$GHG_{emissions} = GHG_{wetlands} + \frac{GHG_{equipment}}{Project\ Life}$$

Where,

$GHG_{emissions}$ = Total annual GHG emissions (MT CO_2e per year)

$GHG_{wetlands}$ = GHG emission rate for mature wetland ecosystem (MT CO_2e per year) (Eq. 5)

$GHG_{equipment}$ = GHG emissions from restoration equipment (MT CO_2) (Eq. 6)

Project Life = Time expected for the increase in capacity to be realized (years). If such data is not available, the applicant may include an estimate based on best available science and provide a justification or use a default of 25 years.

Step 3: Estimate the net GHG benefit

Applicants can estimate the net annual GHG benefit from a mature wetland using Equation 8.

[6] EPA Climate Leaders, Stationary Combustion Guidance (2008)

Equation 8: Total Project GHG Emission Reductions

$$Net\ GHG\ Benefit = GHG_{reductions} - GHG_{emissions}$$

Where,

Net GHG Benefit	=	Net annual GHG benefit (MT CO_2e per year)
$GHG_{reductions}$	=	Total carbon sequestration and emission reductions (MT CO_2e per year) (Eq. 4)
$GHG_{emissions}$	=	Total annual GHG emissions (MT CO_2e per year) (Eq. 7)

C. Next Steps

ARB will continue to evaluate and update the GHG emission reduction quantification methodologies as necessary for future FY GGRF appropriations. Quantification methods are posted on ARB's auction proceeds webpage at: http://www.arb.ca.gov/cc/capandtrade/auctionproceeds/quantification.htm