Nitrogen Management

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Nitrogen Management Protocol

Reducing Nitrous Oxide Emissions through Improved Nitrogen Management in Crop Production

Version 2.1

December 3, 2021

Acknowledgements

Version 2.1

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Table of Contents

Abbreviations and Acronyms 1
1 Introduction 3
2 The GHG Reduction Project 4
2.1 Background 4
2.2 Project Definition 4
2.2.1 Eligible Project Activities 7
2.2.1.1 N Rate Reductions 7
2.2.1.2 Use of Enhanced Efficiency Fertilizers 8
2.2.2 Eligible Crops 9
2.2.3 Eligible Project Area 9
2.3 Defining the Cultivation Year 12
2.4 Project Ownership Structures and Terminology 12
2.4.1 Project Owners issued CRTs 13
2.4.2 Entities with Project Management Roles 14
2.4.3 Entering a Project 15
2.4.4 Leaving a Project 15
2.4.5 Forming or Entering a Cooperative 15
2.4.6 Leaving a Cooperative 16
3 Eligibility Rules 17
3.1 Location 17
3.2 Start Date 17
3.3 Reporting Period 17
3.4 Crediting Period 18
3.5 Additionality 19
3.5.1 The Performance Standard Test 19
3.5.1.1 Performance Standard for Reducing Nitrogen Application Rate 19
3.5.1.1.1 Grace Period 22
3.5.1.2 Performance Standard for the Use of Enhanced Efficiency Fertilizers (EEFs) 22
3.5.2 The Legal Requirement Test 23
3.5.3 Ecosystem Services Credit and Payment Stacking 24
3.5.3.1 Credit Stacking 24
3.5.3.2 Payment Stacking 25
3.6 Regulatory Compliance 27
4 The GHG Assessment Boundary 29
5 Quantifying GHG Emission Reductions 33
5.1 Primary Effect N_2O Emission Reductions 35
5.1.1 N_2O Emission Reductions from Eligible Project Activities (NMQuanTool) 35
5.1.2 Baseline N Rates 36
5.1.2.1 Hierarchical Approaches for Determining Baseline N Rates 37
5.1.2.1.1 Historical N Management Records (Approach 1) 37
5.1.2.1.2 Historical Agronomic Expert Recommendations (Approach 2) 37
5.1.2.1.3 County Average Benchmarks (Approach 3) 38
5.1.2.2 Baseline Synthetic N Rates 38
5.1.2.3 Baseline Organic N Rates 39
5.1.3 Project Synthetic N Rates 40

5.1.3.1 Increases in Synthetic N from Cultivation Years in which CRTs are Not Claimed 42
5.1.3.2 Increases in Synthetic N Rate from Shifting Crop Production Outside Project Boundaries (Leakage) 43
5.1.4 N_2O Emissions from Increases in Organic N Rates 45
5.1.4.1 Direct N_2O Emissions from Corn in the North Central Region 45
5.1.4.2 Direct N_2O Emissions other than from Corn in the North Central Region 46
5.1.4.3 N_2O Emissions from Leaching, Volatilization, and Runoff from Increases in Organic N 47
5.1.4.4 Changes in Project Organic N Rates 48
5.1.4.4.1 Increases in Organic N from Cultivation Years in which CRTs are not Claimed 50
5.2 Secondary Effect GHG Emissions 51
5.2.1 GHG Emissions from Increased Electricity Usage 52
5.2.2 GHG Emissions from Increased Fossil Fuel Consumption 52
6 Project Monitoring 54
6.1 Project Monitoring Plan 54
6.2 Cooperative Monitoring Plans 55
6.3 Field and Project Data Monitoring Requirements 55
6.4 Supplemental Field Data Monitoring 72
7 Reporting and Record Keeping 73
7.1 Project Submittal Documentation 73
7.1.1 Determining Field Serial Numbers 73
7.2 Annual Reports and Documentation 73
7.2.1 Project Monitoring Report 74
7.2.2 Cooperative Monitoring Report 74
7.3 Record Keeping 74
7.3.1 Record Keeping for Projects 74
7.4 Project Reporting Period and Verification Cycle 75
7.4.1 Additional Reporting and Verification Options for Projects 75
7.4.1.1 Initial Reporting and Verification Period 76
7.4.1.2 Option 1: Verification Period Equaling One Reporting Period 76
7.4.1.3 Option 2: Verification Period Equaling Two Reporting Periods 76
8 Verification Guidance 77
8.1 Preparing for Verification 77
8.2 Verification Sampling and Schedule for Projects and Cooperatives 78
8.2.1 Verification Site Visit Requirements 79
8.3 Standard of Verification 81
8.4 Monitoring Plan 81
8.4.1 Annual Reports 81
8.5 Verifying Eligibility at the Field Level 81
8.6 Core Verification Activities 83
8.7 Nitrogen Management Verification Items 83
8.7.1 Project Eligibility and CRT Issuance 84
8.7.2 Quantification 85
8.7.3 Risk Assessment 86
8.8 Successful and Unsuccessful Verifications 87
8.8.1 Field-Level and Project-Level Errors 87
8.8.1.1 Cumulative Field-Level Error of Sampled Fields 88

8.8.2 Project-Level Errors 88
8.9 Completing Verification 88
9 Glossary of Terms 89
10 References 92
Appendix A Nitrogen Management Review 100
A.1 Nitrogen Management Stakeholder Survey 100
A.2 Literature Review 101
A.2.1 Nitrogen Management Protocol V1.0 Science Advisory Committee Findings 101
A.2.2 Results 102
A.3 Assessment of Excess Nitrogen Use 102
A.3.1 CEAP Cropland Survey Reports 103
A.3.2 USDA ERS Reports 105
A.3.2.1 *Conservation-Practice Adoption Rates Vary Widely by Crop and Region* 106
A.3.2.2 *Nitrogen in Agricultural Systems: Implications for Conservation Policy* 106
A.3.3 IPNI Nutrient Use Geographic Information System (NuGIS) 107
A.4 Summary of Findings 111
Appendix B Summary of Performance Standard Test Development and Additionality Assessment 112
B.1 Practices and Data Availability 112
B.2 Nitrogen Cycling and Nitrogen Use Efficiency 114
B.3 Nitrogen Use Efficiency (NUE) as N Rate Reduction Performance Standard Threshold 116
B.4 Development of County- and Crop-Specific NUE Benchmarks 117
B.4.1 Database Overview 118
B.4.1.1 USDA National Agricultural Statistics Service (NASS) Quick Stats 118
B.4.1.2 USDA Agricultural Resource Management Survey (ARMS) Crop Production Practices Tailored Reports 118
B.4.1.3 International Plant Nutrition Institute (IPNI) Nutrient Use Geographic Information System (NuGIS) 119
B.4.2 Estimating State Average N Rates for Non-Survey Years 120
B.4.3 Estimating County- and Crop-Specific Average N Rates 121
B.4.4 Calculating County- and Crop-Specific Yields 122
B.4.5 Estimating County- and Crop-Specific NUE Benchmarks 122
B.5 Nitrogen Management Protocol Eligibility Lookup Tool 122
B.6 Use of Nitrification Inhibitor or Switch to Slow Release Fertilizer Performance Standard 123
B.6.1 Adoption Rate of Enhanced Efficiency Fertilizers 123
B.6.2. Financial Barriers 124
B.6.3 Additionality Assessment 124
B.7 Assessing Additionality in California 125
Appendix C Overview of Water Quality Regulations: Impacts on Legal Requirements and Regulatory Compliance 126
C.1 Clean Water Act 126
C.2 California Dairy General Order 128
C.3 California Irrigated Lands Regulatory Program 129
C.4 Coastal Zone Management Act 130
C.5 Safe Drinking Water Act 130
C.6 Fertilizer Content Labeling Laws 131
Appendix D Methodology for Determining $Frac_{LEACH}$ Values 132

Appendix E Default Values for Average Fertilizer N Concentration and Fertilizer Weights 134
Appendix F Modeling to Develop Nitrogen Management Quantification Tool (NMQuanTool) 135
F.1 Overview....135
F.2 Stratification: Geography and Associated Climate....136
F.3 Baseline Determination....137
F.4 Modeling Approach....139
F.5 Results....141
F.6 Tillage Practice and Increased N_2O Emissions....141
F.7 Uncertainty....142

List of Tables

Table 2.1. Eligible Project Activities....5
Table 2.2. Eligible Crops and Regions....6
Table 2.3. Project Ownership Types & Account Types....12
Table 3.1. Payment Stacking Scenarios....27
Table 4.1. Description of all Sources, Sinks, and Reservoirs....31
Table 5.1. 100-year Global Warming Potential for Non-CO_2 GHGs....33
Table 6.1. Field Monitoring Parameters....56
Table 6.2. Additional Field Management Data....70
Table 8.1. Summary of Field-Level Eligibility Criteria for a Nitrogen Management Project....82
Table 8.2. Eligibility Verification Items....84
Table 8.3. Quantification Verification Items....85
Table 8.4. Risk Assessment Verification Items....86
Table A.1. Priority Practices and Resources Supporting Consistent N_2O Emission Reductions....101
Table A.2. Findings from CEAP Cropland Reports on Regions Applying Appropriate N Rates 105
Table A.3. Shares of Treated Acres that Did Not Meet the Rate Criterion, by Crop, in 2006 ... 107
Table A.4. Total Nitrogen Applications Above Criterion Rate by Farm Production Region, 2006....107
Table B.1. List of Priority Practices and Data Availability....113
Table B.2. NASS Crop-Specific Chemical Usage Survey Years....121
Table B.3. Yield Conversion Factors....122
Table D.1. Evapotranspiration Conversion Factors....132

List of Figures

Figure 2.1. Eligible County-Crop Combination....11
Figure 2.2. Example Cooperative Ownership/Management Structure....13
Figure 4.1. General Illustration of the GHG Assessment Boundary....30
Figure 5.1.Quantification of GHG Emission Reductions Overview....34
Figure A.1. 12 Watersheds (in yellow) for CEAP Cropland Regional Assessments....104
Figure A.2. 2014 IPNI NuGIS County-Level N Balance Data....109
Figure A.3. 2014 IPNI NuGIS County-Level N Use Data....110
Figure B.1. Nitrogen Sources, Cycling, and Losses in Agricultural Systems....114
Figure F.1. Cropland areas included in the analysis, overlaid with county-rectified CEAP regions....137

List of Equations

Equation 3.1. Annual Nitrogen Use Efficiency 20
Equation 3.2. Annual Total N Rate for Field in Project 20
Equation 3.3. Passing Performance Standard Test for Reducing Synthetic N Rates....21
Equation 3.4. Average Total N Rate for Field over Baseline Look-Back Period 22
Equation 3.5. Demonstrating Total N Rate Reduced from the Baseline to the Project....22
Equation 5.1. GHG Emission Reductions 35
Equation 5.2. Percentage Reduction in Synthetic N Rate from Baseline to Project 36
Equation 5.3. Sum of Primary Effect Emission Reductions for all fields in Project 36
Equation 5.4. Baseline Average Synthetic Fertilizer N Rate on Field 38
Equation 5.5. Baseline Annual Synthetic Fertilizer N Rate on Field in Year of Baseline Look-Back Period....39
Equation 5.6. N Rates for Dry N-Containing Synthetic Fertilizer in Year of Baseline Look-Back Period....39
Equation 5.7. N Rates of Liquid N-Containing Synthetic Fertilizer in Year of Baseline Look-Back Period....39
Equation 5.8. Baseline Average Organic Fertilizer N Rate on Field 39
Equation 5.9. Baseline Annual Organic Fertilizer N Rate on Field in Year of Baseline Look-Back Period....40
Equation 5.10. N Rates of Solid N-Containing Organic Fertilizer in Year of Baseline Look-Back Period....40
Equation 5.11. N Rates of Liquid N-Containing Organic Fertilizer in Year of Baseline Look-Back Period....40
Equation 5.12. Project Synthetic Fertilizer N Rate for Field....41
Equation 5.13. N Rates for Dry N-Containing Synthetic Fertilizer in Project 41
Equation 5.14. N Rates of Liquid N-Containing Synthetic Fertilizer in Project....41
Equation 5.15. Change in Synthetic N on Field from Previous Cultivation Year Not Claiming CRTs....42
Equation 5.16. Previous Cultivation Year Synthetic Fertilizer N Rate for Field....42
Equation 5.17. Normalized Project Yield for Each Year in the Baseline....44
Equation 5.18. Increase in Project Synthetic N Rate Due to Production Shifting (Leakage) 45
Equation 5.19. Primary Effect GHG Emissions from Increases in Organic N....45
Equation 5.20. Direct N_2O Emissions from Organic N Changes in the Corn Belt....46
Equation 5.21. Direct N_2O Emissions from Organic N Changes Outside the Corn Belt 46
Equation 5.22. N_2O Emissions from LVRO from Increases in Organic N Per Field....47
Equation 5.23. Change in N Rate of Organic Fertilizer for Field in Project....49
Equation 5.24. Project Organic Fertilizer N Rate for Field 49
Equation 5.25. N Rates of Solid N-Containing Organic Fertilizer in Project 49
Equation 5.26. N Rates of Liquid N-Containing Organic Fertilizer in Project....50
Equation 5.27. Change in N Rate of Organic Fertilizer for Field in Previous Cultivation Year....50
Equation 5.28. Previous Cultivation Year Organic Fertilizer N Rate for Field....51
Equation 5.29. Direct Secondary Effect Emissions from Project Activities 51
Equation 5.30. Increased Secondary Emissions from Electricity Use in Project 52
Equation 5.31. Option 1 – Increased Secondary Emissions from Fossil Fuel Use in Project....53
Equation 5.32. Option 2 – Increased Secondary Emissions from Fossil Fuel Use in Project....53

Abbreviations and Acronyms

ac	Acre or Acres
ARMS	USDA Agricultural Resource Management Survey
BMP	Best management practices
C-AGG	Coalition on Agricultural Greenhouse Gases
CFR	United States Code of Federal Regulations
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPS	NRCS Conservation Practice Standard
CRT	Climate Reserve Tonne
CSP	Conservation Stewardship Program
CWA	Clean Water Act
DNDC	DeNitrification-DeComposition (biogeochemical process model)
EEF	Enhanced efficiency fertilizer
EPA	United States Environmental Protection Agency
GHG	Greenhouse gas
GIS	Geographic Information System
HEL	Highly erodible land
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
lb	Pound
LVRO	Leaching, volatilization, and runoff
Mg	Megagram
MRTN	Maximum return to nitrogen
MRV	Monitoring, Reporting and Verification
MSU-EPRI	Michigan State University and Electric Power Research Institute
N_2O	Nitrous oxide
N	Nitrogen
NASS	USDA National Agricultural Statistics Service
NCR	North Central Region of the United States
NH_3	Ammonia
NH_4^+	Ammonium
NI	Nitrification inhibitor
NMP	Nutrient or Nitrogen Management Plan
NO_3^-	Nitrate
NO_x	Nitrogen oxides
NOAA	National Oceanic and Atmospheric Administration
NPS	Nonpoint source

NRCS	Natural Resource Conservation Service of the USDA
NUE	Nitrogen use efficiency
PFP	Partial Factor Productivity
RCPP	Climate Action Reserve Rice Cultivation Project Protocol
Reserve	Climate Action Reserve
SAC	Climate Action Reserve Science Advisory Committee
SRF	Slow release fertilizer
SSR	Source, sink, and reservoir
T-AGG	Technical Working Group on Agricultural Greenhouse Gases
TMDL	Total maximum daily load
TSP	Technical Service Provider (recognized by NRCS)
USDA	United States Department of Agriculture

1 Introduction

The Climate Action Reserve (Reserve) Nitrogen Management Protocol provides guidance to account for, report, and verify greenhouse gas (GHG) emission reductions associated with the implementation of cropland nitrogen management best practices. This protocol is designed to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with a nitrogen management project.

The Climate Action Reserve is an environmental nonprofit organization that promotes and fosters the reduction of greenhouse gas (GHG) emissions through credible market-based policies and solutions. A pioneer in carbon accounting, the Reserve serves as an approved Offset Project Registry (OPR) for the State of California's Cap-and-Trade Program and plays an integral role in supporting the issuance and administration of compliance offsets. The Reserve also establishes high quality standards for offset projects in the North American voluntary carbon market and operates a transparent, publicly-accessible registry for carbon credits generated under its standards.

Project developers that initiate nitrogen management projects use this document to quantify and register GHG reductions with the Reserve. The protocol provides eligibility rules, methods to calculate reductions, performance-monitoring instructions, and procedures for reporting project information to the Reserve. Additionally, all project reports receive independent verification by ISO-accredited and Reserve-approved verification bodies. Guidance for verification bodies to verify reductions is provided in the Reserve Verification Program Manual[1] and Section 1 of this protocol.

[1] Available online at http://www.climateactionreserve.org/how/verification/verification-program-manual/.

2 The GHG Reduction Project

2.1 Background

Nutrient management refers to the addition and management of nutrients and soil amendments to agricultural soils to increase the supply of essential nutrients to crops. Nitrogen is generally the most important nutrient from an agronomic standpoint, as it is typically the primary nutrient limiting crop yields and must often be added more frequently and in greater amounts than other nutrients such as phosphorus and potassium. Nitrogen is also the major soil nutrient of concern regarding GHG emissions, because once nitrogen enters the soil, it can be converted to nitrous oxide (N_2O), a potent GHG with a relatively high Global Warming Potential (GWP).[2] Nutrient management then, for the purposes of this protocol, is the management of nitrogen applied to agricultural soils, primarily via synthetic and organic fertilizers, and is hereafter referred to as Nitrogen Management.

Agricultural N_2O emissions are a key source of GHG emissions in the United States. In 2016, they accounted for approximately 76.7 percent of total N_2O emissions and 4.4 percent of total GHG emissions. Estimated emissions from this source in 2016 were 283.6 million metric tons of carbon dioxide equivalent (MMT CO_2e), which were 13.2 percent higher than 1990 levels. From 1990 to 2016, on average, cropland specifically accounted for approximately 70 percent of total direct N_2O emissions[3] and 81 percent of total indirect[4] N_2O emissions.[5]

The objective of a nitrogen management project under the Nitrogen Management Protocol is to reduce N_2O emissions by adopting practices that further improve Nitrogen Use Efficiency (NUE) beyond what is projected to typically happen in the future as standard nitrogen management practices, absent any incentives provided by a carbon market. The Nitrogen Management Protocol provides eligibility criteria for approved nitrogen management practices and approaches for quantifying N_2O emission reductions that occur as a result of adopting the approved practices for eligible crops in eligible regions across the United States.

2.2 Project Definition

For the purpose of this protocol, a nitrogen management project ("project") is defined as the adoption and maintenance of one or more *eligible project activities* during the cultivation year of an *eligible crop,* on one or more fields in an *eligible project area*, that reduce nitrous oxide (N_2O) emissions. Multiple fields, each employing a different combination of crops and project activities, may be managed together under a *single project*, across multiple owners and multiple regions. *Multiple projects* may also be managed together as a "project cooperative" or "cooperative", as described in Section 2.4.

[2] The global warming potential of N_2O in this protocol shall be 298 based on the IPCC's Fourth Assessment Report. This GWP will be used until further guidance is issued by the Reserve.
[3] N_2O emissions from the mineral N available at the site of the management activity(ies) for transformation through the nitrification-denitrification cycle; GHG sources, sinks, and reservoirs (SSR) 1 in this protocol.
[4] N_2O emissions that occur offsite as a portion of N escapes from the site via leaching, volatilization, or runoff (LVRO), and is subsequently converted to N_2O in another location where conditions are favorable; SSR 2 in this protocol.
[5] U.S. Environmental Protection Agency (2018a). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016. *EPA 430-R-18-003*, 5-26. Washington, D.C. Available at https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

Table 2.1 and Table 2.2 below provide a quick overview of the combinations of activities, crops, and regions that are approved under this protocol, as determined by:

1. The results of a literature review of nitrogen management practices shown to consistently reduce N_2O emissions (see Appendix A);
2. The data available for the development of performance standard tests for additionality (see Appendix B); *and*
3. The capabilities of an applicable quantification approach (see Appendix F).

As of the date of adoption of this protocol by the Reserve Board, only project activities listed in Table 2.1 are considered eligible for credit issuance.

Please note that the combination of eligible activities, crops and regions will change over time, as new data allows for the updating of the performance standard tests. The information contained in these tables is illustrative, representing eligible combinations at the time of protocol adoption.

Table 2.1. Eligible Project Activities

Category	Eligible Project Activities	Description
Required	Synthetic N Rate Reduction	Reduction in the annual synthetic nitrogen application rate compared to baseline levels, without going below N demand
Optional	Use of an Enhanced Efficiency Fertilizer (EEF)	*Either,* Application of *nitrification inhibitor* (NI) as defined by AAPFCO[6] and accepted for use by a state's fertilizer control agency, or similar authority *or,* Conversion from conventional fertilizer(s) to *slow release fertilizer(s)* (SRF) as defined by AAPFCO and accepted for use by a state's fertilizer control agency, or similar authority

[6] Association of American Plant Food Control Officials. See http://www.aapfco.org/

Table 2.2. Eligible Crops and Regions

Crop	State[7]
Barley	AZ, CA, CO, ID, MN, MT, ND, OR, PA, VA, WA, WY
Corn (Grain)	CO, GA, IL, IN, IA, KS, KY, MI, MN, MO, NE, NY, NC, ND, OH, PA, SD, TX, WI
Corn (Silage)	IA, MN, NY, ND, PA, WI
Cotton[8]	AR, GA, MS, MO, NC, TN, TX
Oats	IL, IA, KS, MI, MN, NE, NY, ND, OH, PA, SD, TX, WI
Sorghum (Grain)	CO, KS, NE, OK, SD, TX
Spring Wheat (Durum)	MT, ND
Spring Wheat (excluding Durum)	MN, MT, ND, SD
Tomatoes (Processing)	CA
Winter Wheat	CO, ID, IL, KS, MO, MT, NE, OH, OK, OR, SD, TX, WA

Eligible Project Activities are described further in Section 2.2.1, Eligible Crops in Section 2.2.2, and Eligible Project Area in Section 2.2.3. All eligible project activities may be implemented for any eligible crop in any eligible region (assessed at the county level). All eligible activity-crop-county combinations are contained in the Nitrogen Management Protocol Eligibility Lookup Tool,[9] which was developed to simplify the process for project developers to self-assess the eligibility of each of their fields This tool is mandatory for all projects to determine if select activity-crop-county combinations are eligible. It is made available upon request to the Reserve and will be updated outside of the protocol as new data becomes available (See Appendix B for more information).

This protocol employs the use of an emission factor-based nitrogen management quantification tool (NMQuanTool[10]), built in Microsoft Excel, to calculate N_2O emission reductions resulting from the implementation of eligible nitrogen management project activities. In addition to the eligible activities discussed in Section 2.2.1, the NMQuanTool also incorporates the impacts of a given field's tillage practice, specifically the maintenance of conventional till or the switch from conventional till to no till from the baseline to the project, and its impact on N_2O emissions. Certain activity-crop-region scenarios, in combination with a switch to no till in the short-term (i.e., less than 10 continuous years of practicing no till), were found to generate an increase in N_2O emissions from the baseline to the project.[11] All such scenarios are ineligible and have

[7] Note, eligibility is assessed at the county level; eligible States are provided in Table 2.2 for ease.
[8] Cotton eligibility determination is based on "Upland Cotton" data from the USDA National Agricultural Statistics Service (NASS). Insufficient county data existed for "Cotton" for the development of crop- and county-specific average fertilizer rates and nitrogen use efficiency benchmarks, though recent state data is comparable. Either may be cultivated. See Section 2.2, Section 3.5.1 and Appendix B for more information.
[9] The Nitrogen Management Protocol Eligibility Lookup Tool is an easy-to-use Microsoft Excel tool for project developers to check if their prospective fields' activity-crop-county scenarios are eligible. Detailed guidance on how to use the tool will be made available upon request to the Reserve. It also contains the multi-year county- and crop-specific average N rates, yields, and nitrogen use efficiency (NUE) values for all eligible combinations. See Section 3.5.1 and Appendix B for more information.
[10] Detailed guidance on how to use the NMQuanTool can be found in the first spreadsheet of the tool, which will be made available upon request to the Reserve here: http://www.climateactionreserve.org/how/protocols/nitrogen-management/.
[11] Climate regime and the duration of tillage practice have been found in the scientific literature to have varying effects on N_2O emissions. Regional climate has been identified as a major driver for the change in N_2O emissions with the adoption of no till, with emissions increasing in humid climates and decreasing in dry climates. Time since

been incorporated in the Nitrogen Management Protocol Eligibility Lookup Tool.[12] For more information see Appendix F, Section F.6.

2.2.1 Eligible Project Activities

The project activity must be defined very precisely, as it sets what action must be done to earn credits, and thus sets the scope for the project, as well as setting the boundary for regulatory compliance and other key project attributes. As described in Table 2.1, there are two approved project activities for this protocol, both of which have consistent N_2O effects in terms of directional certainty, and the application of which leads to quantifiable reductions in N_2O emissions in comparison to baseline emissions.

The adoption of N rate reductions is mandatory for all projects, whereas the use of Enhanced Efficiency Fertilizers (EEFs) is an optional additional approved project activity.[13] The eligible project activity of N rate reductions in this version of the Nitrogen Management Protocol is limited to reductions in synthetic N rates. All projects will be eligible to generate CRTs for percentage reductions in the application rate of synthetic N compared to baseline application rates, and projects will be eligible to generate CRTs from one of the optional nitrification inhibitors or slow release fertilizers when applied in combination with the synthetic N rate reduction. Projects that employ N rate reductions and both nitrification inhibitors and slow release fertilizers are eligible, however, the NMQuanTool is only capable of quantifying emission reductions associated with the implementation of one of the EEFs and not their combined impacts. Both EEF products achieve the same objective and stacking one another would not be expected to result in cumulative benefits (i.e., benefits are not additive).[14] Additionally, it is not anticipated that multiple EEFs would be applied simultaneously in practice. If seeking CRTs for either of the EEFs, project developers must select only one of them in the NMQuanTool.

With respect to N rate reductions, it's important to note that reductions in annual synthetic nitrogen application rate should not go significantly below N demand. Reducing N rates below crop needs will eventually cause crop yields to decline. To prevent N rates going below N demand, this protocol includes a performance standard based on a NUE metric involving yield (see Section 3.5.1) and addresses significant decreases in yield via the approach to account for leakage (see Section 5.1.3.2).

2.2.1.1 N Rate Reductions

For the purposes of this protocol, N rate reductions are defined as reductions in the annual *synthetic* nitrogen application rate (i.e., the mass applied per acre for the cultivation year of an eligible crop) compared to baseline levels. Multiple safeguards are utilized in this protocol to

adoption of no till also plays a role, with higher emissions initially after adoption (< 10 years) in both humid and dry climates, but over time (≥ 10 years), lower emissions relative to previous emissions from conventional tillage systems.

[12] A table containing all such scenarios can be made available upon request by the Reserve.

[13] EEFs are fertilizer products that can reduce nutrient losses to the environment while increasing nutrient availability for the crop by either slowing the release of nutrients for uptake or altering the conversion of nutrients to other forms that may be less susceptible to losses.

[14] Due to minimal adoption and additive benefit, the modeling to develop the new quantification methodology for V2.0 did not include the effects of NIs and SRFs used together. As a result, the quantification methodology is unable to calculate emission reductions associated with the combined use of a NI and SRF. See Section 5, for more information. Growers have the flexibility to apply the EEF product to best meet their fields' soil and climatic conditions and take into consideration other factors, such as management capabilities and economics.

ensure that growers do not reduce N rates to the extent that yield is significantly reduced,[15] and three hierarchical options are provided for determining baseline N rates (see Section 5.1.2.1). N application rate may vary across the field (i.e., may be applied at different times throughout the cultivation year), so long as the total N applied is used as the input for the performance standard test and in all field-level equations in Section 5. Total organic N applied may increase or decrease in the project area, however, total annual N applied (synthetic and organic) in the project must decrease below baseline levels (see Section 3.5.1.1).[16]

Synthetic fertilizers may be applied in dry form (e.g., granular urea, ammonium nitrate) or liquid form (e.g., urea ammonium nitrate, UAN). Urea is also considered a 'synthetic" fertilizer for the purposes of this protocol. Organic fertilizers may be liquid or solid, and may include unprocessed manure (e.g., beef cattle manure, hog manure, digester effluent and/or solids), other unprocessed organics (e.g., compost) and processed commercial organic fertilizers.

The fertilizer source, application timing and placement are at the discretion of the grower.

2.2.1.2 Use of Enhanced Efficiency Fertilizers

Nitrification inhibitors (NIs) and slow release fertilizers (SRFs) are each a type of enhanced efficiency fertilizer (EEF) with a similar function, that can make nitrogen available to crops over a longer portion of the cultivation year to better match the crop uptake needs. NIs are substances that when applied in addition to the use of an ammonia (NH_3) or ammonium (NH_4^+) fertilizer, delay the nitrification process (the conversion of NH_3 or NH_4^+ to nitrate (NO_3^-)) by depressing the activity of *Nitrosomonas* bacteria, until the NO_3^- can be readily used by crops.[17] SRFs, as their name implies, slow or control the release of soluble nitrogen (NH_4^+ and NO_3^-) to the soil compared to conventional fertilizers, extending N availability to the crop and improving the synchronization between crop uptake and N availability[18]. Both allow the crop to take up more of the nitrogen applied, and ultimately reduce the release of N_2O to the atmosphere.

For the purposes of this protocol, in order for the use of NIs or the switch to SRFs to be eligible for credits, such activities must not have occurred in a field's baseline look-back period (Section 5.1.2, Table 6.2). If NIs or SRFs have been utilized in a given field's baseline look-back period, the field will be unable to earn credits for their use in the project. The use of SRFs and the use of NIs in conjunction is permissible, however, as both types of EEFs work to reduce the conversion rate of supplied nitrogen to N_2O, the additive emissions benefits are either minimal or nonexistent, and thus difficult to quantify. As such, credits can only be earned for applying one of the two EEFs, and Project developers have the option of choosing which one. The EEFs should be applied according to manufacturer recommendations, as well as relevant regulatory or expert recommendations.[19]

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[15] Yield is taken into consideration in the Performance Standard eligibility criteria, and yield also determine whether emissions associated with production leakage must be taken into account, see Section 3.5.1.1 and Section 5.1.3.2 respectively.

[16] Please note, this protocol does not credit for the switch from synthetic N sources to organic N sources. While organic N amendments are allowed, the synthetic N rate must decline from the baseline to the project, and any N_2O emissions associated with increases in organic N rate from the baseline to the project are quantified and deducted from the final emission reductions (See Equation 3.5).

[17] CSP (2014b).

[18] ICF (2013).

[19] International Plant Nutrition Institute (IPNI), Nutrient Source Specifics one-page fact sheet: No. 26, *Nitrification Inhibitors* downloaded 07/31/2018 at: http://www.ipni.net/publication/nss.nsf/0/21B8084A341C98E085257E3C0077595B/$FILE/NSS-26%20Nitrification%20Inhibitors.pdf. NRCS CSP NI Guidance essentially states that if not applied at planting the NI

2.2.2 Eligible Crops

For the purposes of this protocol, all eligible crops are specifically listed in Table 2.2 above.

The list of eligible crops will be expanded as the requisite data become available to allow inclusion of further crops in an updated quantification methodology.[20]

Please note, this protocol does not credit the removal or replacement of more nitrogen intensive crops from the rotation, with less nitrogen intensive crops (e.g., eliminating corn to avoid or substantially reduce use of nitrogen fertilizer). Emission reductions are quantified annually on a field by field basis, comparing the cultivation of one crop in the project's reporting period against the cultivation of the same crop on the same field in the baseline period (e.g., corn data are always compared to corn data). Thus, crop rotations and other interannual impacts (e.g., crop residues incorporated) are not directly accounted for, but each crop grown in the rotation should be compared to the cultivation of the same crop on the same field in the baseline.

Eligible crops may have either been historically grown on the given field, in which case yield records will need to be provided, or be newly introduced in the project.

2.2.3 Eligible Project Area

For the purposes of this protocol, the project area is defined as an eligible crop field or fields on which eligible project activities take place, located in an eligible region. Fields should be configured to exclude areas that do not meet the eligibility requirements set out below (for instance, the field boundary should be drawn to exclude areas containing histosol soils, as those are ineligible). Fields that are split by minor breaks consisting of ineligible areas (i.e., fields split by roads or watercourses) can still be considered a single field.

The project area must adhere to the following criteria:

- Each field must be clearly delineated
- The area within each field must be continuous
- The same primary crop must be grown throughout each field within a reporting period
- The field on which the baseline crop is grown must be the same field on which the project crop is grown[21]
- Exclude roads, watercourses and other physical boundaries (i.e., such areas will not be included in project area acreage)
- The project area shall not contain any histosols[22]
- The project may contain tile-drained fields, as long as tile-drains were in place during the baseline period (i.e., not installed for the purposes of the project)

will be ineffective and goes on to give specific recommendations for how many days certain products should be applied relative to planting date. Project developers and verifiers should consult guidance from the manufacturers as to any application timing guidance for the product in question.

[20] An addendum to the 2014 USDA *Quantifying Greenhouse Gas Fluxes in Agriculture and Forestry: Methods for Entity-Scale Inventory* of field measurement datasets on N_2O emissions in California specialty crops is anticipated at some point in 2018, or sometime thereafter, and may provide the necessary data for expansion of the Reserve's Nitrogen Management Protocol to include California specialty crops.

[21] See Section 5.1.2 for further details on baseline setting requirements.

[22] Histosols are found at all altitudes, but the vast majority occurs in lowlands. Common names are peat soils, muck soils, and bog soils. See USDA-NRCS, Keys to Soil Taxonomy. Available at https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/class/taxonomy/?cid=nrcs142p2_053580.

- If the project area includes land classified as highly erodible land (HEL)[23], that land must meet the Highly Erodible Land Conservation provisions to be eligible under this protocol
- If the project area includes land classified as wetlands,[24] that land must meet the Wetlands Conservation provisions to be eligible under this protocol[25]

To be an *eligible project area* the field must also be located in a region for which there are applicable NUE benchmarks for use in the performance standard test for additionality. All eligible activity-crop-region combinations, and their respective NUE benchmarks and average N rates, can be found in the Nitrogen Management Protocol Eligibility Lookup Tool. Figure 2.1 highlights the eligible counties based on these conditions, and the number of possible crops eligible within each county. Not all fields within a project or cooperative are required to be located in the same region.

[23] Highly erodible land is defined as "land that has an erodibility index of 8 or more" in Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2. Part 12.21 further outlines how HEL is identified and how the erodibility index is calculated.

[24] Wetlands generally have a predominance of hydric soil and are inundated or saturated by surface or groundwater for various durations over the year. See Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2 for the definition of wetlands. It is also worth noting that wetlands in the project area may also be impacted by the applicability conditions in Section 1.10 of this protocol.

[25] As outlined in Title 7 of the Code of Federal Regulations, Subpart A, Part 12.5(b), and in Section 510.10 of the National Food Security Act Manual. Such exemptions may include wetlands farmed prior to 1985, wetlands with minimal effect, or wetlands with mitigation measures in place.

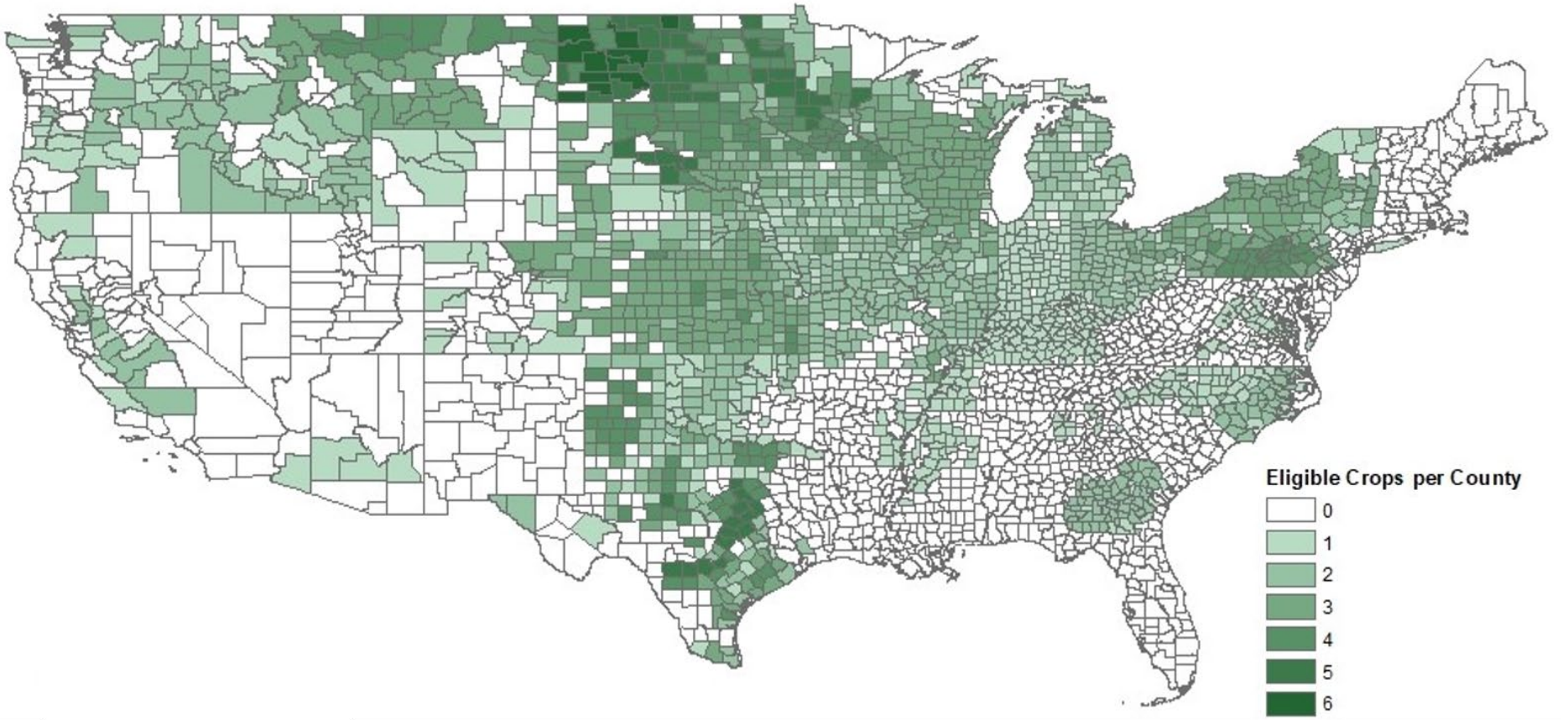

Figure 2.1. Eligible County-Crop Combination

2.3 Defining the Cultivation Year

For the purposes of this protocol, a cultivation year is generally defined as the period between the first day after harvest of the last primary crop on a field and the last day of harvest of the current primary crop on a field. A primary crop is defined as the main production crop grown on a field in a given year (e.g., corn is a primary crop and may be grown on its own or with a cover crop). A cover crop is defined as a crop planted for seasonal vegetative cover during non-crop production periods in a primary crop rotation, that is not harvested and is instead returned to the soil[26]. If there are multiple primary crops in rotation, each type of primary crop (e.g., corn in a corn-soybean rotation) has a distinct cultivation year. Since this protocol is currently only applicable to annual primary crops, the cultivation year is approximately 12 months.[27] One complete cultivation year for corn in a corn-soy rotation, for example, begins with post-harvest residue management for the soy crop harvested in the fall of one calendar year, continues with field preparation, seeding, and cultivation of the corn crop, and culminates upon completion of the corn harvest in the fall of the next calendar year. Cover crops established between the successive production of primary crops shall be included as part of the cultivation year of the subsequent primary crop (See Section 5.1.3). See Section 3.5.1.1 for guidance relating to fertilizer applications during the cultivation of crops for which CRTs are not being sought.

2.4 Project Ownership Structures and Terminology

A nitrogen management project can be implemented using various ownership structures. Table 2.3 below sets out the terminology used to describe the different parties involved in a Nitrogen Management project, whether such parties are necessary in different circumstances, and associated account types that will be necessary.

Table 2.3. Project Ownership Types & Account Types

Term	Definition	Required?	Registry account type
Field Manager	The entity with management control of the project activities. Unless evidence is provided to the contrary, it's assumed this person/entity holds the GHG rights. This may or may not be the Landowner, Project Owner, Project Developer, Project Participant, Cooperative Developer, or Cooperative Participant.	Yes. There will always be a field manager identified, but they may not play any role in the monitoring, reporting and verification (MRV)	Depends. May be any of the following: ▪ None ▪ Project Owner ▪ Project Developer
Landowner	The entity listed on the deed to the property as the landowner.	No, unless they play one of these other roles.	Depends. May be any of the following: ▪ None ▪ Project Owner ▪ Project Developer
Project Owner (PO)	The entity which holds rights to the CRTs from the project at time of issuance.	Yes. There will always be a PO identified.	Project Owner or Project Developer, if applicable.

[26] CSP (2017)

[27] As the protocol expands in future versions, primary crops with cultivation years shorter than a calendar year (e.g., lettuce) or longer than a calendar year (e.g., perennials) may be included, which would likely necessitate changes in the definition of "cultivation year" as approximately twelve months.

Term	Definition	Required?	Registry account type
Project Developer	The entity that does the MRV for the project as required by the protocol.	Yes. There will always be a project developer identified, although it may or may not be a separate entity from the PO.	Project Developer
Cooperative Developer (CD)	The entity which does the MRV for the cooperative as required by the protocol. The CD may or may not also be a PO.	Yes, if there is a cooperative to manage.	Project Developer
Cooperative Participant	A Project Owner whose project or field(s) is being managed as part of a cooperative, with a separate CD.	Yes, if the project is part of a cooperative.	Project Owner or Project Developer, depending on the desired functionality.

Every field will need to have a Field Manager, and every project will need to have a Project Owner. If those are not the same entity (e.g., Company A signs agreements with 1000 farmers saying that Company A will own the GHG rights, and Company A is thus the Project Owner), then the verifier would need to confirm that the Project Owner has a written contract with (and signed by) the Field Manager. Field Managers and landowners may not be directly involved in the project, or they may be Project Owners or project developers. For every single project, at least one of these entities will have a Project Developer registry account. The Project Developer is responsible for project monitoring, reporting, and verification (MRV). If this is *not* the same entity as the entity who will own the GHG rights, then the owner of the GHG rights will need to have a separate Project Owner registry account.

See Figure 2.2 below for a graphical illustration of a potential project ownership and management structure.

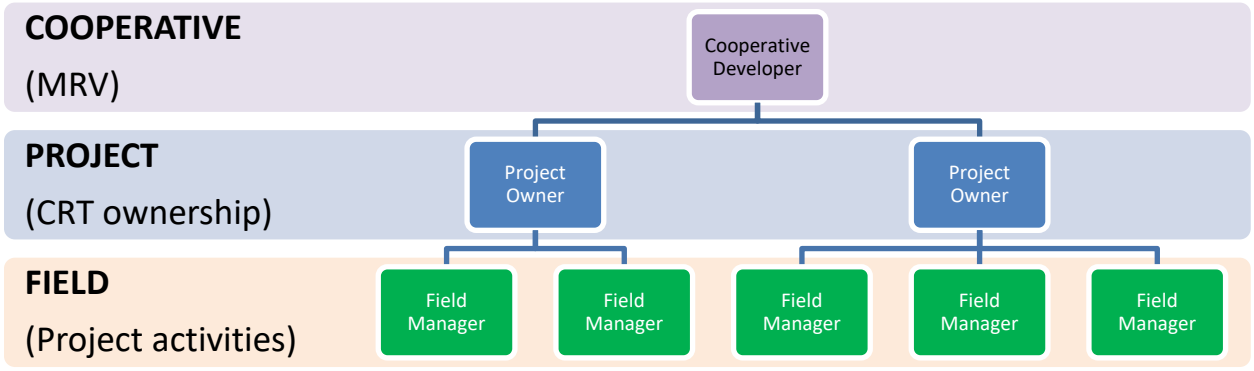

Figure 2.2. Example Cooperative Ownership/Management Structure

2.4.1 Project Owners issued CRTs

A single entity must be designated to be the Project Owner for each project, and only that party will be issued CRTs for that project. As set out in Table 2.3 the type of account needed by the Project Owner will depend on whether they also play a management role in the project and take

on MRV responsibilities for that project. Project management responsibilities will be discussed in Section 2.4.2 below.

The Project Owner is responsible for the accuracy and completeness of all information submitted to the Reserve, and for ensuring compliance with this protocol, even if they contract with an outside entity to carry out project development activities. The Project Owner must have a Reserve registry account and must sign all required legal attestations (e.g., Attestation of Title, Attestation of Voluntary Implementation, and Attestation of Regulatory Compliance). [28] In the case of project cooperatives, each Project Owner must sign an attestation for their respective project.

2.4.2 Entities with Project Management Roles

A single entity must be designated to take on formal management of a project and be responsible for the MRV for that project. The entity taking on management of the project will be referred to generically as the "project developer". The project developer may also be the Project Owner for a given project, or not. The project developer will be responsible for all aspects of MRV for the project, except for signing the attestations, which must be done by the Project Owner.

A "Cooperative Developer" is the entity that manages reporting and verification for a project cooperative (i.e., two or more individual nitrogen management projects that report and verify jointly). A cooperative may consist of nitrogen management projects each involving a unique Project Owner. A Cooperative Developer must have an account with the Reserve. The term "project developer" will be used throughout this document to refer to both the responsible management entity for each project and, in the case of cooperatives, the entity responsible for managing the cooperative.

A Cooperative Developer must open a Project Developer account on the Reserve and must remain in good standing throughout the duration of the projects and cooperative(s) it manages. Failure to remain in good standing will result in all account activities of the participant projects in the cooperative(s) managed by the respective Cooperative Developer being suspended until issues are resolved to the satisfaction of the Reserve. In order for a Cooperative Developer to remain in good standing, Cooperative Developers must perform as follows:

- Complete cooperative contracts with Project Owners (see Section 2.4.5 on Joining a Cooperative)
- Engage the services of a single verification body for all nitrogen management projects enrolled in the cooperative in any given verification period
- Coordinate the submittal, monitoring, and reporting activities required by this protocol for all projects in the cooperative(s), observing all project/cooperative deadlines
- Coordinate a verification schedule that maintains appropriate verification status for the cooperative. Document the verification work and report to the Reserve on an annual basis how completed verifications demonstrate compliance (see Section 8.2)
- Maintain a Reserve account in good standing

[28] Information regarding Reserve accounts and the process for project submittal and registration is available here: http://www.climateactionreserve.org/how/projects/register/.

2.4.3 Entering a Project

Individual fields may join a project by being added to the project's Project Submittal Form (if joining a project at initiation) or by being added through the Field Enrollment & Transfer Form (if joining once the project is underway).

The project developer managing the project that receives the new fields will be responsible for submitting the Field Enrollment & Transfer Form, listing the field(s) that are now joining their project, as well as updating a list of enrolled fields contained within the form. Emission reductions occurring on new fields entering a project may start counting toward the project's CRTs in the reporting period during which the field joined the project. Emission reductions will be reported as a single combined project for the reporting period in which the transfer occurred. Any period of time that has already been reported and verified under a single project will not be included in reporting under the newly combined project.

Each field will only be eligible for a maximum of ten reporting periods (or less if they join a project already underway, as the project as a whole will only be eligible for a maximum of ten reporting periods). All fields in a project must use the same version of this protocol, and if a field from one project joins another project, then the newest version of the protocol in use between them must be adopted for the newly combined project.

Projects that have already been submitted to the Reserve may choose to join another existing project by submitting a Field Enrollment & Transfer Form to the Reserve. Again, it will be the project developer managing the receiving project that is responsible for submitting the Field Enrollment & Transfer Form to the Reserve.

2.4.4 Leaving a Project

Fields must meet the requirements in this section in order to change projects or leave to become their own project and continue reporting emission reductions to the Reserve. In all cases, emission reductions must be attributed to one project for a complete reporting period, as defined in Section 3.3, and no CRTs may be claimed by a project for a field that does not participate and report data for a full reporting period. Project activities on an individual field may be terminated and the field may be removed from the project at any time. Reporting for each field must be continuous.

In order for a field or fields to leave a project and join another existing project, the Project Owner for the receiving project must submit a Field Enrollment & Transfer Form to the Reserve, noting that it is a "transfer project" and identifying the project from which it transferred, and the project to which it is being transferred. Reporting under the destination project shall continue according to the guidance in Section 7.2.

For fields that leave a project to become an individual project, the deadline for submittal of the subsequent monitoring or verification report (whichever is sooner) is extended by 12 months beyond the deadline specified in Section 7.4. The Project Owner must submit either a monitoring report or verification report (whichever is due) by this new deadline in order to keep the project active with the Reserve. The project developer setting up the new project will need to submit a Project Submittal Form to the Reserve to initiate the new project.

2.4.5 Forming or Entering a Cooperative

The Cooperative Developer functions as the project developer for each project enrolled in the cooperative(s) they manage. The Cooperative Developer will initiate the creation of the

cooperative by submitting a Cooperative Submittal Form. Individual nitrogen management projects may join a cooperative by being included in the cooperative's Cooperative Submittal Form[29] (if joining a cooperative at initiation) or by being added through the submission of a Cooperative Enrollment & Transfer Form (if joining once the cooperative is underway). If the Cooperative Developer is not the Project Owner for one or more projects within the cooperative, the appropriate Project Owner account(s) will be confirmed at the time of project submittal. All documentation related to the cooperative and its participant projects is submitted by the Cooperative Developer. After successful verification, CRTs are issued to the accounts of the Project Owners for each project.

Emission reductions occurring on individual projects or new projects entering a cooperative are reported as part of the cooperative during the reporting period in which the transfer occurred.[30] The project will begin reporting with the cooperative no earlier than the beginning of the cooperative's current verification period. If the project has already been registered, either as an individual project or as part of another cooperative, reporting under the new cooperative may not include any period of time that has already been reported and verified.

The crediting periods of the individual projects within a cooperative are derived from their individual project start dates (See Section 3.2) and are not affected by the crediting periods of other projects within the cooperative. All projects within a cooperative must follow the same version of this protocol. If a project that is subject to a more recent version of the protocol wishes to enter an existing cooperative, the rest of the projects in that cooperative must elect to upgrade to the newer version of the protocol.

2.4.6 Leaving a Cooperative

Individual nitrogen management projects must meet the requirements in this section in order to leave or change cooperatives and continue reporting emission reductions to the Reserve. Reporting must be continuous.

Individual Project Owners may elect to leave a cooperative and participate as an individual nitrogen management project for the duration of their crediting period, effective as of the day after the end date of the project's most recently registered reporting period. To leave a cooperative and become an individual nitrogen management project, the Project Owner must submit a Project Submittal Form to the Reserve, noting that it is a "transfer project" and identifying the cooperative from which it is transferring. The Project Owner must also designate a new project developer for the project and ensure that entity has a Project Developer account with the Reserve. For projects that leave a cooperative to become an individual project, the deadline for submittal of the subsequent monitoring or verification report (whichever is sooner) is extended by 12 months beyond the deadline specified in Section 7.2. The new project developer must submit either a monitoring report or verification report (whichever is due) by this new deadline in order to keep the project active in the Reserve.

To leave one cooperative and enter another cooperative, the Project Owner must submit a Cooperative Enrollment & Transfer Form to the Reserve prior to enrolling in the new cooperative. Reporting under the destination cooperative shall continue according to the guidance in Section 7.2.

[29] All forms referenced in this section are available at: http://www.climateactionreserve.org/how/program/documents/.
[30] The transfer is considered to have occurred once the Reserve has approved the Cooperative Transfer Form and the New Project Enrollment Form.

3 Eligibility Rules

Projects must fully satisfy all the eligibility rules set out in this section in order to register a nitrogen management project with the Reserve. All fields participating in a project must meet the following key criteria, as well as the definition of a nitrogen management project (Section 2.2), in order for the project to be eligible.

Section 3.1:	Location	→	*U.S. and U.S. tribal areas, in areas corresponding to approved quantification approaches*
Section 3.2:	Start Date	→	*No more than 12 months prior to submission*
Section 3.5:	Additionality	→	*Meet performance standard*
		→	*Exceed legal requirements*
		→	*Meet payment/credit stacking requirements*
Section 3.6:	Regulatory Compliance	→	*Compliance with all applicable laws*

3.1 Location

Project fields must be located in regions in the United States (U.S.) as listed in Table 2.2 and seen in Figure 2.1.[31]

3.2 Start Date

The project developer must nominate a start date for the nitrogen management project, as well as for each field within the project. The start date for a nitrogen management project is defined as the first day of the cultivation year of an eligible crop, on an eligible field (nominated as the field that triggers the start date), in which eligible project activities are implemented. Projects must be submitted to the Reserve for listing before the end of the nominated field's initial cultivation year.[32] For all other fields, the project developer must nominate a start date for each field, and each field must be submitted within 24 months of the field's start date.

3.3 Reporting Period

The reporting period is the period of time over which GHG emission reductions from project activities are quantified. The reporting period under this protocol is one complete cultivation year of an eligible crop, hereafter referred to as an "eligible crop year" (typically a 12-month period). During the initial reporting period, a project may seek CRTs for one or two cultivation years (if the latter, there may only be one ineligible cropping year in between the eligible cultivation years, i.e., two eligible crops spread out over a maximum of three years).

When a project comprises multiple eligible crop fields, the reporting period in a given year starts on the earliest date that a field being submitted for credits begins its cultivation year, and the reporting period ends on the latest date that a field being submitted for credits ends its cultivation year. This will mean that a project may experience overlapping reporting periods, i.e., a reporting period may end in November of a given year, but if a winter crop is grown on a field submitted to the project for crediting in the next cultivation year, the subsequent project

[31] A complete listing of eligible counties and their applicable crop systems can be found in the Nitrogen Management Protocol Eligibility Lookup Tool, available from the Reserve upon request.

[32] Projects are considered submitted when the Project Developer has fully completed and filed the appropriate Project Submittal Form, available at: http://www.climateactionreserve.org/how/program/documents/.

reporting period may actually begin that same November, potentially prior to the end of the last reporting period.

Despite this, there will be no risk of double issuance of emission reductions, for several reasons:

- quantification of emission reductions occurs on a field by field basis, based on the cultivation year of the given field
- fields can only be registered to one project at any given point in time, therefore fields can only have emission reductions issued to one project for any given reporting period
- field reporting periods cannot overlap, because they are defined by the field's cultivation year. The new cultivation year will only start once the previous crop harvest *on that field* has concluded.

Activities that will *not* count as a reporting period include:

- Fields left fallow;
- Fields cultivating an ineligible crop; and
- Fields cultivating an eligible crop, but either do not meet protocol requirements (such as the performance standard, verification requirements, regulatory compliance requirements, etc.), or are voluntarily withdrawn for that eligible crop year

The field must continue to meet continuous monitoring and reporting requirements, even if not eligible to generate CRTs in a given cultivation year. See Section 5.1.3.1 and Section 5.1.4.4.1 for guidance regarding N usage for cultivation years where CRTs are not being sought.

3.4 Crediting Period

The crediting period for projects under this protocol is defined as ten reporting periods. The crediting period applies at the project level, so that a project may have a maximum of ten reporting periods, but each field also has a limit of ten reporting periods per crediting period.

Only eligible crop years in which CRTs are being sought will be treated as reporting periods and count towards a project's crediting period (and towards the ten-year reporting period limit for each field being credited). Thus, in any given year if no CRTs are being sought on any field enrolled in the project, that year will not be counted as a reporting period towards the project's crediting period (or any of the fields enrolled in the project). If CRTs are being claimed for one or more fields in a year, then that will count as a reporting period towards the project's crediting period. Continuous reporting must be maintained throughout the crediting period (see Section 7.2 for reporting requirements).

Crediting periods may be renewed one time. Thus, a project may have a maximum of two crediting periods, each comprising of a maximum of ten reporting periods, for a total maximum of twenty reporting periods. Each field will also have a maximum of ten reporting periods per crediting period, for a total maximum of twenty reporting periods. Note that each initial reporting period can be a maximum of two cultivation years.

During the 12 months before or after the end of a project's tenth reporting period, project developers may apply for a project's eligibility under a second crediting period. The project must meet the eligibility requirements of the most recent version of this protocol, including any updates to the performance standard test (Section 3.5.1.1). The baseline established in the first crediting period of the project shall be used for the project's second crediting period.

The Reserve will issue CRTs for GHG reductions quantified and verified according to this protocol for a maximum of two crediting periods after the project's start date. If, at any point in the future, the approved project activity adopted on a field becomes legally required, emission reductions may be reported to the Reserve for that field up until the commencement of the cultivation year during which the practice is required by law to be adopted. Upon the effective date of the new legal requirement, the Reserve will cease to issue CRTs for GHG reductions for the legally required project activity for that field (see Section 3.5.2 for further guidance).

3.5 Additionality

The Reserve intends to register only projects that yield surplus GHG reductions that are additional to what would have occurred in the absence of a carbon offset market.

Projects must satisfy all of the following tests to be considered additional:

1. The performance standard test (Section 3.5.1)
    a. N rate reductions
    b. Use of Enhanced Efficiency Fertilizer Products
2. The legal requirement test (Section 3.5.2)
3. The credit/payment stacking test (Section 3.5.3)

3.5.1 The Performance Standard Test

Projects pass the performance standard test by meeting a performance threshold, i.e., a standard of performance applicable to all nitrogen management projects, established by this protocol. The performance standard test is applied at the field level, rather than to the project as a whole. Performance standards are specified below according to the type of project activity being implemented. All projects must pass the performance standard test for reducing nitrogen application rate (Section 3.5.1.1) in order to be eligible. All projects that pass the performance standard test for reducing nitrogen rate and adopt the use of nitrification inhibitors or a switch to slow release fertilizers, are deemed to automatically pass the performance standard test for the use of the enhanced efficiency fertilizer (see Section 3.5.1.2).

The performance standard research and rationale for the specific performance standards outlined below are summarized in Appendix B.

3.5.1.1 Performance Standard for Reducing Nitrogen Application Rate

The performance standard for this project activity is a nitrogen use efficiency (NUE) metric, based on how productive the cropping system is in comparison to its nitrogen input. The NUE is simply calculated in units of crop yield per unit of nitrogen applied, as demonstrated in Equation 3.1 below.[33] Gains in NUE can be realized from N rate reductions to levels that do not go below N demand and affect crop yield, and from yield improvements via the implementation of other fertilizer best management practices.

[33] Dobermann, A (2007). Nutrient use efficiency – measurement and management. International Plant Nutrition Institute (IPNI), USA. Fertilizer Best Management Practices: General Principles, Strategy for their Adoption and Voluntary Initiatives vs Regulations. Papers presented at the IFA International Workshop on Fertilizer Best Management Practices 7-9 March 2007, Brussels, Belgium. International Fertilizer Industry Association (IFA). 1-28. Available at: https://www.fertilizer.org/ItemDetail?iProductCode=8387Pdf&Category=AGRI&WebsiteKey=411e9724-4bda-422f-abfc-8152ed74f306

Equation 3.1. Annual Nitrogen Use Efficiency

$$NUE_{P,f} = \frac{Y_{P,f}}{NR_{P,f}}$$

Where,			Units
$NUE_{P,f}$	=	Nitrogen use efficiency calculated for field *f* during the cultivation year in the current reporting period of the project *P*	
$Y_{P,f}$	=	Annual eligible crop yield for field *f* during the cultivation year in the current reporting period of the project *P*; see Table B.3. Yield Conversion Factors in Appendix B for crop production unit conversion factors	lb/ac
$NR_{P,f}$	=	Total annual[34] N rate (including synthetic and organic forms of N) for field *f* during the cultivation year in the current reporting period of the project *P*, see Equation 3.2	lb/ac

Equation 3.2. Annual Total N Rate for Field in Project

$$NR_{P,f} = NR_{P,S,f} + NR_{P,O,f}$$

Where,			Units
$NR_{P,f}$	=	Total annual N rate (including synthetic and organic forms of N) for field *f* during the cultivation year in the current reporting period of the project *P*	lb/ac
$NR_{P,S,f}$	=	Annual synthetic N rate for field *f*, during the cultivation year in the current reporting period of the project *P*; see Equation 5.12	lb/ac
$NR_{P,O,f}$	=	Annual organic N rate for field *f,* during the cultivation year in the current reporting period of the project *P*; see Equation 5.24	lb/ac

Annual yield ($Y_{P,f}$) is defined as the average yield (gross weight (pounds) of crop removed from field, *f*, per acre) for each eligible crop grown per field, *f*, in the project, *P*, during the current reporting period. Total annual N rate ($NR_{P,f}$) is defined as the total nitrogen rate (synthetic N fertilizer rate ($NR_{P,S}$) plus organic N fertilizer rate ($NR_{P,O}$), pounds N per acre), applied to each field, *f*, throughout the cultivation year (~12 months) in the current reporting period of the project, *P*. This includes any synthetic and organic N applied to the primary crop and subsequent cover crop in the current cultivation year, and via any application method, including N applied through irrigation (i.e., fertigation).

A field, *f*, passes the performance standard test when its reporting period (i.e., annual) NUE, calculated for each eligible crop cultivation year of the project, *P*, meets or exceeds the applicable county- and crop-specific NUE benchmarks ($NUE_{avg,Co,c}$) found in the Nitrogen Management Protocol Eligibility Lookup Tool, as exemplified in Equation 3.3 below. The county- and crop-specific NUE benchmarks represent the estimated three-year, crop-specific county average NUE based on data from the International Plant Nutrition Institute (IPNI) Nutrient Use Geographic Information System (NuGIS) and USDA National Agricultural Statistics Service (NASS).[35] Three-year average county and crop-specific yields and N rate estimates can also be found in the Nitrogen Management Protocol Eligibility Lookup Tool. The county- and crop-

[34] In this context, "annual" is used to mean "one cultivation year," as defined by the protocol.

[35] The Reserve calls this the "estimated" three-year, crop-specific county average NUE because this value is calculated based on annual county average farm fertilizer N inputs per cropland acre from IPNI NuGIS, and on crop-specific state average N rate applications and crop-specific county average yields from USDA NASS for the years 2010-2012. Data for calculating the true mean NUE of each crop and county are not currently available.

specific average NUE benchmarks, N rates, and yields will be updated following the publication of new data by IPNI and NASS. Project developers should use the most up to date tool and data available at the time of submitting or verifying each project or field. More information on the development of the NUE benchmarks can be found in Appendix B.

Equation 3.3. Passing Performance Standard Test for Reducing Synthetic N Rates

$$NUE_{P,f} \geq NUE_{avg,Co,c}$$

Where, Units

$NUE_{P,f}$ = Nitrogen use efficiency calculated for field *f* during the cultivation year in the current reporting period of the project *P*

$NUE_{avg,Co,c}$ = Multi-year average nitrogen use efficiency for crop, *c*, in county, *Co*; found in Nitrogen Management Protocol Eligibility Lookup Tool (see Appendix B for more information)

Each eligible field within a project must pass the performance standard test each reporting period (i.e., each cultivation year) in order to be awarded CRTs for that reporting period. Note, for projects with an initial reporting period spanning two cultivation years, the NUE ($NUE_{P,f}$), annual yield ($Y_{P,f}$), and total annual N rate ($NR_{P,f}$) must be calculated separately for each cultivation year within the reporting period. However, if a field does not pass the performance standard in an eligible crop year, it does not forfeit eligibility for the remainder of the crediting period, so long as the field maintains continuous reporting to the Reserve and is able to pass the performance standard in the subsequent reporting period for the same eligible crop.

Likewise, a field growing both eligible and ineligible crops (in successive cultivation years) does not need to pass the performance standard test during the ineligible crop years to maintain eligibility, but continuous reporting to the Reserve is required. If the N application rates (synthetic and/or organic) while growing ineligible crops increases relative to their average baseline N rates, rather than forfeiting eligibility for the subsequent eligible cultivation year, the associated increases in N must be included in the subsequent eligible cultivation year's project N rates (see Section 5.1.3.1 and Section 5.1.4.4.1). The same mechanisms are used during the cultivation year of an eligible crop in which CRTs are not being sought. These restrictions are intended to ensure excessive N is not applied in intervening years, with the intent to have residual N then affect the subsequent eligible cultivation year[36]. Verifiers shall review ineligible crop year reporting data as part of their eligibility assessment for the next eligible crop year. See Section 6.3 for reporting requirements.

Lastly, while synthetic N rate must be reduced from the baseline to the project to be eligible for CRTs, organic N rate is allowed to increase from the baseline to the project, so long as *total N rate* decreases. Projects must demonstrate that the total N rate applied to the given field in the project is less than the total N rate applied to field over the baseline look-back period, as calculated in Equation 3.4 and Equation 3.5 below. The baseline look-back period and additional guidance on baseline setting are detailed in Section 5.1.2. Section 5.1.2.1 sets out flexible alternative means to set average baseline N rates in the absence of historical records.

[36] This prevents the project from increasing the ineligible crop's N use to intentionally build residual N on the field, which would result in N reductions in subsequent eligible years that may be larger than would have otherwise been possible without risk of yield loss.

Equation 3.4. Average Total N Rate for Field over Baseline Look-Back Period

$$NR_{B,f,avg} = NR_{B,S,f,avg} + NR_{B,O,f,avg}$$

Where,			Units
$NR_{B,f,avg}$	=	Total average N rate (including synthetic and organic forms of N) over the baseline look-back period for field *f*	lb/ac
$NR_{B,S,f,avg}$	=	Baseline average N rate of total synthetic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.4	lb/ac
$NR_{B,O,f,avg}$	=	Baseline average N rate of total organic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.8	lb/ac

Equation 3.5. Demonstrating Total N Rate Reduced from the Baseline to the Project

$$NR_{P,f} < NR_{B,f,avg}$$

Where,			Units
$NR_{P,f}$	=	Total annual N rate (including synthetic and organic forms of N) for field *f* during the cultivation year in the current reporting period of the project *P*, see Equation 3.2	lb/ac
$NR_{B,f,avg}$	=	Total average N rate (including synthetic and organic forms of N) over the baseline look-back period for field *f*, see Equation 3.4	lb/ac

3.5.1.1.1 Grace Period

At the beginning of a project's first crediting period, each field shall be given a grace period for the first two eligible cultivation years to meet or exceed the applicable NUE performance benchmark in the Nitrogen Management Protocol Eligibility Lookup Tool. During the grace period, a modified performance standard shall be applied in which the field passes the performance standard so long as the eligible crop field's NUE increases each reporting period. Implementation of the approved project activity shall be fully creditable during this grace period. However, CRT issuance will be delayed for all CRTs generated by a field during its grace period, until such time as the field's NUE meets or exceeds the NUE benchmark established in the Nitrogen Management Protocol Eligibility Lookup Tool. If a field passes the NUE threshold and completes verification in its third eligible cultivation year (e.g., for corn, the third time CRTs are sought for growing corn on that field, after the field's start date), then CRTs shall be issued for any credits for the grace period. If the field does not pass the NUE in its third eligible cultivation year, CRTs generated during the grace period will be forfeited.

3.5.1.2 Performance Standard for the Use of Enhanced Efficiency Fertilizers (EEFs)

The Reserve has determined that the use of a nitrification inhibitor or slow release fertilizer is not common practice (see Appendix B for a complete breakdown of the Reserve's evaluation), and the implementation of either activity is considered additional when applied in combination with N rate reductions.[37] All growers applying an eligible EEF pass the performance standard test for the use of a nitrification inhibitor or switch to slow release fertilizer, so long as they pass the performance standard test for N rate reductions and demonstrate an N rate reduction in the project. If nitrification inhibitors or slow release fertilizers have been utilized in a given field's baseline look-back period, project developers must select "None" from the appropriate

[37] Best management practices may be used individually by farmers, but their simultaneous adoption on all crop acres is rare. See Wade et al., 2015.

NMQuanTool drop down menu (Section 5.1.1), whereby EEF benefits for the project will be negated, but the field can still generate emission reductions associated with N rate reductions.

3.5.2 The Legal Requirement Test

All fields enrolled in a project are subject to a legal requirement test to ensure that the GHG reductions achieved by approved project activities on those fields would not otherwise have occurred due to federal, state or local regulations, or other legally binding mandates. A field passes the legal requirement test when there are no laws, statutes, regulations, court orders, environmental mitigation agreements, permitting conditions, binding contractual obligations,[38] or other legally binding mandates (including, but not limited to, legally mandated nutrient management plans,[39] conservation management plans, and deed restrictions) that require adoption or continued use of approved nitrogen management project activities on the field. Additionally, if any law, regulation, or legally binding mandate requiring the implementation of project activities at the field(s) in which the project is located exists, only emission reductions resulting from the project activities that are in excess of what is required to comply with those laws, regulations, and/or legally binding mandates are eligible for crediting under this protocol. The legal requirement test is applied to each field, so if project activities on one field in a project become legally required, it shall not affect the other fields in the project.

The Reserve has determined that unless a regulatory program imposes a quantitative restriction on N rate applications or requires the explicit use of a nitrification inhibitor or switch to slow release fertilizer, then implementing project activities will remain additional. Even where quantitative N rate application limits are imposed, emission reductions resulting from the implementation of project activities that are in excess of what is required to comply with those laws, regulations, and/or legally binding mandates are eligible for crediting under this protocol.

To satisfy the legal requirement test, Project Owners must sign an Attestation of Voluntary Implementation form on behalf of the project.[40] Attestations of Voluntary Implementation must be signed and submitted to the Reserve prior to the commencement of verification activities each time the project is verified (see Section 8). Individuals who are part of a project but are not the Project Owner will not be required to attest to the voluntary nature of project activities to the Reserve. However, supporting documentation should be made available to the verification body during verification, if requested. In addition, the Project Monitoring Plan (Section 6.1) must include procedures that the project developer will follow to ascertain and demonstrate that the project field at all times passes the legal requirement test.

As of the effective date of this protocol, the Reserve could identify no existing federal regulations that explicitly obligate agricultural producers to adopt the nitrogen management practices approved under this protocol. The Reserve did however identify an existing state regulation that explicitly obligates agricultural producers to adopt one of the nitrogen management practices approved under this protocol: the California Central Valley Regional Water Quality Board's Reissued Waste Discharge Requirements General Order for Existing Milk

[38] Contracts with NRCS that must be signed by a grower in order to receive Environmental Quality Incentives Program (EQIP) funds are not considered "legally binding mandates" for the purposes of this legal requirement test, if the only repercussion of violating the contract is not receiving the aforementioned financial incentive (e.g., there is no fine, Notice of Violation, or other legal penalty levied).

[39] If Nutrient Management Plans are legally required, but do not require N rate reductions or specify N rate targets that would require reductions, or do not require the use of a nitrification inhibitor or switch to slow release fertilizer, the field passes the legal requirement test because the project activities are not specifically required. Verification bodies shall evaluate such plans and use their professional judgment to make a determination.

[40] Form available at http://www.climateactionreserve.org/how/program/documents/.

Cow Dairies (Dairy General Order). Due to crop-specific restrictions on nitrogen rate, the Dairy General Order poses a concern regarding the regulatory additionality of offsets generated under the Nitrogen Management Protocol for fields subject to this Order. Any field subject to the Order will only be eligible for emission reductions associated with reductions in N rates beyond the legal mandate. It is important to note though, that the Dairy General Order is only applicable to farms applying manure; farms only applying synthetic N fertilizer are not subject to the Order. More information on the Dairy General Order is provided in Appendix C.2.

A summary of research performed on federal and state requirements is provided in Appendix C.

3.5.3 Ecosystem Services Credit and Payment Stacking

When multiple ecosystem services credits or payments are sought for a single activity on a single field, it is referred to as "credit stacking" or "payment stacking," respectively.[41] Under this protocol, credit stacking is defined as receiving more than one mitigation credit for the same activity on spatially overlapping areas (i.e., on the same acre). Mitigation credits are used to offset the environmental impacts of another entity such as emissions of GHGs, removal of wetlands, or discharge of pollutants into waterways, to name a few. Payment stacking is defined as issuing a payment for a best management or conservation practice that is funded by the government or other parties via grants, subsidies, payments, etc. Any type of conservation or ecosystem service credit or payment received for activities on the project area must be disclosed by the project developer to the verification body and the Reserve on an ongoing basis. The Reserve will determine whether it's appropriate for the project to receive CRTs in any given reporting period for which the project has received other mitigation credits or payments. Where nitrogen management project activities result in emission reductions that go beyond what is quantitively required for any stacked mitigation credit or payment, the Reserve may determine it is appropriate for the project to be issued some or all of the CRTs for the given reporting period.

3.5.3.1 Credit Stacking

Based on a review of mitigation credit markets in the U.S., the additionality of carbon credits under this protocol might be affected by Water Quality Trading (WQT) programs that credit agricultural land (nonpoint sources) for reducing nitrogen runoff to water bodies. The programs can credit practices eligible and ineligible under this protocol. As of 2016, sixteen programs were actively transacting, or beginning transactions of water quality offset credits[42]. Some examples of these markets are:

- Pennvest Nutrient Credit Trading Program (Susquehanna and Potomac watersheds in Pennsylvania)
- Pennsylvania's Chesapeake Bay Watershed Nutrient Credit Trading Program
- Virginia's Chesapeake Bay Watershed Nutrient Credit Exchange Program
- National Pollutant Discharge Elimination System (NPDES) Water Quality Trading (Oregon)
- North Carolina Nutrient Mitigation Program
- Nutrient Offset Program in Santa Rosa, California
- Ohio River Basin Trading Project (Indiana, Kentucky, and Ohio)

Stacking water quality credits with CRTs for practices eligible under this protocol is allowed if any of the following conditions are met:

[41] Cooley, D., & Olander, L., September 2011.
[42] Ecosystem Marketplace. (2016). Alliances for Green Infrastructure: State of Watershed Investment 2016. Washington, D.C: Forest Trends. Available at http://forest-trends.org/releases/p/sowi2016

- The WQT offset agreement is signed after the project field's start date or submittal to the Reserve, whichever is earlier
- The WQT offset program credits practices[43] additional to any practices credited by a nitrogen management offset project
- The Water Quality Credit is measured by a defined unit of reduction such as pounds of nitrogen instead of ecosystem-wide measurement such as acres managed[44]

Lands contracting WQT credits (before or after project field's start date) from the application of practices ineligible for CRTs under this protocol are eligible since they are not considered "stacked." Fields that have received WQT credits in the past, but have not received credits in the year before the field's start date, are also eligible. Fields seeking to stack credits must also meet all other eligibility requirements in this protocol, including the start date requirement in Section 3.2. Upon project commencement, new WQT agreements must be disclosed to the verifier and the Reserve on an ongoing basis. The Reserve maintains the right to determine if credit stacking has occurred and whether it would impact project eligibility, or the issuance of CRTs in any given reporting period.

3.5.3.2 Payment Stacking

The Reserve has identified two USDA Natural Resource Conservation Service (NRCS) programs that provide payments nationwide to support the implementation of agricultural best management practices (BMPs). Authorized by the 2014 Farm Bill, the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) are implemented at the state and county level. Through EQIP, NRCS provides agricultural farmers with payments for implementing Conservation Practice Standards (CPS).[45] Through the Conservation Stewardship Program (CSP), NRCS pays farmers for implementing conservation enhancements above minimum Conservation Practice Standards criteria. NRCS expressly allows the sale of environmental credits from enrolled lands but does not provide any additional guidance on ensuring the environmental benefit of any payment for ecosystem services stacked with an NRCS payment.

The Reserve has identified the following four NRCS standards as being relevant to NM projects:

- Conservation Practice Standard for *Nutrient Management* (CPS 590)[45]
- Conservation Enhancement Activity E590130Z for *improving nutrient uptake efficiency and reducing risk to air quality*
- Conservation Enhancement Activity E590119Z for *improving nutrient uptake efficiency and reducing risk of nutrient losses to groundwater*
- Conservation Enhancement Activity E590118Z for *improving nutrient uptake efficiency and reducing risk of nutrient losses to surface water*

The four standards listed above encompass practices credited under this protocol. The use of NRCS payments to help support reductions in N_2O emissions under this protocol is allowed if

[43] Considering total soil nitrogen reductions from both reducing fertilizer application and applying slow release fertilizers.
[44] According to Gardner and Fox, 2014, crediting different ecosystem services in defined units avoids double crediting the same ecosystem benefit.
[45] Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture (USDA) (2012). "Conservation Practice Standard: Nutrient Management – Code 590". *National Handbook of Conservation Practices (NHCP),* January 2012. Available online at https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/cp/ncps/. Accessed May 2018.

the agreement with NRCS to implement CPS 590, E590130Z, E590119Z or E590118Z was signed after the project field's start date or after the field's submittal to the Reserve, whichever is earlier. Fields seeking to stack payments must also meet all other eligibility requirements in this protocol, including the start date requirement in Section 3.2.

Note that if a field is under an agreement with NRCS to receive payments for activities that do not include reductions in fertilizer application, use of nitrification inhibitors or switch to slow release fertilizers, those payments do not affect field eligibility since the payments were awarded for different activities than those credited by this protocol and are therefore not considered "stacked." The same criteria applies for any other NRCS payments under any other CPS or enhancement that does not include the practices credited under this protocol. Fields that have received CPS 590, E590130Z, E590119Z or E590118Z payments for eligible activities in the past (e.g., before the field's start date) but have not received payments for at least one year are also eligible. To be conservative, fields stacking NRCS CPS 590, E590130Z, E590119Z or E590118Z payments are only eligible to receive CRTs for the portion of the project not funded by public dollars. For example, EQIP payment rates are estimated to provide 50 percent, 75 percent or 90 percent of the cost of practice implementation, with higher percentages awarded if the farmer qualifies as "historically underserved" or as a "limited resource farmer." If a farmer receives an EQIP payment for CPS 590 at the 50 percent level, the number of CRTs issued is to be reduced by 50 percent.

A "yes" response to the question "Is the project stacking?" in Table 3.1 below denotes that the project is only eligible to receive CRTs for the portion of the project not funded by public dollars, as discussed in the paragraph immediately above.

Table 3.1. Payment Stacking Scenarios

Scenario	Is the Project Eligible?	Is the Project Stacking?
1. Field under CPS 590, E590130Z, E590119Z or E590118Z agreement that includes a reduction in fertilizer application, application of nitrification inhibitors or application of slow release fertilizers and agreement was signed *before* the project field's start date or submittal to the Reserve (whichever is earlier).	No	n/a
2. Field under CPS 590 E590130Z, E590119Z or E590118Z agreement for activities that do not include reductions in fertilizer application, application of nitrification inhibitors or application of slow release fertilizers.	Yes	No
3. Field under NRCS agreement for any other CPS or enhancement	Yes	No
4. Field under CPS 590, E590130Z, E590119Z or E590118Z agreement that includes a reduction in fertilizer application, application of nitrification inhibitors or application of slow release fertilizers and agreement was signed *after* the project field's start date or submittal to the Reserve (whichever is earlier).	Yes	Yes[46]
5. Field that ended a contract under CPS 590, E590130Z, E590119Z or E590118Z agreement that includes a reduction in fertilizer application, application of nitrification inhibitors or application of slow release fertilizers during the year before the project field's start date.	No	n/a
6. Field that contracted under CPS 590, E590130Z, E590119Z or E590118Z agreement that includes a reduction in fertilizer application, application of nitrification inhibitors or application of slow release fertilizers in the past but has not received payment for more than one year before the project start date.	Yes	No

3.6 Regulatory Compliance

As a final eligibility requirement, Project Owners must attest that activities on project fields (including, but not limited to, project activities) do not cause material violations of applicable laws (e.g., air, water quality, water discharge,[47] safety, labor, endangered species protection, etc.). To satisfy this requirement, Project Owners must submit a signed Attestation of Regulatory Compliance form prior to verification activities commencing each time a project is verified.[48] Project developers are also required to disclose in writing to the verifier any and all instances of legal violations – material or otherwise – caused by activities on project fields.

If a verifier finds that activities on any given project field(s) have caused a material violation, then CRTs will not be issued for GHG reductions that occurred on that given field during the period(s) when the violation occurred. Individual violations due to administrative or reporting issues, or due to "acts of nature," are not considered material and will not affect CRT crediting. However, recurrent administrative violations directly related to activities on project fields may affect crediting. Verifiers must determine if recurrent violations rise to the level of materiality. If

[46] Project may only credit fertilizer application reductions, nitrification inhibitor reductions or application of slow release fertilizers for the portion not funded by public dollars.
[47] See Appendix C for an overview of water quality rules and regulations that may impact a farm's legal requirements or regulatory compliance.
[48] Attestation of Regulatory Compliance form available at http://www.climateactionreserve.org/how/program/documents/.

the verifier is unable to assess the materiality of the violation, then the verifier shall consult with the Reserve.

Additional information on legal requirements potentially relevant to the regulatory compliance of project activities is included in Appendix C.

4 The GHG Assessment Boundary

The GHG Assessment Boundary delineates the GHG sources, sinks, and reservoirs (SSRs) that must be assessed by project developers in order to determine the net change in emissions caused by a nitrogen management project.[49]

The GHG Assessment Boundary encompasses all the GHG SSRs that may be significantly affected by project activities, including sources of N_2O and CH_4 emissions from the soil, biological CO_2 emissions and soil carbon sinks, and GHG emissions from fossil fuel consumption. For accounting purposes, the SSRs included in the GHG Assessment Boundary are organized according to whether they are predominantly associated with a nitrogen management project's "primary effect" (i.e., the project's intended N_2O reduction), or its "secondary effects" (i.e., unintended changes in carbon stocks, CH_4 emissions, or other GHG emissions).[50] Primary effect emissions include direct and indirect N_2O emissions, the latter coined "LVRO" in this protocol.[51] Secondary effects may include increases in CO_2 emissions associated with fossil fuel consumption from site preparation, as well as increased GHG emissions caused by the shifting of cultivation activities from the project area to other agricultural lands (often referred to as "leakage").[52] Projects are required to account for all SSRs that are included in the GHG Assessment Boundary regardless of whether the particular SSR is designated as a primary or secondary effect.

Figure 4.1 below provides a general illustration of the GHG Assessment Boundary, indicating which SSRs are included or excluded from the project boundary.

Table 4.1 provides a comprehensive list of the GHG SSRs that may be affected by a nitrogen management project and indicates which SSRs must be included in the GHG Assessment Boundary.

[49] The definition and assessment of sources, sinks, and reservoirs is consistent with ISO 14064-2 guidance.
[50] The terms "primary effect" and "secondary effects" come from World Business Council on Sustainable Development / World Resources Institute. (2005). The Greenhouse Gas Protocol for Project Accounting, *World Resources Institute*, Washington, DC. Available at http://www.ghgprotocol.org.
[51] To avoid confusion with secondary effects, this protocol refers to emissions from leaching, volatilization, and runoff as emissions from "LVRO," instead of "indirect N_2O emissions."
[52] Note that leakage emissions are now accounted for as part of PE emissions.

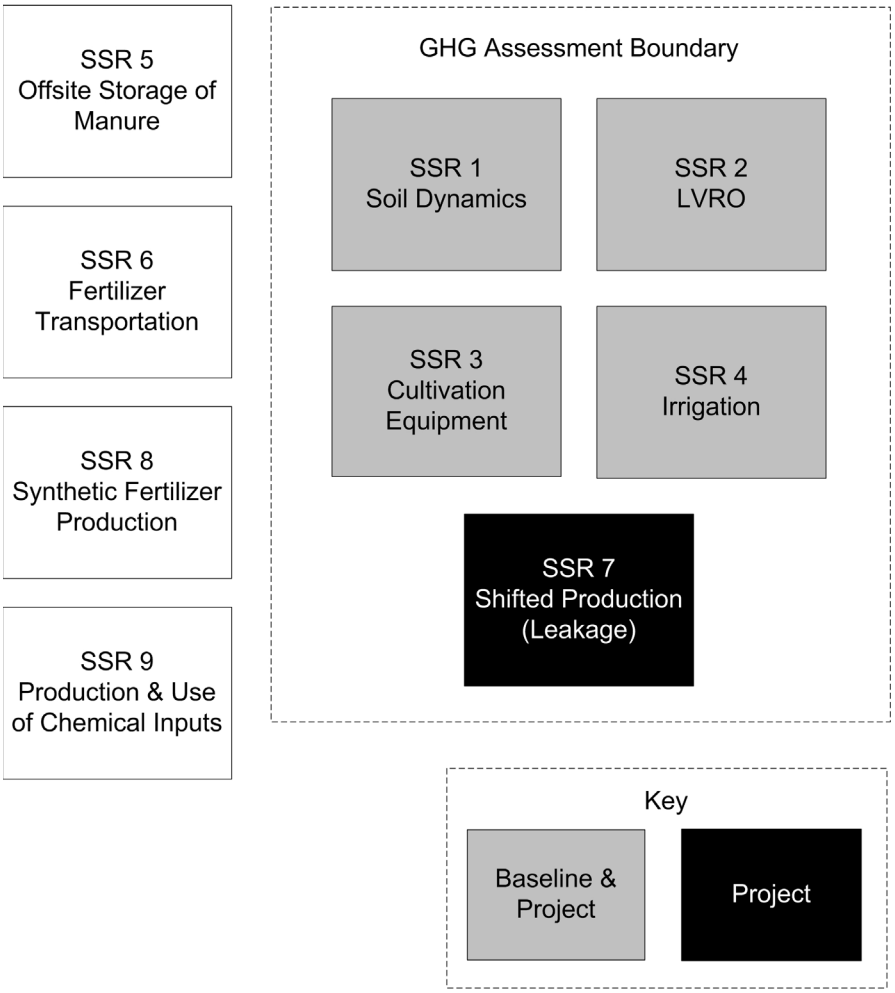

Figure 4.1. General Illustration of the GHG Assessment Boundary

Table 4.1. Description of all Sources, Sinks, and Reservoirs

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Justification/Explanation
Primary Effect Sources, Sinks, and Reservoirs					
1. Soil Dynamics	Soil interactions produce emissions of nitrous oxide, carbon dioxide (biogenic), and possibly methane.	CO_2	E	N/A	Soil carbon is expected to increase slightly or remain stable, therefore excluding it is conservative.
		CH_4	E	N/A	Methane production and oxidation is insignificant for non-flooded soils.
		N_2O	I	Emissions impacts of changes in: ▪ synthetic fertilizers are calculated using the NMQuanTool, (see Section 5.1). ▪ organic fertilizers are calculated using MSU-EPRI Tier II or IPCC Tier I default emission factors (see Section 5.1.4).	The primary effect of a nitrogen management project is a reduction in N_2O emissions from soil.[53]
2. LVRO	Leaching, volatilization, and runoff (LVRO) of applied nitrogen, followed by denitrification into N_2O.	N_2O	I	Indirect emissions impacts from changes in: ▪ synthetic fertilizers are calculated using the NMQuanTool (see Section 5.1) ▪ organic N rate are calculated using protocol equations (see Section 5.1.4.3).	A primary effect of nitrogen management projects, this may be a significant portion of overall N_2O emission reductions.
Secondary Effect Sources, Sinks, and Reservoirs					
3. Cultivation Equipment	Fossil fuel emissions from project equipment.	CO_2	I	Method in Section 5.2	Increased emissions associated with changes in use of cultivation equipment may be significant and must be accounted for.
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.
		N_2O	E	N/A	Excluded, as this emission source is assumed to be very small.
4. Irrigation	Irrigation impacts soil N_2O emissions, and changes in irrigation may increase	CO_2	I	Method in Section 5.2	Changes in irrigation caused by the project may increase associated fossil fuel usage.
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.

[53] These N_2O emissions are referred to as "direct N_2O emissions from soils" by the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

SSR	Source Description	Gas	Included (I) or Excluded (E)	Quantification Method	Justification/Explanation
	associated fossil fuel usage.	N_2O	I	Irrigation status recorded in NMQuanTool (see Section 5.1).	Irrigation may significantly impact soil dynamics.
5. Offsite Storage of Manure	Indirect emissions from changes in storage of manure source.	CO_2	E	N/A	Supply of manure is relatively inelastic, and end-of-life fate is likely to remain land application, therefore this source is excluded.
		CH_4	E	N/A	
		N_2O	E	N/A	
6. Fertilizer Transportation	Changes in fertilizers used may change associated transport emissions.	CO_2	E	N/A	Excluded, as this emission source is assumed to be very small.
		CH_4	E	N/A	Excluded, as this emission source is assumed to be very small.
		N_2O	E	N/A	Excluded, as this emission source is assumed to be very small.
7. Shifted Production (Leakage)	Decreased project yields may result in increased cultivation outside the project area.	CO_2	E	Method in Section 5.2	Any significant decreases in yield must be accounted for, as production is assumed to shift outside of project area.
		CH_4	E		
		N_2O	I		
8. Synthetic Fertilizer Production	Decreases in synthetic fertilizer use may affect a decrease in fertilizer production.	CO_2	E	N/A	It is conservative to exclude this category as emissions from this SSR will decrease.
		N_2O	E	N/A	
		CH_4	E	N/A	
9. Production and Use of Chemical Inputs	Changes in nutrient management practices may impact how much lime or herbicides are used on fields.	CO_2	E	N/A	Excluded, as approved project activities are unlikely to materially increase the use of lime or herbicide on fields.
		CH_4	E		
		N_2O	E		

5 Quantifying GHG Emission Reductions

GHG emission reductions from a nitrogen management project are quantified by using both the equations in this section, as well as the NMQuanTool. Emission reductions are quantified (using Equation 5.1 below) by calculating the emission reductions (in metric tons of carbon dioxide equivalents (tCO_2e)) associated with the implementation of eligible nitrogen management project activities (Equation 5.3), and then subtracting any increases in emissions associated with both increases in organic N rates (e.g., manure N) (see Section 5.1.4) and/or secondary emissions (see Section 5.2). Project developers will need to use Equation 5.2 and the guidance in Section 5.1 to calculate the percentage reduction in synthetic N rate for each field in the project reporting period, and select the percentage reduction to the nearest percentage reduction value available in the NMQuanTool. More information on how to use the NMQuanTool to calculate emission reductions from implementing eligible project activities can be found in the tool and in Section 5.1.1. Background information on the modeling effort to produce NMQuanTool can be found in Appendix F. Baseline and project synthetic N rates are calculated in Section 5.1.2 and Section 5.1.3, respectively. Crop production shifting (leakage) and its impact on project synthetic N rate are assessed in Section 5.1.3.2.

Primary effect emissions associated with increases in organic N rates are calculated in Section 5.1.4.4. Baseline and project organic N rates are calculated in Section 5.1.2 and Section 5.1.4, respectively. Finally, increases in secondary effect emissions associated with increases in cultivation equipment usage are addressed in Section 5.2.

An overview of the quantification process can be seen in Figure 5.1.

As of this writing, the Reserve relies on values for global warming potential (GWP) of non-CO_2 GHGs published in the IPCC Fourth Assessment Report: Climate Change 2007 (AR4).[54] The value relevant for this protocol is provided in Table 5.1 below, and is to be used for all nitrogen management projects unless and until the Reserve issues written guidance to the contrary.

Table 5.1. 100-year Global Warming Potential for Non-CO_2 GHGs

Non-CO_2 GHG	100-Year GWP (CO_2e)
Nitrous Oxide (N_2O)	298

The timeline over which emission reductions are quantified is specified in Section 3.3 and Section 7.4. The quantification of emission reductions is carried out separately for each individual field within a project. Similarly, the quantification of emission reductions is carried out separately for each individual project within the cooperative; the cooperative structure does not change the quantification methodology contained within this section. CRTs are serialized and issued to individual projects, rather than the cooperative.

[54] Available here: https://ipcc.ch/publications_and_data/publications_and_data_reports.shtml

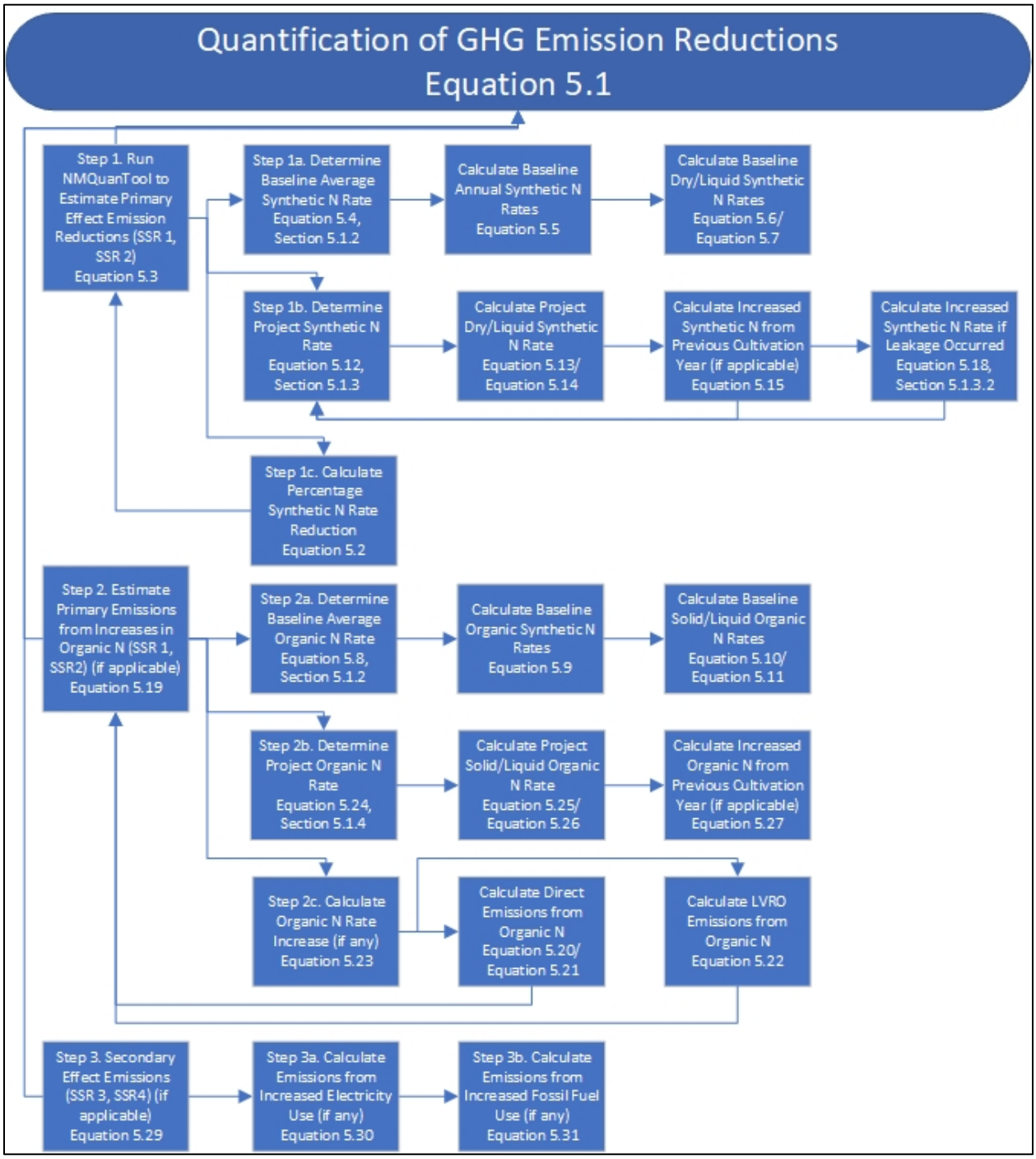

Figure 5.1.Quantification of GHG Emission Reductions Overview

Equation 5.1. GHG Emission Reductions

$$ER = (PER - PE_O) - SE$$

Where,			Units
ER	=	Total emission reductions from the project area for the reporting period*	tCO_2e
PER	=	Total primary effect GHG emission reductions from implementation of eligible project activities over the entire project area, see Equation 5.3 and Section 5.1	tCO_2e
PE_O	=	Total primary effect GHG emissions from organic N rate increases over the entire project area, see Equation 5.19 and Section 5.1.4	tCO_2e
SE	=	Increased emissions from cultivation equipment and irrigation,[55] see Equation 5.29 and Section 5.2	tCO_2e

** It is important to note that the reporting period (other than the initial) for this protocol is one cultivation year (~12 months). As such, the protocol refers frequently to annual N rates, which should be thought of as the N rate over one complete cultivation year.*

5.1 Primary Effect N_2O Emission Reductions

Primary effect emission reductions are the intended reductions in N_2O emissions from the primary SSRs (SSR1, SSR2) within the GHG Assessment Boundary stemming from project activities. They are determined by following the steps in this section.

5.1.1 N_2O Emission Reductions from Eligible Project Activities (NMQuanTool)

Emission reductions resulting from the implementation of eligible project activities are calculated using the Nitrogen Management Quantification Tool (NMQuanTool). Prior to using the NMQuanTool, project developers must first check the Nitrogen Management Protocol Eligibility Lookup Tool to confirm their fields' activity-crop-count combinations are eligible. The NMQuanTool calculates the changes in both direct and indirect N_2O emissions from the baseline to the project, associated with percentage reductions in synthetic N rates in fixed increments, and optionally also the use of a nitrification inhibitor or the switch to a slow release fertilizer. Project developers must calculate percentage reductions in synthetic N rates from the baseline per project field, per eligible cultivation year, pursuant to Equation 5.2 and the guidance set out in Section 5.1.2 and Section 5.1.3 for determining baseline average and project annual synthetic N rates, respectively. Project developers must then round down the reduction in synthetic N rate to the nearest applicable value and select that percentage reduction as the Nitrogen Fertilizer Reduction (%) in the NMQuanTool. The use of a nitrification inhibitor or slow release fertilizer, region, crop, irrigation and tillage practice are also all selected from drop-down menus in the NMQuanTool. If EEFs were used during a field's baseline and will be used in the project, project developers must select "None" from the appropriate dropdown menu to negate N_2O emission reduction benefits from project EEF use. Complete guidance on the data required and how to run the NMQuanTool can be found in Sheet 1 of the NMQuanTool (see Table 6.1 for a summary of NMQuanTool inputs). A copy of the latest version of the NMQuanTool (along with associated instructions) can be made available upon request to the Reserve.[56] The NMQuanTool calculates the primary effect emission reductions per field and provides a sum total of emission reductions for the project up to a limited number of fields, as exemplified in Equation 5.3 below.

[55] Throughout Section 5, equations will distinguish between calculations which must be performed at the field versus project level. When guidance is provided for a project, but not a field, the guidance should be assumed to apply to both.

[56] See: http://www.climateactionreserve.org/how/protocols/nitrogen-management/.

Equation 5.2. Percentage Reduction in Synthetic N Rate from Baseline to Project

$$NR_{\Delta P,S,f} = \frac{(NR_{B,S,f,avg} - NR_{P,S,f})}{NR_{B,S,f,avg}} \times 100$$

Where,			Units
$NR_{\Delta P,S,f}$	=	Percentage synthetic N rate reduction from baseline to project on field *f**	
Δ	=	Change from baseline to project	
$NR_{B,S,f,avg}$	=	Average baseline N rate of total synthetic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.4	lb/ac
$NR_{P,S,f}$	=	N rate of total synthetic fertilizer for field *f* in project *P*, see Equation 5.12	lb/ac

** The percent reduction in N rate should be rounded down to the nearest increment allowed for in the most current version of the NMQuanTool.*

Equation 5.3. Sum of Primary Effect Emission Reductions for all fields in Project

$$PER = \sum_{f} PER_f$$

Where,			Units
PER	=	Total primary effect GHG emission reductions from implementation of eligible project activities over the entire project area, see Section 5.1 and NMQuanTool	tCO_2e
PER_f	=	Total primary effect GHG emission reductions from implementation of eligible project activities per field, *f*, see Section 5.1 and NMQuanTool	tCO_2e

5.1.2 Baseline N Rates

The baseline scenario is the continuation of the historical cultivation and N management practices where, in the absence of the nitrogen management project, N fertilizer is applied in a "business as usual" manner. As stipulated in Section 2.2.3, N fertilizer application during the baseline and project crediting period must be compared using the same crop(s) grown on the same field.

This protocol utilizes a baseline look-back period to set baseline average N rates for comparison against annual N rates applied each cultivation year in the project. The baseline look-back period is defined as the three most recent cultivation years of the given crop on the given field, prior to the field's project start date. Depending on the historical cultivation at the project field, the baseline look-back period could, for example, consist of the previous three years (monoculture), six years (three cultivation years of a two-crop rotation), or nine years (three cultivation years of a three-crop rotation) prior to the field's start date. The baseline average N rate (either synthetic and/or organic) is defined as the average amount of N applied to the eligible crop in the project field over the baseline look-back period.

Once an appropriate baseline look-back period is identified, the baseline average synthetic N rate ($NR_{B,S,f,avg}$) and baseline average organic N rate ($NR_{B,O,f,avg}$) (if applicable) must be calculated using Equation 5.4 and Equation 5.8, respectively. There are multiple approaches for determining baseline average N rates, as set out in Section 5.1.2.1. Depending on the approach followed, Equation 5.5 and Equation 5.9 must be used to calculate the *annual* synthetic N rates ($NR_{B,S,f,t}$) and *annual* organic N rates ($NR_{B,O,f,t}$,) applied during each eligible crop cultivation year within the baseline look-back period, as necessary to determine the baseline average N rates.

Any N applied to cover crops historically during the baseline look-back period should not be included.

Fertilizer N rates used in the equations throughout this protocol are in units of pounds per acre (lb/ac). Equation 5.6 and Equation 5.7 are used to determine each field's respective baseline synthetic N rate in terms of pounds of nitrogen applied per acre for each type of synthetic fertilizer (i.e., dry and/or liquid), and Equation 5.10 and Equation 5.11 are used to determine each field's respective baseline organic N rate in terms of pounds of nitrogen applied per acre for each type of organic fertilizer (i.e., solid and/or liquid), using information more readily available to the project (such as fertilizer mass and volume and field size). In general, the amount of N-containing fertilizer is multiplied by the N concentration (NC_j) of the fertilizer. Default information on N concentrations and weights of various N-containing fertilizers is provided in Appendix E, though farm management records, commercial fertilizer labels, and/or laboratory tests on the N content of organic sources are preferable, when available, as discussed in Section 5.1.2.1.1.

5.1.2.1 Hierarchical Approaches for Determining Baseline N Rates

The determination of the baseline average N rate for synthetic and organic N is carried out using one of the following three hierarchical approaches:

1. Historical N management records for that crop and field
2. Historical records of N rate recommendations from independent third-party agronomic experts for that crop and field for the years in the baseline look-back period
3. Estimated historical county average N using the Nitrogen Management Protocol Eligibility Lookup Tool

Note for Approach 1, historical eligible crop yield records must also be provided to demonstrate previous crop cultivation and authenticate the corresponding N rates.

5.1.2.1.1 Historical N Management Records (Approach 1)

Due to its finer spatial resolution (site specificity) and closest depiction of the historical cultivation and N management practices at the field, project developers *must* use Approach 1 if grower-specific historical application records or data to support historical application are available. Three years' worth of data from the baseline look-back period is required to set an average synthetic and an average organic N rate (Equation 5.4, Equation 5.8). Records that may satisfy a verifier as to historical N management may include fertilizer application records, precision agriculture technology records, invoices or receipts for fertilizer purchases, fertilizer inventories, as-applied maps, and/or grower spreadsheets or other recording systems. This list is not exhaustive and is meant to provide a few examples of evidence that may satisfy a verifier. Written records of some or all of the above will be necessary. Project developers are encouraged to seek guidance from the Reserve to ensure the records they intend to provide are sufficient. If insufficient data exists for Approach 1, then project developers may use either Approach 2 or Approach 3. In all cases written records will be necessary.

5.1.2.1.2 Historical Agronomic Expert Recommendations (Approach 2)

If a project developer or grower had historically solicited an independent third-party agronomic expert[57] for N application recommendations for the specific crop and field in question, in line with the years in the give crop and field's baseline look-back period (See Section 5.1.2), these

[57] For the purposes of this protocol, an agronomic expert is considered any individual with specialized knowledge, skill, education, experience, or training in crop and/or soil science; no official certification is implied or required.

recommendations may be provided to set the baseline N rate, from which N rate reductions must be made in the project. Such guidance must be in writing. Agronomic rate recommendations must be based on field specific soil conditions (such as utilizing soil samples), climate, and crop needs. If multiple N rates are recommended, the baseline N rate must be based on the lowest recommended application rate for the specific field and crop. At least one years' worth of data from the baseline look-back period is required, though three years' worth is preferable to set an average synthetic and an average organic N rate (Equation 5.4, Equation 5.8). Additionally, if the agronomic guidance did or does not specify organic N rate application recommendations apart from synthetic or total N rate application records, then the baseline organic N rate is given a value of zero by default. As such, any organic N rate applied in the project will be accounted for as an increase in organic N rate, as calculated in Equation 5.23 and Equation 5.24, and addressed in Section 5.1.4.

Project developers pursuing Approach 2 should seek guidance from the Reserve to ensure the guidance and records they intend to use are sufficient.

5.1.2.1.3 County Average Benchmarks (Approach 3)

If historical application records (Approach 1) or agronomic guidance (Approach 2) are unavailable or insufficient for the given field and crop, the three-year average county- and crop-specific N rate estimates ($NR_{avg,Co,c}$), retrievable from the Nitrogen Management Protocol Eligibility Lookup Tool, may be used as the baseline average synthetic N rate ($NR_{B,S,f,avg}$) from which synthetic N rate reductions must be made in the project. Approach 3 is not applicable for the determination of baseline organic N fertilizer rate; thus, the baseline organic N input ($NR_{B,O,f,avg}$) is given a value of zero by default for any projects using this approach. As such, like with Approach 2, any organic N rate applied in the project will be accounted for as an increase in organic N rate, as calculated in Equation 5.23 and Equation 5.24, and addressed in Section 5.1.4. If Approach 3 is being followed for a given field, then Equation 5.4 through Equation 5.11 below do not need to be used for calculating average and annual N rates.

5.1.2.2 Baseline Synthetic N Rates

Equation 5.4. Baseline Average Synthetic Fertilizer N Rate on Field

$$\boldsymbol{NR_{B,S,f,avg}} = \frac{\sum_t \boldsymbol{NR_{B,S,f,t}}}{\boldsymbol{3}}$$

Where,			Units
$NR_{B,S,f,avg}$	=	Baseline average N rate of total synthetic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period	lb/ac
$NR_{B,S,f,t}$	=	Baseline annual N rate of total synthetic fertilizer for field *f* in year *t* of the baseline look-back period, see Equation 5.5	lb/ac
3	=	Number of eligible crop years included in the baseline look-back period	

Equation 5.5. Baseline Annual Synthetic Fertilizer N Rate on Field in Year of Baseline Look-Back Period

$$NR_{B,S,f,t} = \sum_j NR_{B,DS,j,f,t} + \sum_j NR_{B,LS,j,f,t}$$

Where,			Units
$NR_{B,S,f,t}$	=	Baseline annual N rate of total synthetic fertilizer for field *f* in year *t* of the baseline look-back period	lb/ac
$NR_{B,DS,j,f,t}$	=	N rate of dry synthetic, *DS*, fertilizer type *j* on field *f* in year t of the baseline look-back period, see Equation 5.6	lb/ac
$NR_{B,LS,j,f,t}$	=	N rate of liquid synthetic, *LS*, fertilizer type *j* on field *f* in year t of the baseline look-back period, see Equation 5.7	lb/ac

Equation 5.6. N Rates for Dry N-Containing Synthetic Fertilizer in Year of Baseline Look-Back Period

$$NR_{B,DS,j,f,t} = MF_{B,DS,j,f,t} \times NC_{B,DS,j,t}$$

Where,			Units
$NR_{B,DS,j,f,t}$	=	N rate of dry synthetic fertilizer *j* for field *f* in baseline *B* in year *t*	lb/ac
$MF_{B,DS,j,f,t}$	=	Mass of dry synthetic N-containing fertilizer *j* applied to field *f* per acre in baseline *B* in year *t*	lb/ac
$NC_{B,DS,j,t}$	=	N concentration of dry synthetic fertilizer *j* in baseline *B* in year *t*, see Farm Records or Appendix E	

Equation 5.7. N Rates of Liquid N-Containing Synthetic Fertilizer in Year of Baseline Look-Back Period

$$NR_{B,LS,j,f,t} = VF_{B,LS,j,f,t} \times MF_{B,LS,j,t} \times NC_{B,LS,j,t}$$

Where,			Units
$NR_{B,LS,j,f,t}$	=	N rate of liquid synthetic fertilizer *j* for field *f* in baseline *B* in year *t*	lb/ac
$VF_{B,LS,j,f,t}$	=	Volume of liquid synthetic N-containing fertilizer *j* applied to field *f* per acre in baseline *B* in year *t*	gallon/ac
$MF_{B,LS,j,t}$	=	Mass of liquid synthetic fertilizer *j* per gallon of fertilizer in baseline *B* in year *t*	lb/gallon
$NC_{B,LS,j,t}$	=	N concentration of liquid synthetic fertilizer *j* in baseline *B* in year *t*, see Farm Records or Appendix E	

5.1.2.3 Baseline Organic N Rates

Equation 5.8. Baseline Average Organic Fertilizer N Rate on Field

$$NR_{B,O,f,avg} = \frac{\sum_t NR_{B,O,f,t}}{3}$$

Where,			Units
$NR_{B,O,f,avg}$	=	Average baseline N rate of total organic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period	lb/ac
$NR_{B,O,f,t}$	=	Annual baseline N rate of total organic fertilizer for field *f* in year *t* of the baseline look-back period, see Equation 5.9	lb/ac
3	=	Number of eligible crop years included in the baseline look-back period	

Equation 5.9. Baseline Annual Organic Fertilizer N Rate on Field in Year of Baseline Look-Back Period

$$NR_{B,O,f,t} = \sum_{j} NR_{B,SO,j,f,t} + \sum_{j} NR_{B,LO,j,f,t}$$

Where,			Units
$NR_{B,O,f,t}$	=	Baseline annual N rate of total organic fertilizer for field *f* in year *t* of the baseline look-back period	lb/ac
$NR_{B,SO,j,f,t}$	=	N rate of solid organic, *SO*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period, see Equation 5.10	lb/ac
$NR_{B,LO,j,f,t}$	=	N rate of liquid organic, *LO*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period, see Equation 5.11	lb/ac

Equation 5.10. N Rates of Solid N-Containing Organic Fertilizer in Year of Baseline Look-Back Period

$$NR_{B,SO,j,f,t} = MF_{B,SO,j,f,t} \times NC_{B,SO,j,t}$$

Where,			Units
$NR_{B,SO,j,f,t}$	=	N rate of solid organic fertilizer *j* for field *f* in baseline *B* in year *t*	lb/ac
$MF_{B,SO,j,f,t}$	=	Mass of solid organic N-containing fertilizer *j* applied to field *f* per acre in baseline *B* in year *t*	lb/ac
$NC_{B,SO,j,t}$	=	N concentration of solid organic fertilizer *j* in baseline *B* in year *t*, see Farm Records or Appendix E[58]	

Equation 5.11. N Rates of Liquid N-Containing Organic Fertilizer in Year of Baseline Look-Back Period

$$NR_{B,LO,j,f,t} = VF_{B,LO,j,f,t} \times MF_{B,LO,j,f,t} \times NC_{B,LO,j,t}$$

Where,			Units
$NR_{B,LO,j,f,t}$	=	N rate of liquid organic fertilizer *j* for field *f* in baseline *B* in year *t*	lb/ac
$VF_{B,LO,j,f,t}$	=	Volume of liquid organic N-containing fertilizer *j* applied to field *f* per acre in baseline *B* in year *t*	gallon/ac
$MF_{B,LO,j,f,t}$	=	Mass of liquid organic N-containing fertilizer *j* applied to field *f* in baseline *B* in year *t*	lb/gallon
$NC_{B,LO,j,t}$	=	N concentration of liquid organic fertilizer *j* in baseline *B* in year *t*, see Farm Records or Appendix E[59]	

Note that where sufficient baseline look-back period data are not available to calculate annual baseline N rates, alternative approaches set out in Section 5.1.2.1 may be used.

5.1.3 Project Synthetic N Rates

For each reporting period, the project synthetic N rates applied over the eligible crop cultivation year for each field is calculated using Equation 5.12 through Equation 5.18 below. When calculating the project N rates, any synthetic N applied to cover crops grown between the harvest of the previous primary crop and the subsequent eligible crop, shall be included in the

[58] For processed commercial organic fertilizer, N contents following manufacturer's specifications can be used. For unprocessed manure, default manure N contents are shown in Appendix E and are consistent with Edmonds et al. (2003) cited in U.S. Environmental Protection Agency. (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. *EPA 430-R-11-005*. Washington, D.C.

[59] *Ibid.*

synthetic N rate for the eligible cultivation crop in question. Project synthetic N rate (Equation 5.12) always includes the total amount of synthetic N (both dry and/or liquid sources) applied to the field during the eligible crop cultivation year (Equation 5.13, Equation 5.14), and depending on the project, may need to be increased for increases in synthetic N rate applied to the field during a previous cultivation year where CRTs were not sought (Equation 5.15) and/or for production shifting leakage (Equation 5.18). The percentage reduction between the baseline average synthetic N rate and the project synthetic N rate must then be calculated for each field, see Equation 5.2, and entered in the NMQuanTool, as discussed in Section 5.1.1.

Equation 5.12. Project Synthetic Fertilizer N Rate for Field

$$\boldsymbol{NR_{P,S,f} = \sum_j NR_{P,DS,j,f} + \sum_j NR_{P,LS,j,f} + NR_{\delta S,f} + NR_{ps,f}}$$

Where,			Units
$NR_{P,S,f}$	=	N rate of total synthetic fertilizer for field *f* in project *P*	lb/ac
$NR_{P,DS,j,f}$	=	N rate of dry synthetic fertilizer type *j* on field *f,* see Equation 5.13	lb/ac
$NR_{P,LS,j,f}$	=	N rate of liquid synthetic fertilizer type *j* on field *f,* see Equation 5.14	lb/ac
$NR_{\delta S,f}$	=	Change in synthetic N rate between baseline look-back period and previous cultivation year (prior to project cultivation year) in which CRTs were not earned. If synthetic N rate did not increase from the previous cultivation year, then $NR_{\delta S,f}$ = 0. See Equation 5.15	lb/ac
δ	=	Change from baseline look-back period to previous cultivation year	
$NR_{ps,f}$	=	Increase in synthetic N rate due to production shifting, if applicable, see Equation 5.18	lb/ac

Equation 5.13. N Rates for Dry N-Containing Synthetic Fertilizer in Project

$$\boldsymbol{NR_{P,DS,j,f} = MF_{P,DS,j,f} \times NC_{P,DS,j}}$$

Where,			Units
$NR_{P,DS,j,f}$	=	N rate of dry synthetic fertilizer *j* for field *f* in project *P*	lb/ac
$MF_{P,DS,j,f}$	=	Mass of dry synthetic N-containing fertilizer *j* applied to field *f* in project *P*	lb/ac
$NC_{P,DS,j}$	=	N concentration of dry synthetic fertilizer *j* in project *P*, see Farm Records or Appendix E	

Equation 5.14. N Rates of Liquid N-Containing Synthetic Fertilizer in Project

$$\boldsymbol{NR_{P,LS,j,f} = VF_{P,LS,j,f} \times MF_{P,LS,j} \times NC_{P,LS,j}}$$

Where,			Units
$NR_{P,LS,j,f}$	=	N rate of liquid synthetic fertilizer *j* for field *f* in project *P*	lb/ac
$VF_{P,LS,j,f}$	=	Volume of liquid synthetic N-containing fertilizer *j* applied to field *f* per acre in project *P*	gallon/ac
$MF_{P,LS,j}$	=	Mass of liquid synthetic fertilizer *j* per gallon of fertilizer in project *P*	lb/gallon
$NC_{P,LS,j}$	=	N concentration of liquid synthetic fertilizer *j* in project *P*, see Farm Records or Appendix E	

5.1.3.1 Increases in Synthetic N from Cultivation Years in which CRTs are Not Claimed

To be eligible for CRTs, the synthetic N rate must be reduced from the baseline to the project. The Nitrogen Management Protocol allows flexibility in dealing with instances where the project developer either cannot or does not want to claim CRTs for a given crop cultivation year (See Section 3.5.1.1). These restrictions are intended to ensure excessive N is not applied in intervening years, with the intent to have residual N then affect the subsequent eligible crop cultivation year.

If CRTs are not earned in the previous cultivation year (prior to the project cultivation year) and if synthetic N rate increased from baseline levels in the previous cultivation year, that increase in synthetic N rate must be included in the project cultivation year. The project developer must include the increase in Equation 5.12 when calculating the synthetic N rates for the project cultivation year. Increases in synthetic N rates for cultivation years in which CRTs are not being sought will be calculated using Equation 5.15 and Equation 5.16 below, and then included in Equation 5.12 above.

If CRTs are earned in the previous cultivation year (prior to the project cultivation year), proceed to Section 5.1.3.2.

Equation 5.15. Change in Synthetic N on Field from Previous Cultivation Year Not Claiming CRTs

$$NR_{\delta S,f} = NR_{pcy,S,f} - NR_{B,S,f,avg}$$

Where,			Units
$NR_{\delta S,f}$	=	Change in synthetic N rate on field *f* between baseline look-back period and previous cultivation year (prior to project cultivation year) in which CRTs were not earned. If synthetic N rate did not increase from the previous cultivation year, then $NR_{\delta S,f} = 0$	lb/ac
δ	=	Change from baseline look-back period to previous cultivation year	
$NR_{pcy,S,f}$	=	N rate of total synthetic N fertilizer for field *f* from a previous cultivation year, *pcy*, for which CRTs were not earned, see Equation 5.16	lb/ac
$NR_{B,S,f,avg}$	=	Baseline average N rate of total synthetic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.4	lb/ac

Equation 5.16. Previous Cultivation Year Synthetic Fertilizer N Rate for Field

$$NR_{pcy,S,f} = \sum_{j} NR_{pcy,DS,j,f} + \sum_{j} NR_{pcy,LS,j,f}$$

Where,			Units
$NR_{pcy,S,f}$	=	N rate of total synthetic N fertilizer for field *f* from a previous cultivation year, *pcy*, in which CRTs were not earned	lb/ac
$NR_{pcy,DS,j,f}$	=	N rate of dry synthetic fertilizer type *j* on field *f,* see Equation 5.13	lb/ac
$NR_{pcy,LS,j,f}$	=	N rate of liquid synthetic fertilizer type *j* on field *f,* see Equation 5.14	lb/ac

5.1.3.2 Increases in Synthetic N Rate from Shifting Crop Production Outside Project Boundaries (Leakage)

Econometric studies have reported considerable price elasticity for corn.[60] Therefore, it is assumed in this protocol that a statistically significant decrease in corn yields due to project activities would result in an increase of production outside of the project area. The same assumption is held true for all eligible crops. The increased emissions associated with this shift in production must be estimated if project-related yield losses are statistically-significant compared to historical average yields in the baseline look-back period. If yield decreases in a statistically significant manner compared to historical average yields, then significant leakage would have occurred, and the project synthetic N rate in Equation 5.12 must be increased proportionately to the shift in production.

The historical average yield is calculated from the three eligible crop years in the baseline look-back period prior to the start date in alignment with the same three years for the baseline fertilizer records. If a catastrophic yield loss occurred due to extreme weather during a historical eligible crop year, yield data for that year may be excluded from the calculation of average historical yield; however, if those yield data are excluded, the historical period over which the average historical yield is calculated must be extended to include another historical eligible year (i.e., so that the same number of valid eligible crop years is used to determine the average historical yield). Verifiers shall use their professional judgment to determine whether it was appropriate to exclude an anomalous yield. If yield data is lacking for any of the three baseline years, because such data was not recorded, then the project developer can extend the historical period to include yield from further years, until three years of yield data are available. The average historical yield value shall be fixed for the duration of a field's crediting period, but shall be (re)calculated at the start of each crediting period.

In order to determine if crop yields have decreased in a statistically significant manner across the project area during the cultivation year as a result of project activities, the annual yield from the project area must be compared to the historical average yield over the baseline look-back period from the same project area. Because yields fluctuate annually depending on numerous climatic drivers, for this evaluation yields are normalized to historical average annual county yields using USDA National Agricultural Statistics Service (NASS) statistics,[61] according to the procedure below.

This normalization procedure must be followed for each cultivation year to demonstrate that the yields from the project area have not declined due to project activities. The following procedure is applicable at the field level and must be applied to each field in the project.

1. For each year *t* in the baseline look-back period (see Section 5.1.2), normalize (y_norm_t) the yield of the project field ($Y_{P,f,t}$) by the county average for that historical year ($Y_{Co,t}$) using Equation 5.17. The distribution of y_norm_t will have the same number data points as the number of eligible crop years in the baseline look-back period (i.e., three years).

[60] Huang, H., & Khanna, M., 2010.
[61] This dataset is robust and published on a regular, annual schedule. Available at http://quickstats.nass.usda.gov. See Appendix B for more information.

Equation 5.17. Normalized Project Yield for Each Year in the Baseline

$$y_norm_t = \frac{Y_{P,f,t}}{Y_{Co,t}}$$

Where,			Units
y_norm_t	=	Normalized yield of field *f* in project *P* for year *t*	
$Y_{P,f,t}$	=	Yield of field *f* in project *P* in year *t*	yield/ac
$Y_{Co,t}$	=	County, *Co*, average yield in year *t* (based on USDA NASS statistics)	yield/ac
t	=	Year in 3-year baseline look-back period	

y_norm_t must be determined for each year t in the baseline look-back period (t_1, t_2, and t_3) and for the current cultivation year, t_0.

2. Take the standard deviation, *s*, and mean of the y_norm_t distribution:

$$s = stdev(y_norm_{t1}, y_norm_{t2}, y_norm_{t3})$$

$$y_norm_{t,avg} = average(y_norm_{t1}, y_norm_{t2}, y_norm_{t3})$$

3. Calculate the minimum yield threshold below which normalized yields are significantly smaller than the historical average. This shall be done as follows:

$$y_\mathbf{min} = y_norm_{t,avg} - (2.92 \times s)$$

Where 2.92 is the t-distribution value with 95 percent confidence for a one-tailed test with two degrees of freedom (i.e., *n* is 3),[62] and *s* is the standard deviation of the y_norm_t distribution, as calculated in Step 2.

4. For the cultivation year, t_0, for the current reporting period, normalize (y_norm_{t0}) the yield of the project field ($Y_{P,f,t0}$) by the county average ($Y_{Co,t0}$) for the current cultivation year, using Equation 5.17 but replacing *t* with t_0, and compare this value to *y_min*. **If y_norm_{t0} is smaller than y_min, it must be assumed that leakage occurred, and emissions increased outside of the project area**. The project must account for the shifted production via an increase in the project synthetic N rate, as set out in Equation 5.18. If y_norm_{t0} is greater than or equal to *y_min*, any leakage associated with production shifting is reasonably expected to be *de minimis*, and no adjustments to the project synthetic N rate are required.

[62] The t-distribution value of 2.920 = t(0.05, n-1), where n is 3, and n-1 degrees of freedom is 2. If there are less than three data points (e.g., less than three eligible crop years in the baseline look-back period), a different t-distribution value must be substituted for 2.920. Specifically, where n=2, t-value=6.314.

Equation 5.18. Increase in Project Synthetic N Rate Due to Production Shifting (Leakage)

$$NR_{ps,f} = \left(1 - \frac{y_norm_{t0}}{y_min}\right) \times NR_{P,S,f}$$

Where,			Units
$NR_{ps,f}$	=	Increase in synthetic N rate due to production shifting, *ps*, outside of the project boundary for field *f*	lb/ac
y_norm_{t0}	=	Normalized project yield for field *f*	yield/ac*
y_min	=	Minimum yield threshold below which normalized yields are significantly smaller than the historical average for field *f*	yield/ac
$NR_{P,S,f}$	=	N rate for total synthetic fertilizer for field *f,* see Equation 5.12**	lb/ac
t_0	=	Cultivation year in the current reporting period	

** Any appropriate unit of yield for given crop can be used, as long as the units for y_norm_{t0} are the same as the units for y_min.*
*** Note that $NR_{P,S,f}$ should first be imported into this equation* from *Equation 5.12 prior to adding $NR_{ps,f}$. Then $NR_{ps,f}$ should be included in the final total synthetic N rate in Equation 5.12, thus avoiding a circular reference.*

5.1.4 N_2O Emissions from Increases in Organic N Rates

If organic N rates increase in the project as compared to the baseline average organic N rate, emissions associated with these increases must be subtracted from the total calculated primary effect GHG reductions for each reporting period. Two main sources of primary effect N_2O emissions from increases in organic N rates must be taken into account: 1) direct N_2O emissions from soil (SSR1) and 2) emissions from leaching, volatilization, and runoff (LVRO) (SSR 2). The total primary effect emissions are summed together at the project level using Equation 5.19. Direct N_2O emissions from soil, from increases in organic N rate, must be calculated using one of two equations, depending upon whether the fields in question are cultivating corn and are located in the North Central Region[63] (i.e., the corn belt) (Equation 5.20), or cultivating eligible crops other than corn and/or are outside the North Central Region (Equation 5.21). LVRO from increases in organic N rate are calculated using Equation 5.22.

Equation 5.19. Primary Effect GHG Emissions from Increases in Organic N

$$PE_O = \sum_f (N_2O_{O,Dir,f} + N_2O_{O,LVRO,f})$$

Where,			Units
PE_O	=	Total primary effect N_2O emissions from organic N for the project	tCO_2e/ac
$N_2O_{O,Dir,f}$	=	Direct N_2O emissions from increased organic N applied to field *f*, see Equation 5.20 or Equation 5.21	tCO_2e/ac
$N_2O_{O,LVRO,f}$	=	N_2O emissions from leaching, volatilization, and runoff from increased organic N applied field *f*, see Equation 5.22	tCO_2e/ac

5.1.4.1 Direct N_2O Emissions from Corn in the North Central Region

The direct N_2O emissions from increases in organic N rates when growing corn in the North Central Region are calculated using the increase in organic N rate in the project (Equation 5.23)

[63] The U.S. States in the North Central Region include: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin.

and the MSU-EPRI Tier 2 emission factor developed for cropping systems in the North Central Region of the U.S.,[64] as seen in Equation 5.20.

Equation 5.20. Direct N_2O Emissions from Organic N Changes in the Corn Belt

$$N_2O_{O,Dir,f} = \frac{EF_{NCR} \times \frac{44}{28} \times GWP}{2204.62}$$

Where,			Units
$N_2O_{O,Dir,f}$	=	Direct N_2O emissions from eligible crop years from field *f*	tCO_2e/ac
EF_{NCR}	=	Adjusted MSU-EPRI Tier 2 emission factor for corn cropping systems in the North Central Region	
44/28	=	Unit conversion from lb N_2O-N to lb N_2O, where 44 is the molecular weight of N_2O and 28 is twice the atomic weight of N	
GWP	=	Global warming potential of N_2O. This value shall be 298 until further guidance is issued by the Reserve. See Table 5.1	
2204.62	=	Conversion from lb CO_2e to tCO_2e	lb/t

and,

$$EF_{NCR} = 0.67 \times \left[e^{(0.0067 \times NR_{\Delta O,f})} - 1\right]$$

Where,			Units
$NR_{\Delta O,f}$	=	Increase in organic N rate on field *f,* see Equation 5.23	lb/ac

5.1.4.2 Direct N_2O Emissions other than from Corn in the North Central Region

The direct N_2O emissions from increases in organic N rates outside the North Central Region are calculated using the increase in the increase in organic N rate in the project (Equation 5.23) and the IPCC Tier 1 default emission factor for N_2O emissions from organic N, using Equation 5.21.

Equation 5.21. Direct N_2O Emissions from Organic N Changes Outside the Corn Belt

$$N_2O_{O,Dir,f} = \frac{0.01 \times NR_{\Delta O,f} \times \frac{44}{28} \times GWP}{2204.62}$$

Where,			Units
$N_2O_{O,Dir,f}$	=	Direct N_2O emissions from increased organic N applied to field *f*	tCO_2e/ac
0.01	=	IPCC Tier 1 default emission factor for N_2O emissions from organic N	
$NR_{\Delta O,f}$	=	Increase in organic N rate on field *f,* see Equation 5.23	lb/ac
44/28	=	Unit conversion from lb N_2O-N to lb N_2O, where 44 is the molecular weight of N_2O and 28 is twice the atomic weight of N	
GWP	=	Global warming potential of N_2O. This value shall be 298 until further guidance is issued by the Reserve. See Table 5.1	
2204.62	=	Conversion from lb CO_2e to tCO_2e	lb/t

[64] Millar et al. (2012). *Methodology for Quantifying Nitrous Oxide (N_2O) Emissions Reductions by Reducing Nitrogen Fertilizer Use on Agricultural Crops*. American Carbon Registry, Winrock International, Little Rock, Arkansas. July 2012.

5.1.4.3 N_2O Emissions from Leaching, Volatilization, and Runoff from Increases in Organic N

N_2O emissions from LVRO from increases in organic N must be accounted for in determining primary effect GHG reductions and are determined according to Equation 5.22 below.

Equation 5.22. N_2O Emissions from LVRO from Increases in Organic N Per Field

$$N_2O_{O,LVRO,f} = \frac{\left[\left(NR_{\Delta O,f} \times 0.20 \times 0.01\right) + \left(NR_{\Delta O,f} \times Frac_{LEACH} \times 0.0075\right)\right] \times \frac{44}{28} \times GWP}{2204.62}$$

Where,			Units
$N_2O_{O,LVRO,f}$	=	N_2O emissions from leaching, volatilization, and runoff from increased organic N applied to field *f* for the reporting period	tCO_2e/ac
$NR_{\Delta O,f}$	=	Increase in organic N rate on field *f,* see Equation 5.23	lb/ac
0.20	=	IPCC default factor for the fraction of all organic fertilizer N inputs that volatizes as NH_3 and NO_x (IPCC parameter name: FracGASM)	
0.01	=	IPCC default emission factor for N_2O emissions from atmospheric deposition of N on soil and water surfaces and subsequent volatization (IPCC parameter name: EF4)	
$Frac_{LEACH}$	=	Fraction of organic N inputs that is lost through leaching and runoff. See Box 5.1 and Appendix D	
0.0075	=	IPCC default emission factor for N_2O emissions from N leaching and runoff (IPCC parameter name: EF5)	
44/28	=	Unit conversion from lb N_2O-N to lb N_2O	
GWP	=	Global warming potential of N_2O. This value shall be 298 until further guidance is issued by the Reserve. See Table 5.1	
2204.62	=	Conversion from lb CO_2e to tCO_2e	lb/t

Box 5.1. Determining $Frac_{LEACH}$ for Increased Project Organic N Rates

The fraction of N inputs lost through leaching and runoff ($Frac_{LEACH}$) is an important input in Equation 5.22 where LVRO emissions associated with increases in organic N are calculated. Whether or not leaching occurs may vary due to inter-annual variability in levels of precipitation and evapotranspiration.

Most fields will apply a $Frac_{LEACH}$ value calculated based on precipitation and evaporation data from a nearby weather station, according to the methodology outlined in Appendix D.[65]

Fields with certain site-specific characteristics, however, are required by this protocol to use fixed default $Frac_{LEACH}$ values. Specifically, fields with tile drains shall use the fixed default value of $Frac_{LEACH}$ = 0.3, even if that county otherwise would have applied a $Frac_{LEACH}$ value of 0.[66]

All other fields, including those fields using irrigation, shall apply the $Frac_{LEACH}$ value calculated according to Appendix D. The IPCC recommends a $Frac_{LEACH}$ default of 0.3 for all irrigated fields (except those receiving drip irrigation). The Reserve assumes that "emergency irrigation" years will have $Frac_{LEACH}$ values more similar to fields receiving drip irrigation.[67] Because of this, any non-irrigated fields receiving emergency irrigation in year of severe or extreme drought shall apply the $Frac_{LEACH}$ value determined by comparing precipitation and potential evapotranspiration data (i.e., calculating $Frac_{LEACH}$) instead of the 0.3 value. The Reserve believes this methodology maintains consistency with IPCC guidelines for determining $Frac_{LEACH}$.

5.1.4.4 Changes in Project Organic N Rates

This section provides the calculation method for primary effect N_2O emissions (PE_O) from *increases* in organic N rate applications. Organic N rate is allowed to increase from the baseline to the project, so long as total N rate decreases from the baseline to the project (see Equation 3.5, Section 3.5.1.1).If organic N rate increases in the project from the baseline, emissions associated with these increases must be subtracted from the total calculated primary effect GHG reductions (Equation 5.1), for each reporting period. If organic N rate remains the same or decreases from the baseline and the project on the given field, then PE_O = 0 in Equation 5.1. Project developers must follow Equation 5.23 through Equation 5.27 below to determine the increase in organic N rate per field. The associated increase in N_2O emissions at the field and project levels are then calculated in Section 5.1.4.

[65] Once data becomes available, the Reserve plans to streamline project accounting by calculating the value for $Frac_{LEACH}$ by county and publishing those values on the Reserve website.

[66] This default value for tile-drained fields is consistent with the IPCC methodology, based on analysis performed in Nevison, Cynthia. "Background Paper on Indirect N_2O Emissions from Agriculture," G*ood Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Background paper published 2003 to inform the 2006 update to the Revised 1996 National Inventory Guidelines, Available at: http://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_6_Indirect_N2O_Agriculture.pdf. Nevison's analysis reviewed case studies that took place in the Midwestern U.S., generally in fields of corn or soybeans, underlain with tile drains to confirm whether the IPCC methodology was appropriate for these systems.

[67] "Emergency irrigation" is requisite irrigation to prevent crop failure in years of severe drought in systems that are typically not irrigated, for example, in a county that has received a USDA Secretarial disaster designation due to severe drought in a given cultivation year.

Equation 5.23. Change in N Rate of Organic Fertilizer for Field in Project

$$NR_{\Delta O,f} = NR_{P,O,f} - NR_{B,O,f,avg}$$

Where,			Units
$NR_{\Delta O,f}$	=	Change in organic N rate on field *f*. If the organic N rate decreases in the project relative to the baseline, then $NR_{\Delta O,f} = 0$	lb/ac
$NR_{P,O,f}$	=	N rate of total organic fertilizer for field *f* in project *P*, see Equation 5.24	lb/ac
$NR_{B,O,f,avg}$	=	Average baseline N rate of total organic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.8	lb/ac

The total organic fertilizer N rate for a particular field *f* is calculated as the sum of N rates of all solid and liquid (slurry) organic N sources and calculated in Equation 5.24 below.

Equation 5.24. Project Organic Fertilizer N Rate for Field

$$NR_{P,O,f} = \sum_{j} NR_{P,SO,j,f} + \sum_{j} NR_{P,LO,j,f} + NR_{\delta O,f}$$

Where,			Units
$NR_{P,O,f}$	=	N rate of total organic fertilizer for field *f*	lb/ac
$NR_{P,SO,j,f}$	=	N rate of solid organic fertilizer type *j* on field *f,* see Equation 5.25	lb/ac
$NR_{P,LO,j,f}$	=	N rate of liquid organic fertilizer type *j* on field *f,* see Equation 5.26	lb/ac
$NR_{\delta O,f}$	=	Increase in organic N rate between baseline and previous cultivation year for which CRTs were not earned, if applicable, see Equation 5.27	

Equation 5.25. N Rates of Solid N-Containing Organic Fertilizer in Project

$$NR_{P,SO,j,f} = MF_{P,SO,j,f} \times NC_{P,SO,j}$$

Where,			Units
$NR_{P,SO,j,f}$	=	N rate of solid organic fertilizer *j* for field *f* in project *P*	lb/ac
$MF_{P,SO,j,f}$	=	Mass of solid organic N-containing fertilizer *j* applied to field *f* per acre in project *P*	lb/ac
$NC_{P,SO,j}$	=	N concentration of solid organic fertilizer *j* in project *P*, see Farm Records or Appendix E[68]	

[68] For processed commercial organic fertilizer, N contents following manufacturer's specifications can be used. For unprocessed manure, default manure N contents are shown in Appendix E and are consistent with Edmonds et al. (2003) cited in U.S. Environmental Protection Agency. (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. *EPA 430-R-11-005*. Washington, D.C.

Equation 5.26. N Rates of Liquid N-Containing Organic Fertilizer in Project

$$NR_{P,LO,j,f} = VF_{P,LO,j,f} \times MF_{P,LO,j,f} \times NC_{P,LO,j}$$

Where,			Units
$NR_{P,LO,j,f}$	=	N rate of liquid organic fertilizer *j* for field *f* in project *P*	lb/ac
$VF_{P,LO,j,f}$	=	Volume of liquid organic N-containing fertilizer *j* applied to field *f* per acre in project *P*	gallon/ac
$MF_{P,LO,j,f}$	=	Mass of liquid organic N-containing fertilizer *j* applied to field *f* in project *P*	lb/gallon
$NC_{P,LO,j}$	=	N concentration of liquid organic fertilizer *j* in project *P*, see Farm Records or Appendix E[69]	

5.1.4.4.1 Increases in Organic N from Cultivation Years in which CRTs are not Claimed

As discussed in Section 5.1.3.1 with synthetic N rates, if CRTs are not earned in the previous cultivation year (prior to the project cultivation year) and if organic N rate increased from baseline levels in the previous cultivation year, that increase in organic N rate must be included in the project cultivation year. The project developer must include the increase in Equation 5.24 when calculating the organic N rates for the project cultivation year. Increases in organic N rates for cultivation years in which CRTs are not being sought will be calculated using Equation 5.27 and Equation 5.28 below, and then included in Equation 5.24 above.

If CRTs are earned in the previous cultivation year (prior to the project cultivation year), proceed to Section 5.2.

Equation 5.27. Change in N Rate of Organic Fertilizer for Field in Previous Cultivation Year

$$NR_{\delta O,f} = NR_{pcy,O,f} - NR_{B,O,f,avg}$$

Where,			Units
$NR_{\delta O,f}$	=	Change in organic N rate on field *f* between baseline look-back period and previous cultivation year (prior to project cultivation year) for which CRTs were not earned. If organic N rate did not increase from the previous cultivation year, then $NR_{\delta O,f} = 0$	lb/ac
δ	=	Change from baseline look-back period to previous cultivation year	
$NR_{pcy,O,f}$	=	N rate of total organic N fertilizer for field *f* from a previous cultivation year, *pcy*, in which CRTs were not earned, see Equation 5.28	lb/ac
$NR_{B,O,f,avg}$	=	Baseline average N rate of total organic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period, see Equation 5.8	lb/ac

[69] *Ibid.*

Equation 5.28. Previous Cultivation Year Organic Fertilizer N Rate for Field

$$NR_{pcy,O,f} = \sum_{j} NR_{pcy,SO,j,f} + \sum_{j} NR_{pcy,LO,j,f}$$

Where,			Units
$NR_{pcy,O,f}$	=	N rate of total organic N fertilizer for field *f* from a previous cultivation year, *pcy*, in which CRTs were not earned	lb/ac
$NR_{pcy,SO,j,f}$	=	N rate of solid organic fertilizer type *j* on field *f* in previous cultivation year, *pcy,* see Equation 5.25	lb/ac
$NR_{pcy,LO,j,f}$	=	N rate of liquid organic fertilizer type *j* on field *f* in previous cultivation year, *pcy,* see Equation 5.26	lb/ac

5.2 Secondary Effect GHG Emissions

Secondary effect emissions are unintentional changes in GHG emissions from the secondary SSRs within the GHG Assessment Boundary. Secondary effect emissions may increase, decrease or go unchanged from the baseline look-back period as a result of the project activities. If emissions from secondary SSRs *increase* as a result of the project, these emissions must be subtracted from the total calculated primary effect GHG reductions for each reporting period in Equation 5.1.

However, if the project can demonstrate that electricity and/or fossil fuel usage is reasonably expected to increase by five percent or less, relative to baseline usage, the emissions associated with such increased usage need not be accounted for. In order to assess whether usage has increased by more than five percent relative to baseline usage, levels of electricity and fossil fuel usage may be estimated through a conservative method proposed by the project developer and deemed acceptable by the verifier. The project developer could assert to their verifier and demonstrate that no significant changes have occurred in their management practices (e.g., the same or commensurate equipment is being used, the same number of fertilizer applications are being made, the same irrigation frequency is maintained, etc.). If the verifier is satisfied that electricity and/or fossil fuel usage did not increase by more than five percent, then there is no need to calculate such emissions. If electricity and/or fossil fuel usage is reasonably expected to have increased by more than five percent, then the project developer must account for emissions associated with such increases by using the equations in this section. Equation 5.29 accounts for any increased CO_2 emissions from increased consumption of fossil fuels or electricity associated with the operation of cultivation equipment (SSR 3) and irrigation systems (SSR 4).

Equation 5.29. Direct Secondary Effect Emissions from Project Activities

$$SE = \sum_{f} \left(SE_{EL,f} + SE_{FF,f} \right)$$

Where,			Units
SE	=	Net secondary effect GHG emissions for projects due to project activities	tCO_2e
$SE_{EL,f}$	=	Net secondary effect GHG emissions from increased electricity use in the project cultivation year relative to baseline look-back period for field *f*, as calculated using Equation 5.30	tCO_2e
$SE_{FF,f}$	=	Net secondary effect GHG emissions from increased fossil fuel consumption in the project cultivation year relative to the baseline look-back period for field *f*, as calculated using either Option 1 in Equation 5.31 or Option 2 in Equation 5.32	tCO_2e

5.2.1 GHG Emissions from Increased Electricity Usage

Emissions from the additional usage of electricity needs to be quantified and accounted for, as seen in Equation 5.30.

Equation 5.30. Increased Secondary Emissions from Electricity Use in Project

$$SE_{EL,f} = \frac{\left(QE_f \times EF_{EL,f}\right)}{1000}$$

Where,			Units
$SE_{EL,f}$	=	Net secondary effect GHG emissions from increased electricity use in the project cultivation year relative to baseline look-back period for field *f*	tCO_2e
QE_f	=	Total increase in electricity consumed during the project cultivation year relative to the baseline look-back period for field *f*	kWh
$EF_{EL,f}$	=	Carbon emission factor for electricity used, referenced from the most recent U.S. EPA eGRID emission factor publication.[70] Projects shall use the annual total output emission rates for the subregion where the project is located	kg CO_2e/kWh
1000	=	Conversion from kg CO_2e to tCO_2e	kg/t

5.2.2 GHG Emissions from Increased Fossil Fuel Consumption

Emissions from the additional consumption of fossil fuels from the increased usage of cultivation equipment and irrigation systems needs to be quantified and accounted for. Two options are provided below.

Option 1, Equation 5.31, calculates emissions based on the time needed for each nitrogen management-related field operation, the horsepower required for this field operation, and a default emission factor for GHG emissions per horsepower-hours. If fuel consumption records are insufficient, Option 1 must be used. Option 1 is designed to require minimal documentation. The project developer must provide manufacturers' specifications on the horsepower requirements for the N application equipment used, and the time needed per acre for N application. The time needed for N application should be reported based on work-hour records. However, lacking those records, they may be derived based on the average operation or ground speed of the equipment and the application width per pass (e.g., width of boom).

Option 2, Equation 5.32, calculates emissions based on the fuel consumption for field operations related to nitrogen management and a default emission factor for GHG emissions per unit of fuel consumed.

[70] Available online at: http://www.epa.gov/cleanenergy/energy-resources/egrid/

Equation 5.31. Option 1 – Increased Secondary Emissions from Fossil Fuel Use in Project

$$SE_{FF,f,1} = \left(\sum_i \left(EF_{HP-hr,P,i,f} \times HP_{P,i,f} \times t_{P,i,f}\right) - \sum_k \left(EF_{HP-hr,B,k,f} \times HP_{B,k,f} \times t_{B,k,f}\right)\right) \times 10^{-6}$$

Where,		Units
$SE_{FF,f,1}$	= Option 1 for calculating the increase in secondary emissions from an increase in fossil fuel use on field *f*	tCO_2e/ac
$EF_{HP-hr,P,i,f}$	= Emission factor for project operation *i* on field *f*. Default value is 1311 for gasoline-fueled operations and 904 for diesel-fueled operations[71]	g CO_2e/HP-hr
$HP_{P,i,f}$	= Horsepower requirement for project operation *i* on field *f*	HP
$t_{P,i,f}$	= Time required to perform project operation *i* on field *f*	hr/field
$EF_{HP-hr,B,k,f}$	= Default emission factor for baseline operation *k* on field *f*. Default value is 1311 for gasoline-fueled operations and 904 for diesel-fueled operations[72]	g CO_2e/HP-hr
$HP_{B,k,f}$	= Horsepower requirement for baseline operation *k* on field *f*	HP
$t_{B,k,f}$	= Time required to perform baseline operation *k* on field *f*	hr/field
10^{-6}	= Conversion from g CO_2e to tCO_2e	

Optional Method for Determination of *t*

If time records are not available, use the method below in both baseline and project estimates.

$$t = \frac{4046.86}{(width \times speed \times 1000)} \times A_f$$

Where,		Units
t	= Time requirement for field operation	hr
4046.86	= Area unit conversion	m^2/ac
width	= Application width covered by equipment	m
speed	= Average ground speed of the operation equipment	km/hr
1000	= Length unit conversion	m/km
A_f	= Size of field *f*	ac

Equation 5.32. Option 2 – Increased Secondary Emissions from Fossil Fuel Use in Project

$$SE_{FF,f,2} = \frac{\sum_j \left[(FF)_{PR,j} \times EF_{FF,j}\right]}{1000}$$

Where,		Units
$SE_{FF,f,2}$	= Option 2 for calculating the increase in secondary emissions from an increase in fossil fuel use on field *f*	tCO_2e/ac
$FF_{PR,j}$	= Total change in fossil fuel consumption for field *f* during the reporting period, by fuel type *j*	gallon
$EF_{FF,j}$	= Fuel-specific emission factor. Default values are 17.4 for gasoline and 13.7 for diesel[73]	kg CO_2/gallon
1000	= Conversion from kg CO_2e to tCO_2e	kg/t

[71] California Air Resources Board, OFFROAD2007. Available at https://www.arb.ca.gov/msei/offroad2007_docs.htm.
[72] *Ibid*.
[73] *Ibid*.

6 Project Monitoring

The Reserve requires a Monitoring Plan and Monitoring Report to be established for all monitoring and reporting activities associated with the project or cooperative. The Monitoring Plan serves as the basis for verifiers to confirm that the monitoring and reporting requirements in this section and Section 7 have been and continue to be met, and that consistent, rigorous monitoring and record keeping is ongoing at the project fields. The Monitoring Plan must cover all aspects of monitoring and reporting contained in this protocol and must specify how data for all relevant parameters in Table 6.1 are collected and recorded. Projects must develop a Project Monitoring Plan (PMP) in accordance with the guidance in Section 6.1. Cooperatives must develop Cooperative Monitoring Plans (CMPs) both at an aggregate-level and field-level in accordance with the guidance in Section 6.2.

At a minimum, the Monitoring Plans shall include a description of management of the fields and ownership of the emission reductions; the methods and frequency of data acquisition; a record keeping plan (see Section 7.3 for minimum record keeping requirements), and the role of individuals performing each specific monitoring activity. The Monitoring Plan should include quality assurance/quality control (QA/QC) provisions to ensure that data acquisition and recordkeeping are carried out consistently and with precision.

Finally, the Monitoring Plan must include procedures that the project developer follows to ascertain and demonstrate that the project at all times passes the legal requirement test and the regulatory compliance requirements (Section 3.3.2 and 3.6, respectively).

Project developers are responsible for monitoring the performance of the project.

6.1 Project Monitoring Plan

The PMP, together with the Project Monitoring Report (PMR) outlined in Section 7.2.1, will serve as the basis for verification bodies to confirm that the monitoring and reporting requirements in Sections 6 and 7 are met for individual projects, and that consistent, rigorous monitoring and recordkeeping is ongoing at the project field(s). The PMP must be developed and maintained by the project developer. The PMP must specify how required field data (Section 6.3) are collected, recorded, and managed at each field. The PMP must also outline procedures for developing and submitting a complete PMR in accordance with Section 7.2.1. It is the responsibility of the project developer to ensure that the PMP meets all requirements specified and is kept on file and up-to-date for verification.

The PMP must outline the following:

- Number of fields of the project
- Description of entities involved in the management of project field(s)
- The methods and frequency of data acquisition, including a plan for monitoring the field data outlined in Section 6.3, which includes a plan for detailed record keeping and maintenance that meet the requirements for minimum record keeping in Section 7.3.1
- The role of individuals performing each specific monitoring activity
- QA/QC provisions to ensure that data acquisition and recordkeeping are carried out consistently and with precision
- Procedures describing how the field perimeter GIS shape file and/or *.kml file will be created

- Procedures describing how the reporting period, crediting period, verification schedule, and quantification results will be tracked for each field
- Procedures or methods for ensuring that the Project Owner holds title to the GHG emission reductions as required in Section 2.5.2
- Procedures that the project developer will follow to ascertain and demonstrate that the project field at all times passes the legal requirement test and regulatory compliance (Section 3.5.2 and Section 3.6 respectively)
- Procedures the project developer will follow to track which fields have passed the performance standard and which are in a grace period with delayed crediting (see Section 3.5.1.1.1)

6.2 Cooperative Monitoring Plans

There can be gains in efficiency through centralized monitoring for cooperatives. A Cooperative Developer may organize their Cooperative Monitoring Plan (CMP) such that information from individual projects is collected and processed together. However, all information and documentation must be organized in such a manner that the verifier can assess that the requirements of this protocol have been met for each individual project field. For example, it is acceptable to submit a single spreadsheet of nitrogen application data for the cooperative, but the nitrogen application data for each individual project field must still be clearly defined within that spreadsheet The CMPs must adhere to the same criteria listed for PMPs in Section 6.1 for each individual project within the cooperative.

6.3 Field and Project Data Monitoring Requirements

Table 6.1 below sets out all the prescribed monitoring parameters necessary to calculate baseline and project emissions. Field monitoring parameters must be determined according to the data source and frequency specified for all eligible crop years. Table 6.1 specifies monitoring requirements for field monitoring parameters required of all project fields.

Table 6.1 below sets out all the additional field management data that must be collected for both eligible and ineligible crop years. Section 7.3 provides further guidance on specific record-keeping requirements.

If a field has been submitted for enrollment in a project, but CRTs have yet to be requested for that field, then the monitoring report can simply note that the field has not yet requested CRTs, and no further data is required for that field. Once CRTs have been requested for a field, full monitoring data as set out below will be required for that field for as long as it remains enrolled in the project.

Table 6.1. Field Monitoring Parameters

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 3.1 Equation 3.3	$NUE_{P,f}$	Nitrogen use efficiency (NUE)calculated for field *f* during the current cultivation year for purposes of the performance standard		c, o	Annual	Calculated from farmer records
Equation 3.1	$Y_{P,f}$	Annual yield on field *f* in project *P*	lb/ac	o	Annual	Farmer records
Equation 3.1 Equation 3.2 Equation 3.5	$NR_{P,f}$	Annual total project N rate for all fertilizers on field *f*	lb/ac	c, o	Annual	Farmer records
Equation 3.2 Equation 5.2 Equation 5.12 Equation 5.18	$NR_{P,S,f}$	Annual synthetic N rate for field *f*, during the current cultivation year of the project *P*	lb/ac	o	Annual	Farmer records
Equation 3.2 Equation 5.23 Equation 5.24	$NR_{P,O,f}$	Annual total project organic nitrogen application rate for field *f*	lb/ac	c, o	Annual	Farmer records
Equation 3.3	$NUE_{avg,Co,c}$	Multi-year county-and crop-specific NUE used as benchmark in performance standard test for additionality		r	Annual	Found in Nitrogen Management Protocol Eligibility Lookup Tool

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 3.4 Equation 3.5	$NR_{B,f,avg}$	Total average N rate (synthetic and organic) over the baseline look-back period for field *f*	lb/ac	c	Annual	Farmer records
Equation 3.4 Equation 5.2 Equation 5.4 Equation 5.15	$NR_{B,S,f,avg}$	Average baseline N rate of total synthetic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period	lb/ac	o	Annual	Farmer records
Equation 3.4 Equation 5.8 Equation 5.23 Equation 5.27	$NR_{B,O,f,avg}$	Average baseline N rate of total organic fertilizer for field *f*, calculated from all eligible crop years during the field's baseline look-back period	lb/ac	o	Annual	Farmer records
N/A	$Y_{avg,Co,c}$	Multi-year county- and crop-specific yield. May be used as annual yield substitute due to extreme weather in performance standard test for additionality and in leakage assessment if historical records are missing or insufficient.	lb/ac	r	Annual	Found in Nitrogen Management Protocol Eligibility Lookup Tool
N/A	$NR_{avg,Co,c}$	Multi-year county- and crop-specific N rate for use in baseline Approach 3	lb/ac	o	Annual	Found in Nitrogen Management Protocol Eligibility Lookup Tool

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.1	ER	Total emission reductions for project area for the reporting period	tCO_2e	c	Annual	
Equation 5.1 Equation 5.3	PER	Total primary effect GHG emission reductions from implementation of eligible project activities over the entire project area	tCO_2e	c	Annual	Calculated from farmer records using NMQuanTool
Equation 5.1 Equation 5.19	PE_O	Total primary effect GHG emissions from organic N rate increases over the entire project area	tCO_2e	c	Annual	Calculated from farmer records
Equation 5.1 Equation 5.29	SE	Net secondary effect GHG emissions for project due to project activities	tCO_2e	c	Annual	Calculated from farmer records
N/A	Field Name	Field Serial Number		o	Annual	Farmer records; NMQuanTool input
N/A	State	State in which field is located		o	Annual	Farmer records; NMQuanTool selection
N/A	County	County in which field is located		o	Annual	Farmer records; NMQuanTool selection
N/A	Crop	Eligible crop cultivated on field		o	Annual	Farmer records; NMQuanTool selection

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
N/A Equation 5.31	Field Acres A_f	Size of field	acres	o	Annual	Farmer records; NMQuanTool input
N/A	Irrigated	No – non-irrigated field; Yes- irrigated field		o	Annual	Farmer records; NMQuanTool selection
N/A	Enhanced Efficiency Fertilizer	None – no EEF used on field; Slow Release – Slow release fertilizer used on field; Nitrification Inhibitor – nitrification inhibitor used on field		o	Annual	Farmer records; NMQuanTool selection
N/A	Conversion to Short-Term No Till	No – maintain till or have practiced no till in the long-term (i.e., ≥ 10 years) Yes – switch from till to no-till in the short-term (i.e., < 10 years)		o	Annual	Farmer records; NMQuanTool selection
		Year started practicing no till				
		# of years practicing no till				
Equation 5.2	$NR_{\Delta P,S,f}$	Percentage synthetic N rate reduction from baseline to project on field *f*		c, o	Annual	Calculated from Farmer records; NMQuanTool input

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.4 Equation 5.5	$NR_{B,S,f,t}$	Annual baseline N rate of total synthetic fertilizer for field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Once	Farmer records
Equation 5.5	$NR_{B,S,f,t}$	Baseline annual N rate of total synthetic fertilizer for field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Annual	Farmer records
Equation 5.5 Equation 5.6	$NR_{B,DS,j,f}$	N rate of dry synthetic, *DS*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Annual	Farmer records
Equation 5.5 Equation 5.7	$NR_{B,LS,j,f}$	N rate of liquid synthetic, *LS*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Annual	Farmer records
Equation 5.7	$VF_{B,LS,j,f,t}$	Volume of liquid synthetic N-containing fertilizer *j* applied to field *f* per acre in baseline *B* in year *t*	gallon/ac	c, o	Annual	Farmer records
Equation 5.7	$MF_{B,LS,j,t}$	Mass of liquid synthetic fertilizer *j* per gallon of fertilizer in baseline *B* in year *t*	lb/gallon	c, o	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.7	$NC_{B,LS,j,t}$	N concentration of liquid synthetic fertilizer *j* in baseline *B* in year *t*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)
Equation 5.8 Equation 5.9	$NR_{B,O,f,t}$	Annual baseline N rate of total organic fertilizer for field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Once	Farmer records
Equation 5.9 Equation 5.10	$NR_{B,SO,j,f,t}$	N rate of solid organic, *SO*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Annual	Farmer records
Equation 5.9 Equation 5.11	$NR_{B,LO,j,f,t}$	N rate of liquid organic, *LO*, fertilizer type *j* on field *f* in year *t* of the baseline look-back period	lb/ac	c, o	Annual	Farmer records
Equation 5.10	$MF_{B,SO,j,f,t}$	Mass of solid organic N-containing fertilizer *j* applied to field *f* per acre in baseline year *t*	lb/ac	o, m	Annual	Farmer records
Equation 5.10	$NC_{B,SO,j,t}$	N concentration of solid organic fertilizer *j* in baseline year *t*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.11	$VF_{B,LO,j,f,t}$	Volume of liquid organic N-containing fertilizer *j* applied to field *f* per acre in baseline year *t*	gallon/ac	o, m	Annual	Farmer records
Equation 5.11	$MF_{B,LO,j,f,t}$	Mass of liquid organic N-containing fertilizer *j* applied to field *f* in baseline *B* in year *t*	lb/gallon	o, m	Annual	Farmer records
Equation 5.11	$NC_{B,LO,j,t}$	Nitrogen concentration of liquid organic fertilizer *j* in baseline year *t*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)
Equation 5.12 Equation 5.13	$NR_{P,DS,j,f}$	N rate of dry synthetic fertilizer type *j* on field *f*	lb/ac	c, o	Annual	Farmer records
Equation 5.12 Equation 5.14	$NR_{P,LS,j,f}$	N rate of liquid synthetic fertilizer *j* for field *f* in project	lb/ac	c	Annual	Farmer records
Equation 5.12 Equation 5.15	$NR_{\delta S,f}$	Change in synthetic N rate on field *f* between baseline and previous cultivation year	lb/ac	c,o	Annual	Farmer records
Equation 5.12 Equation 5.18	$NR_{ps,f}$	Increase in synthetic N rate due to production shifting, *ps*, outside of the project boundary for field *f*	lb/ac	c,o	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.13	$MF_{P,DS,j,f}$	Mass of dry synthetic N-containing fertilizer *j* applied to field *f*	lb/ac	c, o	Annual	Farmer records
Equation 5.13	$NC_{P,DS,j}$	N concentration of dry synthetic fertilizer *j*		r	Annual	Farmer records
Equation 5.14	$VF_{P,LS,j,f}$	Volume of liquid synthetic N-containing fertilizer *j* applied to field *f* per acre in project *P*	gallon/ac	o, m	Annual	Farmer records
Equation 5.14	$MF_{P,LS,j}$	Mass of liquid synthetic fertilizer *j* per gallon of fertilizer in project *P*	lb/gallon	o, m	Annual	Farmer records
Equation 5.14	$NC_{P,LS,j}$	Nitrogen concentration of liquid synthetic fertilizer *j* in project *P*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)
Equation 5.15 Equation 5.16	$NR_{pcy,S,f}$	N rate of total synthetic N fertilizer for field *f* from a previous cultivation year, *pcy*, for which CRTs were not earned	lb/ac	c	Annual	Farmer records
Equation 5.16	$NR_{pcy,DS,j,f}$	N rate of dry synthetic fertilizer type *j* on field *f*	lb/ac	c	Annual	Farmer records
Equation 5.16	$NR_{pcy,LS,j,f}$	N rate of liquid synthetic fertilizer type *j* on field *f*	lb/ac	c	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.17 Equation 5.18	y_norm_t; y_norm_{t0}	Normalized yield for each year *t* in the baseline look-back period and for the current cultivation year t_0	yield/ac	r, o	Annual	Farmer records; USDA NASS statistics
Equation 5.17	$Y_{P,f,t}$	Yield of field *f* in project *P* in year *t*	yield/ac	r, o	Annual	Farmer records; Found in Nitrogen Management Protocol Eligibility Lookup Tool; See Section 5.1.3.2
Equation 5.17	$Y_{Co,t}$; $Y_{Co,t0}$	County, *Co*, average yield in year *t* in the baseline look-back period and in the current cultivation year t_0 (based on USDA NASS data)	yield/ac	r	Annual	USDA NASS statistics
N/A	s	Standard deviation of the y_norm_t distribution	yield/ac	c	Annual	Farmer records; See Section 5.1.3.2
N/A	$y_norm_{t,avg}$	Mean of the y_norm_t distribution	yield/ac	c	Annual	Farmer records; See Section 5.1.3.2
Equation 5.18	y_min	Minimum yield threshold below which normalized yields are significantly smaller than the historical average for field *f*	yield/ac	c	Annual	

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.18	$NR_{ps,f}$	Increase in synthetic N rate due to production shifting, *ps*, outside of the project boundary for field *f*	lb/ac	c	Annual	
Equation 5.19 Equation 5.20 Equation 5.21	$N_2O_{O,Dir,f}$	Direct N_2O emissions from increased organic N applied to field *f*	tCO_2e/ac	c	Annual	Farmer records
Equation 5.19 Equation 5.22	$N_2O_{O,LVRO,f}$	N_2O emissions from leaching, volatilization, and runoff from increased organic N applied field *f*	tCO_2e/ac	c	Annual	Farmer records
Equation 5.20	EF_{NCR}	Adjusted MSU-EPRI Tier 2 emission factor for corn cropping systems in the North Central Region		r, c	Annual	Default values; Farmer records
Equation 5.20 Equation 5.21 Equation 5.22 Equation 5.23 Equation 5.24 Equation 5.27	$NR_{\Delta O,f}$	Increase in organic N rate on field *f*	lb/ac	o	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.22	$Frac_{LEACH}$	Fraction of organic N inputs that is lost through leaching and runoff		r	Annual	Box 5.1 and Appendix D and available per reporting year on Reserve website
Equation 5.24 Equation 5.25	$NR_{P,SO,j,f}$	N rate of solid organic, *SO*, fertilizer type *j* on field *f*	lb/ac	c, o	Annual	Farmer records
Equation 5.24 Equation 5.26	$NR_{P,LO,j,f}$	N rate of liquid organic fertilizer *j* on field *f* in project *P*	lb/ac	o, m	Annual	Farmer records
Equation 5.24	$NR_{\delta O,f}$	Increase in organic N rate between baseline and previous cultivation year for which CRTs were not earned, if applicable	lb/ac	c, o	Annual	Farmer records
Equation 5.25	$MF_{P,SO,j,f}$	Mass of solid organic N-containing fertilizer *j* applied to field *f* per acre in project *P*	lb/ac	o, m	Annual	Farmer records
Equation 5.25	$NC_{P,SO,j}$	N concentration of solid organic fertilizer *j* in project *P*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)
Equation 5.26	$VF_{P,LO,j,f}$	Volume of liquid organic N-containing fertilizer *j* applied to field *f*	gallon/ac	o, m	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.26	$MF_{P,LO,j,f}$	Mass of liquid organic N-containing fertilizer *j* applied to field *f*	lb/gallon	o, m	Annual	Farmer records
Equation 5.26	$NC_{P,LO,j}$	Nitrogen concentration of liquid organic fertilizer *j*		o, m, r	Annual (unless unchanged)	Farmer records, fertilizer N-content label or laboratory tests preferable (default reference data also included in Appendix E)
Equation 5.27 Equation 5.28	$NR_{pcy,O,f}$	N rate of total organic fertilizer for field *f* from previous cultivation year in which CRTs were not earned	lb/ac	c, o	Annual	Farmer records
Equation 5.28	$NR_{pcy,SO,j,f}$	N rate of solid organic fertilizer type *j* on field *f* in previous cultivation year *pcy*	lb/ac	c, o	Annual	Farmer records
Equation 5.28	$NR_{pcy,LO,j,f}$	N rate of liquid organic fertilizer type *j* on field *f* in previous cultivation year *pcy*	lb/ac	c, o	Annual	Farmer records
Equation 5.29 Equation 5.30	$SE_{EL,f}$	Net secondary effect GHG emissions from increased electricity use in the project cultivation year relative to baseline look-back period for field *f*	tCO_2e	c	Annual	Farmer records

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.29 Equation 5.31 Equation 5.32	$SE_{FF,f}$	Net secondary effect GHG emissions from increased fossil fuel consumption in the project cultivation year relative to the baseline look-back period for field *f*	tCO_2e	c	Annual	Farmer records
Equation 5.30	QE_f	Total increase in electricity consumed during the project cultivation year relative to the baseline look-back period	kWh	o	Annual	Farmer records
Equation 5.30	$EF_{EL,f}$	Carbon emission factor for electricity used	kg CO_2e/kWh	r	Annual	From the most recent U.S. EPA eGRID emission factor publication. Projects shall use the annual total output emission rates for the subregion where the project is located
Equation 5.31	$EF_{HP\text{-}hr,P,i,f}$	Emission factor for project operation *i* on field *f*	g CO_2e/HP-hr	r	Annual	Default value is 1311 for gasoline-fueled operations and 904 for diesel-fueled operations
Equation 5.31	$HP_{P,i,f}$	Horsepower requirement for project operation *i* on field *f*	HP	o, r	Annual	

Equation Reference	Parameter	Description	Data Unit	Calculated(c) Measured (m) Reference(r) Operating Records (o)	Measurement Frequency	Comment
Equation 5.31	$t_{P,i,f}$	Time required to perform project operation *i* on field *f*	hr/field	c, o	Annual	Farmer records or calculated
Equation 5.31	$EF_{HP\text{-}hr,B,k,f}$	Default emission factor for baseline operation *k* on field *f*	g CO_2e/HP-hr	r	Annual	Default value is 1311 for gasoline-fueled operations and 904 for diesel-fueled operations
Equation 5.31	$HP_{B,k,f}$	Horsepower requirement for baseline operation *k* on field *f*	HP	o, r	Annual	
Equation 5.31	$t_{B,k,f}$	Time required to perform baseline operation *k* on field *f*	hr/field	c, o	Annual	Farmer records or optional method
Equation 5.32	$FF_{PR,j}$	Total change in fossil fuel consumption for field *f* during the reporting period, by fuel type *j*	gallon	o	Annual	
Equation 5.32	$EF_{FF,j}$	Fuel-specific emission factor	kg CO_2/gallon	r	Annual	Default value is 17.4 for gasoline and 13.7 for diesel

Table 6.2. Additional Field Management Data

Description	Calculated (c) Measured (m) Referenced (r) Operating Records (o)	Measurement Frequency	Comment
Copy of NMQuanTool used to calculate emission reductions for reporting period	c	Each reporting period	
Copy of Nitrogen Management Protocol Eligibility Lookup Tool	c	Each reporting period	
Copy of Nitrogen Management Protocol Leakage Assessment Tool	c	Each reporting period	
GIS shapefile for each field	r	Each cultivation year	Delineate areas of fertilizer application for given cultivation year
Serial number for each field	r	Once	See Section 7.1.1
Start date for each field	r	Once	
Field size	o	Each cultivation year	
Crop grown (previous cultivation year, current cultivation year & planned for next cultivation year)	o	Each cultivation year	
Planting dates	o	Each cultivation year	
Harvesting dates	o	Each cultivation year	
Regulatory violations	o	Each cultivation year	All information regarding problems identified by relevant regulators (i.e., Notices of Violations, Consent Orders, OSHA citations, ECHO reports etc).
Evidence LRT met	o	Each cultivation year	Copies of air, water, and land use permits relevant to project activities
Evidence of emission reduction ownership			Contractual arrangements between project developer and Project Owner(s) (if applicable).
Fertilizer application method	o	Each cultivation year	Method and type of equipment used

Description	Calculated (c) Measured (m) Referenced (r) Operating Records (o)	Measurement Frequency	Comment
Nitrification inhibitor application dates	o	Each cultivation year	NIs must be applied with nitrogen applications that take place within 30 days prior to planting time[74]
Fertilizer purchases	o	Each cultivation year	Records / receipts & inventory
Agronomic guidance for project fields	o	Each cultivation year	Including any test results for analysis of soil, plant tissue, fertilizer N content etc.
Cover crop	o	Each cultivation year	
Cover crop – planting date	o	Each cultivation year	
Cover crop – termination date	o	Each cultivation year	
Baseline historical use of EEFs	o	Once	

[74] International Plant Nutrition Institute (IPNI), Nutrient Source Specifics one-page fact sheet: No. 26, *Nitrification Inhibitors*, accessed 6/13/2018, here: http://www.ipni.net/publication/nss.nsf/0/21B8084A341C98E085257E3C0077595B/$FILE/NSS-26%20Nitrification%20Inhibitors.pdf.

6.4 Supplemental Field Data Monitoring

In addition to the required field-level data and information specified in Section 6.3, project developers may choose to monitor and keep records of additional field data. Project developers are encouraged to monitor and retain supplemental records for *all* nitrogen management activities and *all* crops once a project is underway, including practices and crops not currently eligible for crediting at this time. Additional records may be of use in the event that quantification methodologies become available for currently ineligible practices and crops in future versions of this protocol. Further, while not required, supplemental data collected for eligible crop years may further assist project developers in successfully completing verification by providing verification bodies with additional information to corroborate project implementation activities and emission reductions from the project.

Supplemental monitoring parameters could include detailed records of dates and other aspects of management data collected and/or test results from the implementation of any enabling or adaptive management practices (e.g., variable rate technology and the results of supplemental pre-plant or pre-sidedress[75] soil nitrate tests, field-composite soil tests, and replicated strip trials).

[75] An application of fertilizer between the rows of growing crops is known as a “sidedress” application.

7 Reporting and Record Keeping

This section provides requirements and guidance on reporting rules and procedures. A priority of the Reserve is to facilitate consistent and transparent information disclosure among project developers.

7.1 Project Submittal Documentation

For each nitrogen management project, project developers must provide the following documentation to the Reserve in order to submit a project for listing on the Reserve.

- Project Submittal form
- Project Submittal *.csv file

The Project Submittal form will be available for individual projects and cooperatives. Both individual projects and cooperatives will also be required to submit a project submittal *.csv file, which shall include the initial "List of Enrolled Fields"; each field's serial number (according to Section 7.1.1 below), county and state, CEAP region; and the names of project developers for each field. The List of Enrolled Fields shall include all fields enrolled in the project or cooperatives at the time of submittal. Once verification commences (i.e., at the NOVA/COI stage), projects and cooperatives will be required to update the list to include all fields actually enrolled in the project or cooperative at that point (e.g., if fields have been added or removed from the project or cooperative between submittal and contracting a verifier [76]). The list must also be updated prior to each subsequent annual verification.

7.1.1 Determining Field Serial Numbers

The field serial number, which must be included in the List of Enrolled Fields, shall be determined by the following algorithm, with each element separated by a dash (-):

First State postal abbreviation, followed by the first letter of the County, followed by degrees of the most north-western point of the field (latitude then longitude, both reported to four decimal places), followed by the acreage of the field.[77] (Example: CA-B-39.6123-121.5332-76 would be a 76-acre field in Butte County, CA.)

7.2 Annual Reports and Documentation

Once a project has been listed on the Reserve, project developers must provide the following documentation to the Reserve in order to register a nitrogen management project with the Reserve. This documentation must be submitted to the Reserve within 12 months of the end of each reporting period in order for the Reserve to issue CRTs for quantified GHG reductions.

The following documentation is required of both individual projects and cooperatives:

- Signed Attestation of Regulatory Compliance form
- Signed Attestation of Voluntary Implementation form
- Signed Attestation of Title form

[76] See the Reserve Verification Program Manual at http://www.climateactionreserve.org/how/program/program-manual/.

[77] Because all fields will be located in the United States, the latitude will always be positive (i.e., degrees north of the equator), and longitude will always be negative (i.e., degrees west of the Prime Meridian). Therefore, in the example serial number, the field in Butte County California is at *+39.6123º latitude, and -121.5332º longitude.*

- Project Monitoring Reports (as outlined in Sections 7.2.1)
- Verification Report
- Verification Statement

With the exception of the Project Monitoring Reports, outlined in Section 7.2.1, all of the above project documentation will be available to the public via the Reserve's online registry. Further disclosure (e.g., of the Project Monitoring Reports) and other documentation may be made available on a voluntary basis through the Reserve, at the request of the project developer.

7.2.1 Project Monitoring Report

For each cultivation year, for each *field* within a project, the following information must be included in an annual Project Monitoring Report (PMR) that will be submitted to the Reserve as a *.csv file:

- All the data set out in Section 6.3
- Whether the field had previously been enrolled in a different nitrogen management project
    - If so, include the name of the project, dates of enrollment, and a brief description of the circumstances for leaving the previous project
- Whether the field includes land classified as HEL or wetlands
- The field's emission reduction calculation results for the current verified cultivation year *OR* a statement indicating that the field is in an ineligible crop year or CRTs are not being pursued for the given cultivation year[78]
- Total project ERs

7.2.2 Cooperative Monitoring Report

Projects taking part in a cooperative may utilize a common Cooperative Monitoring Report (CMR) template, with information common to all projects in the cooperative, but each project must submit their own PMR, with sufficient information necessary to ensure verification of all Nitrogen Management Protocol requirements for that project. If a project had previously been enrolled in a different cooperative, the name of the cooperative, dates of enrollment, and a brief description of the circumstances for leaving the previous cooperative must be included in the CMR for the applicable project.

7.3 Record Keeping

For purposes of independent verification and historical documentation, project developers are required to keep all information outlined in this protocol for a period of fifteen years after the information is generated or credits are issued utilizing such information (whichever is longer). This information will not be publicly available, but may be requested by the verifier or the Reserve.

7.3.1 Record Keeping for Projects

The project developer should retain the following records and documentation, as well as documentation to substantiate the information in the annual PMR and all field-level data and calculations. These records include:

- All data set out in Section 6.3

[78] Note that a project must report continuously (e.g., submit a project report annually), for all enrolled fields, even if CRTs are not being claimed for any given field in a given cultivation year.

- Copies of any USDA NRCS determinations and/or documentation of NRCS approval of conservation systems, if field includes wetlands or HEL land, respectively
- Executed Attestation of Title, Attestation of Regulatory Compliance, and Attestation of Voluntary Implementation forms
- Records demonstrating any material change (or lack thereof) in equipment type or usage for crop cultivation, fertilizer application, and/or irrigation (e.g., purchase or lease records for equipment, field-level fossil fuel use records, manufacturer's HP specifications, hours spent on N application)
- Results of annual emission reduction calculations
- Initial and annual verification records and results
- Time-stamped digital photographs of fields and fertilizer management activities (where available)
- As-applied maps

7.4 Project Reporting Period and Verification Cycle

Project emission reductions must be quantified and verified on an annual basis. As detailed in Section 3.3, the reporting period is the length of time over which GHG emission reductions are quantified and reported to the Reserve. Project developers must report GHG reductions resulting from project activities during each reporting period.

Both reporting periods and cultivation years must be contiguous; there can be no time gaps in reporting during the crediting period of a project or a cooperative once the initial reporting period has commenced.[79] If the crop rotation on the project field includes ineligible crops (e.g., soy in a corn/soy rotation), the project field must report continuously on the field's management practices, even though the project field shall only receive credit for project activities implemented on eligible crop fields. Similarly, if CRTs are not being sought in any given cultivation year for eligible crops, reporting must continue.

The "verification period" is the length of time over which GHG emission reductions from project activities are verified. To provide flexibility and help manage verification costs associated with nitrogen management projects, there are four verification options to choose from after a project's initial verification and registration. Regardless of the option selected, project developers must report GHG reductions resulting from project activities during each reporting period. Under this protocol, a verification period may cover multiple reporting periods (see Section 7.4.1). The end date of any verification period must correspond to the end date of a reporting period.

A project developer may choose to utilize one option for the duration of a project's crediting period, or may choose different options at different points during a single crediting period. Regardless of the option selected, reporting periods must be contiguous; there may be no time gaps in reporting during the crediting period of a project once the initial reporting period has commenced.

7.4.1 Additional Reporting and Verification Options for Projects

For individual projects, there are four verification options to choose from, which provide the project developer more flexibility and help manage verification costs associated with nitrogen management projects. The project developer may choose two options for the initial reporting

[79] An project can willingly forfeit CRTs for an entire cultivation year in accordance with the zero-credit reporting period policy in Section 3.3.3 of the Reserve Program Manual.

period and an additional two options after a project has completed its initial verification and has been issued credits.

A project developer may choose to use one option for the duration of a project's crediting period. Project developers must continue reporting during ineligible crop years (see Section 6.3 for requirements). Ineligible crop years do not require verification, and as such, do not count against the number of months included in a given verification period (see options below). Verifiers shall review N rate records for any interim ineligible year(s) as a component of verifying eligibility in the subsequent eligible crop year (see Section 3.5.1.1).

If a field joins a project, that field will immediately be subject to the verification schedule of the project moving forward (e.g., for the first reporting period that field is enrolled in the new project). If a field or fields exits a project to become a separate project, that new project is subject to the reporting and verification requirements of an initial reporting and verification period. In other words, that new project's first verification may not take advantage of Options 2 or 3, below.

7.4.1.1 Initial Reporting and Verification Period

The reporting period for projects undergoing their initial verification and registration cannot exceed two complete eligible crop cultivation years (with a maximum of one year in between where no CRTs are being sought). Once a project is registered and has had at least one complete reporting period of emission reductions verified, the project developer may choose one of the verification options below.

7.4.1.2 Option 1: Verification Period Equaling One Reporting Period

Under this option, the verification period may not exceed one reporting period, which may be slightly greater or less than 365 days. Verification with a site visit is required for CRT issuance.

7.4.1.3 Option 2: Verification Period Equaling Two Reporting Periods

Under this option, the verification period cannot exceed two reporting periods and the PMP and PMR must be submitted to the Reserve for each reporting period. The PMP and PMR must be submitted for projects that choose Option 2 in order to meet the annual documentation requirement of the Reserve program. They are meant to provide the Reserve with information and documentation on project operations and performance. They also demonstrate how the project monitoring plan was met over the course of the first half of the verification period. They are submitted via the Reserve online registry, but are not publicly available documents. The monitoring plan and report shall be submitted within 30 days of the end of the reporting period. In the case of a multi-crop rotation, a 24-month verification period that consists of two non-consecutive eligible crop years is allowable, with no more than one interim ineligible crop year (e.g., verification could cover 24 months of data within a 36-month timeframe).

Under this option, CRTs may be issued upon successful completion of a site visit verification for GHG reductions achieved over a maximum of 24 months. CRTs will not be issued based on the Reserve's review of PMPS or PMRs. Project developers may choose to have a verification period shorter than 24 months.

8 Verification Guidance

This section provides verification bodies with guidance on verifying GHG emission reductions associated with the project activity. This verification guidance supplements the Reserve's Verification Program Manual and describes verification activities specifically related to nitrogen management projects.

Verification bodies trained to verify nitrogen management projects must be familiar with the following documents:

- Climate Action Reserve Program Manual
- Climate Action Reserve Verification Program Manual
- Climate Action Reserve Nitrogen Management Protocol

The Reserve Program Manual, Verification Program Manual, and project protocols are designed to be compatible with each other and are available on the Reserve's website at http://www.climateactionreserve.org.

Only ANSI-accredited verification bodies with lead verifiers trained by the Reserve for this project type are eligible to verify nitrogen management project reports. Verification bodies approved under other project protocol types are not permitted to verify nitrogen management projects.[80]

In addition, each verification team must include an agronomist or crop advisor with at least 5 years' experience. The agronomist or crop advisor will provide additional support and expertise with interpreting information, assessing field conditions, reviewing, and interviewing project developers and any relevant staff onsite.

8.1 Preparing for Verification

The project developer is responsible for coordinating all aspects of the verification process, coordinating with the verification body, Project Owners, Field Managers, and the Reserve, and submitting all necessary documentation to the verification body and the Reserve.

The project developer is responsible for selecting a single verification body for the project for each reporting period. The same verification body may be used up to six consecutive years (the number of consecutive years allowed, according to the Reserve Verification Program Manual[81]). Verification bodies, including the agronomist or crop advisor, must pass a conflict of interest (COI) review against the project developer, and all Project Owners. Consequently, the submitted List of Enrolled Fields in a project and the submitted List of Enrolled Projects in a cooperative must be updated by the project developer prior to the COI review.

Each year, project developers must make the PMPs and PMRs available to the verification body. These documents must meet the requirements in Sections 6 and 7. In all cases, the above documentation should be made available to the verification body after the NOVA/COI process is complete. Project Owners must sign all attestations and may assist the project developer in other aspects of project development, but ultimate responsibility for project

[80] Information about verification body accreditation and Reserve project verification training can be found on the Reserve website at http://www.climateactionreserve.org/how/verification/.
[81] Available at http://www.climateactionreserve.org/how/verification/verification-program-manual/.

monitoring reports and verification compliance is assigned to the project developer. For all projects, a field is considered verified if it is in the pool of fields under consideration for site visits and/or desktop verifications, even if not selected for either a site visit or desktop verification (see Section 8.2 for details on sampling for verification).

As a preliminary step in preparing for verification, the project developers may choose to exclude fields from the pool of fields that may be selected for verification activities. Project developers must report to the verification body all instances of field exclusion. The excluded fields shall be removed from the acreage totals and from field numbers used to determine field eligibility and verification sampling methodologies (in Section 8.3) and are therefore not considered verified.

8.2 Verification Sampling and Schedule for Projects and Cooperatives

Guidelines for verification sampling and verification schedules are the same for individual projects and cooperatives. This approach allows a consistent application of verification requirements, regardless of size or number of fields in the project, or whether the projects are combined into a cooperative or not.

There are three levels of verification that cooperative or projects go through each reporting period. At time of verification, sampling is made at the level of a Field Manager. Field Managers are those entities with management control over agricultural management activities for one or more fields within the project area.

Every reporting period a subset of Field Managers in a given project or cooperative (a minimum of ½ of the square root of all Field Managers in the project or cooperative) will be subjected to a site visit verification. Every reporting period a subset of Field Managers (a minimum of ½ of the square root of all Field Managers in the project, not being those Field Managers selected for a site visit verification for that given reporting period) will be chosen for a desktop verification. Note that for all projects a minimum of 2.5% of all Field Managers in the project will be subjected to a verification in every reporting period.

The verifier shall consider which Field Managers have not been selected in the past for either a site visit or desktop verification, meaning those Field Managers who have not yet been selected shall have a higher probability of selection with each subsequent verification event, but all Field Managers will have a nonzero probability of selection during any given round of verification services. In all cases, the verification schedule shall be established by the verification body using a combination of risk-based and random sampling, according to the verification schedule and sampling methodologies outlined in Section 8.2.1. The verifier shall undertake a risk assessment to set the number of fields per Field manager to be visited.

These sampling methodologies establish a minimum, and possible range, of site visit frequencies, as well as guidance on circumstances in which the verification body is encouraged to add fields beyond the minimum number of fields required for site visit and/or desktop verification. The verifier may use professional judgment to determine the number of additional fields and method for selecting fields if a risk-based review indicates a high probability of non-compliance. The verification minimum sampling requirements are mandatory regardless of the mix of entry dates represented by the group of fields in the project (and by the group of growers in the grouped project).

The initial site visit verification schedule for a given year shall be established after the completion of the NOVA/COI process. The schedule should be established as soon as possible after the commencement of verification activities, at a minimum, so as to include both risk-based and random sampling for the selection of site visited fields. This is meant to allow for the project developer and verification body to work together to develop a cost effective and efficient site visit schedule. Specifically, once the sample fields designated for a site visit have been determined, the verification body shall document all fields selected for planned site visit verification and provide a list of fields receiving a visit to the project developer and the Reserve[82]. The project developer shall be responsible for all site visit planning. Following this notification, the project developer shall supply the verification body with all the required documentation to demonstrate field-level conformance to the protocol. When a verification body determines that additional sampling is necessary due to suspected non-compliance, however, a similar level of advance notice may not be possible.

Though significant advance notice of a field's selection for a site visit is required, project developers shall not be given advanced notice of which fields' data will be subject to desktop verification in a given year. A field shall be prepared for desktop verification during every verification period, so long as the field's Monitoring Plan is implemented and up to date, the Field Report submitted to the project developer, and all recordkeeping requirements of this protocol are followed.

Regardless of the size of a project or cooperative, if the project contains any fields that did not pass site visit verification the year before and wish to re-enter the project, those fields must have a full verification with site visit for the subsequent reporting period. These fields must be site visited in addition to the verification sampling methodology and requirements outlined below in Section 8.2.1. In all cases, when determining the sample size for site visits and desktop verifications, the verification body shall round up to the nearest whole number. The documentation requirements for performing a site visit verification and desktop verification are the same. A desktop verification is equivalent to a full verification, without the requirement to visit the site. A verification body has the discretion to visit any site in any verification period if the verification body determines that the risks for that field warrant a site visit.

8.2.1 Verification Site Visit Requirements

This protocol requires verifiers use a combination of risk-based and random sampling to select Field Managers for site visits. The sampling methodology for projects or cooperatives shall take place in three steps:

1. Site visit verifications selected via field-manager risk assessment: Verifiers shall select Field Managers for site visits first through a risk-based approach. The verifiers' risk evaluation may presume higher risk exists on Field Managers with larger fields or fields that contribute more to the emission reductions, fields that implement a novel practice change, fields that have recently implemented a new practice change from prior reporting periods, or have exhibited challenges during past verifications, etc. Field Managers representing a minimum of one-half the square root of the total number of Field Managers the project must be visited. If selection of higher risk Field Managers does not meet this threshold, verifiers proceed to step 2 to select additional fields via random sampling.

[82] If the Reserve has indicated staff will be performing oversight on the verification activities, this list must be provided as soon as it is available. If Reserve staff are not performing oversight on the verification activities, this list must be provided with the submittal of the verification report.

2. Additional site visit verifications selected via random sampling: Once the verifier has selected Field Managers for site visits through the risk-based approach, additional Field Managers shall be selected at random. The verification body shall randomly select additional Field Managers until the number of site visits meets a minimum threshold of Field Managers representing at least one half the square root of the total number of Field Managers in the project (or a higher number chosen by the verifier, if appropriate, based on higher project or cooperative-level risk – see further description below).

3. Desktop verifications selected via random sampling: Verification bodies shall randomly select a sample of Field Managers to undergo a desktop verification equal to the square root of the total number of Field Managers in the project (rounded up to the next whole number). Field Managers selected for site visit verifications based on steps 1 and 2 shall not be eligible for selection for desktop verification during that year.

The verification body shall be allowed to increase the number of site visits performed above the minimums described above based on levels of perceived project-level or cooperative-level risk identified during verification. Specific risks identified during the verification could include Field Managers with fields generating large proportions of the emission reductions of the project, lack of historical records, and/or demonstrated poor communication of project activities and implementation between Field Managers and project developers. If the verifiers and project developer disagree on the number of Field Managers or fields to be visited, they should contact the Reserve. Each verification report must contain a description of the sampling methodology, number of fields visited, and justification for higher levels of sampling (e.g., due to higher levels of risk). Once field managers have been selected for site visits, verifiers will use their discretion to determine the number of fields under management by the field managers that they will visit or study via other means.

Once field managers (and the fields they manage) have been selected for site visits, verifiers may seek Reserve approval to forgo a actual site visit, if sufficient proxy data exists such that a verifier considers it unnecessary for a member of the verification team to physically visit the relevant field(s) themselves. Examples of proxy data that may satisfy a verifier in this regard include where the project developer has engaged an independent third-party with agronomic expertise (such as local NRCS staff and/or local University extension service staff) to instead undertake a site visit. A verifier might have a third-party complete a signed statement attesting that the things a verifier considered highest risk and for which a site visit would be most useful, have been confirmed by that third-party. A verifier may propose to undertake a remote site visit, whereby a party walks the ground and provides live video feed to the verifier. In assessing a request for a remote site visit, the Reserve will take into consideration guidance prepared by the ANSI National Accreditation Board (ANAB) on the use of remote site visit verifications, as well as any guidance forthcoming on the use of remote site visit verifications prepared by any other offset registry or program, and any guidance the Reserve itself develops for such activities.

All parties should be on notice that Reserve approval will be needed for each field managers for which the verifier proposes to not physically visit their field themselves, and that granting of such approval is by no means guaranteed, and does not serve as precedent for future reporting periods. Verifiers should seek Reserve approval as early as possible in order to determine if such approval is likely in any given circumstances.

8.3 Standard of Verification

The Reserve's standard of verification for nitrogen management projects is the Nitrogen Management Protocol (this document) and the Reserve Program Manual and Verification Program Manual. To verify a nitrogen management project, verification bodies apply the guidance in the Verification Program Manual and this section of the protocol to the standards described in Sections 2 through 7 of this protocol. Sections 2 through 7 provide project definitions, eligibility rules, methods to calculate emission reductions, performance monitoring instructions and requirements, and procedures for reporting project information to the Reserve.

8.4 Monitoring Plan

The PMP serves as the basis for verification bodies to confirm that the monitoring and reporting requirements in Section 6 and Section 7 have been met, and that consistent, rigorous monitoring and recordkeeping is ongoing by the project and/or cooperative developer and all enrolled fields. Verification bodies shall confirm that the PMP or CMP cover all aspects of monitoring and reporting contained in this protocol and specifies how data for all relevant parameters in Section 6.3 are collected and recorded.

8.4.1 Annual Reports

The project developer must annually submit field data for projects to the Reserve. The PMR will consist of a *.csv file and attachments, as described in Section 7.2.1. Verification bodies must review the PMR to confirm project information and data collected according to the PMP. The project developer or cooperative developer must annually submit a PMR or CMR to the Reserve. The report will consist of a *.csv file and attachments. Verification bodies must review the PMR or CMR to confirm project information and data collected according to the PMP or CMP. The verification body will need to review field data during desktop verifications of randomly selected fields in a project. The field data must be made available to the verification body in order to confirm field-level information collected according to the PMP or CMP.

8.5 Verifying Eligibility at the Field Level

Verification bodies must affirm each project field's eligibility during site visit and/or desktop verifications according to the rules described in this protocol. The table below outlines the eligibility criteria for each project field. This table does not present all criteria for determining eligibility comprehensively; verification bodies must also look to Section 3 and the verification items listed in Table 8.3.

Table 8.1. Summary of Field-Level Eligibility Criteria for a Nitrogen Management Project

Eligibility Rule	Eligibility Criteria	Frequency of Rule Application
Start Date	Each field will have a unique start date. One or more fields will be chosen to trigger the project start date. The start date for each field / project will be the first day of the cultivation year, which begins immediately after completion of the previous crop's harvest, in which the approved project activity is adopted at the field. Projects must be submitted for listing before the end of the cultivation year representing the project start date. All subsequent fields must be submitted for listing before the end of the second cultivation year following the field's start date.	Every verification verifier must confirm for each new field
Location and Crop Type	The field is located in an approved area of the U.S. and U.S. tribal areas and contains a corresponding eligible crop, according to Section 2.2 and Section 3.1.	Every verification
Performance Standard	The field passes the performance standard test for its respective county-crop combination according to Section 3.5.1.1. Fields previously in an ineligible year must also demonstrate that N loading has not occurred since the last verification to pass the performance standard test.	Every verification
Legal Requirement Test	Signed Attestation of Voluntary Implementation form and monitoring procedures for ascertaining and demonstrating that the project passes the legal requirement test.	Every verification
Legal Title to CRTs	Signed Attestation of Title and monitoring procedures for ascertaining and demonstrating legal title to the CRTs.	Every verification
Regulatory Compliance	Signed Attestation of Regulatory Compliance form and disclosure of all legal violations to verification body; project activities and project fields must not cause material violations of applicable laws. In particular, no violations to the Safe Drinking Water Act or Clean Water Act, due to agricultural discharges.	Every verification
HEL classification	If the project area includes land classified as HEL, that land must meet the Highly Erodible Land Conservation provisions to be eligible.	Once during first verification
Wetland classification	If the project area includes land classified as wetlands that land must meet the Wetlands Conservation provisions to be eligible.	Once during first verification

8.6 Core Verification Activities

The Nitrogen Management Protocol provides explicit requirements and guidance for quantifying the GHG reductions associated with the implementation of approved nitrogen management project activities on project fields. The Verification Program Manual describes the core verification activities that shall be performed by verification bodies for all project verifications. They are summarized below in the context of a nitrogen management project, but verification bodies must also follow the general guidance in the Verification Program Manual.

Verification is a risk assessment and data sampling effort designed to ensure that the risk of reporting error is assessed and addressed through appropriate sampling, testing, and review. The three core verification activities are:

1. Identifying emission sources, sinks, and reservoirs
2. Reviewing GHG management systems and estimation methodologies
3. Verifying emission reduction estimates

Identifying emission sources, sinks, and reservoirs for each field
The verification body reviews for completeness the sources, sinks, and reservoirs identified for a project, ensuring that all relevant secondary effect SSRs for each field are identified.

Reviewing GHG management systems and estimation methodologies at the field level
The verification body reviews and assesses the appropriateness of the methodologies and management systems that are used to gather data and calculate baseline and project emissions for each field.

Reviewing GHG management systems and estimation methodologies at the project level
The verification body reviews and assesses the appropriateness of the methodologies and management systems that the project uses to gather data and calculate baseline and project emissions on the project level.

Verifying emission reduction estimates at the field level
The verification body further investigates areas that have the greatest potential for material misstatements and confirms whether or not material misstatements have occurred for all fields undergoing verification. This involves site visits to a random sample of project fields, according to the sampling methodology outlined in Section **Error! Reference source not found.**, to ensure systems on the ground correspond to and are consistent with data provided to the verification body, combined with a random sample of desktop verifications of remaining project fields according to Section **Error! Reference source not found.**. In addition, the verification body recalculates a representative sample of the performance or emissions data from fields for comparison with data reported by the project developer in order to confirm calculations of GHG emission reductions.

Verifying emission reduction estimates at the project level
The verification body further investigates areas that have the greatest potential for material misstatements at the project level, including whether yield-loss statistical tests (Section 5.1.3.2) have been performed for the project.

8.7 Nitrogen Management Verification Items

The following tables provide lists of items that a verification body needs to address while verifying a nitrogen management project. The tables include references to the section in the

protocol where requirements are further specified. The table also identifies items for which a verification body is expected to apply professional judgment during the verification process. Verification bodies are expected to use their professional judgment to confirm that protocol requirements have been met in instances where the protocol does not provide (sufficiently) prescriptive guidance. Supplemental monitoring data and records (noted in Section 6.4) are not included in the tables below. However, any supplemental information made available to the verifier by the project developer may be used to raise the verifier's level of assurance that the project activity occurred.

For more information on the Reserve's verification process and professional judgment, please see the Verification Program Manual.

Note: These tables shall not be viewed as a comprehensive list or plan for verification activities, but rather guidance on areas specific to nitrogen management projects that must be addressed during verification.

8.7.1 Project Eligibility and CRT Issuance

Table 8.2 lists the criteria for reasonable assurance with respect to eligibility and CRT issuance for nitrogen management projects. These requirements determine if the project is eligible to register with the Reserve and/or have CRTs issued for the reporting period. If any single requirement is not met on any given field, then that field will be ineligible for issuance of CRTs.[83] Ineligibility of one or more fields may make the entire project ineligible or the GHG reductions from the reporting period may be ineligible for issuance of CRTs, as specified in Section 3.3.

Table 8.2. Eligibility Verification Items

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
2.2	Verify that all verified fields meet the definition of a nitrogen management project	No
2.2	Verify that all fields are comprised of eligible crop-region combinations	No
2.2.3	Verify that all verified fields meet the eligible project area definition	Yes
2.2.1.1	Verify that the total annual N rate decreased below baseline levels	No
2.3	Verify that all verified fields meet the definition of cultivation year	No
2.4	Verify that an appropriate indemnification and GHG reductions rights agreement or agreements have been executed	No
2.4	Verify the project and/or cooperative structure is appropriate	No
2.4	Verify ownership of the reductions by reviewing Attestation of Title, and contracts between Field Managers, and Project Owners	No
2.4	Verify that no fields within the project are simultaneously enrolled in another project	No
2.4	Verify that any fields previously enrolled in another project have followed the proper procedures to enter the new project and leave the old project	Yes

[83] This protocol allows for fields to be removed from a project for any given reporting period, due to ineligibility (or indeed voluntarily for unspecified reasons) and for such fields to be considered potentially eligible to return to the same project or any other project, for future reporting periods. The ability to bring such fields back into the same project, or any other project, may not be reflected in any future compliance nutrient management protocol.

Protocol Section	Eligibility Qualification Item	Apply Professional Judgment?
3.2	Verify accuracy of project start date for all verified fields based on operational records	Yes
3.4	Verify that each field is within the 10-year crediting period	No
3.5.1	Verify that each field meets the performance standard test	No, except for potential extreme weather impacts on yield
3.5.1.1	Verify that each field previously in a year for which CRTs are not being sought applied no more than the permissible N rate range over the cultivation year	Yes
3.5.2	Confirm execution of the Attestation of Voluntary Implementation form to support demonstration of eligibility under the legal requirement test	No
3.5.3	Verify that any ecosystem service payment or credit received for activities on a project field has been disclosed and is allowed to be stacked	No
3.6	Verify that the project activities at all verified fields comply with applicable laws, particularly water quality laws, by reviewing any instances of non-compliance provided by the project developer and performing a risk-based assessment to confirm the statements made by the project developer in the Attestation of Regulatory Compliance form	Yes
3.6	Verify whether the project is located on fields that are classified as Highly Erodible Land or wetlands. If HEL or wetlands are included, verify that the required conservation compliance standards are being met	No
5.1.3.1, 5.1.4.4.1	Verify increases in N rates during cultivation years where CRTs are not being sought are appropriately accounted for	No
6.1, 6.2	Verify that the project Monitoring Plan contains a mechanism for ascertaining and demonstrating that all fields pass the legal requirement test at all times	No
6.3	Verify that field-level and project-level monitoring meets the requirements of the protocol. If it does not, verify that a variance has been approved for monitoring variations	No

8.7.2 Quantification

Table 8.3 lists the items that verification bodies shall include in their risk assessment and re-calculation of the GHG emission reductions. These quantification items inform any determination as to whether there are material and/or immaterial misstatements in the project GHG emission reduction calculations. If there are material misstatements, the calculations must be revised before CRTs are issued.

Table 8.3. Quantification Verification Items

Protocol Section	Quantification Item	Apply Professional Judgment?
4	Verify that all SSRs in the GHG Assessment Boundary are accounted for	No

Protocol Section	Quantification Item	Apply Professional Judgment?
5.1	For each field, and the project as a whole, ensure that the emission reductions associated with reductions in synthetic N rates have been calculated correctly, using the NMQuanTool	No
5.1.3.1, 5.1.4.4.1	For each cultivation year for which CRTs are not being sought, ensure any increases in N rate are properly accounted for	No
5.1.3, 5.1.4.4	For each field, verify that the synthetic and organic N rate changes have been properly quantified	No
5.1.2, 5.1.3	For each field, verify that input parameters for both the baseline and the project are represented by the appropriate data and the calculations are accurate	Yes
5.2.2	For the project, verify that emissions from any increased consumption of fossil fuel and electricity are calculated correctly	Yes
5.1.3.2	For the project, verify that the emissions from crop production leakage are properly accounted for	No, except for potential extreme weather impacts on yield

8.7.3 Risk Assessment

Verification bodies will review the following items in Table 8.4 to guide and prioritize their assessment of data used in determining eligibility and quantifying GHG emission reductions.

Table 8.4. Risk Assessment Verification Items

Protocol Section	Item that Informs Risk Assessment	Apply Professional Judgment?
6, 7	Verify that all contractors and employees are qualified to perform the duties expected. Verify that there is internal oversight to assure the quality of the contractor's work	Yes
6.1, 6.2	Verify that the project has documented and implemented the Project Monitoring Plan and, where appropriate, the Cooperative Monitoring Plan	No
6.1, 6.2	Verify that the project monitoring plans are sufficiently rigorous to support the requirements of the protocol and proper operation of the project	Yes
6.3	Verify that appropriate monitoring data are measured or referenced accurately	No
6, 7, 8	Verify properly informed risk-based sampling for site visit selection	Yes
7.2	Verify that the Project Monitoring Report and any Cooperative Monitoring Report was uploaded to the Reserve software	No
7.2, 7.3	Verify that field data has been gathered and made available to project developers	No
7.3	Verify that all required records have been retained by the project developer	No

8.8 Successful and Unsuccessful Verifications

Successful verification of each field in the sample of fields selected for site visit and desktop verifications results in the crediting of all fields participating in the entire project, as calculated by the project developer according to the quantification methodology in Section 5.

Verification may uncover any number of material and immaterial errors at the field, project or cooperative level, and the extent to which an error was propagated through the project can affect whether a verification is determined to be "unsuccessful." A successful verification will result in the issuance of CRTs for the given field, project or cooperative, whereas any field receiving an "unsuccessful" verification will not be issued CRTs. A project receiving an "unsuccessful" verification for one or more fields, will still be issued CRTs for any fields that receive a "successful" verification.

8.8.1 Field-Level and Project-Level Errors

If material issues arise during verification of a participating field, verification bodies shall issue Corrective Action Requests, as needed. The project developer will need to independently address the issues and required corrective actions. These are described in the verification guidance of this protocol and the Reserve Verification Program Manual. If the error can be corrected at the field level and is the type of error that will not be propagated across an individual's fields or the entire project, then the error shall be corrected and the field verification shall be considered successful. Errors shall be considered immaterial at the field level if they result in a discrepancy that is less than 5 percent of the total emission reductions quantified for that field.

If verification of a field reveals material non-compliance with the protocol, and no corrective action is possible, that field shall receive a negative verification and no CRTs shall be issued for that field, effectively removing the field from the project for that year. When verification is unsuccessful for a participating field, the verification body must verify additional fields until the total number of successful verifications reaches the required number (as described in Section 8.2), starting with fields managed by the same Field Manager, as follows. If the Field Manager managing the unsuccessfully verified field also manages other fields enrolled in the project, the verification body shall site visit a minimum of two additional fields or 5 percent of the remaining unverified fields, whichever is larger, that are managed by that project developer or Field Manager. If the verification of the additional fields is also unsuccessful, no CRTs shall be issued for any of the fields managed by the Field Manager.

Deliberate non-compliance may result in disqualification of the Field Manager including all of their enrolled fields. Additionally, if the Field Manager failing verification and their negatively verified fields re-enter the project the following year, each of the fields that failed verification the previous year shall be required to undergo a site visit, in addition to the minimum sampling requirements in Section 8.2.

Whenever a Field Manager receives a negative verification for all of their enrolled fields, the verification body shall use their professional judgment and a risk-based assessment to determine whether sampling additional fields for site visit verification, beyond the minimum requirements of this protocol, is necessary to verify the entire project to a reasonable level of assurance.

8.8.1.1 Cumulative Field-Level Error of Sampled Fields

Total errors and/or non-compliance shall be determined for the sampled fields and the offset issuance for those fields corrected, as required, by the Verification Program Manual. Should the aggregated error and/or non-compliance rate for the sampled fields be less than 5 percent, CRT issuance for fields not subjected to site visit or desktop verification shall be equal to the amount reported by the project. However, if the aggregated percent error and/or non-compliance rate (i.e., the percentage of verified fields failing verification) for sampled fields is greater than 5 percent, CRT issuance for fields not subjected to site visit or desktop verification shall be reduced by the total amount of aggregated percent error or non-compliance rate.

8.8.2 Project-Level Errors

If verification reveals a potential systemic error, which may be propagated out to the project level (e.g., a qualitative error with regard to the input parameters or a quantitative error repeated in multiple field-level calculations), the verification body shall use their professional judgment to sample additional fields, as necessary, to determine whether the error is truly systemic. Systemic errors must be corrected at the project level.

8.9 Completing Verification

The Verification Program Manual provides detailed information and instructions for verification bodies to finalize the verification process. It describes completing a Verification Report, preparing a Verification Statement, submitting the necessary documents to the Reserve, and notifying the Reserve of the project's verified status.

9 Glossary of Terms

Accredited verifier	A verification firm approved by the Climate Action Reserve to provide verification services for project developers.
Additionality	Project activities that are above and beyond business-as-usual operation, exceed the baseline characterization, and are not mandated by regulation.
Anthropogenic emissions	GHG emissions resultant from human activity that are considered to be an unnatural component of the Carbon Cycle (i.e., fossil fuel destruction, deforestation, etc.).
Baseline look-back period	The baseline look-back period is defined as the three most recent cultivation years of that given crop on that given field, prior to the field's start date.
Biogenic CO_2 emissions	CO_2 emissions resulting from the destruction and/or aerobic decomposition of organic matter. Biogenic emissions are considered to be a natural part of the carbon cycle, as opposed to anthropogenic emissions.
Carbon dioxide (CO_2)	The most common of the six primary greenhouse gases, consisting of a single carbon atom and two oxygen atoms.
Conventional till	Tillage practice that includes one or more passes with tillage implements (e.g., moldboard plow, disk plow, chisel plow, etc.).
CO_2 equivalent (CO_2e)	The quantity of a given GHG multiplied by its total global warming potential. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
Cooperative	Two or more individual nitrogen management projects that report and verify jointly, under a structure known formally as a 'cooperative'. A cooperative may consist of projects involving multiple Project Owners.
Cooperative Developer	The entity that takes on the role of project developer for cooperatives. The Cooperative Developer manages submittals, reporting and verification for a cooperative. A Cooperative Developer must have a Project Developer account on the Reserve.
Cooperative participant	A Project Owner whose project is being managed as a part of a cooperative, with a separate Cooperative Developer.
Cover crop	Crop planted for seasonal vegetative cover during non-crop production periods in a primary crop rotation, that is not harvested and is instead returned to the soil.
Crediting period	The period of time during which a project can generate CRTs. In this protocol, defined as five eligible crop years, which may occur over a period of up to ten years. See Section 3.4 for further definition.
Cultivation year	The period starting immediately after harvest of one primary crop and ending after the next primary planted crop is harvested the following calendar year. See Section 2.3 for further definition.
Effective date	The date of adoption of Nitrogen Management Protocol Version 2.1 by the Reserve Board.
Eligible crop year	One complete cultivation year in which an eligible crop (see Section 2.2.2) is grown. Eligible crop years are not required to be consecutive.

Emission factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g., metric tons of carbon dioxide emitted per barrel of fossil fuel burned).
Enhanced efficiency fertilizer (EEF)	Fertilizer products that can reduce nutrient losses to the environment while increasing nutrient availability for the crop by either slowing the release of nutrients for uptake or altering the conversion of nutrients to other forms that may be less susceptible to losses. Nitrification inhibitors and slow release fertilizers are the two eligible EEFs in this protocol.
Field	A delineated contiguous cropland area, utilized to produce, or physically capable to produce, a single crop or rotation of crops, for which the basic management practices are all similar. See Section 2.2.3 for additional specifications.
Field Manager	Any entity that has the ability to control decision making on project fields, including farmers, their employees, or even entities that have legal ownership or control, such as landlords, state agencies etc. A Field Manager could include an individual, corporation, or other legally constituted entity, city, county, state agency, or combination thereof that has fee ownership and/or legal control of the land within the project area. Field Managers may or may not be directly involved in project development.
Fossil fuel	A fuel such as coal, oil, and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse gas (GHG)	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), or perfluorocarbons (PFCs).
GHG reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG sink	A physical unit or process that removes GHG from the atmosphere.
GHG source	A physical unit or process that releases GHG into the atmosphere.
Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2.
Highly erodible land (HEL)	Land that has an erodibility index of eight, as defined in Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2. Part 12.21 further outlines how HEL is identified and how the erodibility index is calculated. Must implement HEL Conservation provisions to be eligible. See Section 3.6 for details.
Indirect emissions	Reductions in GHG emissions that occur at a location other than where the reduction activity is implemented, and/or at sources not owned or controlled by project participants.
Landowner	The entity listed on the deed to the property as the landowner.
Methane (CH_4)	A potent GHG with a GWP of 25, consisting of a single carbon atom and four hydrogen atoms.
MMBtu	One million British thermal units.
Nitrification inhibitor	Substance that when applied in addition to the use of an ammonia (NH_3) or ammonium (NH_4^+) fertilizer, delay the conversion of NH_3 or NH_4^+ to nitrate

	(NO_3^-) (i.e., the nitrification process) by depressing the activity of *Nitrosomonas* bacteria, until the NO_3^- can be readily used by crops. Must be defined by AAPFCO as such and accepted for use by a state's fertilizer control agency or similar authority. Optional project activity. See Table 2.1.
Nitrogen Use Efficiency (NUE)	A measure of productivity per unit of N application typically defined as the proportion of all nitrogen inputs that are removed in harvested crop biomass.
Nitrous Oxide (N_2O)	A potent GHG with a GWP of 298, consisting of two nitrogen atoms and one oxygen atom.
No till	Tillage practice characterized by the use of seed drills and fertilizer applications with no additional tillage events or implements; surface residues are not incorporated into the soil and there is limited disturbance to the soil profile.
Primary crop	Defined as the main production crop grown on a field in a given year (e.g., corn is a primary crop and may be grown on its own or with a cover crop).
Project baseline	A "business as usual" GHG emission assessment against which GHG emission reductions from a specific GHG reduction activity are measured.
Project developer	The term '*project developer'* will be used throughout this document to refer to both the responsible management entity for each project, and, in the case of cooperatives, the entity responsible for managing the cooperative.
Project Owner	Any entity which holds rights to the CRTs from the project at the time of issuance.
Slow release fertilizer	Fertilizers that slow or control the release of soluble nitrogen (NH_4^+ and NO_3^-) to the soil compared to conventional fertilizers, extending N availability to the crop and improving the synchronization between crop uptake and N availability; encompasses controlled release fertilizers. Must be defined by AAPFCO as such and accepted for use by a state's fertilizer control agency or similar authority. Optional project activity. See Table 2.1.
Synthetic N rate reduction	Reduction in the annual synthetic nitrogen application rate (i.e., the amount applied per acre for the cultivation year of an eligible crop) compared to baseline levels, without going below N demand. Mandatory project activity. See Table 2.1.
Technical Service Provider (TSP)	Technical Service Providers are individuals or businesses that have technical expertise in conservation planning and design for a variety of conservation activities. TSPs may be hired by farmers, ranchers, private businesses, nonprofit organizations, or public agencies to provide these services on behalf of the NRCS. TSPs must be certified by NRCS.
Verification	The process used to ensure that a given participant's GHG emissions or emission reductions have met the minimum quality standard and complied with the Reserve's procedures and protocols for calculating and reporting GHG emissions and emission reductions.
Verification body	A Reserve-approved firm that is able to render a verification statement and provide verification services for operators subject to reporting under this protocol.
Wetland	Wetlands generally have a predominance of hydric soil and are inundated or saturated by surface or groundwater for various durations over the year. See Title 7 of the Code of Federal Regulations, Subpart A, Part 12.2 for the definition of wetlands. Must implement the Wetland Conservation provisions to be eligible. See Section 2.2.3 for details.

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Appendix A Nitrogen Management Review

The Climate Action Reserve (Reserve) has conducted a significant revision to its Nitrogen Management Protocol to expand applicability to additional practices, regions, and crops, while enhancing usability, simplifying quantification, and maintaining scientific accuracy.[84] Nitrogen Management Protocol Version 1.1 (V1.1) was limited to quantifying, monitoring, and verifying reductions in greenhouse gas (GHG) emissions, namely nitrous oxide (N_2O) emissions, from reductions in synthetic nitrogen application rate (N rate) on corn fields in the U.S. North Central Region (i.e., the Midwest). This appendix details the steps taken by the Reserve to prioritize the practices, crops, and regions for inclusion in the update to Nitrogen Management Protocol Versions 2.0 and 2.1 (V2.0 and V2.1).

A.1 Nitrogen Management Stakeholder Survey

As a first step, the Reserve developed and issued a survey in Fall 2016 to stakeholders for their recommendations on what future revisions and expansions (i.e., additional practices, crops, regions and quantification methodologies) for the Reserve to prioritize for possible inclusion in the update from V1.1 to V2.0/2.1. The specific nutrient management practice options given in the survey included N-rate reduction (for additional crops and regions than in the current version of the protocol), the 4Rs (Right Rate, Right Time, Right Source, Right Place), cover crops, manure management, the use of Enhanced Efficiency Fertilizers[85] (EEFs), and precision agriculture. Participants included members from the original Nitrogen Management Protocol Workgroup and Science Advisory Committee (SAC), project developers, aggregators, agricultural science professionals, and methodology developers. After publishing an assessment of the survey results,[86] the Reserve discussed the outcomes and our biggest takeaways in a public meeting in the start of 2017. These consisted of the following:

1. California needs to be a priority region for inclusion (based on number of recently completed studies and for any future consideration by California Air Resources Board (ARB)), in addition to other regions with large emissions reduction potential.
2. Maintain flexibility when prioritizing crops for inclusion, with a focus on the major field crops and California specialty crops, and incorporate multi-year crop rotations.
3. The 4Rs and the use of EEFs were the priority practices recommended for inclusion.
4. When it comes to quantification, simple and easy-to-use emission factor-based models are critical and preferable over the more-complicated process-based models.

Equally worth mentioning here is the stakeholders' feedback on the surveyed practices not prioritized for inclusion, summarized as follows:

- Manure Management – difficulty in determining N_2O emissions resulting strictly from manure when both varying amounts of manure and synthetic fertilizer are applied and how a changing balance of manure to synthetic fertilizer ratio affects N_2O emissions

[84] The revision was made possible thanks to the support of the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Conservation Innovation Grant (CIG) program, as part of the "Demonstration of a Scalable Nutrient Management Project to Reduce Nitrous Oxide Emissions and Generate Voluntary or Compliance Greenhouse Gas Credits" CIG led by Environmental Defense Fund (EDF).
[85] Slow and controlled release N fertilizer (coated or encapsulated), nitrification inhibitor-treated, urease inhibitor-treated N fertilizer, or products treated with both nitrification and urease inhibitors are considered EEF products.
[86] See Nitrogen Management Survey Results Memo. Available at: http://www.climateactionreserve.org/how/protocols/nitrogen-management/revision/.

- Cover Crops – the full effects on N_2O emissions remain inconclusive; additional challenge of distinguishing between different species of cover crops
- Precision Agriculture – associated emission reductions may already be accounted for as a function of the N rate reduction practice, questioned data availability, and stressed the importance of capturing spatial heterogeneity

A.2 Literature Review

The Reserve then conducted an expansive literature review to assess whether there were enough published studies and statistics supporting the N_2O reductions benefits of the stakeholder survey priority practices. The results of this review, as found below in Table A.1, signified a growing scientific literature on the effects of the 4Rs and EEFs on N_2O emissions. Note, only resources demonstrating a consistent decrease in N_2O emissions from the implementation of the priority practice are listed. For example, Omonode et al. (2017) found that neither N source nor placement influenced the relationship between N_2O and net recovery efficiency (of nitrogen by the crop), and Burzaco et al. (2013) found that the optimal timing (i.e., side-dress timing) actually increased N_2O emissions. As such, neither of the studies are listed in Table A.1 next to the respective priority practices.

Table A.1. Priority Practices and Resources Supporting Consistent N_2O Emission Reductions

Stakeholder Survey Priority Practice	Resource/Reference
4Rs	
Right Rate	Eagle et al. (2017); Omonode et al. (2017); Pape et al. (2016); Venterea et al. (2016); Vyn et al. (2016); Wade et al. (2015); Culman et al. (2014); Eve et al. (2014); Shcherbak et al. (2014); Biggar et al. (2013); Burzaco et al. (2013); Burger and Horwath (2012); Eagle et al. (2012); Hoben et al. (2011); Ribaudo et al. (2011); Millar (2010)
Right Time	Eagle et al. (2017); Omonode et al. (2017); Pape et al. (2016); Venterea et al. (2016); Vyn et al. (2016); Wade et al. (2015); Biggar et al. (2013); Eagle et al. (2012); Ribaudo et al. (2011)
Right Source	Eagle et al. (2017); Eagle et al. (2012)
Right Place	Eagle et al. (2017); Biggar et al. (2013); Wade et al. (2015); Eagle et al. (2012); Ribaudo et al. (2011)
EEFs	
Use of Nitrification Inhibitor	Eagle et al. (2017); Lam et al. (2017); Burger et al. (2016); Snyder (2016); Eve et al. (2014); Burzaco et al. (2013); Eagle et al. (2012)
Use of Nitrification Inhibitor and Urease Inhibitor	Lam et al. (2017); Snyder (2016); Venterea et al. (2016); Pape et al. (2016); Decock (2014); Biggar et al. (2013);
Switch to Slow Release / Controlled Release Fertilizer	Snyder (2016); Eve et al. (2014); Biggar et al. (2013); Eagle et al. (2012)

A.2.1 Nitrogen Management Protocol V1.0 Science Advisory Committee Findings

The Reserve also revisited the previous materials and findings from the Science Advisory Committee (SAC)[87] adjourned during the development of Nitrogen Management Protocol V1.0 for further support on practices to prioritize in V2.0/2.1. The SAC refined and rated a list of

[87] The Reserve together with the Nicholas Institute of Duke University assembled a group of leading scientific experts to form a Science Advisory Committee (SAC). The purpose of the SAC was to help the Reserve interpret and apply the best available science into the Nitrogen Management Protocol. Committee membership was by invitation from the Reserve and the Nicholas Institute.

potential nitrogen management practices for inclusion in the protocol using criteria such as the available number of side-by-side comparisons showing measured N_2O reductions in the field, whether these studies showed consistent results, and whether N_2O emission reductions were direct or indirect, to denote in a general sense which ones were ready for inclusion in the protocol based on the best available science. Resources reaffirming the science related to the practices were discussed. Of importance to note here, the following practices were the only ones acknowledged as ready for inclusion in the protocol based on the best available science:

- Reducing amount of N applied, without going below N uptake demand
- Use of nitrification inhibitors or nitrification inhibitors combined with urease inhibitors
- Changing fertilizer composition (source) [specifically, switch from anhydrous ammonia to urea][88]
- Changing to use slow release fertilizer

A copy of the complete SAC findings can be found in the Appendices of Nitrogen Management Protocol V1.1, and can also be made available by the Reserve upon request.

A.2.2 Results

The updated literature review and review of the SAC findings solidified the Reserve's initial takeaways from the stakeholder survey. Accordingly, the 4Rs and use of EEFs received the highest priority for inclusion in V2.0/2.1, in terms of developing performance standards for additionality (see Appendix B) and methods for quantifying GHG emission reductions (see Appendix F) that occur as a result of adopting the practice(s) for different crops in different regions.

As detailed in Appendix F, the Reserve contracted with Mark Easter Consulting, LLC to develop the new quantification methodology for V2.0/2.1. While the Reserve presented our technical contractor with the complete list of priority practices (and left the inclusion of other practices open for consideration) only the practices included as eligible project activities in V2.0/2.1 were shown to have statistically significant N_2O reduction benefits in the USDA GHG Methods Document[89] (i.e., the "Blue Book"), of which the new quantification methodology is based on.[90]

A.3 Assessment of Excess Nitrogen Use

In addition to an updated literature review on nitrogen management practices' N_2O reduction benefits, the Reserve also conducted an analysis to assess where nitrogen is being applied in excess amounts (i.e., above agronomic events), and where there is greater potential for nitrogen management project implementation. The following details our findings.

[88] For certain fertilizer sources.
[89] Eve et al. 2014.
[90] If practices' N_2O reduction benefits or potential benefits could be shown to be statistically significant based on analyses of flux measurements in field studies across the U.S., practice scalars were developed in the Blue Book. When the USDA GHG Methods were originally produced, and in the forthcoming update, time was spent examining various practices, including right time, place, and source, to see which were supported by reliable field measurements and which were not. Where certain 4Rs could not be shown to have a statistically significant effect, practice scalars could not be developed. This could change as new data become available and the USDA methods are further updated.

A.3.1 CEAP Cropland Survey Reports

As detailed in Appendix F, the new quantification methodology for Nitrogen Management Protocol V2.0 has been stratified by 12 Conservation Effects Assessment Project (CEAP) regions.[91] CEAP Cropland Surveys were conducted to quantify the effects of conservation practices commonly used on cultivated cropland in the 12 regions shown in yellow in Figure A.1 during 2003–06[92]. The surveys included collecting information on the application of commercial fertilizers (rate, timing, method, and form) for crops grown the previous 3 years. The following criteria were used to identify the *appropriate* rate of nutrient application for each crop or crop rotation:

- The rate of nitrogen application, including the sum of both commercial fertilizer and manure nitrogen available for crops in the year of application, is
    - less than 1.4 times the amount of nitrogen removed in the crop yield at harvest for *each* crop,[93] except for wheat and other small grain crops
    - less than 1.6 times the amount of nitrogen removed in the crop yield at harvest for small grain crops (wheat, barley, oats, rice, rye, buckwheat, emmer, spelt, and triticale); and
    - less than 60 pounds of nitrogen per bale of cotton harvested

The CEAP findings have been prepared in a series of 12 reports.[94] The results on the percent of all cropped acres, for all crops in rotation, meeting the N rate criteria can be found in Table A.2.

[91] The Conservation Effects Assessment Project (CEAP) was initiated by USDA NRCS to estimate conservation benefits for reporting at the national and regional levels and to establish the scientific understanding of the effects and benefits of conservation practices at the watershed scale. As CEAP evolved, the scope was expanded to provide research and assessment on how to best use conservation practices in managing agricultural landscapes to protect and enhance environmental quality. CEAP regions transcend State borders and represent broad geographic regions with similar climate, physiography, and land use.

[92] A follow-up survey to assess progress was also conducted in 2011 in the Chesapeake Bay Region.

[93] The 1.4 ratio of application rate to yield represents 70-percent use efficiency for applied nitrogen, which has traditionally been accepted as good nitrogen management practice. The 30 percent “lost” includes plant biomass left in the field, volatilization during and following application, immobilization by soil and soil microbes, and surface runoff and leaching losses. A slightly higher ratio is used for small grain crops to maintain yields at current levels. See CEAP Cropland Reports in Reference Section.

[94] A list of CEAP regions and corresponding reports are available at http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/?cid=nrcs143_014144

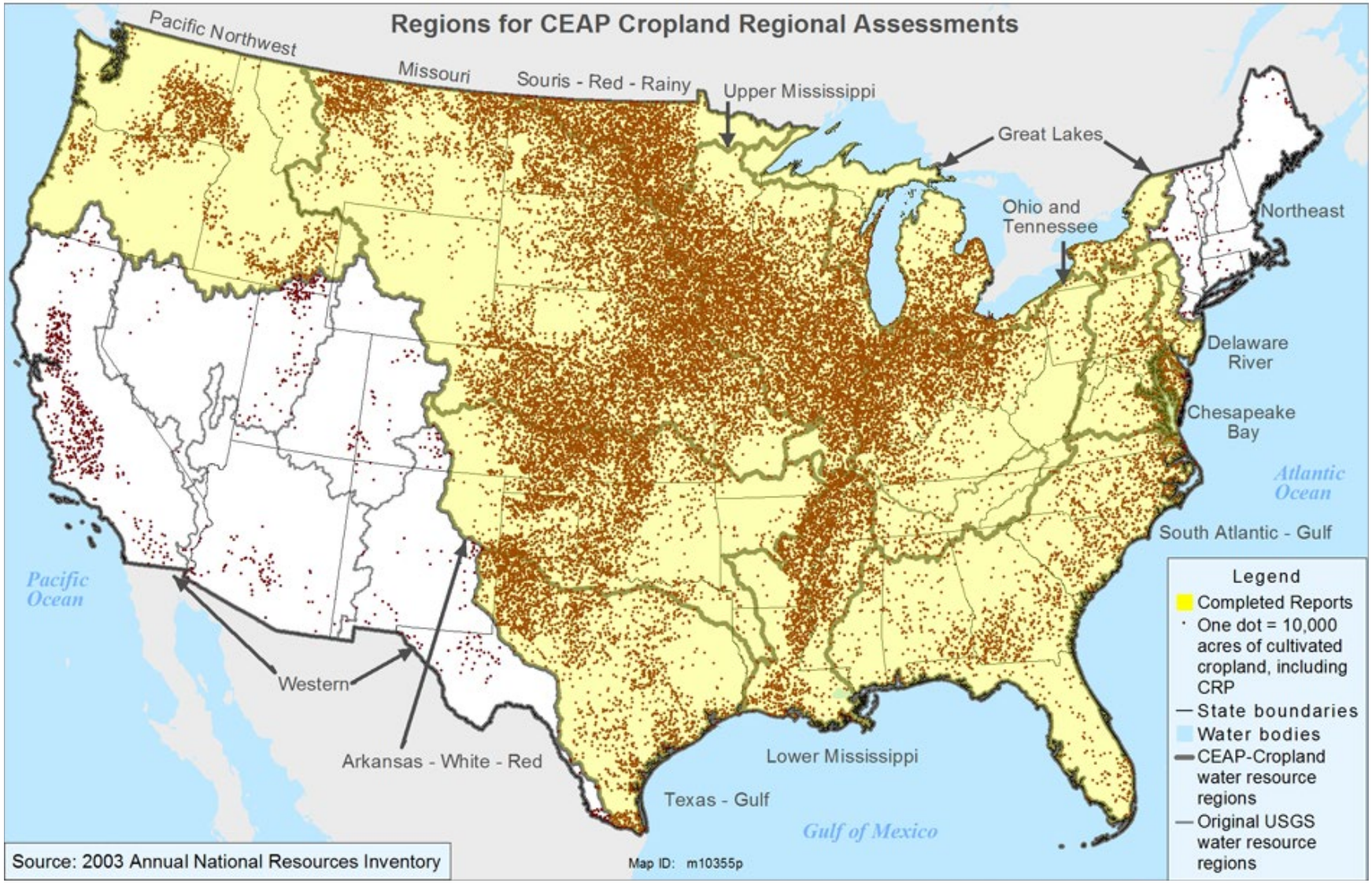

Figure A.1. 12 Watersheds (in yellow) for CEAP Cropland Regional Assessments

Table A.2. Findings from CEAP Cropland Reports on Regions Applying Appropriate N Rates

CEAP Cropland Report / Region	Eligible Crops Grown	Cropland Acres Meeting Appropriate N Rate Criteria[95] (%)
Arkansas White Red Basin	Corn Cotton Sorghum Wheat	59
Chesapeake Bay Region	Corn	23[96].
Delaware River Basin	Corn	43
Great Lakes Region	Corn Wheat	40
Lower Mississippi River Basin	Corn Cotton Sorghum Wheat	23
Missouri River Basin	Corn Wheat	63
Ohio-Tennessee River Basin	Corn Wheat	39
Pacific Northwest Basin	Barley Wheat	64
Souris-Red-Rainy Basin	Barley Corn Wheat	71
South Atlantic Gulf Basin	Corn Cotton Wheat	45
Texas Gulf Basin	Cotton (Upland) Sorghum Wheat	51
Upper Mississippi River Basin	Corn Wheat	39

A.3.2 USDA ERS Reports

Two recent studies conducted by the USDA Economic Research Service (ERS) provide a snapshot on the adoption of nutrient management practices that are supported by USDA conservation programs. All the data presented in both studies are derived from the Agricultural Resource Management Survey (ARMS).

[95] Based on all crops in rotation meeting the nitrogen rate criteria. For example, if corn and soybeans were on a 2-year rotation and that corn was grown during the year the CEAP surveys were conducted, then the N rate on both the corn and the previous year's soybean crops were assessed. If the application rate on corn met the rate criterion but excess nitrogen was applied to soybeans, then the rotation was identified as not meeting the criterion. This leads to the CEAP assessment reporting a smaller percentage of crop acres meeting the rate criterion than others (e.g., USDA ERS) may report.

[96] Note, the CEAP Cropland Conservation Progress Report for the Chesapeake Bay Region found the percent of cropped acres applying the appropriate nitrogen application rate on all crops in rotation declined by 9 percent from 32 percent in 2003-2006 to 23 percent in 2011.

A.3.2.1 *Conservation-Practice Adoption Rates Vary Widely by Crop and Region*

This analysis by Wade et al. (2015) evaluated the number of farmers applying nitrogen at rates greater than, equal to, or less than agronomic rates, and focused only on the application of commercial nitrogen on acres that do not receive manure[97] and on land planted to corn, soybean, wheat, and cotton.

The report defined a maximum agronomic or "benchmark" rate based on procedures outlined in the USDA/NRCS CEAP Cropland Reports (See Section A.3.1): for corn and wheat, the benchmark nitrogen application rate was 1.4 and 1.6 times expected removal, respectively, less a nitrogen credit of 40 pounds per acre for fields where soybeans were grown in the previous year, and for cotton, the benchmark rate was equal to 60 pounds of nitrogen per bale of expected yield, less a nitrogen credit of 40 pounds per acre for fields where soybeans were grown in the previous crop year.

The study compared their benchmarks to reported N rates at the field level, and found that nitrogen is applied at more than the benchmark rate on:

- 36 percent of corn acres (2010 data) by an average rate of 39 pounds per acre;
- 19 percent of cotton acres (2007 data) by an average rate of 40 pounds per acre;
- 22 percent of spring wheat acres (2009 data) by an average rate of 30 pounds per acre; and
- 25 percent of winter wheat acres (2009 data) by an average rate of 24 pounds per acre.

The study also found that farmers spent approximately $965 million on corn, cotton, and wheat nitrogen applications over benchmarks.[98]

A.3.2.2 *Nitrogen in Agricultural Systems: Implications for Conservation Policy*

This report by Ribaudo et al. (2011) explored the use of nitrogen in U.S. agriculture for producers of barley, corn, cotton, oats, peanuts, sorghum, and wheat during the survey year covered by ARMS data, and assessed changes in nutrient management by farmers that may improve nitrogen use efficiency. It defined the agronomic application N rate as applying no more nitrogen (commercial and manure) than 40 percent more than that removed with the crop at harvest, based on the stated yield goal, including any carryover from the previous crop. This definition is also consistent with CEAP.

Because the crops covered in the analysis were surveyed in different years, 2006 was specified as a reference year to examine the extent to which best nitrogen management practices are being followed. The report's findings revealed the application rate criterion was not met on over 53 million acres treated with nitrogen (32 percent). Cotton had the highest percentage of treated acres not meeting the rate criterion (47 percent), followed by corn (35 percent). However, corn accounted for 50 percent of all treated crop acres not meeting the rate criterion. The complete results on U.S. treated acres per crop *not* meeting the rate criterion can be found in Table A.3.

[97] The application of commercial fertilizer can be more carefully calibrated than the application of manure, which can vary in terms of nutrient content and is more difficult to precisely apply.
[98] Cost estimates were based on over-application quantities and annual ammonia nitrate prices.

Table A.3. Shares of Treated Acres that Did Not Meet the Rate Criterion, by Crop, in 2006

Crop	Did Not Meet N Rate Criteria	
	Treated Acres (%)	Treated Acres (Acres)
Barley	14	444,650
Corn	35	26,618,235
Cotton	47	5,906,020
Oats	33	906,840
Peanuts	1	7,370
Sorghum	24	1,288,800
Soybeans	3	505,820
Wheat	34	16,934,720
TOTAL	32	53,531,200

From a regional standpoint, in terms of nitrogen application in excess of the criterion rate, the study found that the USDA Farm Production Regions[99] of the Corn Belt and Lake States received the greatest amounts of excess nitrogen, as seen in Table A.4.

Table A.4. Total Nitrogen Applications Above Criterion Rate by Farm Production Region, 2006

USDA Farm Production Region	States Included	Excess N (1,000 tons N)
Appalachia	NC, KY, TN, VA, WV	36
Corn Belt	IL, IN, IA, MO, OH	298
Delta	AR, LA, MI	1
Lake States	MI, MN, WI	185
Mountain	AZ, CO, ID, MT, NE, NM, UT, WY	7
Northeast	CT, DE, MA, MD, NE, NH, NJ, NY, PA, RI, PA	44
Northern Plains	KS, ND, NE, SD	84
Pacific	CA, OR, WA	1
Southeast	AB, FL, GA, SC	5
Southern Plains	OK, TX	18

A.3.3 IPNI Nutrient Use Geographic Information System (NuGIS)

The International Plant Nutrition Institute (IPNI) Nutrient Use Geographic Information System (NuGIS) integrates multiple spatial datasets to create county-level estimates of nutrients (N, P and K) applied to the soil in fertilizer and livestock manure, nutrients removed by harvested agricultural crops, and remaining nutrient balances per total cropland acre across the lower 48 states.

[99] In terms of crop production. the Corn Belt has the largest number of farms with crops (i.e., 283,975 farms) and the most harvested acres (i.e., 81.5 million acres) of all USDA production regions. Collectively, the Corn Belt, Lake States, and the Great Plains account for 53 percent of all farms with crops and 71 percent of all harvested acres. Crop production in the Eastern United States is characterized by mostly smaller farms. Collectively, the Northeast, Appalachia, and Southeast regions have about 28 percent of farms with crops, but account for less than 12 percent of all harvested acres.

The basic NuGIS model is a very simple field based partial nutrient balance algorithm:

> Balance = Farm fertilizer nutrient used + Recoverable manure nutrient use + Biological fixation – Nutrient in harvested crops[100]

The most up-to-date results on N balance and N use are viewable through the color maps in Figure A.2 and Figure A.3, respectively. The analysis on N balance reveals areas of both highly positive (where more N is available than taken up by crops) and highly negative (where not enough N is available for crop needs) balances. The counties with positive N balances are in shades of green in Figure A.2. The counties using greater amounts of N are in darker shades of blue in Figure A.3.

See Appendix B for more information on IPNI NuGIS.

[100] Fixen et al., 2012

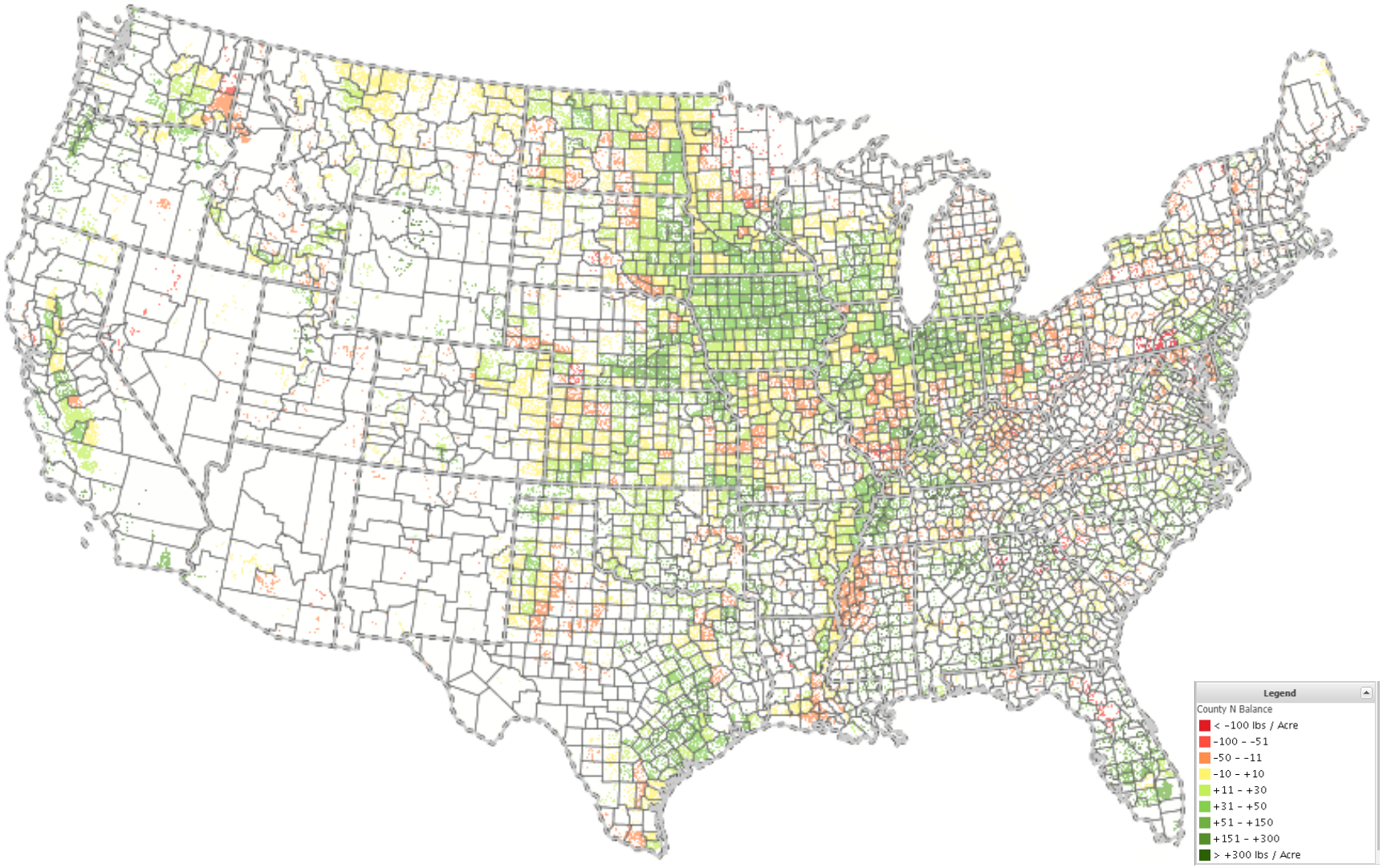

Figure A.2. 2014 IPNI NuGIS County-Level N Balance Data

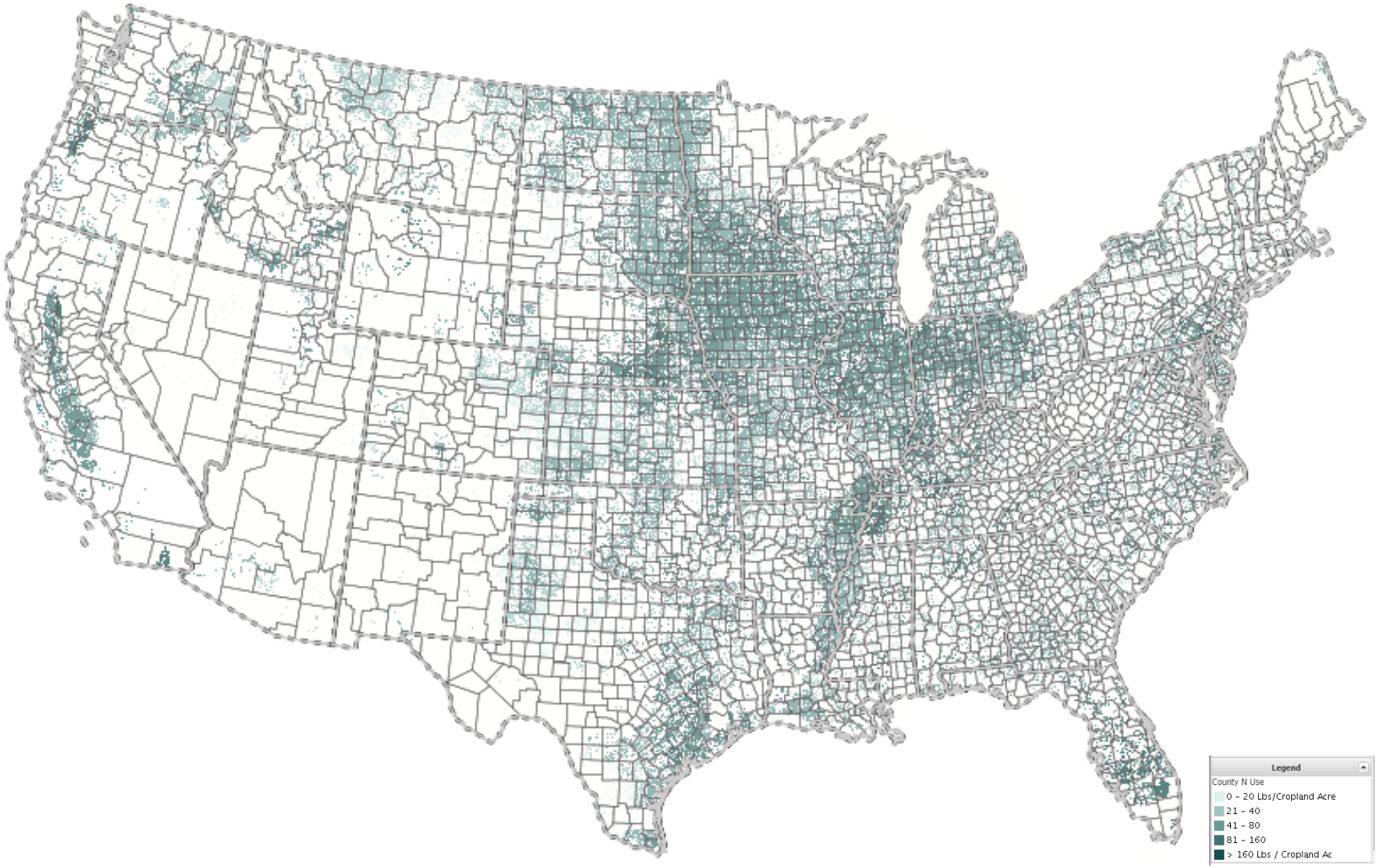

Figure A.3. 2014 IPNI NuGIS County-Level N Use Data

A.4 Summary of Findings

While it's challenging to assess whether, where, and how much excess nitrogen is being used at the farm or field level, the results from the CEAP Cropland Reports, USDA ERS Reports, and IPNI NuGIS help shed light on regions with greater potential for nitrogen management projects. For example, based on the findings of the CEAP surveys, counties in the Ohio-Tennessee River Basin[101] and the Upper Mississippi River Basin,[102] where only 39 percent of cropland acres were meeting the CEAP N rate criteria, may have more potential for nitrogen management projects than counties in the Souris-Red-Rainy Basin,[103] where 71 percent of cropland acres were meeting the CEAP N rate criteria. The results from the USDA ERS reports, which upheld similar criteria to the CEAP reports, reinforce the takeaways of the greater potential for projects in these regions, as do the more recent county-level N balance and N use assessments completed by IPNI as part of the NuGIS project. Note, the NuGIS results also indicate positive N balance and project potential in the California Central Valley.

[101] The Ohio-Tennessee River Basin includes a significant portion of seven states— Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, and West Virginia—and small parts of seven additional states. See Figure A.1.
[102] The Upper Mississippi River Basin includes large parts of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, and small areas in Indiana, Michigan, and South Dakota. See Figure A.1.
[103] The Souris-Red-Rainy Basin consists of parts of North Dakota and Minnesota, and a small part of the northeast corner of South Dakota. See Figure A.1.

Appendix B Summary of Performance Standard Test Development and Additionality Assessment

This appendix summarizes performance standard development and research into industry trends in nitrogen management practices in crop cultivation that have the potential to reduce nitrous oxide (N_2O) emissions. This appendix primarily lays out the background, rationale, and development of the performance standard test for the approved project activities of reducing synthetic nitrogen application rate (N rate) and using nitrification inhibitors or switching to a slow release fertilizers, which were identified in the Reserve's literary review (see Appendix A), Fall 2016 Stakeholder Survey, other methodologies,[104] and by the Nitrogen Management Protocol V1.0 Science Advisory Committee (SAC) [105] as practices with consistent N_2O emission reduction potential *and* for which there is an applicable quantification approach (see Appendix F).

B.1 Practices and Data Availability

While the complete 4R nutrient stewardship principles (right rate, right time, right source, and right place) and Enhanced Efficiency Fertilizers (EEFs) were prioritized for consideration in V2.0 (see Appendix A), the lack of comprehensive datasets[106] on "business as usual" nitrogen management practices hindered the development of performance standards for a number of these practices, as shown in Table B.1.

The USDA Agricultural Resource Management Survey (ARMS) and National Agricultural Statistical Service (NASS) datasets, as well as the International Plant Nutrition Institute (IPNI) Nutrient Use Geographic Information System (NuGIS) dataset, discussed further below, were used to analyze common practice nitrogen management, and where sufficient data were available, research outcomes informed development of a performance standard. The only complete performance standards currently included in the protocol are for 1) N rate reduction projects, and 2) N rate reduction projects and the use of a nitrification inhibitor or the switch to a slow release fertilizer.

[104] Millar et al., 2010.
[105] The SAC findings are contained in Nitrogen Management Protocol V1.1 available at: http://www.climateactionreserve.org/how/protocols/nitrogen-management/
[106] The Background Paper on Quantification of N_2O Mitigation Options, prepared by Terra Global Capital for the Reserve provides an extensive review of datasets considered for use in developing the performance standard (available at http://www.climateactionreserve.org/how/protocols/nitrogen-management/dev/). Only the most promising and comprehensive of datasets are discussed here.

Table B.1. List of Priority Practices and Data Availability

Priority List of Practices to Include in Nitrogen Management Protocol (Based on Stakeholder Survey Results)	Are comprehensive data available to develop performance standard?			Is a standardized quantification methodology for N_2O emissions currently available that meets Reserve criteria?[107]
	USDA ARMS	USDA NASS	IPNI NuGIS	
Right Rate[108] - Reduce N Applied without Going Below N Demand	Yes	Yes	Yes	Yes
Right Time - Switch from Fall to Spring N Application[109]	Yes	No	No	No
- Split N Applications	No	No	No	No
Right Source - Switch from Anhydrous Ammonia to Urea	No	No	No	No
Right Place - Apply N Below Soil Surface[110] (i.e., Closer to Roots)	No	No	No	No
Use of Enhanced Efficiency Fertilizers (EEFs) - Nitrification and Urease Inhibitors - Nitrification Inhibitors (only) - Urease Inhibitors (only) - Slow Release Fertilizers / Controlled Release Fertilizers	Yes[111]	No	No	Yes

[107] See Appendix F.
[108] Note, average N rate from ARMS and NASS is crop-specific and based on synthetic and manure N; average N rate from IPNI NuGIS does not include manure and is per all cropland.
[109] Not applicable to Winter Wheat.
[110] That is, fertilizer is injected or incorporated at time of application.
[111] It should be noted that 'N inhibitor' as defined in the USDA ARMS dataset includes nitrification inhibitors, urease inhibitors and chemical coated (slow release or controlled release) fertilizers. Only aggregated data on penetration rates for 'N inhibitors' are publicly available. The exact ARMS survey question has varied over the years, and has generally been broadly phrased. In the 2010 corn survey, for example, producers were asked to select among three specific types, other, or none: 1 Nitrification inhibitors (such as N-Serve); 2 Urease inhibitors (such as Agrotain); 3 Chemical-coated fertilizers (such as sulfur-coated urea and polymer-coated urea); 4 Other inhibitors; 5 None.

B.2 Nitrogen Cycling and Nitrogen Use Efficiency

Metrics to set a performance standard threshold must be simple and consistent. Though the annual N fertilization rate may seem like a straightforward metric for setting a performance threshold, particularly for practices that reduce nitrogen rates, it is not a consistent metric. More specifically, fields that receive an equal amount of N fertilizer can vary drastically in terms of yield, how much N crops take up, how much N is lost, and how much residual N remains after crop uptake, all of which influence the quantity of N available for processes that lead to N_2O emissions. This difference in efficiency across sites can be understood if one considers the nitrogen cycle.

Nitrogen cycles through cropland systems in a way that is influenced by a wide range of site-specific variables such as soil type, climate, cropping system and previous and current nitrogen management. A simplified diagram of the N cycle is depicted in Figure B.1 below.

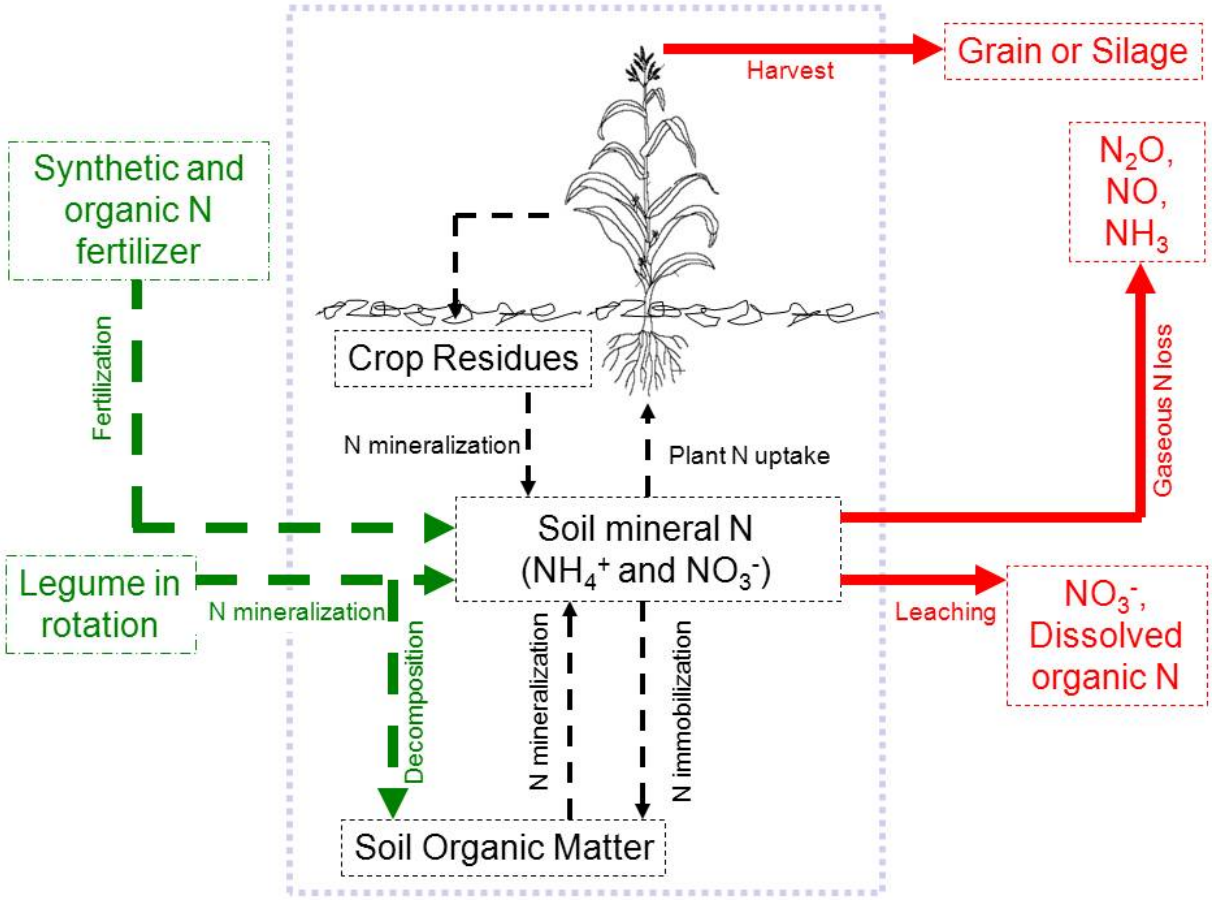

Figure B.1. Nitrogen Sources, Cycling, and Losses in Agricultural Systems[112]
Wide red arrows represent losses from the system, wide dashed green arrows external inputs and narrow dashed arrows internal recycling. The purple dotted line marks the accounting boundary.

N inputs in most agricultural systems consist of synthetic N fertilizer (e.g., anhydrous ammonia or urea), organic fertilizer (e.g., manure, compost, or sewage sludge), or carryover from legumes in the rotation. N can also become available through mineralization of organic matter or

[112] Drawing of corn plant was obtained from www.inra.fr with N Cycle added.

residual soil N carried over from one cultivation year to the next. Major N losses include leaching, ammonia (NH_3) volatilization or emission of nitrogen oxides (NO_x), N_2O, or nitrogen gas (N_2). Finally, N is also removed from the system through harvest, with the amount of N removed by harvest depending on the crop type and crop usage (e.g., corn for grain versus silage). As a consequence, the most appropriate N rate for a given field will vary drastically across and within cropping systems and regions.

The common best management practice for N rates is to apply nitrogen in amounts closer to the agronomic rate, where only as much nitrogen as crops can use is applied. Agronomic nitrogen rates depend on the crop, crop rotation, expected yield, weather, timing of application, soil, and other conditions, as detailed above. As seen in Appendix A, the maximum agronomic rate is frequently defined as applying no more nitrogen (commercial and manure) than 1.4 times the amount of nitrogen removed in the crop yield at harvest for corn, sorghum, and tomatoes, 1.6 times the amount of nitrogen removed in the crop yield at harvest for small grain crops (barley, oats, spring wheat, and winter wheat), and less than 60 pounds of nitrogen per bale of cotton harvested.

The most comprehensive evaluations of N budgets and N cycling in the system take into account all N inputs, losses and internal N cycling. A commonly used metric in the industry to characterize N budgets of cropland systems is nitrogen use efficiency (NUE). The NUE takes the form of a ratio that considers an output (e.g., crop biomass at harvest or economic yield) as the numerator and input (N supply) as the denominator.[113] The crop biomass at harvest (i.e., the "biological yield") can include either total aboveground plant dry matter or total plant N, whereas the economic yield includes either grain yield or total grain N.[114] The N supply can be from soil (N mineralization, carryover of residual N, N credit from legumes), fertilizer (organic or synthetic), or soil plus fertilizer.[115] Consequently, various working definitions and methodologies to measure and calculate NUE are in circulation, each of which finds their use in answering particular agronomic, ecological or economic questions. NUE can be used at various geographic scales, from studying and fine-tuning the N budget of a single field to evaluating nitrogen balances at a watershed or landscape scale.

At a landscape scale, NUE has been used by IPNI,[116] the Agricultural Sustainability Institute at UC Davis, and other entities as an important indicator to evaluate the sustainability and performance of various agricultural regions and cropping systems.[117] Regardless of the definition used for NUE, higher values for NUE generally reflect improved utilization of N by the crop, often decreasing the risk for harmful loss of N to the environment, such as N_2O emissions.

A performance standard threshold that is solely based on N fertilizer rates will be insufficient to deduce performance consistently across sites, due to the inability to account for site-specific factors. A high N rate threshold may be appropriate for high-yielding fields, but not for marginal fields within the same geographic region. Additionally, the inherent risk in a performance standard that is solely based on reductions in N fertilizer rates is overlooking potential reductions in yield. With increasing demand for food (due to increasing population and consumption), any shift in N management must sustain crop yield. If reductions in N fertilizer decrease crop yields, GHG emissions could actually increase, because production that

[113] Ladha, J.K., Pathak, H., Krupnik, T.J., et al., 2005.
[114] Ibid.
[115] Ibid.
[116] NuGIS, Fixen, 2010.
[117] Fixen, 2010; Ladha et al., 2005; Rosenstock et al., In Review.

compensates for yield losses could shift to less efficient regions or production systems (negative leakage). Incentives for GHG mitigation should therefore avoid reducing yield by much in highly efficient systems.[118] Furthermore, a performance standard test based on N fertilizer rates would be inequitably disadvantageous to early actors who have already begun applying N rates closer to agronomic amounts and advantageous to laggards who continue to apply N in excessive amounts.

A performance metric based on NUE (i.e., productivity per unit of N application) rather than absolute N rate can overcome these issues. NUE-based performance metrics reflect nitrogen management that limits N losses to the environment and maximizes N use by crops to maintain and enhance yield.

B.3 Nitrogen Use Efficiency (NUE) as N Rate Reduction Performance Standard Threshold

In the previous section, it was explained how a performance threshold for reducing N rates shall be based on some measure of NUE. Ideally, all inputs, losses (including N removed by harvest), and internal recycling should be considered when characterizing cropland NUE. However, in practice, such data are lacking, both in terms of regional data sets needed to set a threshold, as well as site-specific data that would be needed to compare a field's performance against the threshold. The only data readily available to assess these respective NUE values and set NUE thresholds is limited to synthetic and organic fertilizer N inputs and cropping yields. Though more comprehensive NUE metrics, which include many additional variables, may approximate NUE more accurately in theory, these more comprehensive metrics can become rather complicated and opaque, making their use less desirable in the context of an offset protocol. For testing additionality, the focus should be on metrics for which sufficient data are available to define the common practice and that can be calculated for individual fields using historic and project data that is readily available to the grower. Metrics that reflect the system's N budget to its fullest extent will require additional data gathering and field sampling that are likely prohibitive to conduct at a field scale due to practical and financial constraints.

One of the goals with the update to V2.0 was to make the protocol easier to use while upholding scientific integrity. As such, V2.0 uses the simplest form of crop production efficiency (i.e., where the output is the harvested crop yield), termed the Partial Factor Productivity (PFP), as the NUE metric in its performance standard test for N rate reductions. The NUE demonstrates how productive the cropping system is in comparison to its nutrient input, and is calculated in Equation 3.1 in units of crop yield per unit of N fertilizer applied – both of which should be part of any practical record-keeping for growers and are required by this protocol. Because NUE is a ratio, it always increases when N rate decreases and/or yield increases[119]. This might lead one to falsely conclude that the lowest fertilizer rate would result in the most efficient cropping system. However, reducing rates significantly below the agronomic rate, would in turn compromise yield and reduce NUE. The more valuable increases in efficiency come from yield improvement. For example, the NUE for N applied to U.S. corn increased by 50 percent between 1975 and 2006. This increase did not result from a decrease in N application rates. In

[118] Eagle, A., L. Olander, L.R. Henry, K. Haugen-Kozyra, N. Millar, and G.P. Robertson. 2012. Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States: A Synthesis of the Literature. Report NI R 10-04, Third Edition. Durham, NC: Nicholas Institute for Environmental Policy Solutions, Duke University.
[119] Doberman, A., 2007. *Nutrient use efficiency – measurement and management*. In: Kraus, A., Isherwood, K. and Heffer, P., Eds., Fertilizers Best Management Practices. Proceeding of International Fertilizer Industry Association, Brussels, Belgium, 7-9 March 2007, 1-22

fact, rates applied rose by 24 percent, but better genetic and improved management boosted yields by no less than 86 percent.[120]

A similar reporting metric – a ratio of Nitrogen Applied divided by Yield (A/Y) – is required to be calculated and provided in Nitrogen Management Plans (NMPs) by all growers regulated under the California Central Valley Regional Water Quality Control Boards' Irrigated Lands Regulatory Program (ILRP). The A/Y metric was developed by the NMP Technical Advisory Work Group (Work Group), consisting of Central Valley agricultural coalitions, representatives from California Department of Food and Agriculture (CDFA) and University of California Cooperative Extension, and practicing agronomists and crop experts. Per this Work Group's recommendation, the advantages of using the A/Y ratio as a *nitrogen removal* reporting metric are rapid data collection, consistent reporting across all crops and across reporting years, ease of calculation, and a tangible meaning of the relationship between the Applied Nitrogen and the Yield (see Appendix C for more information).

The simplified NUE calculated in this protocol only considers applied N and does not take into account all available N sources. However, if a large number of producers in a specific region apply relatively low N rates to a given crop because they account for potential residual N at the beginning of the cultivation year or legume N credits, the region- and crop-specific average NUE will be relatively large. Vice versa, if the selection of an appropriate N rate to a given crop is not commonly discounted for residual N or N credit from legumes, the region- and crop-specific-average NUE will be relatively large. Therefore, simple region- and crop-specific -average NUE values implicitly take into account the adoption of best management practices with respect to N rate, and can be used as thresholds to ensure additionality and promote environmental integrity.

It should also be noted that while the Nitrogen Management Protocol determines the additionality of emission reductions based on a metric that normalizes N rates by using crop yield, quantification of N_2O emission reductions in the protocol is based on synthetic N rate reductions (with or without the implementation of other eligible project activities) quantified for a given project.

B.4 Development of County- and Crop-Specific NUE Benchmarks

Importantly for the development of the performance standard test, simple indicators such as NUE scale more easily than complex forms, provided reliable statistics on input use and crop yields are available. In developing NUE metrics to set performance standard thresholds in V2.0, the Reserve looked to improve the spatial scale from the state to the county level, and the temporal scale from annual to multiple years to create performance benchmarks more relatable to a specific grower's conditions at the farm or field-level than the annual state average performance benchmarks used in V1.1. However, there is currently no database containing average fertilizer N application rates or amount of N applied to planted or treated acres for specific crops at the U.S. county level. The following details the methods employed by the Reserve to get around this data gap and estimate multi-year county- and crop-specific average fertilizer nitrogen rates with the best available data. Complete equations detailing the Reserve's methodology for developing county- and crop-specific benchmarks are available by request.

[120] Snyder, C.S. and T.W. Bruulsema, 2007. *Nutrient Use Efficiency and Effectiveness in North America: Indices of Agronomic and Environmental Benefit*. International Plant Nutrition Institute. North Cross, Georgia. June 2007

B.4.1 Database Overview

The data used in the development of multi-year county- and crop-specific average N rates were derived from the USDA ARMS and NASS datasets and the IPNI NuGIS dataset

B.4.1.1 USDA National Agricultural Statistics Service (NASS) Quick Stats

The USDA's National Agricultural Statistics Service (NASS) conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture, including production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of U.S. producers. Two are of particular importance to the Nitrogen Management Protocol: 1) the Agricultural Chemical Use Program and 2) the Agricultural Yield survey.

The NASS Agricultural Chemical Use Program[121] is USDA's official source of statistics about on-farm chemical use and pest management practices. Since 1990, NASS has surveyed U.S. farmers to collect information on the chemical ingredients they apply to agricultural commodities through fertilizers and pesticides. On a rotating basis, the program currently includes field crops (row crops and small grains), fruits, vegetables, and nursery and floriculture crops. Each survey focuses on the top-producing states that together account for the majority of U.S. acres or production of the surveyed commodity. Data are available at the state level for all surveyed states, and includes percentage acreage treated, number of applications, rates of application, and total amounts applied of nitrogen (available annually for field crops, intermittently for fruits and vegetables).

The NASS Agricultural Yield survey[122] provides farmer reported survey data of expected crop yields used to forecast and estimate crop production levels throughout the cultivation year. The survey is conducted monthly in all states (except AK and HI) running from May through November. Small grains (winter wheat, spring wheat, barley, oats) data are collected from May through August. Row crop (corn, cotton, sorghum) data are collected from August through November. Vegetable (tomato) data are collected from April through September. California tomato processors are surveyed separately. Data are available annually for all eligible crops. This dataset is robust and published on a regular, annual schedule.

NASS is also responsible for conduct the Census of Agriculture (COA) every five years, providing the only source of consistent, comparable, and detailed agricultural data for every county in America.

The results of chemical use and yield surveys and the Census of Agriculture are made readily available through the NASS Quick Stats Database.[123]

B.4.1.2 USDA Agricultural Resource Management Survey (ARMS) Crop Production Practices Tailored Reports

USDA's Agricultural Resource Management Survey (ARMS)[124] is an annual survey of farm and ranch operators administered by the USDA Economic Research Service (ERS) and NASS.

[121] Available at: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/index.php
[122] Available at: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Agricultural_Yield/index.php
[123] The Quick Stats Database (searchable database) is the most comprehensive tool for accessing agricultural data published by NASS. It allows you to customize your query by commodity, location, or time period. Available at: https://quickstats.nass.usda.gov/.
[124] Available at: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Ag_Resource_Management/index2.php.

ARMS gathers data on field-level production practices, farm business accounts, and farm households. The ARMS collects production practices and cost of production data on selected commodities (*field crops only* – barley, corn, cotton, oats, sorghum, spring wheat, winter wheat), and is conducted in three data collection phases:

- The initial phase, (Phase I), ARMS Screening survey, collects general farm data such as crops grown, livestock inventory, and value of sales.
- The second phase, (Phase II), collects data associated with agricultural production practices, resource use, and variable costs of production for specific commodities. Commodities are surveyed on a predetermined rotation with up to five commodities surveyed in a given year. Farm operators provide data on fertilizer and nutrient applications, pesticide applications, pest management practices, and irrigation.
- The final phase, (Phase III) collects whole farm finance, operator characteristics, and farm household information. Farm operators provide data on farm operating expenditures, capital improvements, assets, and debt for agricultural production. In addition, operators provide data on farm-related income, government payments, the source and amount of off-farm income, and characteristics of themselves and their household.

This approach helps link commodity production activities and conservation practices with the farm business and operator household. Each phase of ARMS contains multiple versions of the survey questionnaire. The commonality of questions across versions provides one facet of data integration. The target commodity distinguishes questionnaires.

Data on the nutrient management practices of U.S. producers of the select field crops are available through/derived from the ARMS Crop Production Practices Tailored Reports.[125]

B.4.1.3 International Plant Nutrition Institute (IPNI) Nutrient Use Geographic Information System (NuGIS)

The International Plant Nutrition Institute (IPNI) is a not-for-profit, science-based organization dedicated to the responsible management of plant nutrition for the benefit of the human family. The Nutrient Use Geographic Information System (NuGIS) project is sponsored and directed by IPNI. The two primary objectives of this project are to assess nutrient use efficiency (NUE) and balance in crop production and identify weaknesses in the balance estimation processes and the datasets used for these estimations. NuGIS integrates multiple tabular and spatial datasets to create ***county-level*** estimates of nutrients (N, P and K) applied to the soil in fertilizer and livestock manure, and nutrients removed by harvested agricultural crops, per ***total cropland acre*** across the lower 48-states. Nutrient balances, inputs and removal efficiencies were estimated at three-year averages in five-year increments, coinciding with the USDA Census of Agriculture, from 1987 – 2007, and annually for 2010, 2011, and 2012.[126] Geospatial techniques were used to estimate balances and efficiencies for 8-digit hydrologic units using the county-level data.[127] Results are viewable through an interactive color map or exportable as tabular data.

[125] ARMS Tailored Reports allow the public user to view and download a variety of statistics summarizing the ARMS data. The user can select from several menus to create custom reports on topics ranging from the farm balance sheet to pesticide application methods. The tailored reports tool is segmented in two broad sections: 1) Farm Structure and Finance and 2) Crop Production Practices. For the latter, data were last updated April 23, 2015, reflecting the 2013 survey. Available at: https://data.ers.usda.gov/reports.aspx?ID=17883.
[126] As of February 23, 2015, "2012" is the most recent year of analysis.
[127] Available at: http://nugis.ipni.net/About%20NuGIS/.

Data for estimating the nutrients from commercial fertilizers, including detailed information on the county the fertilizer was sold in, the formulation of fertilizer sold as well as the intended use of the fertilizer, were provided by the Association of American Plant Food Control Officials (AAPFCO).[128] A detailed report of the development, testing, and implementation of the methods used to import and analyze AAPFCO data and produce annual county-level nutrient input estimates is available by contacting nugis@ipni.net.

B.4.2 Estimating State Average N Rates for Non-Survey Years

The USDA ARMS and NASS databases each provide state- and crop-specific average fertilizer N rate data for the same field crops in the same survey year. However, ARMS does not provide data on non-field crops, namely tomatoes, nor does it provide any data on crop yield, or any data at the county level, all of which are needed to develop county-specific NUE benchmarks. NASS also contains N rate data from more recent survey years. As such, NASS fertilizer N rate data was ultimately chosen over ARMS for completeness and consistency.

Because the eligible crops in this protocol were surveyed in different years, we specified reference years of 2010, 2011, and 2012, to estimate three-year average N rate applications. The three years selected correspond to the most recently available annual county-level N rate data estimates from IPNI NuGIS.

We then adapted procedures described in the 2011 USDA Economic Research Service (ERS) Report, *Nitrogen in Agricultural Systems: Implications for Conservation Policy,*[129] to estimate annual N rates for crops in their non-survey years, under the assumption that the percentages of planted acres treated with N and N application rates remain stable between the three reference years.[130] Specifically, we calibrated weights based on the change in planted acres[131] from the NASS survey year to the survey year in question, using the USDA published estimates of planted acres for 2010, 2011, and 2012.[132] Note, if planted acreage data for a given crop is not available, it was assumed the crop is not cultivated in the given state or county, or at least not in the given year. The annual state average N rates from the NASS survey year were then multiplied by the respective weights to estimate state average N rates for the non-survey reference years.

Table B.2 displays the relevant NASS survey year per eligible crop. Note, with the exception of oats, N rate data was available for all eligible crops in one of the three reference years. For oats, the most recently available N rate data (from survey year 2015) was adjusted as described above to estimate average state N rates for oats for each one of the three reference years.

[128] AAPFCO provides commercial fertilizer sales data each year for fertilizer products sold as tons of fertilizers, state and county sold in, year sold, season sold, container sold in, fertilizer type code, formulation as percent N, P_2O_5, and K_2O and the intended use of the fertilizer sold. IPNI used these AAPFCO values as a basis for estimating the nutrients applied with farm use commercial fertilizers at the county level.
[129] Ribaudo et al., 2011.
[130] We maintain the assumption that the percentage of planted acres treated with N would remain constant from 2010 through 2012 throughout the analysis.
[131] Note, while fertilizer-related data is available intermittently depending on the crop-specific survey year, NASS provides data on crop-specific planted acres at the state and county levels on an annual basis. However, if planted acreage data is not available, it is assumed the crop is not planted in the given state or county in the given year.
[132] USDA NASS 2018

Table B.2. NASS Crop-Specific Chemical Usage Survey Years

Eligible Crop	NASS Chemical Use Survey Year[133]
Barley	2011
Corn (Grain + Silage)	2010
Cotton (Upland)	2012
Oats	2015
Sorghum	2011
Spring Wheat	2012
Tomatoes (Processing)	2010
Winter Wheat	2012

B.4.3 Estimating County- and Crop-Specific Average N Rates

NASS provides state-and crop-specific average N rates for all crop-specific treated acres and IPNI NuGIS provides state- and county-specific N rates for all cropland acres. To arrive at estimates for three-year county- and crop-specific average N rates, the following steps were followed:

1. Adjusted the IPNI NuGIS-derived state- and county-specific farm nitrogen fertilizer inputs from per cropland acre to per *treated* cropland acre
    a. Divided the nitrogen inputs per cropland acre by the percentage of cropland acres in the state or county treated with fertilizer
    b. Obtained cropland acreage and treated cropland acreage from the 2012 Census of Agriculture (CoA) via NASS Quick Stats
        i. Removed pastured acreage from total cropland acreage when calculating the percentage of cropland acres treated with fertilizer
    c. Maintained the assumption that the percentage of treated acres remains constant from year to year over the reference years 2010-2012

2. Calculated the percentage change between the adjusted IPNI NuGIS-derived annual state-specific N input and the NASS-reported annual state- and crop-specific average N rate for each eligible state and crop and each reference year

3. Multiplied the state-and crop-specific percentage changes to the applicable adjusted IPNI NuGIS-derived annual county-specific N inputs to arrive at estimates for annual county- and crop-specific N rates for each eligible county and crop and each reference year
    a. That is, the adjusted annual county N inputs from NuGIS were multiplied by the same amount (i.e., percentage change) as the adjusted annual state N inputs from NuGIS were to match the state- and crop-specific N rates from NASS
    b. Put simply, cropland county data were adjusted by the same proportional change between cropland state data and crop-specific state data to estimate crop-specific county data

4. Averaged the annual county- and crop-specific N rate data for each reference year to derive three-year county- and crop-specific average N rates

[133] The NASS crop-specific survey years correspond to the same crop-specific years of the ARMS.

All average N rate estimates can be found in the Nitrogen Management Protocol Eligibility Lookup Tool, as discussed in Section B.5.

B.4.4 Calculating County- and Crop-Specific Yields

Annual county- and crop-specific yields were derived from NASS for each reference year.[134] To compute NUEs, crop yields and N rates must both be in the same units. V2.0 used N rates reported in pounds per acre. As such, crop yields had to be converted from the units reported in NASS to pounds per acre. See Table B.3 for the conversion factors used in this assessment.

Table B.3. Yield Conversion Factors

Eligible Crop	NASS Reported Yield Units	lb/bu[135]	lb/ton
Barley	bushels/ac	48	
Corn	bushels/ac	56	
Corn Silage	tons/ac		2000
Cotton (Upland)	lb/ac	32	
Oats	bushels/ac	32	
Sorghum	bushels/ac	56	
Spring Wheat	bushels/ac	60	
Tomatoes (Processing)	tons/ac		2000
Winter Wheat	bushels/ac	60	

B.4.5 Estimating County- and Crop-Specific NUE Benchmarks

The same NUE equation[136] is used to calculate the three-year county- and crop-specific average NUEs for developing performance standard thresholds as well as to determine project NUEs, based on projects' crop yield and fertilizer application records per eligible crop year, as described in Section 3.5.1.1.

B.5 Nitrogen Management Protocol Eligibility Lookup Tool

NUE benchmarks could only be developed for N rate-crop-county combinations where data were available. Specifically, if crop-specific state-level average N rate or county-level yield records were unavailable in NASS and/or county-level N rates per cropland were unavailable in NuGIS, NUE benchmarks could not be developed, for the reasons discussed in Section B.4.Without this data, the additionality of emission reductions resulting from nitrogen management projects cannot be assessed.

As a result, the practice-crop-region combinations eligible in V2.0 are restricted by the results of this assessment (and by the capabilities of the quantification approach – see Appendix F). To

[134] If crop yield data is not available at the county level from NASS, county level NUE benchmarks could not be developed for the specific crop. This is the case for Cotton and is why data for Upland Cotton is used in its place, where available. County level yield data is also unavailable for Sorghum Silage and Fresh Tomatoes.
[135] Yield Conversion Factors were obtained from University of North Carolina at Chapel Hill. See https://www.unc.edu/~rowlett/units/scales/bushels.html
[136] The equation used to calculate the three-year county- and crop-specific average NUEs found in the Nitrogen Management Protocol Eligibility Lookup Tool is identical to Equation 3.1, with the exception that the NUE benchmarks are multi-year averages as opposed to annual metrics calculated each reporting period.

help project developers to both identify the eligible combinations and find the relevant county- and crop-specific NUE benchmarks and average N rates for their project, the Reserve developed the Nitrogen Management Protocol Eligibility Lookup Tool.

All resulting eligible practice-crop-region combinations can be easily found in the Reserve's Nitrogen Management Protocol Eligibility Lookup Tool. The Nitrogen Management Protocol Eligibility Lookup Tool is an easy-to-use Microsoft Excel© workbook that allow users to quickly determine if their project practice-crop-region combination is eligible and to identify the average NUE, N Rate and Yield for their specific crop and county.

B.6 Use of Nitrification Inhibitor or Switch to Slow Release Fertilizer Performance Standard

The performance standard for the switch to a slow release fertilizer (SRF) or the use of a nitrification inhibitor (NI) is based on 1) an evaluation of the adoption rates of each practice in an eligible region for an eligible crop and on 2) a financial barrier test.

B.6.1 Adoption Rate of Enhanced Efficiency Fertilizers

Data on adoption of "Nitrogen inhibitor used" in eligible cropping systems was obtained from USDA ARMS. The USDA ARMS question on Nitrogen inhibitors varies depending on the crop[137] and survey year, and has been broadly phrased to include a variety of types, including nitrification inhibitors, urease inhibitors, and chemical-coated (controlled or slow release) fertilizers, with the presented uptake data grouped to include all possible types. Furthermore, much collected data are statistically unreliable due to a low sample size, most noticeably, including the largest observed penetration rates at the state level for corn and cotton below.

Nationally,[138] USDA ARMS data for various years suggests that Nitrogen inhibitors are currently used on about:

- 12.46 percent of U.S. corn acreage (2010);
- 5.21 percent of U.S. cotton (2007);
- 0.71 percent of U.S. winter wheat acreage (2009);
- 0.54 percent of U.S. oats acreage (2005);
- 0.39 percent of U.S. sorghum acreage (2003); and
- 0.31 percent of U.S. spring wheat acreage (2004)

For a large number of crops, not enough data are available nationally for trend analysis. For where enough data were available, the following trends over time were observed:

- Increase from 10.4 percent to 12.5 percent for corn from 2000 to 2010
- Increase from 1.4 percent to 5.2 percent for cotton[139] from 2000 to 2007; and
- Decrease from 1.1 percent to 0.7 percent for winter wheat from 2000 to 2009

Across all states,[140] the smallest observed penetration rates in the most recent crop survey year were as follows:

[137] Note, ARMS only contains data for field crops and does not contain data for tomatoes.
[138] No data on nitrification inhibitors is available for Barley on the national level.
[139] Unclear if this includes the subset of "upland" cotton.
[140] No data on nitrification inhibitors is available for Oats or Spring Wheat at the state level.

- 3.1 percent of corn acreage in Nebraska (2010)
- 2.0 percent of cotton acreage in Texas (2007)
- 5.1 percent of sorghum acreage in Missouri (2003);[141] and
- 3.0 percent of winter wheat acreage in Illinois (2009)[142]

Across all states, the largest observed penetration rates in the most recent crop survey year were as follows:

- 43.8 percent of corn acreage in Indiana (2010)
- 24.1 percent of cotton acreage in Arkansas (2007)
- 5.1 percent of sorghum acreage in Missouri (2003); and
- 3.0 percent of winter wheat acreage in Illinois (2009)

Because of the aggregation and low sample sizes, the above penetration rates should be interpreted with caution. As a result of the aggregation, it can at least be inferred though that the estimated individual adoption rates of nitrification inhibitors or slow release fertilizers are lower than the rates above.

Additionally, in their *Greenhouse Gas Mitigation Potential of Agricultural Land Management in the United States: A Synthesis of the Literature*, the Technical Working Group on Agricultural Greenhouse Gases (T-AGG), as coordinated by a team at the Nicholas Institute for Environmental Policy Solutions at Duke University, found that Nitrification inhibitors are currently utilized on only 3.4 megahectares (Mha) of U.S. cropland, and because 90 percent of commercial fertilizer is urea or ammonium based, a total area of 92 megahectares (Mha) is available for nitrification inhibitor application.[143]

B.6.2. Financial Barriers

At present, the use of Nitrification inhibitors and slow release fertilizers is also low due to their high cost relative to conventional fertilizers. Nitrification inhibitors have been found to increase the cost of fertilizer by roughly 9 percent[144] or by $8 - $20 per acre,[145] while slow release fertilizers can be 10 to 15 times as expensive per pound of nitrogen, compared to soluble, granular forms.[146]

B.6.3 Additionality Assessment

After evaluating the data available data from USDA ARMS, and considering that their high costs relative to conventional fertilizers continues to be a constraint to adoption and use, the Reserve has determined that these levels of practice uptake are sufficiently low that the use of a Nitrification inhibitor or slow release fertilizer is not common practice, and the implementation of either activity is therefore considered additional, *when* applied in combination with N rate reduction. All growers using an eligible nitrification inhibitor or switching to an eligible slow release fertilizer pass this performance standard test, so long as they pass the performance

[141] Missouri is the only state for which there is data available on nitrification inhibitors for Sorghum.
[142] Illinois is the only state for which there is data available on nitrification inhibitors for Winter Wheat in the most recent survey year.
[143] Eagle et al., 2012
[144] Eagle et al., 2012; Biggar et al., 2013
[145] Burger et al., 2016; U.S. EPA 2013
[146] Neal (undated); McKenzie-Mohr & Associates (undated)

standard test for N rate reductions and demonstrate an N rate reduction in the project from the baseline look-back period.

B.7 Assessing Additionality in California

Concerns have been raised to the Climate Action Reserve about the additionality of any emission reductions from the protocol in California due to the uptake of drip irrigation and consequential reductions in fertilizer application. Recent surveys of irrigation methods in California indicate that an increasing number of growers are using drip and micro-sprinkler irrigation, particularly for higher-value perennial and annual vegetable crops (Tindula, Orang, and Snyder 2013; Orang, Matyac, and Snyder 2008). For example, as of 2010, either drip or micro-sprinkler irrigation was used on more than 70 percent of almond, vineyard, and subtropical orchard crop acreage in California. These low-volume irrigation technologies are used on about 40 percent of existing acreage planted in deciduous trees such as walnuts (Tindula, Orang, and Snyder 2013) and are also increasingly used in processing tomatoes (63 percent), fresh market tomatoes (45 percent), onions (42 percent), cucurbits (39 percent), and other truck crops (35 percent). In some circumstances, drip and micro-sprinklers can be used to irrigate various grain and field crops; however, the cost of these technologies limits their feasibility in these lower-value crops (e.g., drip or micro-sprinklers are used on only 0–15 percent of current acreage planted in field crops).[147]

The Reserve is unaware of any public program mandating drip irrigation for cropping in California. As the studies indicate, this adoption has been driven almost entirely by market forces related to higher yields and more efficient water and fertilizer use; possible reductions in N_2O emissions are one of several important (albeit unintended) environmental co-benefits. Furthermore, while the capital investment required to install drip irrigation on processing tomato fields is partially compensated for by way of yield increases, installing drip for lower value crops (e.g., many forage crops) precludes use, or inapplicable, for example on fields receiving liquid manure, which cannot be applied through drip or sprinkler irrigation systems.[148]

As there are no mandated N use improvements, project developers may use drip irrigation on their fields and be eligible for a nitrogen management project. However, depending on when the practice was adopted, and its impact on N use efficiency, it may be difficult to reduce N rates any further in the project than from what was applied in the baseline look-back period (See Section 5.3.1.1). Encouragingly, other studies point to additional N_2O emission reductions that could be realized from applying nitrification inhibitors in addition to employing drip irrigation.[149]

[147] Culman et al., 2014.
[148] Harter et al., 2017.
[149] Burger et al., 2016.

Appendix C Overview of Water Quality Regulations: Impacts on Legal Requirements and Regulatory Compliance

No federal laws exist that regulate the composition or efficacy of fertilizers. State-level laws addressing composition and/or efficacy are discussed further below. Numerous regulations exist, including at the federal level, concerning the production of fertilizer. However, as fertilizer production is outside the GHG project boundary of this protocol, regulations on fertilizer production are not addressed here. Regulations concerning the use and disposal of hazardous materials, such as fertilizer, and regulations protecting against the contamination of drinking and surface water and air pollution (related indirectly to the land application of fertilizers) are addressed further discussed below.

C.1 Clean Water Act

Though the Reserve could identify no existing federal regulation that explicitly requires implementation of the approved project activity, state or local implementation of the federal Clean Water Act may result in direct and indirect requirements for nutrient management.

The Clean Water Act (CWA) is the federal law regulating water quality for surface waters in the United States. It establishes a comprehensive federal system for regulating the discharge of pollutants into navigable water bodies, while restoring and maintaining the health of the nation's surface waters.[150] The CWA meets these objectives by authorizing water quality standards, requiring and issuing permits for point source discharges (the National Pollution Discharge Elimination System (NPDES)), assisting with the funding of municipal sewage treatment plant construction, and helping with planning to manage nonpoint source pollution. The CWA authorizes EPA as the primary agency tasked with implementation and enforcement, but in practice, most implementation is through state environmental agencies and state-level regulations, and as such state-level implementation can be highly variable. States have the authority to set their own water quality standards, so long as they meet or exceed EPA's minimum requirements.

Though the CWA explicitly defines "point sources" (e.g., industrial or sewage treatment plants, Concentrated Animal Feeding Operations (CAFOs)), it defines nonpoint sources (e.g., agricultural runoff, urban runoff) as anything not considered a point source by the CWA or EPA regulation. The CWA makes it unlawful for point sources to discharge any pollutant into navigable waters without a permit (specifically an NPDES permit). Nonpoint source (NPS) pollution, however, comes from many diffuse sources and is caused by runoff from rainfall or snowmelt moving over and through the ground, picking up pollutants and eventually depositing them in water bodies. When watersheds are successfully meeting the CWA's water quality standards, nonpoint sources are generally unregulated and, in fact, agricultural stormwater discharges and return flows from irrigated agriculture are specifically exempt under the CWA.[151] However, in polluted watersheds that are not attaining the proper water quality standards (i.e.,

[150] The Clean Water Act (CWA) was formerly known as the Federal Water Pollution Control Act (FWPCA), which was first enacted in 1948. Following its significant reorganization and amendments in 1972 and 1977, the FWPCA came to be known by its current name, the CWA. The CWA can be found in 33 U.S.C. §§ 1251-1387.

[151] King, Ephraim, "Nutrients: A National Overview Need for Strong Partnerships & Joint Accountability," U.S. EPA, Office of Science and Technology, Presented at "Nutrient Summit" Springfield, Illinois, 13 September 2010. Available at: http://www.epa.state.il.us/water/nutrient/presentations/ephraim_king.pdf.

"impaired" waters), nonpoint sources may come under regulation as part of efforts to restore water quality.

States are responsible for monitoring water quality of surface waters within their jurisdiction, and biennially, states are required to provide an inventory of the condition of state water bodies and progress toward CWA goals (305(b)) as well as to identify which waters are "impaired" (i.e., not currently meeting water quality standards) or "threatened" (i.e., believed likely to become "impaired" by the time the next "303(d) List" is due).[152] Subsequent to listing waters on the 303(d) List, states are required to prioritize restoration of these waters based on the severity of pollution and begin developing Total Maximum Daily Loads (TMDLs)[153] for these waters. In practice, once a TMDL is established, the state implements a concrete plan to reach this limit through a combination of regulations and voluntary incentives that reduce NPS pollution. EPA funding is typically available to help states implement their nonpoint source management programs.[154] If runoff from agricultural sources is determined to be contributing to the impairment, the TMDL implementation plan typically will include some degree of agricultural best management practices (BMPs). Typically, voluntary incentive payments are the preferred policy mechanism for agricultural sources, as has been the strategy for Maryland, where the state is working towards its Chesapeake Bay TMDL goals through incentive payments which have significantly increased the acres of farmland voluntarily planting cover crops. However, states may also chose to legally require conservation or nutrient management plans, as has recently become the case in California, where the Central Valley Regional Water Quality Control Board (Central Valley Water Board or Water Board) of the State Water Resources Control Board has adopted two key water quality regulations regarding nutrient management: 1) the Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies (Dairy General Order) (See Appendix C.2) and the Irrigated Lands Regulatory Program (ILRP) (See Appendix C.3). Particularly relevant to the Nitrogen Management Protocol, if agriculture is determined to be the source of impairment, and the water body is impaired by high levels of nitrogen (in any of its forms, e.g., nitrate, nitrite, etc.), agricultural BMPs related to nitrogen management are likely to become part of the TMDL.

Circumstances exist where the agricultural producer has significant flexibility for meeting its TMDL obligations. Once a watershed is identified as "impaired," if any agricultural NPS pollution is identified as contributing to a watershed's impairment, agricultural nonpoint sources in that watershed may become limited by a NPS pollution obligation (e.g., a field- or region-specific obligation to help meet a TMDL or other policy mechanism chosen to meet that obligation). Producers often self-select what best management practices will become part of their legally required pollution reduction strategy, typically in the form of Conservation Management Plans, which address a variety of conservation management practices, or in the form of Nutrient Management Plans (NMPs), which focus more on nutrient management practices. As noted in Section 3.5.2, once a practice is self-selected as part of an NPS pollution obligation, the

[152]These reports contribute to the "National Water Quality Inventory" (Part 305(b) of CWA) and the "Impaired or Threatened Waters List" or the "303(d) List" (Part 303(d) of the CWA), respectively. Once identified as impaired or threatened, these waters will appear on the "303(d) List." As this list is updated frequently, project developers and verifiers should refer to the U.S. EPA website for the most up-to-date list of impaired watersheds: http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T.

[153] Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant, such as nitrate, that a given water body can receive without violating water quality standards. The term TMDL, however, is often used to refer to the whole process of establishing a TMDL, including all aspects of TMDL implementation and monitoring.

[154] Specifically, EPA funding is available through CWA Section 319(h) grants specifically for nonpoint source management, while states can also participate in the Clean Water State Revolving Fund (CWSRF) program, in which EPA to provide grants to states to establish loan funds which then provides low-cost financing to third parties (municipalities, non-profits, businesses) to implement water quality infrastructure projects.

Reserve considers that practice non-voluntary, as continued implementation of that practice is required by law, and that practice is no longer considered an eligible project activity for that farm.

Due to localized implementation of the CWA and TMDL strategies, the extent to which NMPs become effectively required by law may vary greatly in terms of flexibility and what is explicitly required (e.g., a project participant may be allowed to self-select practices to include in an NMP for their field, while elsewhere an explicit N rate reduction may be required).

C.2 California Dairy General Order

The California Central Valley Water Board's Reissued Waste Discharge Requirements General Order for Existing Milk Cow Dairies (Dairy General Order or Order) requires owners and operators of dairy farms (Dischargers) in the Central Valley to protect water quality from pollution from nitrates and salts. Farmers must keep records to ensure they are managing manure waste properly, managing nutrient application to cropland to prevent excess runoff, and performing general housekeeping of the dairy facility to reduce threats to water quality.

All dairies receiving coverage under the Dairy General Order are required to develop and implement a Nutrient Management Plan (NMP) for all land application areas. The purpose of the NMP is to budget and manage the nutrients applied to the land application area(s) considering all sources of nutrients, crop requirements, soil types, climate, and local conditions in order to prevent adverse impacts to surface water and groundwater quality. NMPs must be developed by a certified specialist, including a Professional Soil Scientist, Professional Agronomist, or Crop Advisor certified by the American Society of Agronomy or a Technical Service Provider certified in nutrient management in California by the Natural Resources Conservation Service (NRCS). NMPs shall specify the form, source, amount, timing, and method of application of nutrients on each land application area to minimize nitrogen and/or phosphorus movement to surface and/or ground waters to the extent necessary to meet the provisions of the Order. Manure and/or process wastewater will be applied to the land application area for use by the first crop covered by the NMP only to the extent that soil tests indicate a need for nitrogen application. Supplementary commercial fertilizer(s) and/or soil amendments may be added when the application of nutrients contained in manure and/or process wastewater alone is not sufficient to meet the crop needs, as long as these applications do not exceed provisions of the Order. The NMP must take the site-specific conditions into consideration in identifying steps that will minimize nutrient movement through surface runoff or leaching past the root zone.

The Discharger shall develop a nutrient budget for each land application area. The nutrient budget shall establish planned rates of nutrient applications for each crop based on soil test results, manure and process wastewater analyses, irrigation water analyses, crop nutrient requirements and patterns, seasonal and climatic conditions, and the use and timing of irrigation water, and important nutrient application restrictions listed below:

- The rate of application of manure and process wastewater for each crop in each land application area to meet each crop's needs without total nitrogen application rates exceeding 1.4 times[155] the nitrogen that will be removed from the field in the harvested portion of the crop.

[155] The University of California Committee of Experts in Dairy Manure Management (UCCE) review of dairy waste states that based on field experiments and computer models, the appropriate nitrogen loading rate that minimizes nitrogen leaching and maximizes nitrogen harvest is between 140 to 165 percent of the nitrogen harvested.

- Additional applications of nitrogen are allowable if the following conditions are met:
  - Plant tissue testing has been conducted and it indicates that additional nitrogen is required to obtain a crop yield typical for the soils and other local conditions;
  - The amount of additional nitrogen applied is based on the plant tissue testing and is consistent with University of California Cooperative Extension written guidelines or written recommendations from a professional agronomist;
  - The form, timing, and method of application facilitates timely nitrogen availability to the crop; and
  - Records are maintained documenting the need for additional applications.

- If total nitrogen application exceeds 1.65 times total the nitrogen removed from the land application area through the harvest and removal of the previous crop, the Discharger shall either revise the NMP to immediately prevent such exceedance or submit a report demonstrating that the application rates have not and will not pollute surface or ground water

Due to these crop-specific restrictions on nitrogen rate, the Dairy General Order poses a concern regarding the regulatory additionality of offsets generated under the Nitrogen Management Protocol. Any field subject to the Order will only be eligible for emission reductions associated with reductions in N rates below this 40 percent residual N threshold. However, it is important to note that the Order is only applicable to farms applying manure; farms only applying synthetic N fertilizer are not subject to the Order.

C.3 California Irrigated Lands Regulatory Program

The California Central Valley Water Board's Irrigated Lands Regulatory Program (ILRP) regulates the waste discharge requirements (WDRs) adopted by the Water Board for agricultural discharges from commercial irrigated lands[156] to protect both surface and groundwater and reduce impacts of irrigated agricultural discharges to waters of the State. All growers regulated by the ILRP are required to prepare and implement Nitrogen Management Plans (NMPs) and submit NMP Summary Reports to the Water Board to help evaluate potential nitrogen impacts to groundwater and/or surface waters.

The NMP Summary Report collects information on Total Available Nitrogen Applied, and a ratio of Total Available Nitrogen Applied to Total Yield (A/Y Ratio) for each crop grown. The Total Available Nitrogen Applied includes the nitrogen from synthetic fertilizers and organic materials (manure and compost) applied, residual soil nitrogen, and nitrogen in irrigation water. Like the NUE metric used in the protocol's performance standard test for additionality, the advantages of using the A/Y Ratio as a nitrogen *removal* reporting metric are rapid data collection, consistent reporting across all crops and across reporting years, ease of calculation, and a tangible meaning of the relationship between the Applied Nitrogen and the Yield. The A/Y Ratio provides the Water Board with data for analyzing and reporting nitrogen removal, and for developing outreach material for feedback to growers on nitrogen use compared to commonly recommended application rates and to other growers of the same crop in their area. Farm

[156] Land that is irrigated (regardless of water supply source) to produce crops or pasture for commercial purposes must be enrolled in the ILRP. Regulatory coverage is not required only if the property is not used for commercial purposes or if the irrigated land is covered under the Dairy Program.

evaluations then allow the Water Board to determine if additional practices are needed to protect water quality.

As the ILRP mandates nitrogen management reporting and not practices, the program poses little concern to regulatory additionality. However, additional practices may be required at individual farms pending the results of evaluations, and as such, could pose a regulatory additionality concern in the future.

C.4 Coastal Zone Management Act

The Coastal Zone Management Act (CZMA) encourages states/tribes to preserve, protect, restore or enhance natural coastal areas, including wetlands, floodplains, estuaries, beaches, and dunes. Eligible areas border the Atlantic, Pacific, and Arctic Oceans, Gulf of Mexico, Long Island Sound, and Great Lakes. Participation is completely voluntary. To encourage states/tribes to participate, the act makes federal financial assistance available to develop and implement a comprehensive coastal management program. Most eligible states/tribes participate in the program. Section 6217 of the CZMA, administered jointly by EPA and the National Oceanic and Atmospheric Administration (NOAA), specifically supports states to develop and implement nonpoint pollution control programs for coastal areas.[157] Within a guiding document specifying typical measures to control nonpoint source pollution published by the EPA[158] in 1993, commercial N fertilizer is identified as a pollutant to coastal areas. Management measures to reduce pollution include development and implementation of a nutrient management plan focusing on (1) applying nutrients at rates necessary to achieve realistic crop yields, (2) improving the timing of nutrient application, and (3) using agronomic crop production technology to increase nutrient use efficiency. In 2003, EPA updated and expanded the 1993 coastal nonpoint source manual to address the control of agricultural nonpoint source pollution for the entire United States.[159] *National Management Measures to Control Nonpoint Source Pollution from Agriculture* highlights best available, economically achievable means of combating nonpoint source pollution, and discusses monitoring techniques, load estimation techniques, and watershed approaches.

As participation is voluntary, assistance received through CZMA does not affect field eligibility. Any financial assistance received by projects shall be disclosed to the project verifier and Reserve per Section 3.5.3.

C.5 Safe Drinking Water Act

The Safe Drinking Water Act (SDWA), the main federal law to ensure drinking water quality, requires actions to prevent the contamination of surface and ground sources of drinking water (e.g., rivers, lakes, reservoirs, springs, ground water wells, but not private wells, serving less than 25 people). Although EPA is primarily responsible for enforcement of the federal SDWA, states may apply to EPA for the authority to implement the SDWA and its enforcement within their jurisdictions (e.g., “primacy”), so long as they can demonstrate that state standards will be at least as stringent as the national standards and that state water systems meet these standards.

The SDWA authorizes EPA to set national health-based standards limiting the amount of contaminants, such as nitrates and nitrites, in drinking water. In practice, these health-based

[157] See https://coast.noaa.gov/czm/act/
[158] Available at http://water.epa.gov/polwaste/nps/czara/MMGI_index.cfm
[159] Available at http://water.epa.gov/polwaste/nps/agriculture/agmm_index.cfm

standards are legally enforceable limits, called maximum contaminant levels (MCLs). The SDWA includes MCLs for both nitrates and nitrites, for which fertilizer runoff and leaching from agriculture is the major source in drinking water. The MCL for nitrate is set at 10 mg/L or 10 ppm, while the MCL for nitrite is set at 1 mg/L or 1 ppm, both of which are measured in nitrogen.

The SDWA requires states and water suppliers to conduct assessments of potential contamination of water sources, and states are required to implement measures to protect water sources through voluntary incentive programs (to encourage agricultural BMPs) or legal enforcement actions, such as Notices of Violations (NOVs). Any individual discharger could, in theory, be found to be causing levels of nitrate or nitrite to exceed the MCL and receive a Notice of Violation. However, due to the nonpoint source nature of agricultural discharges, it is relatively difficult to identify one agricultural discharger as the source of an impairment and, as such, NOVs are typically only issued against agricultural discharges when the discharge is particularly egregious.

Though one of the main tools to limit agriculture's effect on drinking water quality are agricultural BMPs, to our knowledge, there is no legal requirement within the context of the SDWA to require best nitrogen management practices. However, any case of regulatory non-compliance, such as a NOV due to a violation of the SDWA, must be reported to the verifier, who will determine if the violation is material to the project.

C.6 Fertilizer Content Labeling Laws

There are no federal laws regulating the composition or efficacy of fertilizer in the U.S., but most states have developed their own fertilizer regulatory programs, which are generally administered by their respective departments of agriculture. These regulatory programs typically address efficacy claims and composition statements of the active ingredients displayed on labels for commercially available fertilizer.

The Association of American Plant Food Control Officials (AAPFCO), tasked with making regulation among states uniform, stated that metals in N fertilizer generally do not pose harm to the environment as long as the metal concentration in fertilizer is below a specific threshold.[160] In addition to trace metal composition testing, state fertilizer laws generally require product registration, licensing and efficacy testing to assure that statements made on the label are correct. Also, at the state level, fertilizer is primarily regulated for quality, as for any manufactured good. These regulations are usually administered through the state's department of agriculture.

With the exception of California's Dairy General Order, none of these laws should impact additionality or the eligibility of particular fertilizers in the Nitrogen Management Protocol.

[160] See http://www.aapfco.org/rules.html.

Appendix D Methodology for Determining $Frac_{LEACH}$ Values

As discussed in Section 5.1.4.3, $Frac_{LEACH}$ refers to the fraction of N inputs that is lost through leaching and runoff. This parameter is relevant to calculating N_2O emissions associated with LVRO in the project if there are increases in organic N rates from the baseline scenario (see Equation 5.22). This appendix contains the methodology for determining $Frac_{LEACH}$ values. As noted in Box 5.1, the $Frac_{LEACH}$ value calculated from project year climatological data shall be used for both the baseline and project emissions equations to conservatively quantify the emission reductions due to the project activity in a given year. The methodology for determination of $Frac_{LEACH}$ values is adapted from the IPCC and MSU-EPRI methodologies.[161]

The project developer shall calculate the $Frac_{LEACH}$ value for their project field on an annual basis, based on the USGS hydrologic year of October 1 to September 30.[162] Project developers shall calculate their $Frac_{LEACH}$ value using precipitation and evaporation data from the closest weather station available (preferably within 20 miles). If no weather station within 100 miles has both precipitation and evaporation data available, the project developer may use the monthly U.S. Evaporation and Precipitation maps published by the Climate Prediction Center at NOAA.[163] The project developer shall then convert evaporation data to evapotranspiration, by multiplying each month of data by the following conversion factors from Shaw, R.H. (1982).[164]

Table D.1. Evapotranspiration Conversion Factors

Month	Conversion Factor
January	1
February	1
March	1
April	1
May	1.375
June	1.475
July	1.725
August	1.75
September	1.55
October	1
November	1
December	1

[161] The most significant difference is with regards to the time period over which $Frac_{LEACH}$ is calculated. The IPCC methodology uses the time period of the "rainy season," defined as "the period(s) when rainfall > (0.5*PanEvaporation)", while the MSU-EPRI methodology considers the growing season. However, as the dates of the rainy season, and the growing seasons will vary greatly across the NCR, as well as from year to year, and for the purposes of standardizing this methodology for project implementation, the hydrological year is used here. Additionally, the MSU-EPRI methodology uses the FAO Penman-Monteith equation for estimating potential evapotranspiration and calculating $Frac_{LEACH}$, while the IPCC uses potential evaporation for the calculation.
[162] This time period also corresponds with a typical corn cultivation year in the NCR and is expected to match the reporting period for most projects.
[163] Monthly evaporation available at: http://www.cpc.ncep.noaa.gov/cgi-bin/US_Evaporation-Monthly.sh and Monthly precipitation available at: http://www.cpc.ncep.noaa.gov/cgi-bin/US_Precipitation-Monthly.sh
[164] Available at http://www.ipm.iastate.edu/ipm/icm/2000/5-29-2000/wateruse.html.

Once all monthly precipitation and evapotranspiration data have been collected, monthly data should be totaled for the hydrological year, *t*, October 1 to September 30, and $Frac_{LEACH}$ calculated according to the following equations:

If $\frac{Annual\ Precipitation}{Annual\ Potential\ Evapotranspiration} \geq 1.00$,	$Frac_{LEACH}$ = 0.3
If $\frac{Annual\ Precipitation}{Annual\ Potential\ Evapotranspiration} < 1.00$,	$Frac_{LEACH}$ = 0

Appendix E Default Values for Average Fertilizer N Concentration and Fertilizer Weights

Synthetic Fertilizer N Contents and Weights			
Fertilizer Type	**Form**	**N** (%)	**Weight** (lb/gallon)
Ammonia	dry/liquid	80	NA
Ammonium superphosphate	dry	12-17	--
Ammonium metaphosphate	dry	12	--
Ammonium nitrate	dry	32-34	--
Ammonium phosphate	dry	11-18	--
Ammonium phosphate nitrate	dry	27-30	--
Ammonium phosphate sulfate (APS)	dry	13-16	--
Ammonium polyphosphate (APP)	liquid	10-11	11.65
Ammonium polysulfide (Ammonium sulfate)	liquid	20-21	NA
Ammonium sulfate nitrate	dry	20-30	
Ammonium thiosulfate solution	liquid	12	11.00
Anhydrous ammonia	liquid/gas	82	NA
Aqua ammonia (ammonium hydroixde)	liquid	16-25	NA
Bone meal	dry	0-2	--
Calcium nitrate	dry	15-16	--
Diammonium phosphate sulfur	dry	15-16	--
Diammonium phosphate (DAP)	dry	16-21	--
Monoammonium phosphate (MAP)	dry	11-13	--
Natralene	dry/liquid	40	NA
Nitrogen solutions	liquid	7-58	7-21-7: 11.00 9-18-9: 11.11 12-0-0: 11.00
Nitric phosphate	dry	12-17	--
Potassium nitrate	dry	13	--
Potassium sodium nitrate	dry	15	--
Sodium nitrate (nitrate of soda)	dry	15-16	--
Urea	dry	45-46	--
Urea, sulfur coated	dry	36-38	--
Urea ammonium phosphate	dry	25-58	--
Urea ammonium nitrate (UAN)	liquid	28-32	28%: 11.66 32%: 11.06
Urea phosphate	dry	17	--

Organic Fertilizer N Contents and Weights		
Manure Type	**NC** (lb N/ton)	**Weight** (ton/gallon)
Beef cattle	8.5	8.5
Dairy cattle	6.1	8.4
Hog	11.3	8.4
Poultry	26.9	8.3

Source: Synthetic fertilizer N contents, fertilizer weights, and unit conversion factors are adopted from USDA NRCS Minnesota, Planning – Nutrient Management, Conversion Factors and Tables, Factors and Tables Useful When Planning. Organic fertilizer weights per unit of volume are adopted from: Lorimor, J., Sutton, A., & Powers, W. (2004). Manure Characteristics. *MWPS-18*. Section 1. Second Edition. Ames, IA: Midwest Plan Service. Default manure N contents are consistent with Edmonds et al. (2003) cited in U.S. Environmental Protection Agency. (2011). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. *EPA 430-R-11-005*. Washington, D.C.

Appendix F Modeling to Develop Nitrogen Management Quantification Tool (NMQuanTool)

A major focus of the Climate Action Reserve's (Reserve's) update to V2.0 was to improve the usability and expand the applicability of the protocol to incorporate additional regions, crops and nitrogen management practices, while simplifying the quantification process. After thorough evaluation of existing methods and tools (e.g., COMET-Farm, DeNitrification-DeComposition (DNDC), MSU-EPRI, USDA GHG Methods (the "Blue Book"), IPCC), the Reserve determined the best approach for updating the protocol quantification methodology was to engage an expert third party, technical contractor, Mark Easter Consulting LLC, to develop a new quantification methodology based on Tier 2-style standardized parameters and emission factors. The approach outlined in this appendix was developed and executed by Mark Easter Consulting, LLC. The team consisted of Dr. Keith Paustian, Mark Easter, Amy Swan, Ernest Marx, and Stephen Williams at Colorado State University (CSU). The effort summarized here resulted in the development of the NMQuanTool. A complete background document on the development and application of the NMQuanTool is available as a separate resource on the Reserve's webpage.

F.1 Overview

This appendix describes the standardized assumptions used by the Reserve's technical contractor in modeling baseline GHG emission reductions associated with reducing fertilizer amounts, utilizing enhanced efficiency fertilizers (EEF – slow release fertilizers or nitrification inhibitors), or converting from intensive tillage to no tillage systems. It also describes the modeling approach used by the technical contractor to estimate the baseline emissions from soil processes using the DAYCENT model (Parton *et al.* 1998) with a combination of national data sources. The methodology and standardized baselines are intended to provide accurate estimates of baseline emissions, give certainty over expected project outcomes, minimize project setup and monitoring costs, and reduce verification costs. The resulting emission rates, applied in the protocol as per acre emission factors, preclude the need for project-level modeling by project developers.

Modeling was performed using the same build of the DAYCENT model that was used for estimation of the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013 (U.S. EPA 2016) (U.S. Inventory) compiled by the EPA, and which is incorporated in USDA's entity level GHG quantification tool, COMET-Farm. The DAYCENT model (i.e., daily time-step version of the Century model) is an ecosystem model that simulates plant production and cycling of carbon, nitrogen, and other nutrients in cropland, grassland, forest, and savanna ecosystems on a daily time step. The data were derived from national level soils and weather data sources, the USDA National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL),[165] the USDA national database of crop planting and harvesting dates, the USDA Economic Research Service (ERS) Agricultural Resource Management Survey (ARMS) and the NREL Carbon Sequestration Rural Appraisal (CSRA).[166]

The approach to baseline determination and baseline modeling relied almost exclusively on geographic, historic, physical characteristics of project parcels, and current cropping practices – most of which are publicly available in national geospatial databases – in assigning a baseline

[165]The USDA-NASS Cropland Data Layer (CDL) is an annual raster, geo-referenced, crop-specific land cover data layer. Available at: https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php.
[166] (Paustian Group, unpublished data).

and associated emissions for any given project parcel. The modeled management practices were generated based on survey data from land within the same eco-climatic region and soil type as the project parcel, based on related data sources defined below.

Through this exercise, a minimum of 500 and up to 750 long-term cropland year-point samples were modeled in each of the12 CEAP regions (see Section F.2) in the U.S. lower 48 states for each crop type (corn for grain, corn for silage, sorghum for grain, sorghum for silage, cotton, processing tomatoes, spring grains – barley, oats, spring wheat – and winter wheat). The resulting emission rates for each crop stratum represent an average of the potential N_2O reduction practices at the points modeled within each region. This approach to baseline determination eliminates subjectivity by standardizing the baseline determination based exclusively on stratification (see Section F.2). Similarly, the methodology does not require project developers to execute complex biogeochemical process models. Instead, the methodology provides composite emission rates derived from these same biogeochemical process models utilizing geographic, soil, and cropping system assumptions representative of the project parcel. Compared to the alternative in which project developers would be responsible for asserting and documenting their baseline assumptions, and then conducting modeling themselves.

F.2 Stratification: Geography and Associated Climate

The N_2O emissions analyses and results were stratified by 12 Conservation Effects Assessment Program (CEAP) regions, which were rectified to county boundaries.[167] CEAP regions represent broad geographic regions with similar climate, physiography, and land use. CEAP regions were further stratified by USDA Major Land Resource Areas (MLRA)[168] for the purpose of random point sampling. Using the USDA NASS CDL for years 2010-2016, random point selection was limited to areas within an MLRA in which, 1) at least one year of corn, cotton, sorghum, soybeans, spring grains (barley, oats, spring wheat), tomatoes, or winter wheat was grown, and 2) all crops in rotation from 2010-2016 could be modeled in the COMET-Farm system which includes 33 common U.S. crops. The resulting cropland areas evaluated in this analysis are mapped in Figure F.1. Within each MLRA, a random point sample of 100 points was created within defined cropland areas, and randomly sampled at least 500 and up to 750 point-year data records from within this dataset. A point-year record is the occurrence of a crop growing for a single year within the CDL-predicted crop rotation found at this point. For example, a corn-soybean rotation grown for 10 years at this point would have five point-year occurrences of corn and five point-year occurrences of soybeans. This large point sample (approximately 15 million points) was then subsampled at the CEAP region scale to meet requirements for the uncertainty methods, but also improve efficiency of processing model runs in the COMET-Farm application programming interface (API) system.

[167] A lookup table for CEAP-region to county can be made available by the Reserve per request, and will be available at the Climate Action Reserve's Nitrogen Management webpage.
[168] Major land resource areas (MLRAs) are USDA-defined geographically associated land resource units (LRUs). The 278 major land resource areas are designated by Arabic numbers and identified by a descriptive geographic name in Agriculture Handbook 296. Available at:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053624.

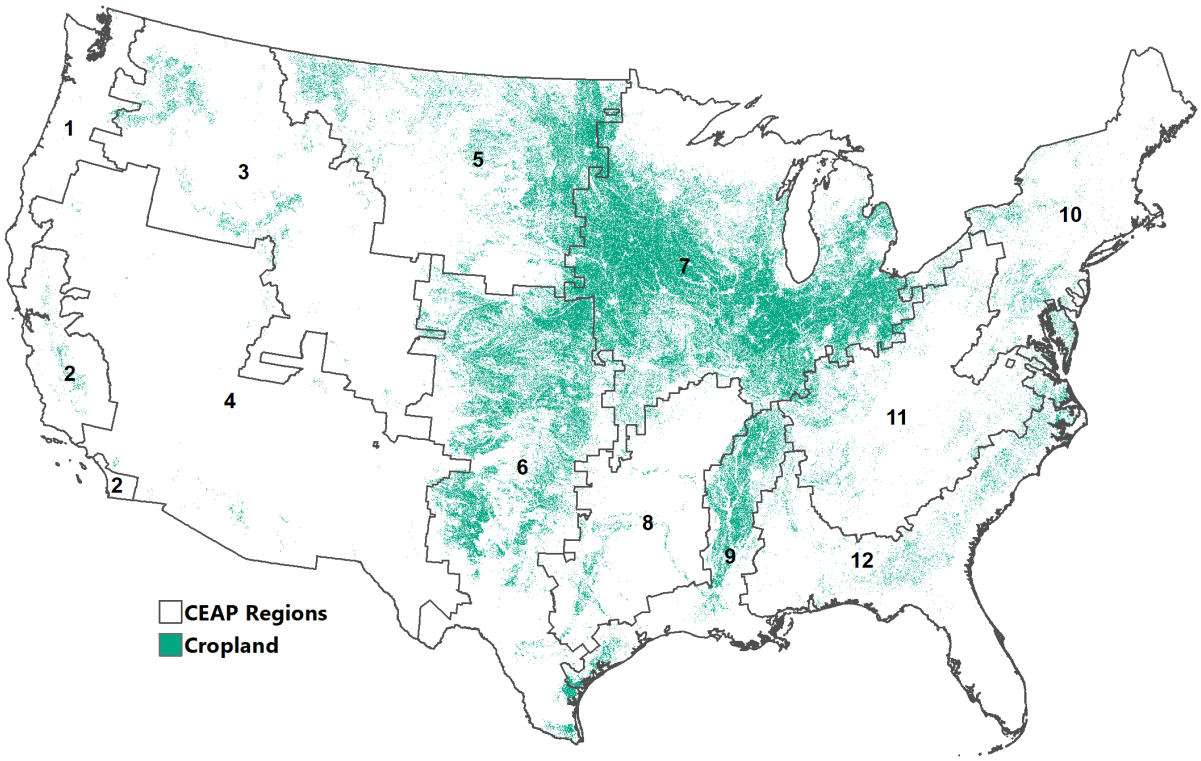

Figure F.1. Cropland areas included in the analysis, overlaid with county-rectified CEAP regions.

F.3 Baseline Determination

The baseline for any given project parcel is defined probabilistically as a composite of the likely crop rotation that might occur on that parcel were a user to implement practices that reduced soil N_2O emissions. The stratification regime defined above in Section F.2 plays a fundamental role in establishing the range of practices and relative probabilities for baseline practice. Based on the stratification element – the CEAP region – the U.S. was first broken into individual super-strata. By first stratifying by CEAP region, the U.S. is effectively subdivided into land areas based on suitability to certain cropping systems and the practices associated with those systems in those geographies. Because CEAP regions are based on agroecological classification, they define areas of similar climate, geomorphology, native vegetation and land management systems – all of which are the fundamental drivers of the biogeochemical processes involved in greenhouse gas emissions. Thus, CEAP regions are better-suited as stratification variables than other land area designations that are politically-based (e.g., states) or defined by a more limited set of criteria (e.g., NRCS Crop Management Zones (CMZ)[169] based on farm management practices).

For each unique super-strata, baseline practices were collected and estimated based on the real-world practices on agricultural land within the same CEAP region, as derived from the CDL, Economic Research Service (ERS) Agricultural Resource Management Survey (ARMS), National Agricultural Statistics Service (NASS), and CSRA. These resources represent the best available data sources for agricultural practice in the U.S. A brief description of the relevant data sources is included below:

[169] Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/tools/rusle2/?cid=stelprdb1247555

- Carbon Sequestration Rural Appraisal (CSRA): Developed by Colorado State University as input data for the COMET tools, the CSRA is derived from a survey instrument filled out by NRCS field staff, and describes historic land use and management (European Settlement to 2000) at the NRCS Land Resource Region (LRR)[170] level.

- Conservation Effects Assessment Project Region (CEAP): Agroecological classification developed by NRCS that defines areas of similar climate, geomorphology, native vegetation, and land management systems across the U.S.

- Soil Survey Geographic Database (SSURGO)[171]: Developed and managed by NRCS, the SSURGO database contains geographically linked information on soil properties including texture. SSURGO data were collected by the USDA National Cooperative Soil Survey, covering the states, commonwealths and territories of the U.S. It was generated from soil samples and laboratory analysis, and represents the finest resolution soil map data available in the U.S.

- Economic Research Service (ERS): Housed within the USDA, ERS gathers a variety of data on crop and livestock practices through its annual Agricultural Resource Management Survey (ARMS). ERS provides both annual and trend data, illustrating shifts in agricultural practice. ERS contains data on nutrient management, irrigation practices, and conservation practices.

- National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL): Data on annual county-average crop area and yields from NASS are used as a secondary data source for availability control of model outputs.

- USDA NASS Agricultural Surveys of planting and harvest dates and Usual Planting and Harvesting Dates for U.S. Field Crops handbook that identifies the usual planting and harvesting dates for United States field crops.

For each CEAP region, relevant variables about baseline conditions were established using these data sources. In many cases, these variables were linked using spatial attributes. For example, CDL data were used to establish the various cropping sequences, and then each crop was assigned nitrogen application rate distributions based on regional ERS ARMS data and crop planting and harvest date reported by the USDA. The following three baseline practices were modeled for across all 12 CEAP regions, for each crop type (corn for grain, corn for silage, sorghum for grain, sorghum for silage, cotton, processing tomatoes, spring grains – barley, oats, spring wheat – and winter wheat) grown in the respective CEAP region, and for both irrigated and non-irrigated lands:

- No N rate reduction (i.e., the default state-level, crop-specific fertilizer rates from the ARMS survey)
- No use of an EEF (slow release fertilizers or nitrification inhibitors)
- No switch to no till (i.e., intensive tillage)

[170] USDA-defined Land Resource Regions (LRRs) are geographically associated MLRAs which approximate broad agricultural market regions. There are 28 land resource regions, and A through U, with the exception of Q, are found in the conterminous 48 states, as found in Agriculture Handbook 296. Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/home/?cid=nrcs142p2_053624.
[171] Available at: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627.

In addition to the cropping and management variables extracted from these data sources, the methodology applied the same area-weight (10 acres) to each point sampled. Therefore, each random point sample is equally represented in the results. A description of the plant management details implemented in the model runs follows:

- Default planting and harvest dates were determined from state-level data, by crop, provided by the USDA NASS.
- Default fertilizer rates were derived from state-level data, by crop, from the ARMS survey. Fertilizer was applied at the time of planting.
- Tillage occurred in the week before planting.
- The effects of EEF practices on soil N_2O emissions were implemented on the model results derived from the DayCent model, as the plant growth effects of slow release fertilizers and nitrification inhibitors are under development for use in the Daycent model.
- Irrigation was simulated so that crops received irrigation water to full water holding capacity in the rooting zone when soil water holding capacity dropped below 55 percent.
- The baseline and conservation scenarios were run for 10 years, using the same weather and soils data for each.
- Crop rotations were built from the cropping sequence identified in the USDA CDL. A crop rotation was built using the sequence of crops predicted by CDL for the period of 2010-2016. This crop rotation was repeated in serial sequence through the modeling period.

F.4 Modeling Approach

In order to model baseline emissions for use in quantifying emission reductions, the composite baseline practices defined in above in Section F.3 were combined with climatic and initial condition inputs. Local weather data inputs were based on values from the PRISM database for 1979-2016 (PRISM Data Group 2017). Weather for each year in the future was modeled based on actual weather from a year in the past (within the last 30 years). Thus, inputs such as temperature and precipitation should reflect recent trends. All modeling was performed using stochastic modeling techniques and the DAYCENT model to evaluate the change in dependent carbon and nitrogen emissions sources across multiple scenarios. More specifically, this was done by modeling the actual rotation at randomly selected points that are currently categorized as cropland. The analysis incorporates composite baselines defined in Section F.3 in a manner consistent with the compilation in the COMET-Farm tool.

Modeling was conducted based on the strata delineated in Section F.2, which include previous land use in addition to the variables used to define the super strata. For each CEAP region, the following methodology was employed by utilizing the Colorado State University parallel computing capability, which includes dedicated database servers and a circa 200 central processing unit (CPU) computing cluster:

1. Cropland points were randomly sampled at the MLRA level within each CEAP region so that points were geographically distributed. At least 500 and up to 750 points containing the crops of interest for this project within each CEAP region were modeled.

2. Initial soil carbon and nitrogen pools at project start were predicted for each data point based on equilibrium ecosystem conditions prior to conversion to cropland, soil data, crop management, and a long-term spinup the DAYCENT model using practices defined in the preceding step.

3. For the cropland baseline scenario, each point was modeled forward applying the baseline crop management practices through the DAYCENT model for 10 years.

4. For the project scenario, each cropland point was modeled forward applying each of the conservation scenarios:
    a. 5 percent to 30 percent fertilizer reductions, modeled in DayCent at 5 percent increments. These were performed in discussion with the Climate Action Reserve and the steering committee.
    b. 40 percent and 50 percent fertilizer reduction, modeled in DayCent, to assess model performance beyond the likely practice levels, so that CSU could examine results for potential spurious model performance in the boundaries of the likely practices. No unusual results were found beyond the likely practices (e.g., 30 percent fertilizer reduction).
    c. Conversion from intensive tillage to no tillage, modeled utilizing N_2O change factors described in the USDA GHG Methods Document to modify the DayCent-predicted N_2O emissions.
    d. Use of slow release fertilizers, modeled utilizing N_2O change factors to described in the USDA GHG Methods Document to modify the DayCent-predicted N_2O emissions.
    e. Use of nitrification inhibitors, modeled utilizing N_2O change factors to described in the USDA GHG Methods Document to modify the DayCent-predicted N_2O emissions.
    f. Combinations of practices a-c above with practices d-f.

5. DAYCENT model results for soil N_2O emissions, modified using N_2O change factors in the USDA GHG Methods Document (described in item 4 above) were summarized as average annual change or emission rates in the ten-year increment following the conversion to a conservation practice.

6. The impact of tillage and EEF use was modeled against DayCent model runs, using the method described for direct soil N_2O emissions in chapter 3, section 3.5.4 of the USDA GHG Methods Document. Emissions factors for conversion to no tillage and/or use of nitrification inhibitors or slow release fertilizes were applied to the emissions predicted by the DayCent model against crops grown under default conditions for planting and harvest dates, fertilizer amounts, irrigation systems and intensive tillage. Fertilizer reductions were used in the fertilizer amounts used to run the DayCent model. For example, a 10 percent fertilizer reduction meant that a corn crop normally receiving 180 pounds of nitrogen per year in the DayCent model run would receive 162 pounds of nitrogen per year, or 18 pounds less in the DayCent model run. The DayCent model, rather than predicting base emissions from the base emission factors described in the USDA GHG Methods Document, was used for two main reasons: 1) The DayCent model predicted direct soil N_2O emissions better than did using the base emission factors described in the USDA GHG Methods Document; and 2) the base emission factors had not been calculated for tomatoes, and was missing for key regions of the country for other crops like oats and barley, meaning a mixed model approach would have to be

reported in the final results (using the IPCC base emission factor for some crops, and the DayCent/DNDC-calculated base emission factor for others).

7. The average emissions reduction and 95 percent confidence intervals were calculated for each crop and CEAP region using Monte Carlo simulation techniques as described in the USDA GHG Methods Document, section 8.1. The IPCC good practice Guidance recommends using Monte Carlo simulation as the preferred method for predicting uncertainty in both dynamic and empirical greenhouse gas models, and is recommended when combining uncertainty effects of multiple factors and when the expected uncertainty is near or higher than 30 percent. Using Monte Carlo simulation allowed us to effectively combine the effects of multiple factors across different soil, crop rotation, and climatic conditions present in the geographically rich CEAP regions. The resulting emission rates are provided by stratum in a tabular form and included as lookup in the Excel tool provided as part of this contract.

8. After well into this effort, the modeling team recommended certain portions of the analysis that were originally proposed be modified or dropped, as follows:
    a. Modeling fertilizer reductions in soybeans was not useful, as soybeans either do not receive nitrogen fertilizers, or when they do, it is in small amounts applied as starter fertilizer and the reductions would yield soil nitrous oxide emissions that were very small.
    b. Oats, barley, and spring wheat were combined into a single category of “spring grains” because the management for these crops was very similar and the emission reductions were nearly identical across the three crop types.
    c. Fresh tomatoes were dropped from the analysis because default fertilizer applications rates were not available, and crop management techniques were highly variable.
    d. Modeling cover crops became highly impractical for a number of reasons, including the regional variation in cover crops systems, the lack of comprehensive information related to how fertilizer application rates were adjusted to account for use of cover crops, and the lack of response of the indirect soil nitrous oxide model to the use of cover crops.

9. Indirect soil N_2O emissions were estimated using the IPCC Tier 1 methods described in the USDA GHG Methods Document, section 3.5.4. This method utilizes emission factors with uniform distributions. The uncertainty of these factors are large (for example, +167 percent/-67 percent for the leaching and runoff fraction), and because the distributions are uniform, the upper bounds of the emissions reduction estimate are often close to zero. As a result, reductions in indirect soil nitrous oxide emissions have a relatively small contribution to the overall emission reductions.

F.5 Results

Over 480,000 point-year model runs were completed on more than 13,900 randomly-sampled cropland points to complete this effort. Emission rate reductions were calculated for only those points where data passed quality control analysis. The full model results have been incorporated into the NMQuanTool and can be made available by the Reserve per request.

F.6 Tillage Practice and Increased N_2O Emissions

Regional climate has been identified as a major driver for the change in N_2O emissions with adoption of no tillage practices, and depending on the region, the potential to mitigate emissions

with no tillage management has been found to only be realized when it's practiced in the long term. Further, the research on the switch to no-till indicates that in some ecoregions, particularly arid/semi regions, there is an increase in N_2O emissions in the short term (i.e., within the first 10 years) after conversion from conventional tillage. As described above in Section F.1, the impact of tillage use was modeled against DayCent model runs, applying emission factors for the conversion to no tillage from the USDA GHG Methods Document to the emissions predicted by the DayCent model against crops grown in different regions under different conditions for fertilizer amounts, irrigation systems and intensive tillage. The modeling effort found that certain activity-crop-region scenarios in combination with a switch to no-till in the short-term result in an increase in N_2O emissions, and a significant increase in uncertainty. All such scenarios have been identified and are ineligible to earn CRTs under this protocol. The results have been incorporated into the Nitrogen Management Protocol Eligibility Lookup Tool. A separate spreadsheet containing all ineligible activity-crop-region scenarios may be made available upon request to the Reserve.

All activity-crop-region scenarios in combination with the maintenance of till (i.e., no switch to no-till) or the switch to long term no-till (at least 10 consistent years) are eligible.

F.7 Uncertainty

Monte Carlo simulation techniques were utilized to calculated mean emission reductions and 95 percent confidence intervals, with 10,000 iterations utilized for each point. Uncertainty for direct soil N_2O was modeled using the methods utilized in the U.S. Inventory. Uncertainty for indirect soil N_2O were calculated using DayCent-predicted values for leaching and volatilization, which were utilized with emission factors described in the indirect soil N_2O method described in the USDA GHG Methods Document.