DRAFT QUANTIFICATION PROTOCOL FOR NITROUS OXIDE EMISSION REDUCTIONS

Public Review Version

Acknowledgements:

This protocol is largely based on the following technical seed documents: (1) *The Science Discussion Document for the Nitrous Oxide Emissions Reduction Protocol; (2)*, the *Technical Background Document for Nitrogen Fertilizer Use Efficiency Protocol and (3) Decision Paper for the Nitrous Oxide Emissions Reduction Protocol July 23, 2009.* This work was commissioned by the Nitrogen Emission Reduction Protocol Technical Working Group, supported financially by the Canadian Fertilizer Institute, coordinated by Climate Change Central and completed by ClimateCheck.

This represents the culmination of several multi-stakeholder science consultation processes and a number of guidance documents. This document represents an abridged and re-formatted version of this work. Special thanks to the Can-Ag MARS Inventory scientists in Agriculture and Agri-Food Canada, in particular Drs Ray Desjardins and Devon Worth, for their invaluable support and contributions of inventory work and the International Plant Nutrient Institute (IPNI), in particular Dr. Cliff Snyder and colleagues for the pioneering work on synthesizing BMP research in nutrient management. And for all the experts consulted along the way in the development of this document.

For additional information / detail on the technical elements of the protocol, Project Developers and other interested parties should refer to these foundational technical seed documents (found at www.carbonoffsetsolutions.ca/).

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1.0 Project and Methodology Scope and Description

The opportunity for generating carbon offsets with this protocol arises from the direct and indirect reductions of greenhouse gas (GHG) emissions achieved through the implementation of a 4-R (Right Source@ Right Rate, Right Time and Right Place) Nitrogen Stewardship Plan for agricultural farmlands, as developed by the Canadian Fertilizer Institute, The Fertilizer Institute in the U.S. and International Plant and Nutrition Institute. Further details on the 4-Rs are included in Section 1.1.

This quantification protocol is written for the farm operator or Project Developer. Some familiarity with, or general understanding of, the operation of farming practices is expected.

1.1 Protocol Scope and Description

This protocol provides a methodology for the quantification of GHG emission reductions from projects which implement best management practices (BMPs) in the context of a comprehensive 4-R (Right Source@, Right Rate, Right Time and Right Place) Nitrogen Stewardship Plan for their farms. The implementation of a comprehensive 4-R Nitrogen Stewardship Plan reduces the amount of nitrogen necessary to optimally grow crops, through the utilization and implementation of the 4-Rs. It is the combination of the 4-Rs that result in real reductions of nitrous oxide emissions; therefore Project Developers must ensure that the entire comprehensive 4-R Nitrogen Stewardship Plan, at the appropriate performance level is implemented (**TABLES 1.1** and **1.2**). Projects that implement only individual elements of the system are not eligible to generate emission reductions using this protocol.

The 4-R Nitrogen Stewardship Plans are categorized into three groups within this protocol: basic, intermediate and advanced. The degree of integration and sophistication of the plan increases from the basic to the advanced 4-R Nitrogen Stewardship Plan. As a result, greater decreases in nitrous oxide emissions by crop event (ie. area under a particular crop in the baseline year vs. the project year) is achieved through the implementation of a more comprehensive (i.e. intermediate and advanced) plan. The 4-R Nitrogen Stewardship Plan must be signed off by an Approved Professional Advisor (APA) see (**Appendix C**).

The scope of this protocol is limited to on-farm reductions of emissions associated with the quantification of nitrogen sources such as fertilizer, manure and crop residues for crop events. It is recognized that farming and cropping systems are complex, often with interdependent practices. It should be noted that farm GHG emissions may be impacted by any number of activities, in addition to emissions from the application of nitrogen fertilizer. However, the reduction coefficients used in this protocol assume that when comparing the project and baseline scenarios for all other aspects of crop production management, the GHG impacts are negligible.

To use this protocol, project developers must provide evidence that a 4-R Nitrogen Stewardship Plan has been implemented. Three years of historical operations data prior to implementation of the 4-R Nitrogen Stewardship Plan, for each crop event (ie. area under a particular crop for a given year) are also required for each participating farm. Farming operations that include pulse crops are eligible to use this protocol. Also, the protocol is applicable to projects in which inorganic fertilizers are utilized in the project condition, however when the agronomic rate of N application is calculated in the 4R N Stewardship Plan, all forms of N are taken into account. Thus those farms that utilize manure are included in this protocol.

This protocol does not address changes in tillage management or summerfallow practices as these activities are addressed in other Alberta Offset System Quantification Protocols. These other protocols can be used in conjunction with this protocol.

TABLE 1.1: Overview of the 4-R Nitrogen Stewardship Plans and BMP/Performance Levels for the Drier Soils in Canada[1]

Performance Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
Basic	• Ammonium-based formulation;	• Apply nitrogen according to recommendation of 4-R N stewardship plan*, using annual soil testing and/or N balance to determine application rate.	• Apply in spring; or • Split apply; or • Apply after soil cools in fall	Apply in bands / Injection	0.85
Intermediate	• Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized nitrogen.	• Apply nitrogen according to qualitative estimates of field variability (landscape position, soil variability)	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized nitrogen	Apply in bands / Injection	0.75
Advanced	• Formula must be Ammonium-based formulation; and • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized nitrogen.	• Apply nitrogen according to quantified field variability (e.g. digitized soil maps, grid sampling, satellite imagery, real time crop sensors.) and complimented by in season crop monitoring	• Apply fertilizer in spring; or • Split apply; or • Apply after soil cools in fall if using slow / controlled release fertilizer or inhibitors / stabilized nitrogen	Apply in bands / Injection	0.75[2]

*4-R N Stewardship Plan must account for all sources of N, including previous crop residues, fertilizer, manure or biosolids applications. Plan also prescribes assessment of N in crop, so this serves to supplement or replace information from soil testing.

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[1] Note – drier soils are defined as those found in Ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0 (see Appendix B).

[2] Consensus was not achieved at the science workshop to determine the Advanced Level modifier because the review scientists were not confident that an actual measurable difference between the Intermediate and Advanced can be proven at this time; therefore more research is required on precision nutrient application and in –season monitoring as part of the suite of BMPs that result in reduced N20 emissions.

TABLE 1.2: Overview of the 4-R N Stewardship Plans and BMP/Performance Levels for Moister Soils in Canada[3].

Performance Level	**Right Source**	**Right Rate**	**Right Time**	**Right Place**	**Reduction Modifier**
Basic	• Ammonium-based formulation;	• Apply N according to recommendation of 4-R N stewardship plan*, using annual soil testing** and/or N balance to determine application rate.	• Apply fertilizer in spring only; or • Split apply. • Apply liquid or solid manure in spring; or • After soil cools in fall	Apply in bands / Injection	0.85
Intermediate	• Ammonium-based formulation;	• Apply N according to 4-R N stewardship plan*, modified by qualitative estimates of field variability (landscape position, soil variability)	• Apply fertilizer or liquid manure in spring only; or • Split apply. • Apply solid manure in spring; or • Apply after soil cools in fall	Apply in bands / Injection	0.75
Advanced	• Ammonium-based formulation; • Use slow / controlled release fertilizers; or • Inhibitors; or • Stabilized nitrogen.	• Apply N according to 4-R N stewardship plan*, modified by quantified field variability (e.g. digitized soil maps, grid sampling, satellite imagery, real time crop sensors.), and complemented by in season crop monitoring	• Apply controlled release fertilizer or inhibitor / stabilized nitrogen fertilizer; or • Apply liquid manure in spring; or • Split apply; • Apply solid manure in spring; or • Apply after soil cools in fall.	Apply in bands / Injection	0.75[4]

*4-R N Stewardship Plan must account for all sources of N, including previous crop residues, fertilizer, manure or biosolids applications. Plan also prescribes assessment of N in crop, so this serves to supplement or replace information from soil testing.

**where appropriate for the crop, and calibration data is available

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[3] Note – moister soils are defined as those found in Ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of 1.0 or higher (see Appendix B). [3] Consensus was not achieved at the science workshop to determine an actual measurable difference with the Advanced level in terms of emission modifier values, therefore more research is required to apply a lower value.

Protocol Approach

This protocol takes a general guidance approach, supplemented by a content prescribed and advisor approved approach. Project Developers must implement a specific set of best management practices (BMPs), as per the general guidance included in this protocol. Then, in order to determine the emissions reduction modifier associated with their project condition, the required BMPs described in **TABLES 1.1** and **1.2** of the protocol must be implemented. This 4-R Nitrogen Stewardship Plan must then be signed-off by an APA to ensure its eligibility for the use of this protocol. The signed-off 4-R Stewardship Plan is not the Offset Project Plan, per se, but it must be in place before the Project can be implemented, and the Offset Project Plan[5] must refer to it.[6]

This protocol assumes that the level of management and resultant emissions prior to implementing the 4R Nitrogen Stewardship Plan is the baseline and the performance levels 'modify' or reduce the emissions relative to the baseline management. This graded approach, which moves to more comprehensive and efficient levels of Nitrogen (N) management results in greater emissions reductions. The protocol does this by requiring more comprehensive data for N recommendations, more extensive monitoring procedures in the 4R N stewardship plan, and more sophisticated BMPs. Thus, the decision for which level a farm will use will be determined according to the cost of the intensive implementation and monitoring needed versus the value of the additional credits earned. Also, it is expected as research advances and more BMPs are developed these will be added to the Quantification Protocol to achieve greater N_2O emission reductions. It should be noted that the baseline management for the project developer is determined also by the APA, such that, in cases where the project developer is already at the basic level of 4-R nitrogen stewardship management this will be the new baseline to compare against - resulting in only a 10% modification or reduction as the project developer moves to intermediate/advanced performance level in the project condition.

Thus, emission reductions are quantified based on the difference between baseline and project for each crop event (ie. area under a particular crop in the baseline, and area under a particular crop in the project – under the 4R Stewardship Plan) and quantified by comparing the N_2O emissions between the baseline and project and applying the emission reduction modifier in order to determine the amount of reductions resulting from the farm's implementation of the 4R Stewardship Plan. Baseline emissions are determined based on <u>three years of data</u>, for the crop event prior to the implementation of the 4R Stewardship Plan and through the quantification of N_2O emissions from agricultural soils following the guidance provided in Canada's National Greenhouse Gas Inventory methodology. In cases

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[5] The Offset Project Plan is a document laying out the details of the project in terms of GHG reductions/removals. It is an essential tool to communicate the details of the project to the verifiers. (Offset Credit Project Guidance document: http://environment.gov.ab.ca/info/library/7915.pdf)

[6] Verifiers reviewing these Projects will need to see a copy of the approved 4R Stewardship Plan to ensure the Offset Project Plan and project Report are in conformance with the 4R Plan. It becomes one more piece of verification criteria for this type of Project.

where three years of historical data on crop events are not available, there is also a flexibility mechanism (refer to Protocol Flexibility section below) which allows Project Developer's to utilize a standardized baseline.

The quantification of direct and indirect N_2O emissions from more sophisticated use of fertilizer in this protocol is based on published emission factors from Canada's National Inventory Report and is calculated as a proportion of the amount of fertilizer nitrogen applied. This quantification is performed on an eco-district basis, which accounts for variables associated with soil type, texture, topography, and climate.

In order to ensure functional equivalence when comparing the baseline and project calculations, the emission reductions are expressed on a per unit mass of crop produced per unit area basis.

1 **FIGURE 1.1: Process Flow Diagram for Project Condition**

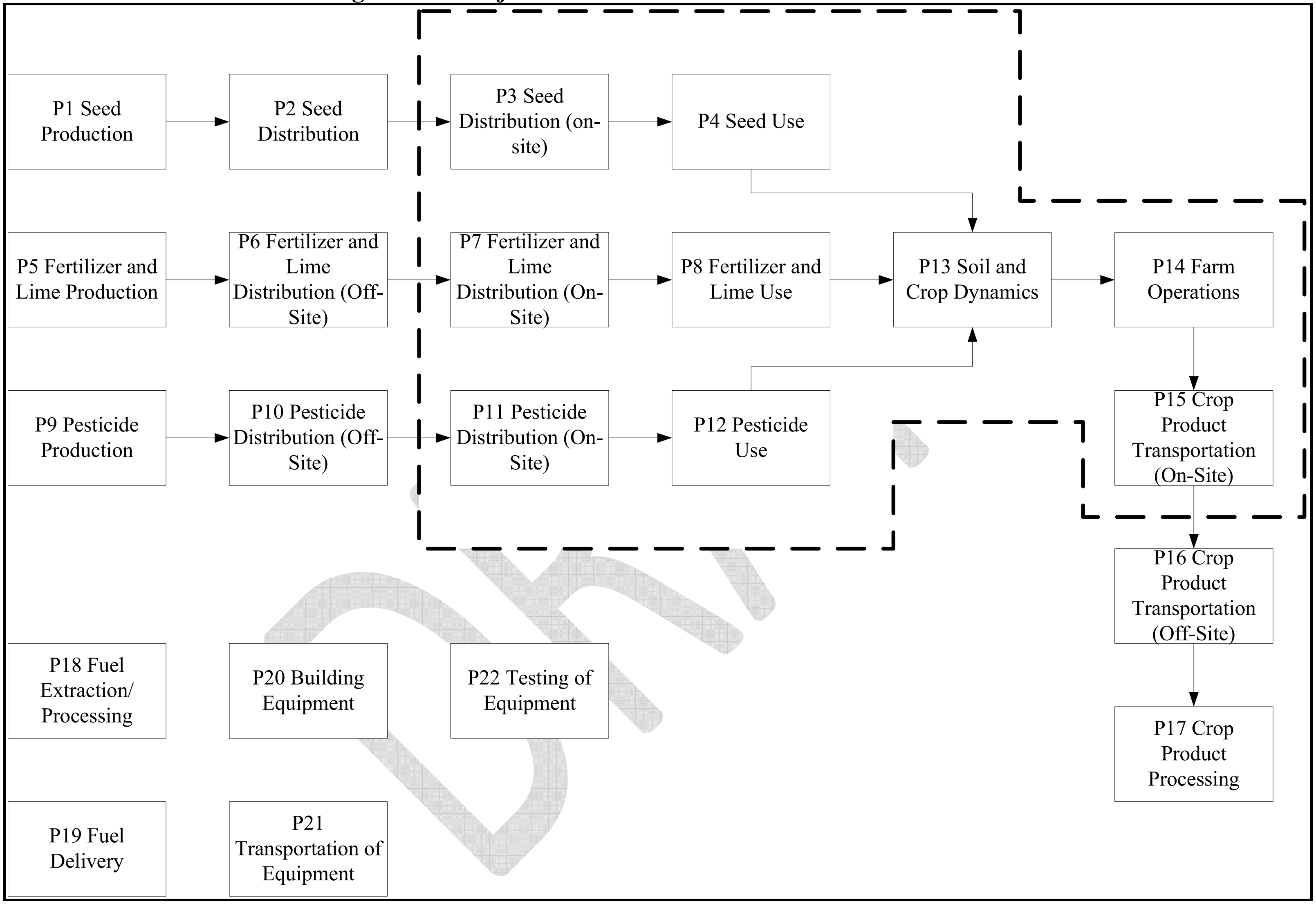

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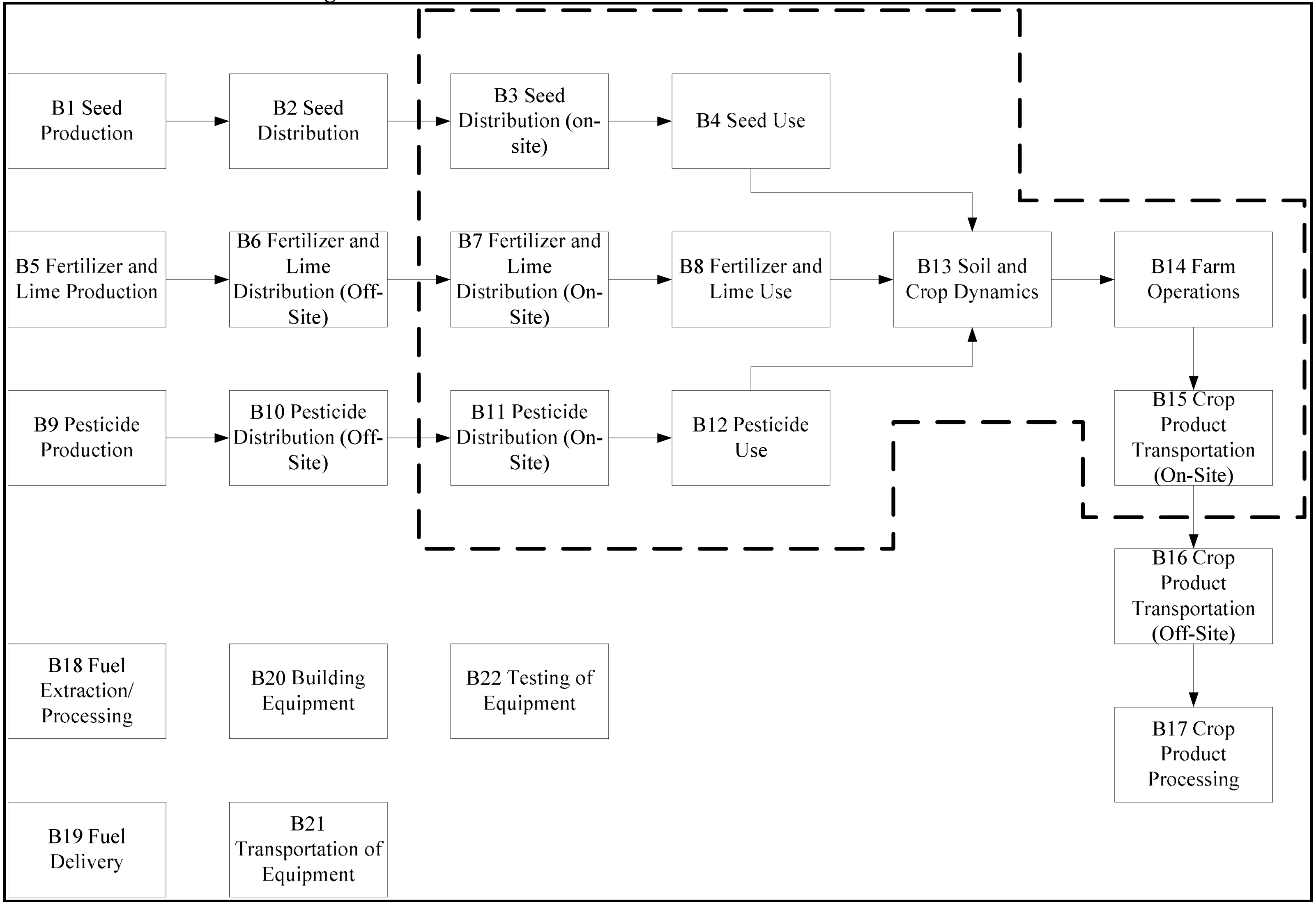
FIGURE 1.2: Process Flow Diagram for Baseline Condition



Protocol Applicability

To demonstrate that a project meets the requirements under this protocol, the Project Developer must provide evidence that:

1. The 4-R Nitrogen Stewardship Plan (as per **APPENDIX A**) has been approved by an Approved Professional Advisor (APA), along with proper identification of the baseline condition;
2. For new crops, three years of baseline data on crop events are required prior to implementing the crop to the project;
3. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol; and,
4. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System. [Of particular note:
    a. [The date of equipment installation, operating parameter changes or process reconfiguration are initiated or have effect on the project on or after January 1, 2002 as indicated by facility records;]
    b. [The project may generate emission reduction offsets for a period of eight years unless an extension is granted by Alberta Environment, as indicated by facility and offset system records. Additional credit duration periods require a reassessment of the baseline condition; and,]
    c. [Ownership of the emission reduction offsets must be established as indicated by land owner/land lessee agreements]

Protocol Flexibility

Flexibility in applying the quantification protocol is provided to Project Developers in the following ways:

1. A Project Developer may choose to select non-consecutive years for crop events to set the baseline to match with data availability and to account for any extra-ordinary growing seasons. However, any gaps between baseline seasons or gaps between the baseline period and project implementation period must be justified such that they are not contributing to an over-estimate of GHG emission reductions. The verifier must provide a written statement of agreement with the approach selected by the Project Developer;
2. The Project Developer may exclude SS P7 Fertilizer and Lime Distribution (On-Site) from quantification provided that it can be demonstrated the implementation of a Nitrogen Stewardship Plan has not increased fossil fuel consumption for fertilizer application or project monitoring. If the implementation of the Nitrogen Stewardship Plan does result in increased fossil fuel consumption (e.g. due to split application of fertilizer) then these incremental GHG emissions must be quantified for SS P7 following the guidance provided in Section 2.5.

3. This protocol applies to a single component of farm operations. As such, this protocol can be combined with other protocols where multiple projects are undertaken to lower overall greenhouse gas emissions from farm operations; and
4. Where provincially available, projects which do not have the required three years of historical data for a particular crop event in the baseline, may apply a standardized baseline approach in order to qualify under this protocol. For each province, the provincial department of agriculture will need to either:
    a. Construct a set of eco-district or ecoregion baselines for N_2O emission factors, working with the national inventory scientists/datasets and conduct validation testing of the baseline emission factors against representative case studies of regionally averaged farm data to ensure the emissions are not substantially over-estimated or under-estimated for the baseline condition; or,
    b. Approve work done by the private sector. It is expected a Guidance Document will be available to inform the approach.

1.2 Glossary of New Terms

Ammonium Based Fertilizer	Any fertilizer which releases more than two-thirds of its N in the ammonium form.
Band Application	Fertilizer placed in a concentrated sub-surface row, where fertilizer row is not spread more than 30% of the row laterally.
Approved Professional Advisor	For the purposes of this protocol the Approved Professional Adviser (APA) is representative of an individual who fits the requirements outlined in **Appendix C.**
Controlled Release Products	Slow or controlled-release nitrogen products delay, slow or control the release of nitrogen from urea. This is done in order to help manage the timing of nitrogen release from fertilizer and help reduce the risk of leaching losses of NO_3^-. Once applied, urea in liquid or granular fertilizer converts to ammonia (NH_3). The NH_3 is then subject to volatilization losses when the urea-based nitrogen fertilizer is applied on the soil surface. Controlled-release fertilizer products available today include products such as urease inhibitors and polymer-coated urea products.
Ecodistrict	A region which has relatively homogenous biophysical and climatic conditions and has an average area of approximately 150,000 Ha. Canada

	consists of approximately 1,000 ecodistricts, of which 400 are considered agricultural.
Fall Application	Fall application, for the purposes of this protocol, is defined as the application of fertilizer to cool soils that have a temperature of 10 degrees Celsius or lower, measured at a depth of 5 cm or deeper. Alternatively, these soils may be identified using the Temperature Map included in **Appendix A**.
Crop Event	The functional unit for the baseline and project calculations - based on the area under a particular crop in a given year.
Drier Soils	Drier soils are soils which are in an eco-region with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0.
Functional Equivalence	The Project and the Baseline should provide the same function, amount or quality of products or services. This type of comparison requires a common metric or unit of measurement (such as emissions per unit mass of crop produced per unit area in a field) for comparison between the Project and Baseline activity. For this protocol, it is the emissions per area, corrected for crop production between the two conditions.
Moister Soils	Moister soils are defined as those found in ecodistricts with a Precipitation/Potential Evapotranspiration ratio (P/PE) of 1.0 or higher. Note: irrigated soils automatically apply an EF_{base} of 1.7% regardless of which ecodistrict they are in (refer to **Appendix B**).
Organic Fertilizer	Organic fertilizers are fertilizers that are derived from animal or vegetable matter and include sources such as manure, slurry, worm castings, peat, seaweed, sewage, and guano.
"Split Apply"	This term implies that nitrogen will be applied in either two or more applications in the spring and/or early summer.

Spring Application	Spring application, for the purposes of this protocol, refers to application of fertilizer after thaw and before seeding.
Urea-Ammonium Nitrate (UAN)	A nitrogen fertilizer solution composed of urea and ammonium nitrate and is considered an ammonium based fertilizer for this protocol. ***But, fall application of UAN is an ineligible use under the conditions of this protocol.***

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the relevant process flow diagrams, consulting with stakeholders (i.e. project developers) and reviewing good practice guidance and other relevant greenhouse gas quantification protocols. This iterative process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1** and **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

FIGURE 2.1: Project Element Life Cycle Chart

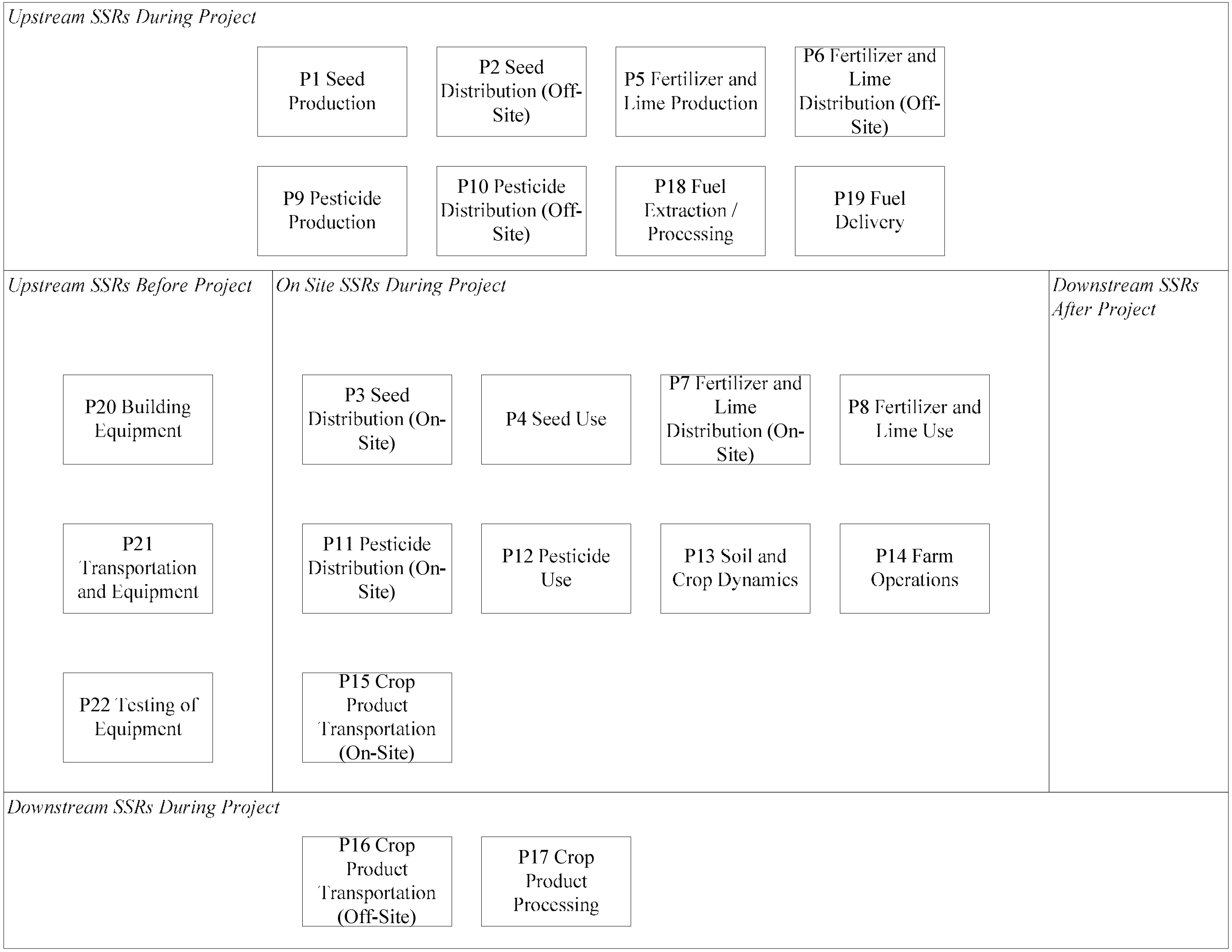


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Seed Production	Seed production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P2 Seed Transportation (Off-Site)	Seeds may be transported to the project site by truck. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P5 Fertilizer and Lime Production	Fertilizer and lime production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P6 Fertilizer and Lime Distribution (Off-Site)	Fertilizer and lime may be transported to the project site by truck. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P9 Pesticide Production	Pesticide production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the baseline condition.	Related
P10 Pesticide Distribution (Off-Site)	Pesticide may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P18 Fuel Extraction and Processing	Each of the fuels used throughout the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related

P19 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by truck, rail or by pipeline, resulting in the emissions of greenhouse gases.	Related
Onsite SS's during Project Operation		
P3 Seed Distribution (On-Site)	Seed would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled
P4 Seed Use	Emissions associated with the use of the seeds. Energy and material inputs would need to be tracked to ensure functional equivalence with the baseline condition.	Controlled
P7 Fertilizer and Lime Distribution (On-Site)	Fertilizer and lime would need to be transported from storage to the field. The implementation of a 4-R Nitrogen Stewardship Plan may result in increases fossil fuel consumption on farm due to split application of fertilizer or increased monitoring requirements. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled
P8 Fertilizer and Lime Use	Emissions associated with the use of the fertilizer and lime. Timing, composition, concentration and volume of fertilizer need to be tracked.	Controlled
P11 Pesticide Distribution (On-Site)	Pesticide distribution would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled
P12 Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of fertilizer need to be tracked to ensure equivalency with the baseline condition.	Controlled
P13 Soil Crop Dynamics	Flows of materials and energy that comprise the cycling of soil and plant carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as carbon dioxide and nitrous oxide.	Controlled
P14 Farm Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the farm facility and related equipment. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
P15 Crop Product Transportation (On-Site)	Crops would need to be harvested and transported from the field to storage. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Controlled

Downstream SS's during Project Operation		
P16 Crop Product Transportation (Off-Site)	Crops would need to be transported from storage to the market by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P17 Crop Product Processing	Inputs of materials and energy involved in the processing and end product utilization of the crop would need to be tracked to ensure functional equivalence with the baseline condition.	Related
Other		
P20 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P21 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
P22 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related

2.2 Baseline Scenario

2.2.1 Identification and Assessment of Possible Baseline Scenarios

An assessment of potential baseline scenarios was conducted based on the recommended methodology from best practice guidance in the Alberta Offset Credit Project Guidance Document (February 2008). Potential baseline options were assessed based on their capacity to quantify the baseline nitrous oxide emissions in a practical manner using available data. Each baseline scenario also contemplated the selection of a static or dynamic approach. **TABLE 2.2**, below, provides a summary of the different baselines considered.

TABLE 2.2:**Assessment of Possible Baseline Scenarios**

1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
1.Historic Benchmark	Assessment of the baseline GHG emissions based on three years of site-specific data from farm operations prior to the implementation of a 4-R Nitrogen Stewardship Plan.	Static	**Accept.** Accurate, historical data of crop management practices and nitrogen use is available for most farms for an appropriate operating period. Historical data best represents the conditions that would have taken place on a specific farm in the absence of the farm implementing a 4-R Nitrogen Stewardship Plan.
2.Performance Standard	Assessment of the GHG emissions from a typical farm. This approach would likely require an industry-wide characterization of fertilizer based GHG emissions per acre of cropland for specific crops.	Dynamic or Static	**Accept.** This approach is acceptable for a flexibility mechanism in cases where the Project Developer does not have three years of historic data.
3.Comparison-based	Assessment of the baseline GHG emissions based on the performance of the project site as compared to a control group.	Dynamic	**Reject.** The fertilizer requirements of individual farms will vary significantly depending on the farm's characteristics and the types of crops being grown. Further, this approach would create unnecessary monitoring and measurement burdens for the project developer without increasing the accuracy of the emission reduction claim.
4. Projection - Based	Assessment of the baseline GHG emissions from the farm site using a model to predict the baseline nitrous oxide emissions per unit of crop produced based on site specific temperatures.	Dynamic	**Reject.** Although a number of pertinent simulation models are available, obtaining the data required to initialize and to drive these models remains a challenging deficiency.

1. Baseline Options	2. Description	3. Static/ Dynamic	4. Accept or Reject and Justify
5.Adjusted Baseline	Assessment of the baseline GHG emissions using site specific data and adjusting for existing nitrous oxide emission reductions occurring due to common industry practices. This approach could be used in conjunction with a performance standard if nitrogen management plans were the normal industry practice	Static or Dynamic.	**Reject.** There is too much variability among fertilizer application practices to generalize the business as usual GHG emission reductions that might be occurring across Canada. The types of fertilizer used the types of soils being farmed, the crops being grown and the types of crop rotations used are all far too variable to develop an accurate adjusted baseline.

2.2.2 Selection of Baseline Scenario

The development of an approach to quantify the baseline emissions associated with nitrous oxide emission reductions prior to the implementation of a 4-R Nitrogen Stewardship Plan requires the examination of a variety of baseline scenarios as described in Section 2.2.1. The main criteria used to evaluate each scenario included data availability, environmental integrity, accuracy, consistency with Alberta project configurations and ease of application (e.g. through monitoring requirements). These approaches included site-specific scenarios and more generalized scenarios that included consideration the application of broader industry performance standards.

The selected baseline condition for this protocol is the historic benchmark based approach described in **TABLE 2.2**, above. Under this scenario, baseline GHG emissions are quantified for each crop event based on the estimated historic nitrous oxide emissions from fertilizer activities. Functional equivalence is maintained between the baseline and the project condition by calculating emissions per kg of crop produced (crop events in the baseline year vs. the project year). While this factor will remain static over time, baseline emissions will vary as a function of the area of land under a specific crop under a specific kind of nitrogen management. The final numbers will have to be adjusted for the crop production differences between the baseline and project emissions to ensure functional equivalence.

The baseline condition for projects applying this protocol is the application of nitrogen fertilizers (organic and/or inorganic) at higher/less efficient application rates compared to the project condition, for each crop event. The baseline condition is defined as the average rate of nitrous oxide emissions from the crop being fertilized, based on the average over the three years prior to project implementation.

The baseline condition is defined including the relevant SS's and processes as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.3**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.3**

FIGURE 2.2 Baseline Element Life Cycle Chart

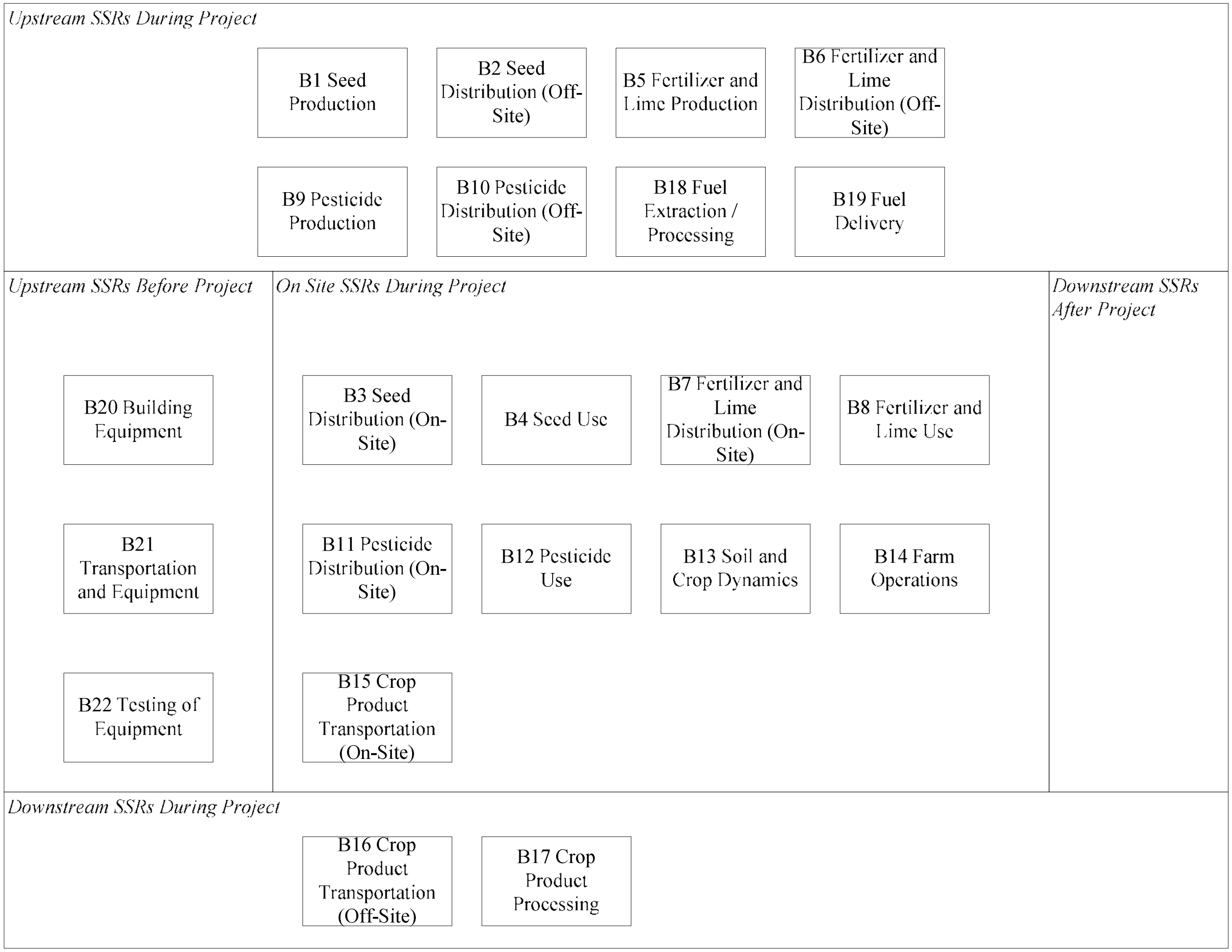


TABLE 2.3: Baseline SS's

1. SS	**2. Description**	**3. Controlled, Related or Affected**
Upstream SS's during Baseline Operation		
B1 Seed Production	Seed production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related
B2 Seed Transportation (Off-Site)	Seed may be transported to the project site by truck, and/or train. The related energy inputs for fuelling this equipment are captured under this SS for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B5 Fertilizer and Lime Production	Fertilizer and lime production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types of energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related
B6 Fertilizer and Lime Distribution (Off-Site)	Fertilizer and lime may be transported to the project site by truck and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B9 Pesticide Production	Pesticide production may include several material and energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate functional equivalence with the project condition.	Related
B10 Pesticide Distribution (Off-Site)	Pesticide may be transported to the farm by truck and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B18 Fuel Extraction and Processing	Each of the fuels used throughout the baseline will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related

B19 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by truck, rail or by pipeline, resulting in the emissions of greenhouse gases.	Related
Onsite SS's during Baseline Operation		
B3 Seed Distribution (On-Site)	Seed would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Controlled
B4 Seed Use	Emissions associated with the use of the seeds. Inputs of embedded energy and materials would need to be tracked to ensure equivalency with the project condition.	Controlled
B7 Fertilizer and Lime Distribution (On-Site)	Fertilizer and lime would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Controlled
B8 Fertilizer and Lime Use	Emissions associated with the use of the fertilizer and lime. Timing, composition, concentration and volume of fertilizer need to be tracked.	Controlled
B11 Pesticide Distribution (On-Site)	Pesticide distribution would need to be transported from storage to the field. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Controlled
B12 Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of fertilizer need to be tracked to ensure equivalency with the project condition.	Controlled
B13 Soil Crop Dynamics	Flows of materials and energy that comprise the cycling of soil and plant carbon and nitrogen, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as carbon dioxide and nitrous oxide.	Controlled
B14 Farm Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the farm facility and related equipment. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
B15 Crop Product Transportation (On-Site)	Crops would need to be harvested and transported from the field to storage. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Controlled
Downstream SS's during Baseline Operation		

B16 Crop Product Transportation (Off-Site)	Crops would need to be transported from storage to the market by truck and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B17 Crop Product Processing	Inputs of materials and energy involved in the processing and end product utilization of the crop would need to be tracked to ensure functional equivalence with the project condition.	Related
Other		
B20 Building Equipment	Equipment may need to be built either on-site or off-site. This includes all of the components of the storage, handling, processing, combustion, air quality control, system control and safety systems. These may be sourced as pre-made standard equipment or custom built to specification. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B21 Transportation of Equipment	Equipment built off-site and the materials to build equipment on-site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination, or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related
B22 Testing of Equipment	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using test anaerobic digestion fuels or fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline conditions were compared and evaluated as to their relevancy using the guidance provided in the Alberta Offset System Draft Guide to Protocol Developers (July 2009). The justification for the exclusion or conditions upon which SS's may be excluded is provided in **TABLE 2.4**, below. All other SS's listed previously are included.

TABLE 2.4: Comparison of SS's

1. Identified SS	2. Baseline (C, R, A)	3. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Inclusion / Exclusion
Upstream SS's				
P1 Seed Production	N/A	Related	Exclude	Excluded as these practices are not impacted by the project activity and emissions are not anticipated to change from the baseline to project condition.
B1 Seed Production	Related	N/A	Exclude	
P2 Seed Transportation (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario. The amount of seed transported between the baseline and project scenarios are likely equivalent.
B2 Seed Transportation (Off-Site)	Related	N/A	Exclude	
P5 Fertilizer and Lime Production	N/A	Related	Exclude	Excluded as fertilizer and lime production will either not change materially from the baseline and project conditions or fertilizer production would decrease in the project condition. Emissions are excluded and it is considered to be conservative.
B5 Fertilizer and Lime Production	Related	N/A	Exclude	
P6 Fertilizer and Lime Distribution (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario. The amount of fertilizer and lime distributed is not anticipated to change from the baseline to project condition.
B6 Fertilizer and Lime Distribution (Off-Site)	Related	N/A	Exclude	
P9 Pesticide Production	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project and fertilizer production should not change materially from the baseline and project conditions
B9 Pesticide Production	Related	N/A	Exclude	
P10 Pesticide Distribution (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are likely functionally equivalent to the baseline scenario. The baseline and project conditions will not be materially different as a result of the project.
B10 Pesticide Distribution (Off-Site)	Related	N/A	Exclude	
P17 Fuel Extraction and Processing	N/A	Related	Exclude	Excluded as emissions from fossil fuel consumption will be equivalent or higher in the baseline condition and are not considered. This is conservative.
B17 Fuel Extraction and Processing	Related	N/A	Exclude	

P18 Fuel Delivery	N/A	Related	Exclude	Excluded as emissions from fossil fuel consumption will be equivalent or higher in the baseline condition and are not considered. This is conservative.
B18 Fuel Delivery	Related	N/A	Exclude	
Onsite SS's				
P3 Seed Distribution (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from seed transportation in the project condition are likely functionally equivalent to the baseline scenario.
B3 Seed Distribution (On-Site)	Controlled	N/A	Exclude	
P4 Seed Use	N/A	Controlled	Exclude	Excluded as the emissions from seeding are likely functionally equivalent to the baseline scenario. Emissions will not change materially as a result of the project.
B4 Seed Use	Controlled	N/A	Exclude	
P7 Fertilizer and Lime Distribution (On-Site)	N/A	Controlled	Include	Included as the implementation of a 4-R Nitrogen Stewardship Plan may increase fossil fuel consumption required for fertilizer application as compared to the baseline scenario.
B7 Fertilizer and Lime Distribution (On-Site)	Controlled	N/A	Exclude	Excluded as any change in GHG emissions due to fertilizer and lime distribution would be captured under the project condition
P8 Fertilizer and Lime Use	N/A	Controlled	Include	Included as the emissions associated with fertilizer and lime use will be materially different between the baseline and project conditions and therefore must be quantified.
B8 Fertilizer and Lime Use	Controlled	N/A	Include	
P11 Pesticide Distribution (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from pesticide transportation are likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B11 Pesticide Distribution (On-Site)	Controlled	N/A	Exclude	
P12 Pesticide Use	N/A	Controlled	Exclude	Excluded as the emissions from pesticide use are likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B12 Pesticide Use	Controlled	N/A	Exclude	
P13 Soil Crop Dynamics	N/A	Controlled	Include	Included as the emissions associated with soil crop dynamics will be materially different between the baseline and project conditions and therefore must be quantified.
B13 Soil Crop Dynamics	Controlled	N/A	Include	
P14 Farm Operations	N/A	Controlled	Exclude	Excluded as the emissions from farm operations are likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B14 Farm Operations	Controlled	N/A	Exclude	
P15 Crop Product Transportation (On-Site)	N/A	Controlled	Exclude	Excluded as the emissions from crop harvesting and transportation are likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B15 Crop Product Transportation (On-Site)	Controlled	N/A	Exclude	

Downstream SS's				
P16 Crop Product Transportation (Off-Site)	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B16 Crop Product Transportation (Off-Site)	Related	N/A	Exclude	
P17 Crop Product Processing	N/A	Related	Exclude	Excluded as the emissions from crop product processing are functionally equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially different as a result of the project implementation.
B17 Crop Product Processing	Related	N/A	Exclude	
Other				
P20 Building Equipment	N/A	Related	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
B20 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
P21 Transportation of Equipment	N/A	Related	Exclude	Emissions from transportation of equipment are not material given the long project life, and the minimal transportation of equipment typically required.
B21 Transportation of Equipment	Related	N/A	Exclude	Emissions from transportation of equipment are not material for the baseline condition given the minimal transportation of equipment typically required.
P22 Testing of Equipment	N/A	Related	Exclude	Emissions from testing of equipment are not material given the long project life, and the minimal testing of equipment typically required.
B22 Testing of Equipment	Related	N/A	Exclude	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.5,** below. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

To determine the total emission reductions associated with the project, there is an iterative quantification process which is to be completed for each crop event. The sequence of calculation is as follows:

1. For each crop event the CO_2e emissions in the baseline and project conditions are calculated using functional units of kilograms (kg) CO_2e per kg of crop produced (dry matter basis).
2. The baseline condition is expressed for each crop event as the three year average kg CO_2e per kg of crop.
3. The project condition is calculated for each crop event on an annual basis using the same functional units.
4. The project value (kg CO_2e per kg crop) is multiplied by the appropriate Reduction Modifer for the NERP performance level to get the emission levels by project crop event;
5. The CO_2e reduction for each project crop event is calculated as the difference between the baseline emissions (kg CO_2e per kg crop) and project emissions (i.e. less the value obtained in No. 4, above (kg CO_2e per kg crop).
6. To get the total emission reductions (kg CO_2e) for crop events, multiply the reduction in No. 5 above by the total kg of dry matter production for the crop and the total area (ha) of the crop fields in the project..

This procedure is repeated for each crop event in the project condition to obtain the aggregate CO_2e emission reductions from the implementation of the Nitrogen Stewardship Plan.

In certain project configurations, the implementation of the Nitrogen Stewardship Plan may result in incremental fossil fuel consumption to distribute fertilizer as compared to the baseline scenario. Where applicable, the incremental project emissions from the distribution of fertilizer must be subtracted from the previously calculated CO_2e reductions that have been summed for all crop events.

This procedure would be repeated for each crop event in the project condition to obtain the aggregate obtain the aggregate GHG emission reductions from the implementation of the Nitrogen Stewardship Plan.

In certain project configurations, the implementation of the Nitrogen Stewardship Plan may result in incremental fossil fuel consumption to distribute fertilizer as compared to the baseline scenario. Where applicable, the incremental project emissions from the distribution of fertilizer must be subtracted from the previously calculated GHG reductions that have been summed for all crop events.

$$\text{Emission Reduction}_{\text{crop i}} = \sum[(\text{Emissions}_{\text{Baseline, crop i}} - \text{Emissions}_{\text{Project, crop i}} * \text{RM}_{\text{crop i}}) *\text{Area}_{\text{crop i, field y}} * \textbf{Crop}\ \text{Production}_{\text{crop i, field y}}] - \text{Emissions}_{\text{Project, Fertilizer Dist}}$$

$$\text{Emissions}_{\text{Baseline, crop i}} = N_2O_{\text{Baseline, crop i}}$$

$$\text{Emissions}_{\text{Project, crop i}} = N_2O_{\text{Project, crop i}}$$

Where:

$\text{Emissions}_{\text{Baseline, crop i}}$ = Average emissions over the three year baseline condition for crop event i (kg N_2O/kg of crop produced).

$N_2O_{\text{Baseline, crop i}}$ = Component of emissions under SS B8 Fertilizer and Lime Use & B13 Soil Crop Dynamics for crop event i (kg N_2O//kg of crop produced).

$\text{Emissions}_{\text{Project, crop i}}$ = Sum of the emissions under the project condition for crop event i (kg N_2O / kg of crop produced).

$N_2O_{\text{Project, crop i}}$ = Component of emissions under SS P8 Fertilizer and Lime Use & P13 Soil Crop Dynamics for crop event i (kg N_2O/kg of crop produced).

$\text{Area}_{\text{crop i, field y}}$ = The area of the crop field in the project condition for crop event i as defined in **TABLE 2.5** (ha).

$\text{Crop Production}_{\text{crop i, field y}}$ = The production from the crop field in the project condition for crop event i, expressed as Dry Matter, as defined in **TABLE 2.5** (kg dry matter / ha).

$\text{RM}_{\text{crop i}}$ = The emission reduction modifier as defined in **TABLE 2.5** for crop event i.

$\text{Emissions}_{\text{Project, Fertilizer Dist}}$ = Sum of the emissions under the project condition SS P7 Fertilizer and Lime Distribution

TABLE 2.5: Quantification Procedures

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P7 Fertilizer and Lime Distribution (On-Site) (Note, this has to be quantified if there are additional N application events relative to the baseline (See Section 1.1, Flexibility Mechanisms)	$\text{Emissions}_{\text{Project, Fertilizer Dist}} = \sum (\text{Vol. Fuel}_{i} * \text{EF Fuel}_{i\ CO2})\ ;\ \sum (\text{Vol. Fuel}_{i} * \text{EF Fuel}_{i\ CH4})\ ;\ \sum (\text{Vol. Fuel}_{i} * \text{EF Fuel}_{i\ N2O})$					
	$\text{Emissions}_{\text{Project, Fertilizer Dist}}$	kg of CO_2; kg CH_4; kg N_2O	N/A	N/A	N/A	Quantity being calculated.
	Incremental Volume of Fuel Consumed to Operate Farm Equipment for Implementation of Nitrogen Stewardship Plan / Vol. Fuel_i	L / m^3 / other	Estimated	Reconciliation of measurements of the volume of fossil fuel (e.g. diesel) consumed per hour of equipment operation or per field. The incremental fossil fuel consumption should be estimated based on the incremental hours of equipment operation required to implement the Nitrogen Stewardship Plan (e.g. due to split application of fertilizer).	Quarterly reconciliation.	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small.
	CO_2 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\ CO2}$	kg CO_2 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	CH_4 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\ CH4}$	kg CH_4 per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's emissions inventory.
	N_20 Emissions Factor for Each Type of Fuel / $\text{EF Fuel}_{i\ N2O}$	kg N_2O per L / m^3 / other	Estimated	From Environment Canada reference documents.	Annual	Reference values adjusted annually as part of Environment Canada reporting on Canada's

						emissions inventory.
P8 Fertilizer and Lime Use & P13 Soil Crop Dynamics	Area of Crop Event - applicable Field at Project Site Under Consideration / Area $_{\text{crop i, field y}}$	ha	Measured	Direct measurement using GPS technology, satellite imagery or approximation from field maps.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	The production of the crop field in the project condition for crop event i , expressed in Dry Matter / Production $_{\text{crop i, field y}}$	kg dry matter	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	Emissions Reduction Modifier / RM $_{\text{crop i}}$	%	Estimated	Emissions modifier based on the 4-R stewardship plan undertaken by the Project Proponent. Values are 0.85 or 0.75 which correspond to the implementation of basic or intermediate / advanced 4-R Nitrogen Stewardship Plans, respectively.	Annually	For more detail please see page 3 for details of the 4-R N stewardship plan.
	$\mathbf{N_2O_{Project,\ crop\ i} = (N_2O_{FN} + N_2O_{res} + N_2O_{IRRI} + N_2O_{VD} + N_2O_{L}) / Production_{crop\ i,\ field\ y}}$					
	Total Nitrous Oxide emission for crop event i / $N_2O_{\text{Project, crop i}}$	kg N_2O /kg dry matter	N/A	N/A	N/A	Quantity being calculated.
	The production of the crop field in the project condition for crop event i , expressed in Dry Matter / Production$_{\text{crop i, field y}}$	kg dry matter/ha	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	$N_2O_{FN} = \sum(N_{\text{Event i}} * EF_{\text{Base}} * RF_{\text{Text}} * 44/28)$					
	Direct Emissions of Nitrous Oxide from Nitrogen Fertilizer /	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.

	N_2O_{FN}					
	Nitrogen Fertilizer Consumption per crop event / $N_{Event\ i}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.
	Emission Factor Related to Local Climatic Conditions / EF_{Base}	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Annually	The value associated with EF_{base} is to be determined based on the eco-district which the farm is located in. The EF_{base} value for each eco-district is listed in **APPENDIX B**. As per the approach used in Canada's National Inventory Report Quantification.
	Average Ratio of Precipitation to potential evapotranspiration for the growing season / P/PE	Mm / mm	Estimated	Determined from Table. See **APPENDIX B.** Drier soils are considered to be those soils which have a P/PE ratio of < 1; while wetter soils have a P/PE ratio ≥ 1.	Annually	As per Canada's National Inventory Report Quantification process.
	Ratio Factor which accounts for a weighted soil texture ratio factor for N_2O for an eco-district / RF_{Text}	-	Estimated	RF_{text} = 1 for prairie regions.	Annually	As per Canada's National Inventory Report Quantification process
	$N_2O_{res} = \sum[(N_{res\ Event\ i} * EF_{base} * RF_{text}) * 44 / 28]$					
	Direct Emissions of Nitrous Oxide from Crop Residue Decomposition per crop event / N_2O_{res}	kg N_2O / /ha	N/A	N/A	N/A	Quantity being calculated based on the average emissions over a three year period.

	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually / $N_{res,\ Event\ i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 30.	Annually	As per Canada's National Inventory Report Quantification process.
	Emission Factor Related to local climatic conditions / EF_{Base}	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area. A proxy for water filled pore space.	Annually	The value associated with EF_{base} is to be determined as per the eco-district to which the farm pertains. The EF_{base} value for each eco-district is listed in **APPENDIX B**. As per Canada's National Inventory Report Quantification process
	Ratio Factor which accounts for a weighted soil texture ratio factor for N_2O for an eco-district / RF_{Text}	-	Estimated	RF_{text} = 1 for prairie regions.	Annually	As per Canada's National Inventory Report Quantification process
	$N_{res,\ Event\ i} = \sum [\ Crop_{Event\ i} * FRAC_{renew} * (\ R_{Ag,\ ,\ Event\ i} * N_{AG,,\ Event\ i} + R_{BG,\ Event\ i} * N_{BG,\ Event\ i}\ )]$					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop event / $N_{res,\ Event\ i}$	kg N / ha	N/A	N/A	N/A	Quantity being calculated.
	Harvested annual dry matter production for Crop x / $Crop_{Event\ i}$	kg dry matter (DM)/kg	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method.

	Fraction of total area under crop that is renewed annually / $FRAC_{renew}$	-	Estimated	For annual crops $FRAC_{renew}$ = 1. In cases which crops are renewed on average every X years, $Frac_{renew}$ = 1/X.	Annually	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Ratio of above-ground residues dry matter to harvested production for crop x / $R_{Ag\text{ , Event i}}$	-	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the sixth column (AG residue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Nitrogen content of above-ground residues for crop / $N_{AG\text{ , Event i}}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the third column (AGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Ratio of below-ground residues to harvested production for crop / $R_{BG\text{, Event i}}$	-	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the seventh column (BGresidue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.

	Nitrogen content of below-ground residues for crop / $N_{BG,\ Event\ i}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the fourth column (BGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	$N_2O_{IRRI} = \sum [(N_{fert,\ Event\ i} + N_{Res,\ Event\ i}) * (0.017 - EF_{base,i}) * FRAC_{IRRI,\ Event\ i} * 44/28]$					
	Emissions from irrigation per crop event / N_2O_{IRRI}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Total fertilizer nitrogen consumption per crop event /$N_{fert,\ Event\ i}$	kg N / ha	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Total amount of crop residue nitrogen that is returned to the cropland annually per crop event / $N_{Res,\ Event\ i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 30.	Annually	As per Canada's National Inventory Report Quantification process.
	Weighted average emission factor for each ecodistrict / $EF_{base,i}$	kg N_2O-N/ kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Annually	The value associated with EF_{base} is to be determined as per the eco-district to which the farm pertains. The EF_{base} value for each eco-district within Alberta is listed in **APPENDIX B**. As per Canada's National Inventory Report

						Quantification process
	Fraction of irrigated cropland per crop event / $FRAC_{IRRI, Event\ i}$	Fraction	Measured	Direct measurement using GPS technology or approximation from field maps.	Annually	Measurement is the most effective method to determine the fraction of irrigated cropland.
	Value attributed to EF_{base} for irrigated land / 0.017	kg N_2O-N/ kg N	Given	Value = 0.017	Annually	As per Canada's National Inventory Report Quantification process
	$N_2O_{VD} = \sum [(N_{Fert\ ,\ Event\ i} * FRAC_f) * EF_{VD} * 44/28]$					
	Indirect Emissions of Nitrous Oxide from Volatilization and Re-deposition of NH_3 and NO_x from Fertilizer Application Events Across Fields per crop event / N_2O_{VD}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Synthetic nitrogen fertilizer consumption per crop event / $N_{fert\ ,\ Event\ i}$	kg N / ha	Estimated	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Fraction of synthetic fertilizer N applied to soils that volatizes as NH_3^- and NO_x-N / $FRAC_f$	(NH_3-N + NO_x-N) / kg	Estimated	Default factor set at 0.1 for commercial fertilizer.	Annually	As per Canada's National Inventory Report Quantification process.

	Emission Factor for N_2O from Nitrogen Redeposited after Volatilization / EF_{VD}	kg N_20 - N / kg N	Estimated	Default factor set at 0.01 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process.
	$N_2O_L= \sum [(N_{Fert , Event i}+ N_{res, Event i}) * FRAC_L * EF_L * 44/28]$					
	Indirect Emissions of Nitrous Oxide from Volatilization and Leaching from Fertilizer Application per crop event / N_2O_L	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Nitrogen fertilizer consumption per crop event / $N_{Fert , Event i}$	kg of actual N / ha	Measured	Direct measurement.	Continuous	Direct measurement is the most accurate method.
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop event / $N_{res , Event i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 30.	Annually	As per Canada's National Inventory Report Quantification process.
	Fraction of Nitrogen Lost in Leachate / $FRAC_L$	-	Estimated	Calculated using 0.3247*P/PE-0.00247, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Monthly	The $FRAC_{leac}$ value for each eco-district within Alberta is listed in **APPENDIX B**. As per Canada's National Inventory Report Quantification process

	Emission Factor for N_2O from Leachate / EF_L	kg N_20 - N / kg N	Default	Default factor set at 0.0125 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process
Baseline SS's						
B8 Fertilizer and Lime Use & B13 Soil Crop Dynamics	$N_2O_{baseline, crop\ i} = (N_2O_{FN} + N_2O_{res} + N_2O_{IRRI} + N_2O_{VD} + N_2O_L) / Production_{crop\ i, field\ y}$ **This equation is the sum of three years baseline data divided by three for each crop event**					
	Total Nitrous Oxide emission for crop event i $N_2O_{baseline, crop\ i}$	kg N_2O /kg dry matter	N/A	N/A	N/A	Quantity being calculated.
	The production of the crop field in the baseline condition for crop event i , expressed in Dry Matter / $Production_{crop\ i, field\ y}$	kg dry matter/ha	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.
	$N_2O_{FN} = \sum(N_{Event\ i} * EF_{Base} * RF_{Text} * 44/28)$					
	Direct Emissions of Nitrous Oxide from Nitrogen Fertilizer per crop event / N_2O_{FN}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Nitrogen Fertilizer Consumption per crop event / $N_{Event\ i}$	kg of actual N / ha	Measured	Direct measurement during application.	Continuous	Direct measurement is the most accurate method.

	Emission Factor Related to Local Climatic Conditions / EF $_{Base}$	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Annually	The value associated with EF_{base} is to be determined based on the eco-district which the farm is located in. The EF_{base} value for each eco-district is listed in **APPENDIX B**. As per the approach used in Canada's National Inventory Report Quantification.
	Average Ratio of Precipitation to potential evapotranspiration for the growing season / P/PE	Mm / mm	Estimated	Determined from Table. See **APPENDIX B.** Drier soils are considered to be those soils which have a P/PE ratio of < 1; while wetter soils have a P/PE ratio ≥ 1.	Annually	As per Canada's National Inventory Report Quantification process.
	Ratio Factor which accounts for a weighted soil texture ratio factor for N_2O for an eco-district / RF $_{Text}$	-	Estimated	RF_{text} = 1 for prairie regions.	Annually	As per Canada's National Inventory Report Quantification process
	$N_2O_{res} = \sum[(N_{res\ Event\ i} * EF_{base} * RF_{text}) * 44 / 28]$					
	Direct Emissions of Nitrous Oxide from Crop Residue Decomposition per crop event / N_2O_{res}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated based on the average emissions over a three year period.
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually / $N_{res,\ Event\ i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 37.	Annually	As per Canada's National Inventory Report Quantification process.
	Emission Factor Related to local climatic conditions / EF $_{Base}$	kg N_2O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation	Annually	The value associated with EF_{base} is to be determined as per the eco-district to which the farm pertains.

				to potential evapotranspiration for the area.		The EF_{base} value for each eco-district is listed in **APPENDIX B**. As per Canada's National Inventory Report Quantification process
	Ratio Factor which accounts for a weighted soil texture ratio factor for N_2O for an eco-district / RF_{Text}	-	Estimated	RF_{text} = 1 for prairie regions.	Annually	As per Canada's National Inventory Report Quantification process
	$N_{res, Event i} = \sum [Crop_{Event i} * FRAC_{renew} * (R_{Ag, , Event i} * N_{AG,, Event i} + R_{BG, Event i} * N_{BG, Event i})]$					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop event / $N_{res, Event i}$	kg N / ha	N/A	N/A	N/A	Quantity being calculated.
	Harvested annual dry matter production for Crop x / $Crop_{Event i}$	kg dry matter (DM)/ kg	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Fraction of total area under crop that is renewed annually / $FRAC_{renew}$	-	Estimated	For annual crops $FRAC_{renew}$ = 1. In cases which crops are renewed on average every X years, $Frac_{renew}$ = 1/X.	Annually	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies.
	Ratio of above-ground residues dry matter to harvested production for crop x / $R_{Ag , Event i}$	-	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the sixth column (AGresidue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been

						modified to account for Canadian specific conditions.
	Nitrogen content of above-ground residues for crop / $N_{AG\text{ , Event i}}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the third column (AGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Ratio of below-ground residues to harvested production for crop / $R_{BG\text{, Event i}}$	-	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the seventh column (BGresidue_ratio) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	Nitrogen content of below-ground residues for crop / $N_{BG\text{, Event i}}$	kg nitrogen / kg dry matter	Estimated	This value is determined using the TABLE F.1 in **APPENDIX F**. The value is from the fourth column (BGresidue_N_conc) for the appropriate crop.	Annually	Values are attained from Holos 2008 methodology (produced by agriculture and agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions.
	$N_2O_{IRRI} = \sum [(N_{\text{fert, Event i}} + N_{\text{Res, Event i}}) * (0.017 – EF_{\text{base,i}}) * FRAC_{\text{IRRI, Event i}} * 44/28]$					

	Emissions from irrigation per crop event / N_2O_{IRRI}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Total fertilizer nitrogen consumption per crop event /$N_{fert,\ Event\ i}$	kg N / ha	Measured	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Total amount of crop residue nitrogen that is returned to the cropland annually per crop event / $N_{Res,\ Event\ i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 37.	Annually	As per Canada's National Inventory Report Quantification process.
	Weighted average emission factor for each ecodistrict / $EF_{base,i}$	kg N_2O-N/ kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Annually	The value associated with EF_{base} is to be determined as per the eco-district to which the farm pertains. The EF_{base} value for each eco-district within Alberta is listed in **APPENDIX B**. As per Canada's National Inventory Report Quantification process
	Fraction of irrigated cropland / $FRAC_{IRRI,\ Event\ i}$	Fraction	Measured	Direct measurement using GPS technology or approximation from field maps.	Annually	Measurement is the most effective method to determine the fraction of irrigated cropland.
	Value attributed to EF_{base} for irrigated land / 0.017	kg N_2O-N/ kg N	Given	Value = 0.017	Annually	As per Canada's National Inventory Report Quantification process
	$N_2O_{VD} = \sum [(N_{Fert\ ,\ Event\ i} * FRAC_f) * EF_{VD} * 44/28]$					

	Indirect Emissions of Nitrous Oxide from Volatilization and Re-deposition of NH_3 and NO_x from Fertilizer Application Events Across Fields per crop event / N_2O_{VD}	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.
	Synthetic nitrogen fertilizer consumption per crop event / $N_{fert , Event i}$	kg N / ha	Estimated	Direct measurement.	Annually	Direct measurement is the most accurate method.
	Fraction of synthetic fertilizer N applied to soils that volatizes as $NH_3^-$and NO_x-N / $FRAC_f$	(NH_3-N + NO_x-N) / kg	Estimated	Factor set at 0.1 for commercial fertilizer.	Annually	As per Canada's National Inventory Report Quantification process.
	Emission Factor for N_2O from Nitrogen Redeposited after Volatilization / EF $_{VD}$	kg N_2O - N / kg N	Estimated	Default factor set at 0.01 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process.
	$N_2O_L = \sum [(N_{Fert , Event i} + N_{res, Event i}) * FRAC_L * EF_L * 44/28]$					
	Indirect Emissions of Nitrous Oxide from Volatilization and Leaching from Fertilizer Application per crop event / N_2O_L	kg N_2O / ha	N/A	N/A	N/A	Quantity being calculated.

	Nitrogen fertilizer consumption per crop event / $N_{Fert, Event\ i}$	kg of actual N / ha	Measured	Direct measurement.	Continuous	Direct measurement is the most accurate method.
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per crop event / $N_{res, Event\ i}$	kg of actual N / ha	Calculated	Calculated as per the equation on page 37.	Annually	As per Canada's National Inventory Report Quantification process.
	Fraction of Nitrogen Lost in Leachate / $FRAC_L$	-	Estimated	Calculated using 0.3247*P/PE-0.00247, where P/PE is the ratio of precipitation and irrigation to potential evapotranspiration for the area.	Monthly	The $FRAC_{leac}$ value for each eco-district within Alberta is listed in **APPENDIX B**. As per Canada's National Inventory Report Quantification process
	Emission Factor for N_2O from Leachate / EF_L	kg N_2O - N / kg N	Default	Default factor set at 0.0125 kg N_2O - N / kg N	Annually	As per Canada's National Inventory Report Quantification process

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in Section 2.5.1 are summarized in **TABLE 2.6,** below.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practices should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.2 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a ‘reality check’;
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and
g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.6: **Contingent Data Collection Procedures**

1.0 Project / Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P7 Fertilizer and Lime Distribution (On-Site)	Incremental Volume of Fuel Consumed to Operate Farm Equipment for Implementation of Nitrogen Stewardship Plan / Vol. Fuel $_{i}$	L / m^{3} / other	Estimated	Estimation of volume of fossil fuel (e.g. diesel) consumed based on equipment ratings and incremental operating hours required to implement the Nitrogen Stewardship Plan (e.g. due to split application of fertilizer).	Quarterly reconciliation.	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small.
P8 Fertilizer and Lime Use & P13 Soil Crop Dynamics	Harvested annual dry matter production for Crop x / Crop$_{, \text{Event } i}$	Kg dry matter ha^{-1}	Measured	Reconciliation with sales volumes of annual dry crop is an acceptable contingency method in cases where direct measurement was not utilized. The value of annual dry crop must be divided by the appropriate area which was used to farm the crop for the year.	Annually	Direct measurement is the most accurate method. In this instance estimation through reconciliation of sales records can be made with high a level of accuracy.
	The production of the crop field in the project condition for crop event i , expressed in Dry Matter / Production$_{\text{crop } i, \text{ field } y}$	kg dry matter	Measured	Reconciliation with sales volumes of annual dry crop is an acceptable contingency method in cases where direct measurement was not utilized. The value of annual dry crop must be divided by the appropriate area which was used to farm the crop for the year.	Annually	Direct measurement is the most accurate method. In this instance estimation through reconciliation of sales records can be made with high a level of accuracy.
Baseline SS's						

B8 Fertilizer and Lime Use & B13 Soil Crop Dynamics	Nitrogen fertilizer consumption per crop event / $N_{Fert, Event\ i}$	kg of actual N / crop event / ha	Measured	Reconciliation with volume in storage and that purchased, and with records of the usage per crop event. The amount of nitrogen that was purchased in the given year can be reconciled with the farmer's records of nitrogen use on the given fields for the crop event.	Annually	Direct measurement is the most accurate. Reconciliation provides for due diligence if direct measurement was not utilized in the historic baseline only when the appropriate records are available to provide accurate evidence of the nitrogen fertilizer usage per crop event.
	The production of the crop field in the baseline condition for crop event i , expressed in Dry Matter / $Production_{crop\ i, field\ y}$	kg dry matter	Measured	Reconciliation with sales volumes of annual dry crop is an acceptable contingency method in cases where direct measurement was not utilized. The value of annual dry crop must be divided by the appropriate area which was used to farm the crop for the year.	Annually	Direct measurement is the most accurate method. In this instance estimation through reconciliation of sales records can be made with high a level of accuracy.
	Harvested annual dry matter production for Crop x / $Crop_{, Event\ i}$	Kg dry matter ha^{-1}	Measured	Reconciliation with sales volumes of annual dry crop is an acceptable contingency method in cases where direct measurement was not utilized. The value of annual dry crop must be divided by the appropriate area which was used to farm the crop for the year.	Annually	Direct measurement is the most accurate method. In this instance estimation through reconciliation of sales records can be made with high a level of accuracy.

1

APPENDIX A:
Soil Temperature Map

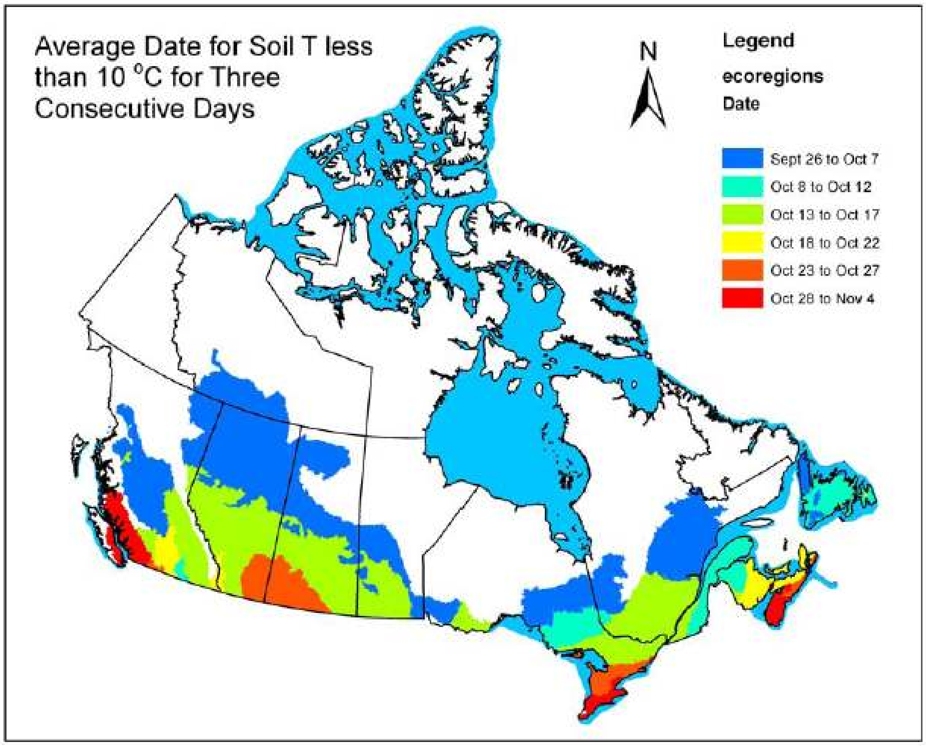


Figure 2. Soil temperature map to indicate day of year (DOY) at which soils can be considered sufficiently cool to allow fall application of fertilizer under the requirements of the NERP. Provided by Devon Worth and Ray Desjardins of Agriculture and Agri-Food Canada.

APPENDIX B:
Eco-District Related Factors (P/PE, $FRAC_{leach}$, EF_{base}).

Note: Drier soils are those soils which have a P/PE ratio of < 1; while moister soils have a P/PE ratio ≥ 1.

TABLE B.1: Eco-District Related Factors

ECODISTRICT	P/PE	$\text{FRAC}_{\text{LEACH}}$	EF_{base}
	mm/mm	%	%
244	0.56	16	0.745
583	0.58	17	0.806
586	0.56	16	0.761
587	0.56	16	0.749
588	0.52	15	0.672
589	0.55	15	0.722
590	0.58	16	0.794
591	0.67	19	0.984
592	0.61	17	0.871
593	0.63	18	0.907
594	0.64	18	0.926
595	0.59	17	0.813
596	0.58	17	0.806
597	0.61	17	0.865
598	0.65	18	0.941
599	0.62	18	0.877
600	0.63	18	0.916
607	0.56	16	0.745
609	0.56	16	0.745
610	0.64	18	0.933
611	0.59	17	0.813
612	0.61	17	0.858
614	0.76	22	1.195
615	0.75	22	1.176
616	0.74	22	1.155
617	0.74	22	1.148
618	0.65	19	0.947
619	0.77	23	1.218
622	0.79	23	1.267
623	0.74	22	1.144
624	0.85	25	1.380
625	0.75	22	1.163
626	0.75	22	1.162
627	0.74	21	1.141
628	0.72	21	1.112
629	0.74	22	1.157
630	0.72	21	1.096
631	0.59	17	0.815
650	0.62	18	0.889
678	0.73	21	1.119
679	0.63	18	0.896
680	0.62	18	0.876
681	0.70	20	1.068
683	0.69	20	1.028

TABLE B.1 (cont): Eco-District Related Factors

ECODISTRICT	P/PE	$FRAC_{LEACH}$	EF_{base}
	mm/mm	%	%
686	0.58	16	0.793
687	0.57	16	0.764
688	0.57	16	0.778
692	0.70	20	1.066
703	0.71	21	1.080
708	0.69	20	1.033
727	0.68	20	1.025
728	0.59	17	0.825
729	0.53	15	0.688
730	0.56	16	0.749
731	0.65	19	0.944
732	0.67	19	0.998
737	0.65	19	0.949
738	0.56	16	0.759
739	0.51	14	0.643
740	0.64	18	0.922
743	0.51	14	0.641
744	0.61	17	0.863
746	0.65	19	0.947
750	0.55	16	0.738
769	0.52	14	0.658
771	0.46	12	0.523
777	0.52	14	0.654
779	0.51	14	0.650
781	0.50	14	0.613
786	0.48	13	0.580
787	0.41	11	0.421
788	0.42	11	0.445
790	0.42	11	0.437
791	0.46	12	0.526
793	0.42	11	0.454
797	0.44	12	0.482
798	0.52	14	0.669
799	0.48	13	0.581
800	0.50	14	0.630
801	0.61	17	0.860
802	0.48	13	0.576
804	0.41	11	0.418
805	0.35	9	0.293
806	0.34	9	0.276
809	0.35	9	0.286
811	0.36	9	0.322
812	0.37	10	0.338
814	0.34	9	0.278
815	0.34	9	0.275

ECODISTRICT	P/PE	$FRAC_{LEACH}$	EF_{base}
	mm/mm	%	%
818	0.38	10	0.365
821	0.34	9	0.269
823	0.35	9	0.284
828	0.36	9	0.317
829	0.36	9	0.323
833	0.35	9	0.281
836	0.35	9	0.292
837	0.36	9	0.319
838	0.37	9	0.331
1016	0.61	17	0.863
1017	0.56	16	0.752
1018	0.57	16	0.770
1019	0.58	16	0.787
9593	0.67	19	0.988
9609	0.75	22	1.180
9687	0.60	17	0.837
9787	0.42	11	0.444

TABLE B.1 (cont): Eco-District Related Factors

APPENDIX C:
Approved Professional Advisor (APA) Requirements

APA Qualification Requirements.

- An APA is a soil, crops, or agronomy-trained individual with field experience. They must have at least the following qualification requirements:
    - Requirements:
        - An agriculture soils-crop science trained two-year diploma or 4-yr BSc ag graduate with at least two years of field level advisory experience; or
        - A Certified Crop Advisor (CCA), these persons have went through a combination of training, experience, study, and have passed CCA certification exams and maintain a continuing education unit (CEU) continuing education system on a two year cycle. They may be an agriculture soils-crop science trained two-year diploma or 4-yr BSc ag graduate, or a person with high school graduation and experience; or
        - An environmental science trained two-year diploma with 4 years of related field experience or 4-yr BSc graduate with 2 years field experience; or
        - An environmental engineer with field experience.
    - All the persons suggested above would need to attend and pass a short-course to be licensed to conduct N_2O NERP 4-R Stewardship Plan sign-offs.
        - Two-day course with training offered by the Canadian Fertilizer Institute on how to conduct NERP 4-R stewardship plan. This course would cover the learning objectives needed to effectively conduct NERP 4-R Stewardship Plans.

APPENDIX D:
Standardized Baseline Considerations

This mechanism is proposed to be used by the Project Developer in cases where there are not three years of historic baseline data. Section 1.1, Flexibility Mechanism No. 4 gives a brief description of how a standardized baseline may be developed and approved for use.

The selected baseline condition for the flexibility mechanism in which the Project Developer does not have the required 3 years of historic data is a performance standard approach. Under this scenario, baseline GHG emissions are quantified based on the average nitrous oxide emissions from fertilizer activities associated for specific crops throughout the growing season. These values developed by Dr. Ray Desjardins and Devon Worth incorporate not only the fertilizer nitrous oxide emissions but as well standardized emissions associated with crop residues, irrigation, leaching and volatization and redeposition losses. While this factor will remain static over time, baseline emissions will vary as a function of the area of land and type of crop under nitrogen management.

The baseline condition for projects applying this protocol is the application of nitrogen fertilizers at higher/less efficient application rates compared to the project condition, per crop event. The baseline condition for this flexibility mechanism is defined as the average rate of nitrous oxide emissions associated with each crop over the applicable area on the farm in which the 4-R Nitrogen Stewardship Plan is implemented. This baseline will be a conservative method to determine the amount of emissions for the baseline scenario as it incorporates the overall average fertilizer application rates for each type of crop for a given region.

NOTE: Preliminary investigations by the NERP protocol working group for developing standardized baselines have demonstrated that more regionally available data (at the ecodistrict preferably, or eco-region (soil zone) needs to be collected to refine the approach, N application rates and yield values at a provincial level do not result in a robust standardized baseline. Further, the baseline emission factors will need to be validated against regionally averaged farm data to ensure emissions are not grossly over-estimated or underestimated for the baseline condition.

If the baselines can be developed, the quantification **TABLE 2.3** will be altered for the baseline quantification as per the table below, while the project quantification remains the same. This calculation requires that three years of crop calculations are required for the baseline condition and are averaged to perform the comparison between baseline and project condition, similar to the calculation for the historical baseline approach.

1.0 Project/ Baseline SS	**2. Parameter / Variable**	**3. Unit**	**4. Measured / Estimated**	**5. Method**	**6. Frequency**	**7. Justify measurement or estimation and frequency**
Project SS's						
B8 Fertilizer and Lime Use & P13 Soil Crop Dynamics	$N_2O_{baseline} = \sum (EF_{region, event\ i} * Area_{Event\ i\ Field\ y})$					
	Total Emissions of N_2O / $N_2O_{baseline}$	kg	N/A	N/A	N/A	Quantity being calculated.
	Total Emissions of N_2O in the baseline / $EF_{region,event\ i}$	kg / Ha	Calculated	Value is determined through the use of the information provided in **APPENDIX E** which provides performance baseline values for each type of crop for each type of region.	Annually	Performance baseline values for each type of crop for each type of region. TO BE DETERMINED
	Area of Applicable Field at Baseline Site Under Consideration / $Area_{Event\ i\ Field\ y}$	ha	Measured	Direct measurement using GPS technology or approximation from field maps.	Annually	Direct measurement is the most accurate method. Estimation can be made with high level of accuracy.

TABLE D.1: Quantification Procedure for the Baseline of Flexibility Mechanism 2.

APPENDIX E:
N Application Rates for Flexibility Mechanism*

*Note - These numbers were used to test the development of a standardized baseline approach. These are the provincial averages for N application for major crops of Alberta, as used in the National GHG Emissions Inventory. These numbers proved to be too coarse for application in a set of standardized baselines for the province and should not be used.

They will be removed in the finalized draft of this protocol when it is posted for public review.

This section has been removed for the public review posting

TABLE E.1: Default N Application Rates associated with specific crops in Alberta.

APPENDIX F:
Emission Factors for Crop Residues

TABLE F1.

Crop Residue Factors from Holos Methodology which is based on IPCC methods but are modified to provide for Canadian conditions.

				Relative dry matter allocation		
Crop	*moisture_content* (w/w)	*AGresidue_N_conc* (kg N kg^{-1})	*BGresidue_N_conc* (kg N kg^{-1})	*Yield_ratio*	*AGresidue_ratio*	*BGresidue_ratio*
Barley	0.12	0.007	0.01	0.38	0.47	0.15
Buckwheat	0.12	0.006	0.01	0.24	0.56	0.20
Canary seed	0.12	0.007	0.01	0.20	0.60	0.20
Canola	0.09	0.008	0.01	0.26	0.60	0.15
Chickpeas	0.13	0.018	0.01	0.29	0.51	0.20
Coloured, white, faba beans	0.13	0.010	0.01	0.46	0.34	0.20
Dry peas	0.13	0.018	0.01	0.29	0.51	0.20
Flaxseed	0.08	0.007	0.01	0.26	0.60	0.15
Fodder corn	0.70	0.013	0.007	0.72	0.08	0.20
Grain corn (shelled)	0.15	0.005	0.007	0.47	0.38	0.15
Hay and forage seed	0.13	0.015	0.013	0.12	0.48	0.40
Hay - grass	0.13	0.016	0.01	0.18	0.12	0.70
Hay - legume	0.13	0.015	0.015	0.40	0.10	0.50
Hay - mixed	0.13	0.015	0.015	0.40	0.10	0.50
Lentils	0.13	0.010	0.01	0.28	0.52	0.20
Mixed grains	0.12	0.0063	0.01	0.33	0.47	0.20
Mustard seed	0.09	0.008	0.01	0.26	0.60	0.15
Oats	0.12	0.006	0.01	0.33	0.47	0.20
Potatoes	0.75	0.020	0.01	0.68	0.23	0.10
Rye	0.12	0.006	0.01	0.34	0.51	0.15
Safflower	0.02	0.010	0.01	0.27	0.53	0.20
Soybeans	0.14	0.006	0.01	0.30	0.45	0.25
Spring wheat, durum	0.12	0.006	0.01	0.34	0.51	0.15
Sunflower seed	0.02	0.010	0.01	0.27	0.53	0.20
Triticale	0.12	0.006	0.01	0.32	0.48	0.20
Winter wheat	0.12	0.006	0.01	0.34	0.51	0.15

Janzen *et al.* 2003.

APPENDIX G
Fossil Fuel Combustion Emission Factors

All fuel combustion emission factors interpreted from Environment Canada's National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada.

Table G1: Fossil Fuel Combustion Emission Factors

Diesel		
Emission Factor (CO_2)	2.730	kg CO_2 per Litre
Emission Factor (CH_4)	0.000133	kg CH_4 per Litre
Emission Factor (N_2O)	0.0004	kg N_2O per Litre
Natural Gas (Electric Utilities)		
Emission Factor (CO_2)	1.891	kg CO_2 per m^3
Emission Factor (CH_4)	0.00049	kg CH_4 per m^3
Emission Factor (N_2O)	0.000049	kg N_2O per m^3
Gasoline		
Heavy-Duty Gasoline Vehicles (3-way catalyst)		
Emission Factor (CO_2)	2.360	kg CO_2 per Litre
Emission Factor (CH_4)	0.000068	kg CH_4 per Litre
Emission Factor (N_2O)	0.0002	kg N_2O per Litre

APPENDIX H:
Underlying Science of the Reduction Modifiers

This section represents the background, context and decisions for the science underlying the Nitrous Oxide Emission Reduction Protocol (NERP) . The initial science coordination and consultation workshop on the NERP protocol was held in Calgary, Alberta, 28 & 29 October 2008. At this Workshop, participating experts approved the general design of the NERP according to the Right Product @ Right Rate, Right Time, Right Place™ stewardship model (4-R) of the Canadian Fertilizer Institute, and implementing the country-specific quantification method of Canada's National Inventory Report (see http://carbonoffsetsolutions.climatechangecentral.com/offset-protocols/alberta-protocol-development-workshops#one; for the participants, presentations, papers and results of the October Workshop.

At the NERP Consultation Workshop, the reduction modifiers associated with the levels of the NERP were approved in principle. This included approval of integration of these principles into Basic, Intermediate, and Advanced levels of the NERP, characterized by increasingly landscape-specific 4-R N Stewardship Plans and BMPs. However, decisions concerning the values for the reduction modifiers were deferred, because the designated attending scientific experts with voting privileges were not able to reach consensus voting on the exact values. Therefore, the NERP technical working group continued work on all outstanding items and on June 30th, 2009 a Webinar session was held with top fertility scientists in Canada to present the science on the BMP performance levels and conservatively reach consensus on the appropriate reduction modifiers associated with each level of NERP performance.

Development of Reduction Modifiers

The participants of the Consultation Workshop reiterated a foundational element of N_2O emission quantification; namely, the complexity of factors controlling N_2O emissions in the landscape must be acknowledged in the derivation of N_2O emission reduction modifiers associated with the BMPs prescribed for the various levels of the NERP. That is, despite the general applicability of the N_2O reduction approach of the NERP, individual studies exist to contradict the NERP approach. Ellert and Janzen (2008) recently described the complexity of predicting N_2O emissions, pointing out the variability of N_2O emissions measured by flux chambers from plots subjected to differing management practices. Zebarth *et al.* (2008) measured the N_2O emissions associated with various rates and times of application of N fertilizer on corn, and concluded that "improved fertilizer N management may not result in reduced N_2O emissions under some conditions". Kachanoski (Pers. Comm.), assessing the relationship of N_2O emissions and yield response in fields receiving variable rate N application, reported significantly higher N_20 flux from locations with the highest yield response. In agreement with the scientific literature, then, the participants of the Consultation Workshop stress that general relationships between BMPs and N_2O emission reductions can be determined by expert judgment based on integration of empirical data, but that these relationships, and the modifiers derived from them, will not hold under all time- and site-specific circumstances. Thus, the development of reduction modifiers for the NERP is similar to the derivation of coefficients for the Canada's National Inventory Report; namely, general trends evident in empirical data can be applied to achieve conservative and generally accurate assessment of N_2O emissions and reductions.

Data to Support Reduction Modifiers

A comprehensive summary and analysis of scientific literature pertinent to the relationship between N management practices and N_2O emissions and reductions is provided in a literature review published by the International Plant Nutrition Institute, *Greenhouse Gas Emissions from Cropping Systems and the Influence of Fertilizer Management* (Snyder *et al.* 2007). To emphasize the potential to reduce N_2O emissions using single BMPs, this document expands on the summary in the IPNI literature review and adds knowledge from other sources to address N_2O reductions associated with 'Right Rate', 'Right Time', and 'Right Place' performance areas.

Reductions Associated with 'Right Rate' Practices

Although the 4-R model stresses the importance of a comprehensive approach to N fertilizer management, the literature provides evidence that substantive reductions to N_2O emissions can be achieved by applying N at the Right Rate. As described in the IPNI literature review (Snyder *et al.* 2008 — Appendix 1; Webinar Decision Paper at http://carbonoffsetsolutions.climatechangecentral.com/files/microsites/OffsetProtocols/ABProtocolDevelopmentWorkshops/NitrousOxideReduction09/NERP_Webinar_Discussion_Paper_July_09.pdf), strategies to achieve Right Rate N application include proper soil testing, and addressing within-field variability of N requirements.

Further studies reinforce the need for detailed assessment of N requirements. In a presentation to the participants of the NERP Consultation Workshop on 28 October 2008, Lemke described the relationship of pre-thaw soil nitrate concentration (which is correlated to over-application of fertilizer N) to N_2O emission estimated at research sites in Alberta (Figure F1). The linear relationship described by these data predicts a decrease of about 9% in N_2O emissions (from 0.899 to 0.809 kg ha^{-1}) for a 10% decrease in soil nitrate (from 10 to 9 ppm). Mulvaney *et al.* (2006), comparing yield-based and soil test-based N recommendations on 102 corn farms, estimated 13% of farmers under-fertilized (by average of 60 kg N ha^{-1}) and 69% over-fertilized (by average of 103 kg N ha^{-1}). By applying N to corn at the economically optimal rate, Hong *et al.* (2007) measured a decrease of 11 kg ha^{-1} of residual soil N to a depth of 90 cm compared to that in fields receiving N rates typical for the midwestern US.

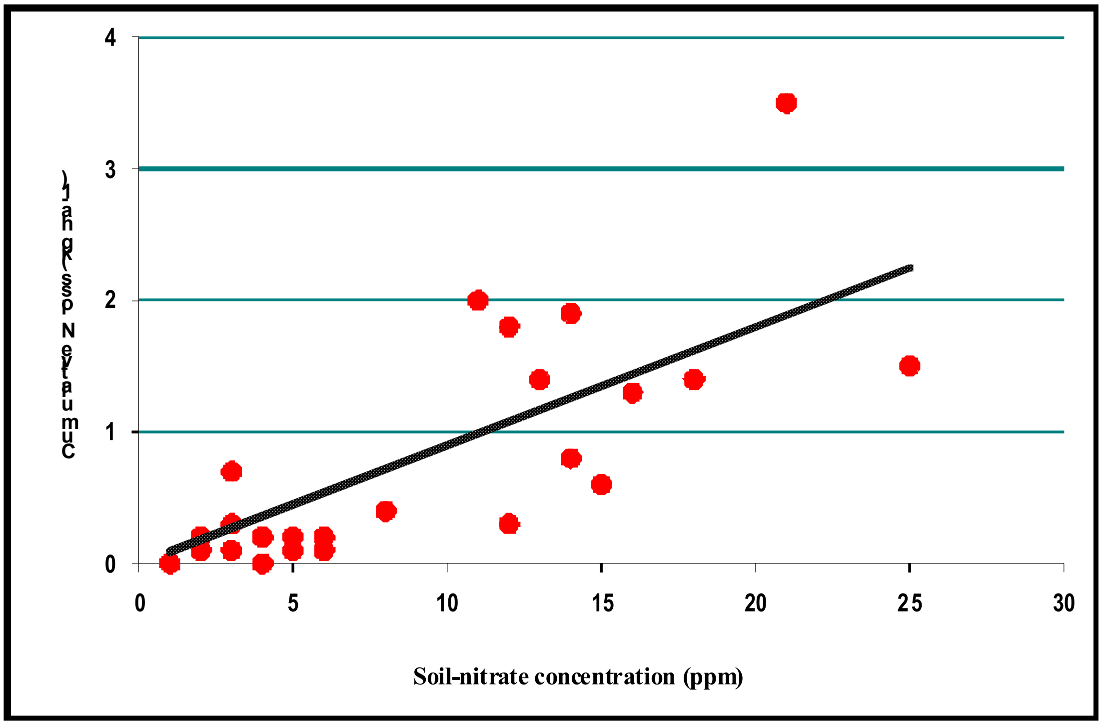


Figure F1. Mean "pre-thaw" soil-nitrate concentration vs. estimated N_2O-N loss at six locations in Alberta (Lemke Pers. Comm.).

Also, other studies have identified the need for within-field variability of N requirements to minimize potential for N losses associated with improper rate of N application. Raun *et al.* (2002) reported that when optical sensor technology was used to recommend in-season variable rate of N application to winter wheat, N use efficiency increased >15% compared to typical and uniform application N rates. In three years of production of irrigated corn in Colorado, Koch *et al.* (2004) determined a 'site-specific management zone-variable yield goal' approach to fertilizer recommendation required 6-46% less N than 'typical farmer uniform rates' to achieve comparable yields.

There is growing evidence that N_2O emissions can increase disproportionately when a threshold level of N fertilizer application is exceeded (Grant *et al.* 2006, Mahli *et al.* 2006). This potential for increased emissions at higher rate of N application, however, is not addressed in the Canada-specific N_2O quantification approach. And, it is likely that such excessive application of N will occur at 'hot spots' within fields, because of localized decrease in N uptake capacity (e.g. eroded sectors), or because of localized increase in potential for N_2O emission (e.g. waterlogged sectors). Thus, it is likely that the landscape-directed application of N in the Intermediate and Advanced levels of the NERP may result in emissions reductions larger than can be attributed to a simple decrease in rate of N application.

Reductions Associated with 'Right Time' Practices

Lemke provided data to the participants of the NERP Consultation Workshop comparing N_2O emissions from soils receiving fertilizer in fall or spring (Table F1). On average in 36 Canadian studies, emissions from fall-applied fertilizer exceeded by about 25% the emissions from spring-applied fertilizer. Further evidence to support this relationship is reported in Hultgreen and Leduc (2003).

Table F1. Emissions of N_2O from N Fertilizer Applied in Fall or Spring as Compared in 36 Studies in Canada (from Lemke Pers. Comm.).

APPLICATION TIME	MEAN	GEOMETRIC MEAN
	$g\ N_2O–N\ ha^{-1}$	
Fall	503	269
Spring	405	212

Coated fertilizer products and nitrification inhibitors are considered as 'Right Time' BMPs, since these products regulate the timing of availability of N for crop uptake. It is clear these products can increase N use efficiency, and short term N_2O emissions have been reported to decrease but more testing is needed to accurately quantify the N_2O reduction associated with these products (Snyder *et al.* 2007).

Reductions Associated with 'Right Place' Practices

Although there may be more factors involved than just placement, it is important to note the Canada-specific quantification approach for N_2O quantification assigns a reduction modifier of 0.8 for N_2O emissions from soils managed under No Till in the Canadian Prairies (Rochette *et al.* 2008). Also, Hultgreen and Leduc (2003) measured generally higher N_2O emissions from surface-applied urea as compared to band placement.

Indirect evidence to support the efficacy of band placement as a practice to reduce N_2O emissions comes from assessment of the value of band placement for increasing crop yield — the logic here is that increased yield relates to increased uptake efficiency of N, which in turn corresponds to decreased accumulation of nitrate in the soil. The Alberta Fertilizer Guide states that band placement supports greater crop yield as compared to broadcast and incorporated (Table F2).

Table F2. The relative effectiveness (%) of methods and time of nitrogen application for increasing crop yield.

	Soil-climatic categories			
Method and time of application	**Dry**	**Medium**	**Wet** [b]	**Irrigated**
Spring broadcast and incorporated	100	100	100	100
Spring banded [a]	120	110	105	110
Fall broadcast and incorporated	90	75	65	95

Fall banded [a]	120	110	85	110

[a] Although spring and fall banded nitrogen were equally effective in research trials, fall banding may be more practical under farm conditions. The extra tillage associated with spring banding may dry the seedbed and reduce yields.

[b] In research trials conducted in the higher rainfall areas, spring broadcast nitrogen was well incorporated and seeding and packing completed within a short period of time. Under farm conditions, shallow incorporation or loss of seedbed moisture resulting from deeper incorporation may cause spring broadcasting to be somewhat less effective than shown here.

Case Study Relating to Assignment of Reduction Modifiers

This case study is based on an experiment conducted on a corn, soybean, winter-wheat rotation from May 2000 to April 2005 at the Elora Research Station near Guelph, Ontario. The data from the experiment are reported in two peer-reviewed articles, with one article focused on N_2O emissions (Wagner-Riddle *et al.* 2007) and the other addressing N use efficiency and nitrate leaching (Jayasundara *et al.* 2007). The experiment assesses “the combined effects of multiple BMPs”, and thus is pertinent to development of the reduction modifiers needed for the NERP. The Conventional System used ploughing and disking and determined fertilizer application rate based on general recommendations for each crop. The Best Management System used No Till (initiated in May 1999), fertilizer application based on soil tests and timed to crop uptake, and a cover crop when possible. For the purpose of this document, the management practices of the experimental systems are tabulated according to the Right Product @ Right Rate, Tight Time Right Place™ model (Table F3).

The experiment used micrometeorological methods to measure N_2O emission in fields of 1.4 ha in area, and applied fertilizer ^{15}N to track N transformations, so continuous and cumulative assessments N use efficiency and of N_2O and NO_3^- dynamics were possible for the five-year study (Table F4).

Table F3. Case study practices for each year of the Conventional System and Best Management System characterized according to a 4-R framework.

	Conventional System	**Best Management System**
	Plough and disk, fertilize to OMAFRA recommendation	No Till, fertilize to soil test and allow N credit for crop residue
2000 (Corn)		
Product	Urea	Urea-ammonium-nitrate
Rate	150 kg N ha^{-1}	50 kg N ha^{-1}
Time	05 June (planting)	04 July (6-leaf stage)
Place	Broadcast and disk	Inject as sidedress
2001 (Soybean)		
Product	none	none
Rate	none	none
Time	none	none
Place	none	none
2002 (Winter Wheat)		
Product	Urea	Urea

Rate	90 kg N ha^{-1}	60 kg N ha^{-1}
Time	23 April (seeding)	23 April (seeding)
Place	Broadcast and disk	Broadcast and disk
2003 (Corn)		
Product	Urea	Urea-ammonium-nitrate
Rate	150 kg N ha^{-1}	60 kg N ha^{-1}
Time	15 May (planting)	02 July (6-leaf stage)
Place	Broadcast and disk	Inject as sidedress
2004 (Soybean)		
Product	none	none
Rate	none	none
Time	none	none
Place	none	none

In each year, the soil managed under Conventional system had (1) lower fertilizer N uptake efficiency, (2) higher mineral N at harvest, and (3) higher direct N_2O emissions. These data thus support the foundation of the NERP; namely, BMPs to ensure 4-R management of N are generally expected to increase nitrogen use efficiency, decrease mineral N during the non-growing season, and decrease direct N_2O emissions from agricultural soil. The mean 36% reduction of direct N_2O emissions in the Best management system (0.786 kg N_2O-N ha^{-1} yr^{-1}) compared to direct emissions from the Conventional system equates to a reduction of 0.38 tCO_2e ha^{-1} yr^{-1}.

Table F4. Case study data of N_2O emission reductions and associated measurements of nitrogen dynamics.

	Fertilizer N Uptake Efficiency[1]	**Total Mineral N at Harvest**[2]	**Total Annual N_2O-N**	**Reduction of Direct N_2O Emission**
	%	kg N ha^{-1}	kg N ha^{-1}	%
2000 (Corn)				
Conventional	24	142.4	2.429 (0.021)	
Best	65	78.4	1.822 (0.058)	25
2001 (Soybean)				
Conventional		53.2	1.100 (0.059)	
Best		28.9	0.964 (0.103)	12
2002 (Winter Wheat)				
Conventional	45	35.7	3.318 (0.352)	
Best	61	21.1	0.888 (0.016)	73

2003 (Corn)				
Conventional	40	63.9	2.677 (0.115)	
Best	58	42.7	2.176 (0.051)	19
2004 (Soybean)				
Conventional			1.442 (0.218)	
Best			1.187 (0.136)	NS
Mean (All crops 2000 through 2004)				
Conventional			2.193 (0.075)	
Best			1.407 (0.046)	36

1 Fertilizer N uptake efficiency is the percentage of fertilizer N recovered in the aboveground crop biomass during the growing season.

2 Total mineral N at harvest represents the total NH_4^+-N and NO_3^--N to a depth of 90 cm extracted with 2 M KCl.

The country-specific approach to quantifying N_2O emissions from agricultural soils includes indirect emissions (Rochette *et al.* 2008). One component of the indirect N_2O emissions are those originating from N leached out of the rooting zone. Jayasundara *et al.* (2007) calculated N loss by leaching from NH_4^+-N + NO_3^--N concentrations (originating from both fertilizer and soil N) in the drainage water at 80 cm depth and from estimates of drainage volume. Over the five years of the experiment, the total mineral leached from the Conventional System was 132.6 kg NO_3^--N ha^{-1}, while that from the Best System was 67.6 kg NO_3^--N ha^{-1}. Canada's country-specific quantification approach calculates indirect N_2O emissions from N leached as 0.025 kg N_2O-N per kg N. Using this emission factor, the total mineral N leached in five years from the Conventional system would result in indirect N_2O emissions of 1.61 tCO_2e ha^{-1}, and that leached from the Best System would create indirect N_2O emissions of 0.82 tCO_2e ha^{-1}. Thus, if mineral N leached to 80 cm is considered a source of indirect N_2O emissions, the data from Jayasundara *et al.* (2007) support the conclusion that Best System would reduce indirect N_2O emissions 0.164 tCO_2e ha^{-1} y^{-1}. If this average estimate of indirect emission reductions is added to the direct N_2O emission reductions associated with the Best Management System, the total reduction is 43% relative to the Conventional System.

The primary difference in management between the Conventional and Best systems involved more sophisticated practice to determine rate of N application. The total N fertilizer applied over the 5 growing seasons of the experimental period in the Conventional System (390 kg ha^{-1}) was substantially higher than that added in the Best Management System (170 kg ha^{-1}). The use of the cover clover crop and the greater yield of soybean in 2001 in the Best Management System indicate N input by biological fixation was lower in the Conventional System. And, the no till practice included in the

Best Management System is considered to increase N_2Oemisisons per unit of N input by 10 % (i.e. RF_{Till} = 1.1 for eastern Canada), according to the Canada-specific N_2O quantification approach. Thus, more comprehensive and detailed analysis of the case study data are necessary to assess whether differences in rate of N application can account for all of the difference in N_2O emissions reported from the two management systems. Also, it is important to note that this case study did not include landscape-directed strategies for N management, and thus this case study represents only the Basic level of implementation of the NERP.

Revised Reduction Modifiers

This Decision Paper has reiterated the importance of rate of N application as a factor in controlling N_2O emissions from agricultural land in Canada. In addition, evidence has been presented to support the assertion that other fertilizer management practices, encompassed in the 4-R stewardship model, can contribute to mitigation of N_2O emissions. N_2O reductions from 10 to 20% associated with these BMPs of Right Product, Right Time, and Right Place are documented. However, the integrated contribution of the non-Right Rate BMPs in the suite of BMPs included in the levels of implementation of the NERP is not completely certain. Thus, it remains for the experts participating in the development of the NERP to seek consensus concerning appropriately conservative reduction modifiers for the Basic, Intermediate, and Advanced levels.

Although empirical evidence to address the N_2O emission reductions associated with a suite of integrated or stacked BMPs within each level of the NERP is lacking, reductions from individual BMPs have been quantified. Listing examples of the emission reductions from single BMPs illustrates the potential to achieve N_2O reductions in addition to simple rate-related reductions thorough implementation of the levels of the NERP (Table F5).

Table F5. 4-R N stewardship plans and BMP/Performance Levels for NERP Prairie

	Right Rate	**Right Time**	**Right Place**
Basic	• Decreased emission per lower N input, if assessment of N requirement leads to decreased N application.	• 20 to 25 % decrease in emissions associated with spring vrs fall application.	• About 10% decrease in emissions with band placement. • 20 % decrease in emissions associated with no till[7].
Intermediate	• Decreased emission per lower N input, if assessment of N requirement leads to decreased N application. • Potential for greater emission reduction if 'hot spots' eliminated by landscape-directed N application.	• 20 to 25 % decrease in emissions associated with spring vrs fall application. • Potential for emission reduction with use of coated products and nitrification inhibitors.	• About 10% decrease in emissions with band placement. • 20 % decrease in emissions associated with no till.
Advanced	• Decreased emission per	• 20 to 25 % decrease in	• About 10% decrease

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[7] The Tillage System Management Protocol attributes offsets associated with lower N_2O emission associated with reduced till and no till. The potential for double counting of these offsets will be addressed in the development of final requirements of the NERP.

	lower N input, if assessment of N requirement leads to decreased N application. • Potential for greater emission reduction if 'hot spots' eliminated by landscape-directed N application.	emissions associated with spring vrs fall application. • Potential for emission reduction with use of coated products and nitrification inhibitors.	in emissions with band placement. • 20 % decrease in emissions associated with no till

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APPENDIX I: Acknowledgements

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