



**Quantification Protocol for Agricultural
Nitrous Oxide Emission Reductions
Specified Gas Emitters Regulation**

Version 2.0

September 2015

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Disclaimer

The information provided in this directive is intended as guidance and is subject to revisions as learnings and new information come forward as part of a commitment to continuous improvement.

This document is not a substitute for the legal requirements. Consult the Specified Gas Emitters Regulation and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the Specified Gas Emitters Regulation or legislation, the Specified Gas Emitters Regulation or the legislation prevails.

All quantification protocols approved under Alberta's Specified Gas Emitters Regulation are subject to periodic review as deemed necessary, to ensure methodologies and science continue to reflect best available knowledge and practices. Any review changes/amendments will not impact the credit duration stream of projects that have been initiated under previous versions of the protocol. Any updates to protocols occurring as a result of the reviews will apply at the end of the first credit duration period for applicable project extensions.

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Summary of Revisions

Version	Date	Summary of Revisions
2.0	August 2015	<ul style="list-style-type: none"> • The Protocol Scope and Applicability were updated to reflect requirements that the entire farm enterprise must be included in the project to qualify under this protocol. It was also specified that manure fertilizers are the only organic fertilizers eligible under the protocol, and that manure nitrogen sources are not subject to nitrous oxide greenhouse gas reductions through application of the 4R reduction modifier. An update was added to require annual soil sampling to inform 4R Plan nitrogen application recommendations in the project condition. These changes were made to strengthen emission reduction assurances under the protocol. • A Protocol Flexibility mechanism in the Baseline Condition was introduced, allowing use of two dynamic baseline approaches in place of a three-year conventional baseline. Use of the dynamic baseline approaches is subject to application of reduction modifiers. • Clarification was provided regarding 4R Accredited Professional Advisor training and qualifications, including a new requirement that Accredited Professional Advisors be approved to operate under the Alberta Institute of Agrologists Greenhouse Gas Assessment and Management Practice Standard. A requirement for at least one member of the verification team or government audit team to take the Canadian Fertilizer Institute 4R Management Plan training. • The Quantification Methodology has changed from area-based to mass-based accounting in order to streamline quantification and reduce verification risk. • The Quantification Methodology to calculate additional emissions associated with incremental fuel use in the project condition was updated. • Manure fertilizer was separated from the reduction modifier in the project emission reduction Quantification Methodology to increase protocol conservativeness. • The Quantification Methodology was amended to reference current emission factors in Alberta Environment and Parks Carbon Offset Emission Factors Handbook. • The Records Requirements section was updated to detail baseline and project records requirements and to align with reasonable assurance verification requirements.
1.0	October 2010	Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions was published for use in the Alberta offset system.

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Related Publications

- Alberta's 2008 Climate Change Strategy
- *Climate Change and Emissions Management Act*
- Carbon Offset Emission Factors Handbook
- Specified Gas Emitters Regulation
- Specified Gas Reporting Regulation
- Technical Guidance for Completing Annual Compliance Reports
- Technical Guidance for Completing Baseline Emissions Intensity Applications
- Additional Guidance for Cogeneration Facilities
- Technical Guidance for Landfill Operators
- Technical Guidance on Third Party Verification
- Technical Guidance for Offset Project Developers
- Technical Guidance for Offset Protocol Developers

1.0 Offset Project Description

Projects that are implemented according to this protocol generate carbon offsets by switching to an integrated set of Beneficial Nitrogen Management Practices (BMPs) for annual cropping systems. These BMPs manage applied nitrogen (N) sources in a more comprehensive and sophisticated way to reduce nitrous oxide (N₂O) emissions associated with nitrogen fertilizer application. These BMPs are integrated into a new technology called a Comprehensive 4R (Right Source at the Right Rate, the Right Time and the Right Place) Nitrogen Stewardship Plan.

Implementing a comprehensive 4R Nitrogen Stewardship Plan (hereafter called the 4R Plan) results in applied nitrogen being used more effectively to grow agricultural crops. Further, implementing the 4Rs together across landscapes generates real reductions of N₂O emissions from agricultural cropping systems. Implementing the entire, comprehensive 4R Plan at the appropriate performance levels as dictated by this protocol is an additional activity and generates offset credits. Projects that implement only individual elements of the new technology are not eligible to generate emission reductions using this protocol.

This quantification protocol is written for professionals with experience and expertise in agronomy, which may include farmers, project developers and/or aggregator representatives. Agricultural professionals will be assisting farmers in designing and implementing the 4R Plan. These professionals must be trained and accredited to apply this protocol. More detail on this accreditation program is given in the next few sections. The project developer/aggregator will work with the farmer and agricultural professional to complete the project(s) in accordance with this protocol and the criteria of the Alberta Offset System.

Project aggregators will be required to present Offset Project Plans covering included farms for an entire crediting period (i.e., carbon offset project plans span the entire eight-year crediting period, or five-year crediting period extension).

1.1 Protocol Scope

The scope of this protocol is limited to on-farm reductions of emissions from nitrogen sources and fuel use associated with the management of synthetic fertilizer, manure fertilizer and crop residues. Greenhouse gas (GHG) reductions associated with carbon sequestration in the soil and off-site emission reductions affected by the manufacture and distribution of nitrogen fertilizers are excluded from the protocol.¹ The exclusion of off-site reductions of fertilizer manufacturing increases conservativeness in emission reduction calculations and limits the scope of quantification to those sources, sinks and/or reservoirs for which data are readily available.

Other emission reduction activities, where quantification protocols exist, can be used in conjunction with this protocol. For example, the Quantification Protocol for Conservation Cropping can be added or stacked to create greater opportunities for farms.

¹ Implementing the protocol will result in reduced applications of nitrogen fertilizer per unit crop grown relative to baseline conditions. It is conservative to exclude upstream emission reductions.

Emission Reduction Activity

Application of nitrogen from synthetic fertilizer, biological fixation, manure fertilizer and crop residues is an important component of agricultural production. Fertilizer-derived nitrogen, like any form of soil mineral nitrogen² (or free or soluble nitrogen), is subject to emission as N₂O either from nitrification/denitrification pathways in the soil, losses through leaching of nitrate, and/or volatilization and redeposition of ammonia gas. BMPs, which synchronize the availability of nitrogen with the requirements of the crop, minimize the emissions of N₂O per unit of crop mass.³

This protocol minimizes these N₂O emission pathways by managing on-farm applied nitrogen sources through the implementation of the BMPs in the 4R Plan, resulting in:

- Optimization of the crop response per unit of added nitrogen; and,
- Minimization of the risk for nitrate-N to accumulate or persist in the soil where it is potentially denitrified and/or emitted directly or indirectly as N₂O, or lost to the system through leaching and runoff.

This 4R Plan is a risk-based approach, informed by over 40 years of peer-reviewed research on the effect specific management practices have on the biological processes that lead to nitrogen losses in North American cropping systems. The 4R Plan is designed to address the risk of nitrogen losses by promoting comprehensive nitrogen management across the 4Rs to achieve the above two outcomes. (See Table 1 and Appendix J for more information on the 4R practices.)

In this protocol, N₂O emissions from agricultural soils are quantified using Canada's Tier II methodology for both baseline and project conditions. The emission reductions from implementing the 4Rs are based on reduction modifiers (RMs), which are conservative, science-derived coefficients for estimating the synergistic effects of superior source, rate, time and place practices on lowering N₂O emissions per unit of crop produced. Table 1 describes 4R practices and the corresponding reduction modifiers for drier soils in Canada.⁴ Project emissions (Tier II method) are multiplied by the Reduction Modifier to provide an adjusted value. This adjusted project emissions value is a conservative estimate of the lower emissions achieved under an integrated system of beneficial management practices.

² Mineral nitrogen refers to NH₄⁺ (ammonium), NO₃⁻ (nitrate) or NO₂⁻ (nitrite).

³ For a literature review of the beneficial nitrogen management practices to minimize nitrous oxide emissions, see Snyder *et al.*, 2007, Greenhouse Gas Emissions from Cropping Systems and the Influence of Fertilizer Management and Snyder, *et al.*, 2009, Review of greenhouse gas emissions from crop production systems and fertilizer management effects.

⁴ Drier soils are defined as those found in EcoDistricts with a precipitation/potential ratio (P/PE) of less than 1.0 (see Appendix A).

Table 1: Overview of the 4R Plan and BMP Performance Levels for the Drier Soils in Canada

Performance Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier ⁱ
Basic	Ammonium-based formulation	<ul style="list-style-type: none"> Apply nitrogen according to recommendation of 4R Planⁱⁱ, using annual soil testing and recommendations developed within the 4R Plan 			0.85
Intermediate	Ammonium-based formulation and/or any of the following enhanced efficiency sources:	<ul style="list-style-type: none"> Apply nitrogen according to qualitative estimates of field variability (landscape position, soil variability) using annual soil testing and recommendations developed within the 4R Plan 	<ul style="list-style-type: none"> Apply in spring; Split apply; or Apply after soil cools to 10°C 	Apply in bands / Injection	0.75
Advanced	<ul style="list-style-type: none"> Slow / controlled release fertilizers Inhibitors; or Stabilized N 	<ul style="list-style-type: none"> Apply nitrogen according to quantified field variability (e.g., digitized soil maps, grid sampling, satellite imagery, real time crop sensors) using annual soil testing and recommendations developed within the 4R Plan 			0.75

i - Scientific development and consensus of the reduction modifiers can be found in the following document: Climate Check, 2009, Decision Paper for Nitrous Oxide Emission Reduction Protocol, prepared for Climate Change Central and Canadian Fertilizer Institute.

ii – The 4R Plan must account for all sources of nitrogen, including previous crop residues, synthetic fertilizer, manure or other organic fertilizers. The reduction modifier is not applied to nitrogen from manure. Fields receiving organic fertilizers other than manure are excluded for the quantification year in which they are applied.

The quantification of direct and indirect N₂O emissions from more sophisticated use of fertilizer are based on published emission factors from Canada’s National Inventory Report and calculated as a proportion of the amount of fertilizer nitrogen applied. This quantification is performed on an EcoDistrict basis, which accounts for variables associated with soil type, texture, topography and climate. To determine the appropriate EcoDistrict for the farm, use maps available on the Agriculture and Agri-Food Canada National Soils Database (NSDB). The greenhouse gases involved in the calculation are shown in Table 2.

Table 2: Relevant Greenhouse Gases Applicable for this Protocol

Specified Gas	Formula	Applicable to Project
Carbon Dioxide	CO ₂	Yes
Nitrous Oxide	N ₂ O	Yes
Methane	CH ₄	Yes

1.2 Protocol Applicability

This protocol is applicable to any farm in Alberta practicing enhanced nitrogen management through implementation of a 4R Plan as described. Projects must be able to provide sufficient records to justify the emission reductions being claimed.

This protocol relies on the proper documentation of field practices and requires that dated farm records and similar direct evidence of practices be retained by the farm operator, Accredited Professional Advisor and project developer, and these are to be made available to the third party verifier and government auditor upon request. See Section 5 for minimum records requirements for projects.

To apply this protocol, the project developer must adhere to all of the following requirements:

- (1) Evidence that an Accredited Professional Advisor-approved 4R Plan has been implemented on each farm being included in the project. All fields of a farm must be enrolled under the 4R program with a clear delineation of the farm enterprise boundary. To avoid leakage⁵ of nitrogen or crop yield, the entire farm enterprise must be under 4R management and must be incorporated into the project. Fields or management units being managed under pasture or ineligible crops are excluded from emission reduction calculations for that year. If ineligible soil amendments are used, then entire crop type where they were used are treated as ineligible crop types for that year.
- (2) Carbon offset quantification is calculated on a mass basis using nitrogen inputs and crop mass per crop type across the farm enterprise:
 - At the field level so long as the fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level; or
 - At the farm level so long as fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level.
 - If the farm is situated within multiple EcoDistricts, offset quantification must be completed separately for each EcoDistrict. Quantification can be done in aggregate across multiple EcoDistricts if the EcoDistrict value resulting in the most conservative offset credit quantification is used for all lands across the entire farm enterprise. Use of this flexibility option is described in Section 1.3.
- (3) The 4R nitrogen management must still occur according to the 4R Plan, with project documentation collected to show conformance to the 4R Plan.

⁵ Leakage refers to the incorrect attribution of applied nitrogen or harvested crop yield to fields or management units which are not under 4R management for the implementation of this offset protocol. Leakage can occur unintentionally (e.g., mistakes in records collection) or unintentionally.

- (4) The 4R Plan shall include a clear identification of the baseline and project condition.
- (5) The 4R Plan shall have been designed and signed and sealed by an Accredited Professional Advisor (see Appendix D).
- (6) All farms being included in the project are being implemented according to the 4R Plan and have received annual sign off by the Accredited Professional Advisor.
- (7) Only annual crops are eligible for participation. Annual crop types, are the same in the baseline and project to ensure equivalency in residue nitrogen accounting and include:
 - wheat (all spring planted types)
 - winter wheat
 - fall rye
 - barley
 - barley silage
 - corn
 - corn silage
 - pulses
 - canola
 - oats
 - flax
 - others.⁶
- (8) Ineligible crops must be included in the 4R plan, but fields containing ineligible crops are excluded from greenhouse gas accounting for that year. This means that both the crop yield and fertilizer applications in fields with ineligible crops are excluded from greenhouse gas accounting for the year. For example, fields under summer fallow must be included in the 4R Plan, for considerations of crop rotation in the cropping program, but are excluded from the greenhouse gas accounting for that year since nitrogen is not applied. Lands under perennial forage grazed by animals, including swath grazing and cattle on stubble, are excluded from GHG accounting under the project since 4R management does not occur. Lands under perennial forage are also excluded from GHG quantification under the protocol. Burning of straw is not an eligible activity under this protocol. Annual forages grown for silage or baling are eligible.
- (9) A farm where fields are receiving manure as fertilizer are eligible to participate under the protocol, but all other organic nitrogen sources are currently excluded from eligibility. If a crop receives an ineligible fertilizer, the entire crop type is excluded from greenhouse gas accounting for the year. When using manure as a soil amendment, the project developer must be able to determine nitrogen content of the manure and manure application rates for quantification under the protocol.
- (10) Crops produced under irrigation in the baseline are also under irrigation in the project for the duration of the project.
- (11) The conventional baseline N₂O emissions are based on the average three crop-type years prior to implementation of the 4R Plan. If a farm experiences a devastating year that results in 50 per cent less crop yield (from a five-year average), that year must

⁶ In this category, the project developer must be able to demonstrate that the amount of straw/residue/biomass nitrogen is equivalent for the crop in both baseline and project conditions.

be removed from the three-year average baseline and replaced with another crop year.

- (12) In order to provide consistency and completeness to the greenhouse gas accounting under this protocol, farms in the project must have all fields enrolled in the 4R program. In the case where ineligible crops are grown, crop yields and fertilizer applied to these fields cannot contribute to greenhouse gas accounting for project emission reductions for that year. Nitrogen fertilizer applications to these ineligible crops must be tracked and clearly separated from project greenhouse gas accounting for that year. In the case of use of ineligible fertilizers in any crop, the entire crop type will be excluded from greenhouse gas accounting under this protocol for the year . For the conventional baseline approach (i.e., historic baseline), any new lands/crops added to the farm will need to be part of a new project since they were not part of the conventional baseline as defined by the farm enterprise boundary.
- (13) When using the conventional baseline approach, all eligible crop types managed by the participating farm occurring in the baseline are included in the 4R Plan and in the quantification of emissions and reductions.
- (14) Project emission reductions must be calculated on a crop mass basis (using Canada's National Inventory Report quantification method as described in this protocol).
- (15) Determining the mass of each crop type produced on the farm is conducted according to the Acceptable Crop Mass Determination Methods outlined in Appendix I of this protocol.
- (16) It is possible that a project developer may initiate a project under this protocol on a parcel of land, but not complete the full project credit period. If this occurs, any future project developers wishing to complete the crediting period will be required to adhere to the original project start date for the parcel of land. The project start date will always be the date at which the project containing the parcel of land was first initiated on the registry, regardless of the current project owner.
- (17) Bilateral agreements between parties are executed as written contracts and should consider the contracting guidance provided in the current Technical Guidance for Offset Project Developers.⁷
- (18) The quantification of reductions achieved by the project is based on actual measurement and monitoring as required in this protocol.
- (19) The project meets the eligibility criteria stated in section 7.0 of the Specified Gas Emitters Regulation. In order to qualify, emissions reductions must:
 - Occur in Alberta;
 - Result from actions not otherwise required by law;
 - Result from actions taken on or after January 1, 2002;
 - Be real, demonstrable and quantifiable;
 - Have clearly established ownership including, if applicable, appropriate, documented transfers of carbon ownership from the land owner to land lessee;
 - Be counted once for compliance; and
 - Be implemented according to ministerial guidelines.

⁷ Alberta Environment and Parks, 2013, Technical Guidance Document for Offset Project Developers.

Project developers need to ensure that farmers implementing projects under this protocol work with an Accredited Professional Advisor to develop and implement a 4R Plan for their farm operations. Sign off by the Accredited Professional Advisor is required as part of the mandatory project documentation required for projects under this protocol. Accredited Professional Advisors are regulated members of the Alberta Institute of Agrolgists (AIA) who have obtained authorization by the AIA to operate under the AIA Practice Standard for the Greenhouse Gas Assessment and Management Practice Area, and have been accredited through the Canadian Fertilizer Institute's 4R training program.⁸ Accredited Professional Advisors also receive supplementary training on the 4R nitrogen stewardship model and the requirements of the 4R Plan described in this protocol. The details of the Accredited Professional Advisor professional accreditation program and required 4R qualifications are described in Appendix B.

The Accredited Professional Advisor is required to:

- (1) Review and sign off on the baseline calculations made by the farmer and the project developer. This involves reviewing project documentation for baseline practices, providing an opinion concerning the appropriateness of the conclusions supported by the documentation, applying flexibility for exclusions of any crops/fields (e.g., summerfallow or ineligible crops), and attesting to the accuracy of calculations based on the documentation. See Section 2 for description of baseline conditions.
- (2) Design and sign off on a 4R Plan for the participating farm. This plan will address all fields and all crops under the control of the farm at the performance level selected by the project developer/farmer. The Accredited Professional Advisor is responsible for ensuring the farm enterprise boundary remains constant throughout the project and that all nitrogen inputs and crop mass are accounted for within the farm enterprise boundary. The details of the design of the 4R Plan are provided in Section 3.
- (3) Provide sign off that the 4R Plan was implemented as designed for each participating farm in the project developer's project. It is expected that nitrogen recommendations from annual soil testing will form the basis for the following year's 4R Plan.⁹ This may involve assessment of activities including weather related disruptions of crop yield and deviations from the original 4R Plan where they occur.
- (4) The Accredited Professional Advisor shall comply with Alberta legislation.

Note: The Accredited Professional Advisor sign off does not constitute formal validation or verification for the project. Independent, third party verification is required for all carbon offset credits being serialized and registered on the Alberta Emissions Offset Registry for use as a compliance option under the Specified Gas Emitters Regulation.

Alberta Environment and Parks requires that at least one member of the verification team and/or government audit team has taken the 4R training program offered by the Canadian Fertilizer Institute¹⁰. Evidence that a verifier completed the training must be included in the verification report.

⁸ The Accredited Professional Advisors Training Program can be accessed on the Canadian Fertilizer Institute website for information purposes. To become an Accredited Professional Advisor, an individual will be required to take an exam.

⁹ The Accredited Professional Advisor is responsible for designing and implementing the soil sampling procedures for the particular protocol performance level (basic, intermediate, and advanced).

¹⁰ Canadian Fertilizer Institute. 2015. GrowZone: NERP Training Program.

1.3 Protocol Flexibility

Flexibility in applying the quantification protocol is provided to project developers in the following ways:

- (1) In the conventional baseline, a project developer may choose to select non-consecutive years for crop types to set the baseline to match with data availability and to account for any extra-ordinary growing seasons. Trend data on extreme weather events to demonstrate how the excluded year is extraordinary will be needed for justification. 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-estimation of greenhouse gas emission reductions.
- (2) One of two dynamic baseline approaches may be employed by calculating the expected project emissions from the estimated baseline emissions and the application of the reduction modifiers outlined in Table 1. See Appendix H for details on the application of the dynamic baseline approaches:
 - In order to provide consistency and completeness to the greenhouse gas accounting under this protocol, farms in the project must have all fields enrolled in the 4R program and need to be part of the project and baseline greenhouse gas accounting;
 - As under the conventional baseline, fields or management units being managed under pasture or ineligible crops are excluded from emission reduction calculations for that year. If ineligible soil amendments are used, the entire crop is prohibited from creating credits in that year;
 - Because the baseline is recalculated each year under the dynamic baseline flexibility mechanisms, additional land and crops acquired by the farm must be included in the project. When this occurs, the project plan must be updated and these new lands and crops will be limited to the duration of the original project's crediting period; and
 - Project developers can begin using Dynamic Baseline One or Dynamic Baseline Two. However, Dynamic Baseline Two can only be used for a maximum of two years. A project cannot switch from Dynamic Baseline One to using the Dynamic Baseline Two.
- (3) The project developer may exclude On-Site Fertilizer and Lime Distribution (see Table 6) from quantification where it can be demonstrated that no increased fuel use due to an additional fertilizer and lime application in the project condition relative to the baseline condition has occurred as a result of implementing the 4R Plan. In cases where the dynamic baseline is used, any 4R management activities that result in extra field passes compared to the farm's previous management activities (e.g., split fertilizer application, new fertilization equipment that results in additional time spent on field such as broadcast to direct fertilizer injection) will require calculation of emissions from increased fuel usage.
- (4) This protocol applies to a single component (nitrogen management) 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.

- (5) If the farm spans over multiple EcoDistricts, projects have the option of treating their farm as a single EcoDistrict providing that they calculate project greenhouse gas emission reductions for the farm using each set of EcoDistrict values and use the most conservative. All sets of calculations using each applicable EcoDistrict will need to be maintained to demonstrate the conservativeness of the chosen EcoDistrict.

1.4 Glossary of Terms

Ammonium-based Fertilizer	Any fertilizer which releases more than two-thirds of its nitrogen 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.
Accredited Professional Advisor	For the purposes of this protocol the Accredited Professional Advisor is a regulated member of the Alberta Institute of Agrologists who fits the requirements outlined in Appendix B.
Controlled Release Products	Slow or controlled-release nitrogen products delay 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 nitrate 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.
Denitrification	The conversion of nitrate to nitrogen gas (dinitrogen and various nitrogen oxides, including N_2O) by soil denitrifying microbes under depleted oxygen conditions.
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 five centimetres or deeper.
Crop Type	The crop type is the operational unit for which N_2O emissions intensity (N_2O per mass of crop) is calculated for the baseline and project. The crop type is the annual crop, with guidance listed in Section 1.2. The crop year is accounted from harvest of previous crop to harvest of current crop.
Drier Soils	Drier soils are soils that are in an EcoDistrict with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0.
Comparable Metrics	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 unit of crop mass between the two conditions.

GPS Coordinates	The description, in alphanumeric characters, of a precise geographic location on earth. For the purposes of GPS navigation, coordinates are most often expressed in latitude and longitude.
Fallowing	Fallow cropland is land that is intentionally left idle or unseeded during a growing season with all plant growth periodically terminated with tillage (summerfallow) or herbicides (chemfallow).
Farm Enterprise	All lands and crops under the control the farmer. The entire Farm Enterprise must be included in the project.
Field Variability — Qualitative	An observation that the soils, topography and nutrient availability in a field vary considerably.
Field Variability — Quantitative	An attempt to take enough samples and observations and run simple statistics to show how variable a field is.
Management Zone	For the purposes of the 4R Plan implementation (and not greenhouse gas accounting), a sub-field unit of a crop that is managed differently from other management zones within the same field. The management zone of the Basic Level is a whole field of a crop type. For the Intermediate Level, the management zone refers to each sub-field of a crop type based on qualitative field variability and the BMP requiring landscape-directed nitrogen application. The management zone of the Advanced Level refers to the delineation of each slope and aspect on the digital map of a field of a crop grown. The level of performance identified in the 4R Plan will dictate nitrogen management.
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 EFeco of 1.7 regardless of which EcoDistrict they are in (refer to Appendix A).
Nitrification	The microbial transformation of ammonium (NH_4^+) forms of nitrogen in a two stage process to nitrite (NO_2^-) and then to nitrate (NO_3^-), as accomplished by <i>Nitrosomonas</i> species and <i>Nitrobacter</i> species bacteria, respectively.
Nitrification Inhibitor	An additive to ammonium-based fertilizers that inhibits <i>Nitrosomonas</i> species bacteria from converting ammonium (NH_4^+) to nitrite (NO_2^-). This effectively keeps the nitrogen in

ammonium form and slows down conversion to the nitrate (which can be denitrified to N₂O and other nitrogen compounds).

Organic Soil Amendment/ Organic Fertilizer	Organic soil amendments (or organic fertilizers) are fertilizers that are derived from animal or vegetable matter and include sources such as manure, slurry, worm castings, peat, seaweed, sewage, guano and others. Manure is the only organic fertilizer applicable for quantification under this protocol.
Precipitation/Potential Evapotranspiration ratio (P/PE)	A measure of the moisture regime in the soil that impacts N ₂ O emission processes.
Professional Agrologist (P.Ag.)	Professional Agrologists are regulated members with the Alberta Institute of Agrologists.
Sink	Any process, activity or mechanism that removes greenhouse gas from the atmosphere and stores it in a reservoir.
Source	Any process or activity that releases greenhouse gas into the atmosphere.
Split Apply	Implies that nitrogen will be applied in either two or more applications in the spring and/or early summer.
Real-time Crop Sensors	Sensors attached to an nitrogen fertilizer applicator used in-crop to assess the crop nitrogen status (greenness) and determine whether or not additional nitrogen fertilizer should be top-dress applied to the crop.
Registered Technologist in Agrology (R.T.Ag.)	Registered Technologists in Agrology are regulated members with the Alberta Institute of Agrologists.
Spring Application	Spring application, for the purposes of this protocol, refers to application of fertilizer after thaw and before or at seeding.
Stabilized Nitrogen	This refers to an nitrogen fertilizer that has been treated with an additive to reduce potential losses via ammonia volatilization (e.g., an urease inhibitor) and nitrification/denitrification (e.g., a nitrification inhibitor) or, a product that slows down the dissolving of the fertilizer and reaction with the soil matrix (e.g., a polymer coating). It can also be used to describe slow-release nitrogen fertilizer products.
Urea-Ammonium Nitrate (UAN)	A nitrogen fertilizer solution composed of urea and ammonium nitrate and is considered an ammonium based fertilizer for this protocol. Note: Fall application of UAN is an ineligible use under the conditions of this protocol.
Variable Rate Application	A method of automatically varying the rate of a crop input based on a prescription map, generated through soil testing. It consists of software and hardware to create the map, control the rate and locate the equipment in the field. Real-time crop sensors can also be used to measure what is needed by the

crop and adjust the rate accordingly in real time.

Yield Monitors

A device mounted on a harvester to record the mass or volume of crop collected. It is typically mated with a GPS receiver to record the location of each yield reading to produce yield maps.

2.0 Baseline Condition

The protocol uses both a static historic benchmark baseline condition (conventional approach), and allows for the use of one of two alternative dynamic baseline approaches (Section 1.3).

Under the conventional baseline condition, greenhouse gas emissions are quantified for each crop type, by performance level, by EcoDistrict, on each farm based on historic N₂O emissions from fertilizer activities, for three years prior to implementation of the 4R Plan. Comparable metrics between the baseline and the project condition are achieved by calculating emissions per mass of crop produced (crop types in the baseline year versus the project year). While this factor will remain static over time, baseline emissions will vary as a function of the mass of a specific crop produced for a farm under a specific kind of nitrogen management. The final numbers will have to be adjusted for the crop mass differences between the baseline and project emissions to ensure consistency.

This protocol assumes a baseline condition for each participating farm where nitrogen fertilizers (organic and/or inorganic) are applied at less efficient application rates or methods (such as source, timing, placement, etc.) from a nitrogen use efficiency perspective, compared to the project condition per crop type. The baseline condition is calculated as the average rate of N₂O emissions from the crop type being fertilized based on the average over the three years prior to project implementation.¹¹ Figure 1 presents the process and material flow for the baseline condition.

Independent survey data of nutrient management practices across the country shows that less than 10 per cent of farms implement a 4R Plan with the guidance of a farm advisor.¹² The 4R Plan as described in this protocol is a technology change at the farm level and represents an additional activity under the Alberta offset system.

The 4R Plan provides this technology change through:

- (1) A comprehensive and professionally-developed nitrogen management plan to account for all sources of nitrogen applied at each farm to address 4R management of nitrogen applicable essentially to all farmers; and
- (2) Providing greater assurance around nitrogen use for all farmers including those that had sophisticated nitrogen practices during the baseline period. Farmers that were already undertaking annual testing or variable rate application would not achieve N₂O emission reductions without the framework of all the BMPs in a 4R Plan (i.e., there can

¹¹ If a farm experiences a devastating year that results in 50% less crop yield (from a five-year average), that year must be removed from the three-year average baseline and replaced with another crop year.

¹² According to recent surveys, 51 per cent of Alberta farms perform soil nutrient soil testing once every three years (IPSOS, 2014 Environmentally Sustainable Agriculture Tracking Survey Summary Report, 2014). A Statistics Canada study in 2001 found that with 44 per cent of farms performing soil testing every two to five or more years. Only 11 per cent of Alberta's farms develop and implement nutrient management plans (Statistics Canada, Agriculture 2001 Census, 2003).

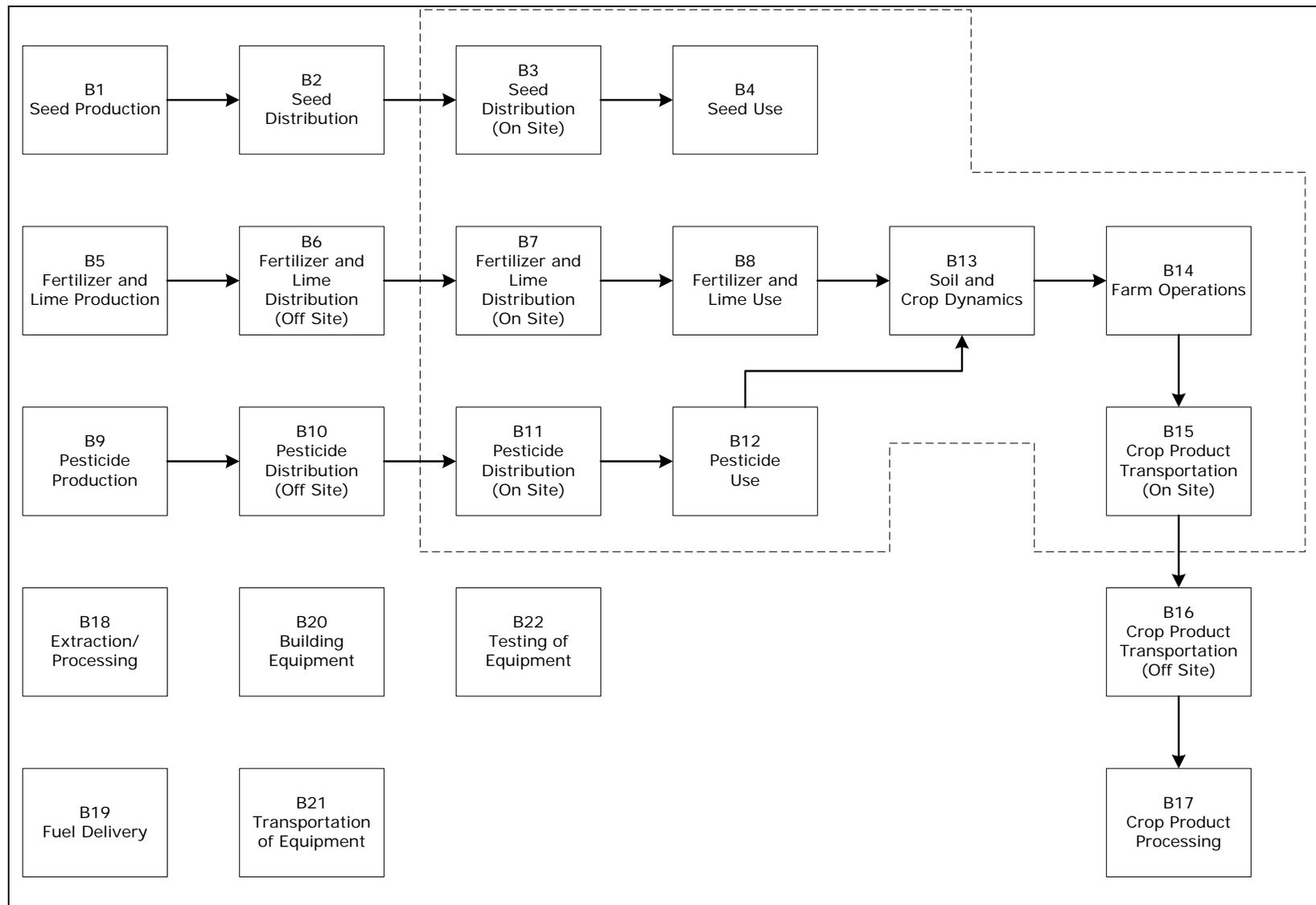
be no assurance that N₂O reductions are achieved without assurance that all 4Rs are addressed).

A flexibility mechanism is offered in Section 1.3 that allows the use of one of two dynamic baseline approaches. Under the dynamic baseline approaches, baseline greenhouse gas emissions are calculated each year and compared to the project condition on an annual basis to calculate emission reductions. Dynamic Baseline One uses measured crop mass from farms (using the acceptable crop mass determination methods in Appendix I). Dynamic Baseline Two uses conservative five-year average default yields for crop risk zones across the province. These values are published annually by Agriculture Financial Services Corporation (see Appendix H). The dynamic baseline approaches include application of either a five per cent or 10 per cent discount factor, depending on the chosen dynamic baseline. (See Section 1.3 and Appendix H for more information).

The Accredited Professional Advisor, as part of the 4R Plan development, identifies the baseline management practice of the participating farm. To avoid leakage of nitrogen amendment or crop mass, the entire farm enterprise must be under 4R management and enrolled under this protocol. Under the conventional baseline, if a farm acquires new land holdings or expanded management on new leased lands where crop types were not included in the baseline for that farm, a new project will need to be implemented. The dynamic baseline approaches require that the entire farm enterprise boundary is under 4R management and included in the project condition for that year.

The comparable metric for calculating emission reductions between baseline and project conditions is achieved by expressing emissions on mass of crop produced basis (for the conventional approach). This ensures that emissions are normalized to a common base unit of production, thereby allowing quantification of equivalent emissions reductions resulting from the project condition.

Figure 1: Process Flow Diagram for Baseline Condition



2.1 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (International Organization for Standardization 2006). Sources and sinks are determined to be either controlled, related or affected by the project and are defined as follows:

- Controlled: The behaviour or operation of a controlled source and/or sink is under the direction and influence of a project developer through financial, policy, management or other instruments.
- Related A related source and/or sink has material and/or energy flows into, out of, or within a project but is not under the reasonable control of the project developer.
- Affected: An affected source and/or sink is influenced by the project activity through changes in market demand or supply for projects or services associated with the project.

Baseline sources and/or sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts, national greenhouse gas inventory scientists and reviewing good practice guidance. This iterative process confirmed that the sources and/or sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagram provided above, the baseline sources and/or sinks were organized into life cycle categories in Figure 2. Descriptions of each of the sources and/or sinks and their classification as controlled, related or affected are provided in Table 3.

Figure 2: Baseline Sources and Sinks for Reducing Nitrous Oxide Emissions

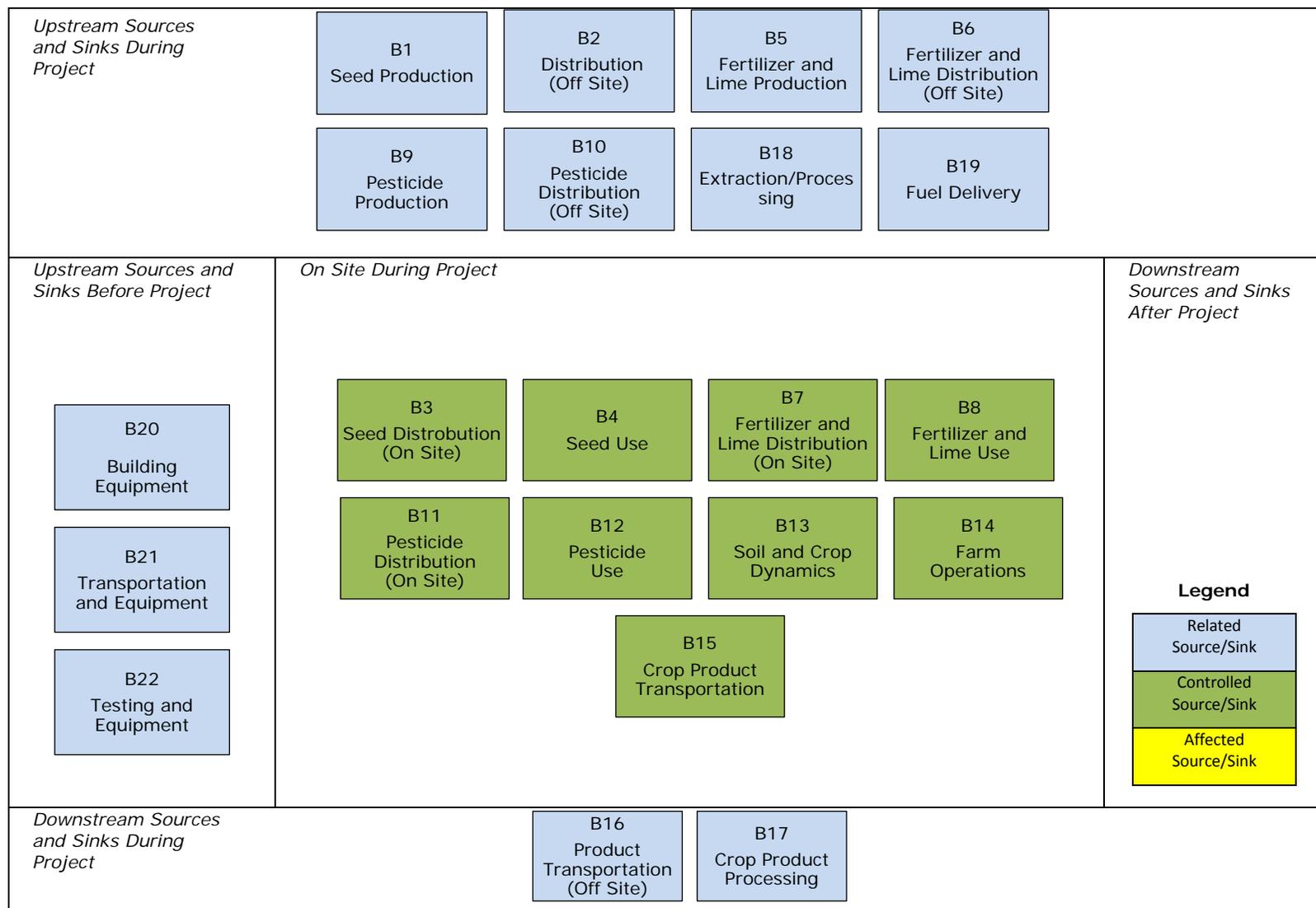


Table 3: Baseline Sources and Sinks

Source/Sinks	Description	Type
<i>Upstream Sources and Sinks During Baseline Operation</i>		
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 comparable metrics 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 source for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics 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 comparable metrics 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 source/sink, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics 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 comparable metrics 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Related
B18 - Fuel Extraction and	Each of the fuels used throughout the baseline will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various	Related

Processing	processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site sources and sinks are considered under this source. Volumes and types of fuels are the important characteristics to be tracked.	
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

On Site Sources and Sinks 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics 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 comparable metrics 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 source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics 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 source/sink for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics 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 comparable metrics 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 N ₂ O.	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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate comparable metrics with the project condition.	Controlled

Downstream Sources and Sinks 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 comparable metrics 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 by courier. Greenhouse gas emissions would be primarily attributed to	Related

the use of fossil fuels to power the equipment delivering the equipment to the site.

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

3.0 Project Condition

The project condition, hereinafter called the 4R Plan, takes forms of nitrogen into account, in particular inorganic (synthetic) fertilizers applied to a particular crop to calculate direct and indirect N₂O emissions. Emission reductions are calculated on a crop by crop basis, known as crop types, in a given year for the entire farm enterprise.

The 4R Plan, with the associated BMPs required for each performance level, are implemented to achieve a reduction of N₂O emissions in the project as compared to the baseline condition. As the performance level increases from Basic to Intermediate/Advanced, the 4R Plan must address more precisely the field variability through the development of more sophisticated BMPs. The greater the performance level, the more potential there is for emission reductions as shown by a larger reduction modifier (Table 1).

A number of resources to describe application of 4R principles are available^{13,14} to support project implementation. The Alberta Nutrient Management Planning Guide¹⁵ is the primary reference for technical elements of the 4R Plan such as assessing fields on site or remotely, soil sampling and testing, calculating fertilizer requirements, etc. The various elements of the 4R Plan and the technical methods pertinent to nutrient management are also integrated in the training provided to Accredited Professional Advisors.

In the case of catastrophic crop failure (owing to drought, frost, hail, weed infestation, etc.), the total mass of crop produced may be decreased to the extent that project emissions per mass of crop exceed baseline emissions. In this event, the fields/crops would be excluded from the mass-based accounting for emission reductions for that year. Implications of nitrogen remaining in the soil due to crop loss must be addressed in the following year's 4R Plan, as confirmed by soil test results reviewed by an Accredited Professional Advisor.

The steps necessary for conforming to the 4R Plan at the various performance levels identified in this protocol are described below.

Basic Performance Level

The 4R Plan at the basic performance level will:

- Be implemented at a scale of whole fields;
- Use legal land locations and aerial photographs to determine field locations and field size;
- Require annual soil testing for each field;
- Describe field-scale sampling and annual soil testing of nitrate-nitrogen remaining in the soil from the previous year to derive fertilizer rate requirements for the upcoming crop year¹⁶;

¹³ International Plant Nutrition Institute. 2011. The 4Rs: Right Source, Right Rate, Right Time, Right Place.

¹⁴ The Accredited Professional Advisors Training Program can be accessed on the Canadian Fertilizer Institute website for information purposes. To become an Accredited Professional Advisor, an individual will be required to take an exam. Anyone can take the course for information, but Accredited Professional Advisors need to pass an exam.

¹⁵ Alberta Agriculture and Rural Development, 2007, Alberta's Nutrient Management Planning Guide.

¹⁶ For a description of acceptable soil sampling best practices see Module 3.1 of the Introduction to 4R Course (Canadian Fertilizer Institute. 2015. GrowZone: NERP Training Program) or Alberta Agriculture and Rural Development, 2007, Alberta's Nutrient Management Planning Guide.

- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year);
- Specify field-specific BMPs for fertilizer application source, rate, place and time;
- Describe yield monitoring for each field, and which crop mass determination method will be used for GHG quantification¹⁷; and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 5.1 for sample data sources).

Intermediate Performance Level

The 4R Plan at the intermediate performance level will:

- Be implemented at a scale of sub-fields (or management zones) for each crop type delineated by qualitative field variability (or areas of above average and below average productivity) based on the grower's experience and the Accredited Professional Advisor's professional judgment;
- Identify management zones by using aerial photographs or field imagery to determine field location and field size, and to delineate management zones;
- Require annual soil testing for each field management zone;
- Describe sub-field sampling and annual soil testing of nitrogen remaining in the soil at the management zone level from the previous year to derive fertilizer rate requirements for the upcoming crop year;
- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year);
- Specify sub-field, management zone-specific BMPs for fertilizer application source, rate, place and time for each management zone;
- Describe yield monitoring for each field and which crop mass determination method will be used for GHG quantification;¹⁸ and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 5.1 for sample data sources).

Advanced Performance Level

The 4R Plan at the advanced performance level will:

- Be implemented at scale of sub-field management zone for each crop type based on a digitized delineation of slope and aspect;
- Use GPS coordinates and digital imagery to determine field location and field size, and to delineate and aggregate sub-field management zones according to slope and aspect;
- Describe sub-field sampling and annual soil testing of nitrogen remaining in the soil at the sub-field management zone level from the previous year to derive fertilizer rate requirements for the upcoming crop year;

¹⁷ Combine-mounted yield monitors can be used for assessment of the 4R Plan, but for GHG quantification, the crop mass must be calculated according to the acceptable crop mass determination methods in this protocol (Appendix I).

¹⁸ Yield monitoring can be used for assessment of the 4R Plan, but for GHG quantification, the crop mass must be calculated according to the acceptable crop mass determination methods in this protocol (Appendix I).

- Will incorporate anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year);
- Specify BMPs for fertilizer application source, rate, place and time for each management zone;
- Describe the use of combine-mounted yield monitors to map yield according to aspect and slope for each sub-field management zone¹⁹; and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 5.1 for sample data sources).

Generating a post-harvest nitrogen assessment is a valuable tool to assess the success of a 4R Plan in meeting crop nitrogen needs, and thereby minimizing N₂O emissions.²⁰ In years where an ineligible organic fertilizer is used, the remaining nitrogen available from these ineligible sources must also be addressed by the Accredited Professional Advisor and incorporated into the following year's nitrogen rate recommendations. Post-harvest assessment does not replace annual soil testing for fertilizer rate recommendations, however. A complete field nitrogen assessment is not practical, because nitrogen in below ground biomass is difficult to measure directly. The 4R Plan will calculate the proportion of nitrogen inputs recovered in the harvested crop.

In exceptional circumstances where soil testing cannot be completed for a certain field in a given year (due to weather and soil conditions), the Accredited Professional Advisor must use their experience and knowledge of the project soils, previous amendments and past and current cropping conditions to recommend rates that ensure no over-application for the upcoming crop.²¹ This is an exception that can only be applied a maximum of once for a field within an entire project crediting period.

3.1 4R Plan Development

The beginning of the project corresponds to the implementation of a 4R Plan as prescribed by this Protocol. Since 4R plans are adjusted to performance level (basic/intermediate/advanced), the activities prescribed by the 4R Plan and the documentation required to substantiate project activity will vary according to the selected performance level. The 4R plan must be created and signed by an Accredited Professional Advisor.

The 4R Plan to be implemented on the project farm shall be signed by the farmer stamped and the Accredited Professional Advisor, and stamped by the Accredited Professional Advisor if applicable. The 4R Plan shall describe the activities to be implemented by the farmer, provide the rationale for determining these activities, and specify the data to be collected to document completion of these activities.

¹⁹ Yield monitoring can be used for assessment of the 4R Plan but crop mass must be calculated according to the acceptable crop mass determination methods for GHG quantification in this protocol (Appendix I).

²⁰ Consider post-harvest assessment for each field, using crop uptake and removal coefficients (Appendices 6A and 6B) of Alberta Agriculture and Rural Development, 2007, Alberta's Nutrient Management Planning Guide.

²¹ Tools available to the Accredited Professional Advisor include (1) Agriculture and Rural Development Recommended Rates in their AgriDex publications for each crop; or (2) a post-harvest assessment of the nitrogen uptake by the crop the year before; and/or (3) the AFFIRM model to predict nitrogen recommendation rates.

4R Documentation

While an independent professional prepares the 4R Plan documentation, these materials, including all background and supporting materials, must still be available to the third party verifier for assessment, including government auditors. The work of the Accredited Professional Advisor supports the work of the verifier, but does not replace it.

Soil Sampling

A soil sampling plan, scaled to correspond with each 4R implementation level management zone, must be included in annual 4R plans. Soil sampling plans will be signed off by the Accredited Professional Advisor. The Accredited Professional Advisor will use annual soil test results from soil sampling programs to inform nutrient recommendations for each management zone in the 4R Plan. The Accredited Professional Advisor will ensure that annual soil sampling conforms to the plan, and that soil test results are used in the plan.

Fertilizer

The 4R Plan must include a report on the quantity, application, timing and type of fertilizer nitrogen applied for each crop type. The pattern of distribution for fertilizer (i.e., the distribution for each crop type) and the resolution of the documentation will vary with the selected performance level.

The required documentation includes data from fertilizer purchase invoices, supported by application recommendations from the Accredited Professional Advisor in the 4R Plan. Total annual fertilizer application is supported with documentation from purchase invoices and application records for each crop type and 4R management zone.

Crop Residues

Calculating the amount of crop residue nitrogen, above ground and below ground, for each crop type is a required nitrogen input needing to be taken into account. This estimate is derived from default look-up tables provide in Appendix E of this protocol. Crop mass is the basis for deriving this nitrogen input so the residue calculations are delineated on the fields according to the selected performance level in the same way as crop mass data is collected and reported for implementation of the baseline and project for the 4R Plan.

In some instances, crop residue management may be complicated by events such as baling. The implications of these events for nitrogen input calculations will need to be addressed in the 4R Plan. For example, the amount of nitrogen removed in these events should be treated as crop mass and using default or measured nitrogen values as appropriate for the performance level.

Table 4: Parameter Description for Calculating Crop Residues

Parameter	Units	Source
Annual crop mass (dry matter)	kg dry matter	Crop mass (see Appendix I)
Crop-specific factors	kg N / kg dry matter	From Table E-1 (see Appendix E): Ratio of above-ground residue dry matter to harvested production (AGresidue_ratio) Nitrogen content of above-ground residues (AGresidue_n_conc) Ratio of below-ground residue dry matter to harvested production (BGresidue_ratio), Nitrogen content of below-ground residues (BGresidue_N_conc)

Manure Soil Amendments

If manure is used on the farm, the N₂O quantification method of Canada's National Inventory Report assumes that all manure nitrogen is available in the year of application. Manure is the only organic soil amendment applicable for quantification under this protocol. Project documentation should describe:

- Analysis or approved sources determining the manure nutrient content of the manure;
- Determination of nutrient application rates per hectare for crops grown;
- Calibration of spreading equipment to attain nutrient application rates;
- Time of year of spreading (if more than one spreading per year, the proportion of annual volume at each spreading); and
- Results of soil tests and nitrogen balance assessment to track the nutrient status of the soil.

Wherever possible, the spreading of manure should be planned at the same level of field variability as is the fertilizer application. It is anticipated that in Alberta manure will make up the large majority of organic soil amendments. Manure spreading must be recorded per crop type at the whole field, sub-field or variable rate application as appropriate for the corresponding performance level (basic/intermediate/advanced). Laboratory manure analysis must be used to determine manure nutrient content. Alternatively, manure production and nutrient content tables from the Alberta Nutrient Management Planning Guide²² will provide another means of estimating nutrient content of manure and nutrient application based on rate of manure application. If manure comes from a confined feeding operation, it is expected that records on the analysis and rate of application will be available from the confined feeding operation.

²² Standard Values for Nutrient Manure Content from Appendix 4A (pgs. 296-297) of the Nutrient Management Planning Guide must be used if laboratory analysis is not undertaken. Alberta Agriculture and Rural Development, 2007, Alberta's Nutrient Management Planning Guide.

Baseline calculations require that farm records be available to support which fields organic fertilizer was applied to. Supporting evidence that organic fertilizer was spread on the land may come from receipts for custom services.

For project implementation, it will be necessary to ensure manure sampling procedures and application rate documentation are kept by the enrolled farmer, the Accredited Professional Advisor and the project developer.

Fertilizer Nitrogen Placement

The 4R Plan requires placing fertilizer in bands, either through injection or in concentrated sub-surface rows. The band must have a fertilizer spread that is not more than 30 per cent of the row laterally.

The general equation to be applied is:

$$\% \text{ Band Concentration} = \text{Width of Spread} / \text{Fertilizer Opener Spacing} * 100$$

Where:

Width of Spread is determined by the type of opener (see Table 5); and

Fertilizer Opener Spacing is the distance between fertilizer openers.

Table 5: Expected Band Concentration in Fertilizer Application

	Width of Spread of Fertilizer in the Row ⁱ											
	2.5 cm (disc or knife)			5.0 cm (spoon or hoe)			7.5 cm (sweep)			10.0 cm (sweep)		
Fertilizer Opener	15	23	30	15	23	30	15	23	30	15	23	30
Fertilizer Concentration	17	11	8	33	22	17	50	30	25	67	44	33

i - The width of spread of fertilizer and seed depends on the type of opener, soil type and moisture content, air

Fall Applied Fertilizers

The 4R Plan allows for some fall application of fertilizers, so long as the temperature of the soil is less than 10° Celsius for three consecutive days. To prove that fall application of fertilizers occurred at the correct time, appropriate data sources must include farm records showing soil temperature readings (a minimum of five centimetres below the soil surface) for three consecutive days. As an alternative to direct soil temperature sampling, nearby publically available weather station data (daily high temperature) can be used to predict soil temperature using the equation below²³. Daily high temperatures for five consecutive days must result in soil temperatures below 10° Celsius using the following equation in order to support appropriate fall application of fertilizers:

$$\text{Soil temperature} = 0.6287t + 0.3339$$

$$t = \text{Air temperature in degrees Celcius (daily high)}$$

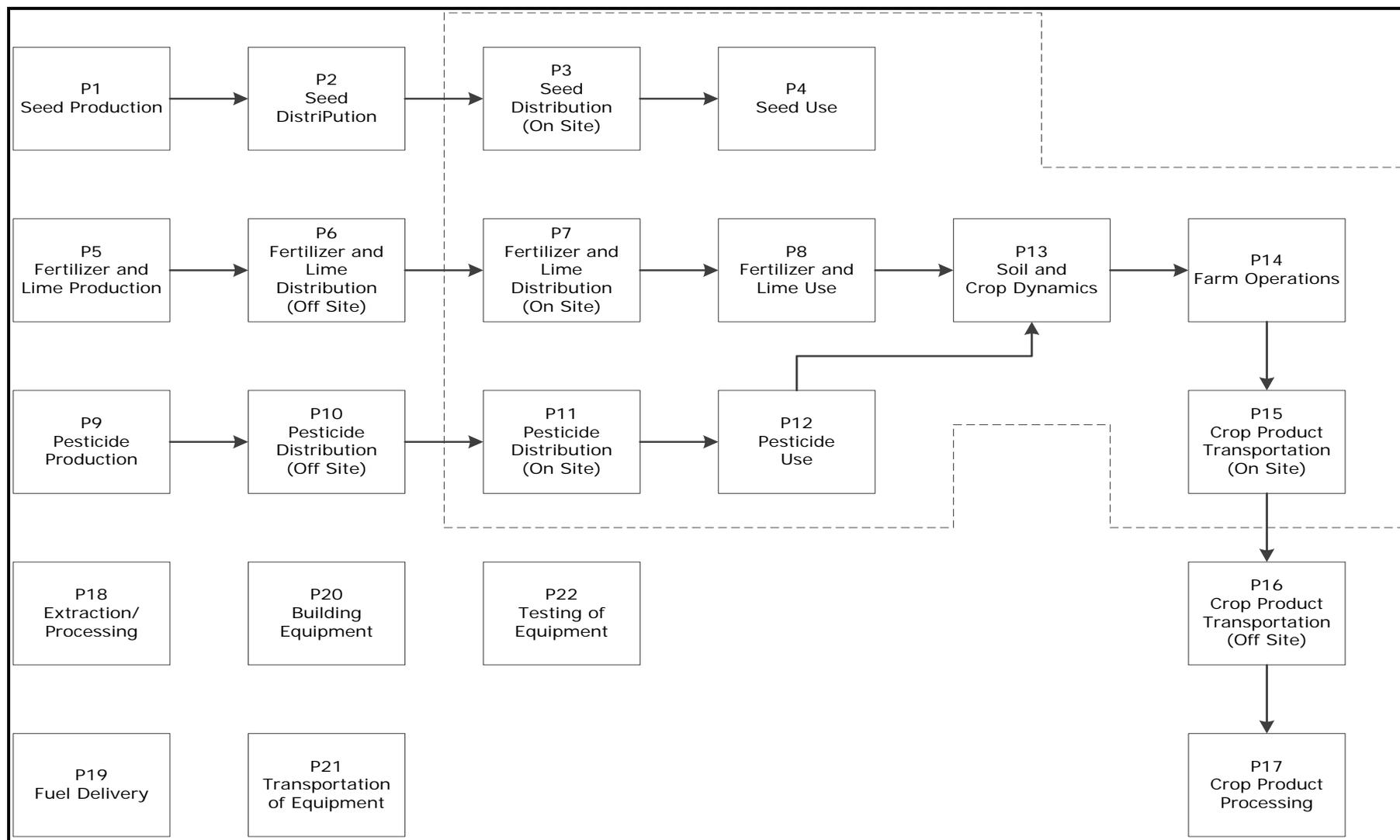
²³ Koehler-Munro et al, 2005, Soil Temperature Dynamics of Adjacent Catenas on Farmland in the Black Soil Zone.

Temperature data can be obtained from the AgroClimatic Information Service that is maintained by Agriculture and Forestry. The Accredited Professional Advisor must ensure that this is well documented in the 4R Plan.

3.2 Project Condition Process Flow

Figure 3 presents the process and material flow for the project condition.

Figure 3: Process Flow Diagram for the Project Condition



3.3 Identification of Project Sources and Sinks

Sources and sinks for the project were identified based on extensive scientific review. Sources and sinks were also identified for the project by reviewing good practice guidance, consulting with technical experts, national inventory scientists and other relevant greenhouse gas technical sources. This iterative process confirmed that the sources and sinks in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided above, the project sources and sinks were organized into life cycle categories in Figure 4. Descriptions of each of the sources and sinks and their classification as controlled, related or affected are provided in Table 6.

Figure 4: Project Sources and Sinks for Reducing Nitrous Oxide Emissions

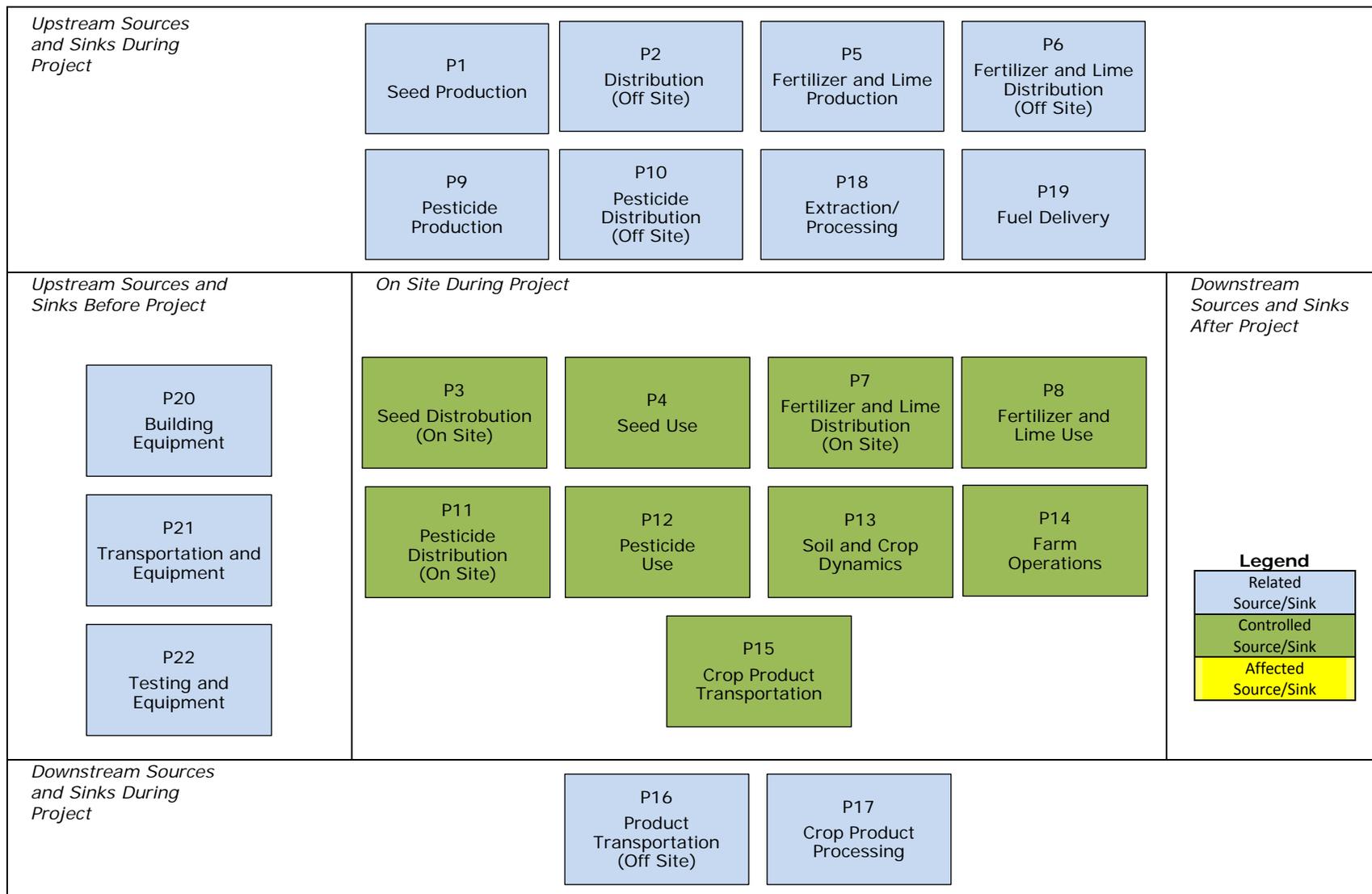


Table 6: Project Condition Sources and Sinks

Source/Sinks	Description	Controlled, Related or Affected
<i>Upstream Sources and Sinks During Project Operation</i>		
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 comparable metrics 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 comparable metrics 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 source/sink, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 ensure comparable metrics 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to	Related

	ensure comparable metrics with the baseline condition.	
P18 - Fuel Extraction and Processing	Each of the fuels used throughout the project will need to be 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 sources/sinks are considered under this source. 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

On Site Sources and Sinks 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 comparable metrics 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 4R 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 source, for the purposes of calculating the resulting greenhouse gas emissions.	Controlled

	Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	
P12 - Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of fertilizer need to be tracked to ensure comparable metrics 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 N ₂ O.	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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled

Downstream Sources and Sinks 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 source, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics 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 comparable metrics 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

4.0 Quantification

Baseline and project conditions were assessed against each other to determine the scope for reductions quantified under this protocol. Sources and sinks were either included or excluded depending how they were impacted by the project condition. Sources that are not expected to change between baseline and project condition are excluded from the project condition. It is assumed that excluded activities will occur at the same manner and magnitude during both the baseline and project conditions. This consistency between the baseline and project condition justifies the exclusion of these emission sources for projects being implemented under this protocol. Project developers must assess these emission sources for their specific project. If these assumptions are not valid for a specific project, the associated emissions must be quantified and documented in the Project Plan and Project Report.

All sources and sinks identified in Tables 5 and 6 are listed in Table 7. Each source and sink is listed as include or excluded. Justification for these choices is provided.

Table 7: Comparison of Sources/Sinks for Baseline and Project

Identified Source/Sinks	Baseline	Project	Quantification	Justification
<i>Upstream Source and Sinks</i>				
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 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 sources are not relevant to the project and pesticide 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 equivalent to the baseline scenario. The baseline and

B10 - Pesticide Distribution (Off Site)	Related	N/A	Exclude	project conditions will not be materially different as a result of the project.
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	

On Site Sources and Sinks

P3 - Seed Distribution (On Site)	N/A	Controlled	Exclude	Excluded as the emissions from seed transportation in the project condition are likely 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 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	Incremental P7 Fertilizer and Lime Distribution (On-Site) emissions are included in cases where implementation of the 4R Plan requires additional passes to apply fertilizer or lime in comparison to normal farm operations.
B7 - Fertilizer and Lime Distribution (On Site)	Controlled	N/A	Exclude	
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 equivalent to the baseline scenario. Further, the baseline and project conditions will not be materially
B11 - Pesticide	Controlled	N/A	Exclude	

Distribution (On Site)				different as a result of the project implementation.
P12 - Pesticide Use	N/A	Controlled	Exclude	Excluded as the emissions from pesticide use are likely 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 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 Sources and Sinks

P16 - Crop Product Transportation (Off Site) ⁱ	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely 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 equivalent to the baseline scenario. Further, the

B17 - Crop Product Processing	Related	N/A	Exclude	baseline and project conditions will not be materially different as a result of the project implementation.
<i>Other</i>				
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.

i - Analysis of the impact of increased crop mass as a result of the project activity on downstream crop transportation and processing emissions was conducted by Cecil Nagy at the Department of Bioresource Policy, Business and Economics, University of Saskatchewan, Saskatoon. Even with a 30% crop mass increase as a result of implementing a 4R Plan, the impact on downstream crop transportation and handling emissions is immaterial to the overall project reduction. See Appendix G for more information.

4.1 Quantification Methodology

This protocol quantifies direct and indirect N₂O emissions per unit of crop produced for each crop type on each farm in the project condition using Canada's Tier II quantification methodology specific to the EcoDistrict where the farm is located. This means that the calculated N₂O emissions are corrected for the predominant soil type, the representative topography and the climate for the farm. See Appendix F for sample calculations.

In the baseline condition, the N₂O emissions are quantified according to the methodology used in Canada's National Inventory Report. Application of the National Inventory Report emission factors and formulae to the geographical location and management practices of each farm during the three years prior to project implementation determines the baseline N₂O emissions in the conventional baseline approach. Section 1.3 and Appendix H describe calculation of the baseline condition under the dynamic baseline approaches.

Carbon offset quantification is calculated on a mass basis using nitrogen inputs and crop mass per crop type, across the entire farm enterprise, in two ways:

- (1) At the field level so long as the fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level; or
- (2) At the farm level so long as fields are in the same EcoDistrict and have the same crop type and 4R Plan performance level.

The basic analytical unit for calculating a reduction in N₂O emissions for a farm occurs for crop type by EcoDistrict by performance level. This means that separate reduction calculations must be made each time the crop type occurs in a different EcoDistrict and/or 4R performance level. For example, a farm which exists within one EcoDistrict, applies only one 4R performance level, and grows only one crop will only require one calculation of emission reductions.

The project developer will need to repeat the quantification of reductions in their entirety for each analytical unit and then sum the reductions across the entire farm enterprise to obtain the GHG claim for that year.

The 4R nitrogen management must still occur according to the 4R Plan, with project documentation collected to show conformance to the 4R Plan.

The direct and indirect emissions of N₂O from soil are calculated according to nitrogen inputs from synthetic fertilizer, manure, and crop residue decomposition per crop type.²⁴ The N₂O emission calculations are based on the total mass of nitrogen per crop type divided by the total crop mass for each particular crop. This results in N₂O emissions per crop mass. Since the baseline represents the nitrogen management practices in place before implementation of the 4R Plan, the baseline emission calculations only account for mass of nitrogen added per crop type. This means that for the baseline condition only the mass of nitrogen inputs and yield per crop type need to be documented. Nitrogen inputs from both organic (synthetic) and organic soil amendments must be accounted for in the baseline condition.

The project condition is initiated by implementation of the 4R Plan. Quantifying N₂O in the project involves accounting for nitrogen inputs and meeting the specified requirements for time,

²⁴ Fields which receive organic soil fertilizers other than manure or crop residue from the remaining year must be included in the 4R Plan, but render that entire crop type ineligible to generate offsets for the year in which they are used.

place, rate and form of fertilizer for the performance level being used. Again, if manure is applied in the project condition, the 4R reduction modifier is not applied to the emissions from these sources.

Projects must account for incremental increases in GHG emissions associated with differences in the nitrogen fertilizer application practices between baseline and project. The Accredited Professional Advisor will assess and document nitrogen fertilizer application practices prior to project implementation as part of developing the initial 4R Plan. As part of this assessment, the Accredited Professional Advisor will establish and document the number of field passes used by the grower for nitrogen fertilizer application prior to project implementation.

Each year of the project, the Accredited Professional Advisor will assess the nitrogen application practices relative to the baseline. Any increased GHG emissions from additional nitrogen application passes relative to the baseline will be calculated and subtracted from the GHG offset assertion for the farm. The methods for accounting for additional passes are explained with worked examples in Appendix K.

4.1.1 Quantification Approach

Quantification of the reductions, removals and reversals of relevant sources and sinks for each of the greenhouse gases will be completed using the methodologies outlined in Table 8. These calculation methodologies serve to complete the following three equations for calculating the emission reductions achieved by comparing the baseline and project conditions per mass of crop produced.

Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and at each performance level on farms. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are summed across the analytical units to derive the carbon reduction claim for the farm for that year. The calculations sequence for each crop type, using the conventional approach, is as follows:

- (1) The CO₂e emissions in the baseline and project conditions are calculated using functional units of kilograms CO₂e per kilogram of crop produced on a dry matter basis. In the equations, the crop type will be referred to as crop *i*, representing the understanding that each project (farm) will consist of a number of crops.
- (2) The baseline condition (in this case, the conventional baseline) is expressed for each crop type as the three year average kg CO₂e per kg of crop produced, or if applying one of the dynamic baselines, a one year measurement of the kg CO₂e per kg of crop produced for each crop type (see Appendix H for description of dynamic baseline quantification).
- (3) Within a single EcoDistrict and a single 4R management level, project condition emissions are calculated for each crop type on an annual basis using the same functional units.
- (4) The sum of emissions from synthetic nitrogen fertilizer and crop residue (kg CO₂e per kg crop produced) is multiplied by the appropriate reduction modifier for the selected 4R performance level to get the emission levels by project crop type. These emissions are then added to emissions associated with manure application, which are not multiplied by the reduction modifier.

- (5) The CO₂e reduction for each project crop type is calculated as the difference between the baseline emissions intensity and project emissions intensity (as calculated in Step 4 above) (kg CO₂e per kg crop produced).
- (6) To derive the total emission reductions (kg CO₂e) for each crop type, multiply the reduction in number 5 above by the total mass of crop produced (kg crop produced) in the project.
- (7) If applicable, emissions reductions from multiple crop types are summed.
- (8) If applicable, emissions reductions from crops in each 4R management level and each EcoDistrict are summed.
- (9) Emissions from additional fuel use are subtracted from the above result to calculate total project emission reductions (see Appendix K for more information on quantification of additional fuel use).

See Appendix F for a sample calculation demonstrating this sequence.

In certain project configurations, the implementation of the 4R Plan may result in increased fossil fuel consumption from additional fertilizer applications (e.g., a split application) compared to management in the baseline scenario. If this occurs, the incremental project emissions from the distribution of fertilizer (Fertilizer and Lime Distribution) must be included in the total project emissions intensity. In order to insure the offset assertion is conservative, offset credits cannot be generated for reducing the number of field passes during the project.

The following equations are applied:

Emission Reduction	=	$\left[\sum_{\text{EcoDistrict } j} \sum_{\text{4R management level } k} [\text{Emissions Intensity}_{\text{Baseline } jk} - \text{Emissions Intensity}_{\text{Project } jk}] * \text{Crop Mass}_{\text{Project}} \right] - \text{Emissions}_{\text{Fert and Lime Dist}}$
Emissions Intensity _{Baseline}	=	$\left[\sum_{\text{crop } i} ((\text{Emissions}_{\text{Man use, } i} + \text{Emissions}_{\text{Manure Soil Crop Dyn, } i} + \text{Emissions}_{\text{Other Fert and Lime Use, crop } i} + \text{Emissions}_{\text{Other Fert Soil Crop Dyn, crop } i}) / \text{Crop Mass}_{\text{baseline } i}) * \text{GWP}_{\text{N2O}} \right]$
Emissions Intensity _{Project}	=	$\left[\sum_{\text{crop } i} [\text{Emissions}_{\text{Manure Use, } i} + \text{Emissions}_{\text{Manure Soil Crop Dyn, } i} + ((\text{Emissions}_{\text{Other Fert and Lime Use, crop } i} + \text{Emissions}_{\text{Other Fert Soil Crop Dyn, crop } i}) * \text{RM}_{\text{PL}}) / \text{Crop Mass}_{\text{Project } i}] * \text{GWP}_{\text{N2O}} \right]$
Crop i	=	Index number for tracking crop types within an EcoDistrict and within a performance level
EcoDistrict j	=	Index number for tracking EcoDistrict types
4R Management Level k	=	Index number for tracking 4R management performance levels, within an EcoDistrict
Emissions Intensity _{Baseline}	=	Sum of the emissions under the baseline condition divided by baseline crop mass
Emissions Intensity _{Project}	=	Sum of the emissions under the project condition divided by project crop mass
Emissions _{Fert and Lime Dist}	=	Emissions under source/sink (SS) P7 Fertilizer and Lime Distribution (On Site)
Emissions _{Manure Soil}	=	Emissions from manure under SS P13/B13 Soil Crop

Crop Dyn		Dynamics
Emissions _{Manure Use}	=	Emissions from manure under SS P8/B8 Fertilizer and Lime Use
Emissions _{Other Fert}	=	Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics
Soil Crop Dyn		
Emissions _{Other Fert and Lime Use}	=	Emissions from inorganic fertilizer and crop residues and under SS P7 Fertilizer and Lime Use
RM _{PL}	=	Emission reduction modifier of 0.85 and 0.75, which correspond to the implementation of Basic or Intermediate/Advanced 4R Plans, respectively
Crop Mass _{Baseline}	=	Crop Mass determined in the baseline for all crops based on a three year average, adjusted to a dry matter basis (conventional approach)
Crop Mass _{Project}	=	Crop Mass determined in the project for all crops, adjusted to a dry matter basis
GWP _{N2O}	=	Global warming potential value for N ₂ O

The dynamic baseline approach outlined in Section 1.3 can be applied in this protocol. See Appendix H for equations required under the dynamic baseline approaches.

Global Warming Potential values and emission factors for fuels can be found in the Carbon Offset Emission Factors Handbook.²⁵

The following calculations can be used to calculate crop mass on a dry matter basis:²⁶

Crop Mass _{dry matter basis}	=	Wet Mass _{sample} x %DM
%DM	=	(Dry Mass _{sample} / Wet Mass _{sample}) x 100%
Crop Mass _{dry matter basis}	=	All Quantification calculations in Table 8 using crop mass values must be conducted on a dry matter basis
%DM	=	Per cent dry matter of the crop
Wet Mass _{sample}	=	Wet mass, or harvest mass, of the bin sample used collected to determine bin moisture content
Dry Mass _{sample}	=	Mass of the bin sample used to determine bin moisture content after it has been dried

²⁵ Alberta Environment and Parks, 2015, Carbon Offset Emission Factors Handbook.

²⁶ Further description of methodologies to determine crop mass on a dry matter basis, including methodologies for drying crop bin samples can be found in the following source: United States Department of Agriculture Natural Resources Conservation Service, 2007, Dry Matter Determination.

Table 8: Quantification Methodology for Conventional Application of this Protocol

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
P7 - Fertilizer and Lime Distribution	$Emissions_{Fert\ and\ Lime\ Dist} = \sum (Vol.\ Fuel * EF_{Fuel\ Ext\ and\ prod\ CO_2} * EF_{Fuel\ Comb\ CO_2}) ; \sum (Vol.\ Fuel * EF_{Fuel\ Ext\ and\ prod\ CH_4} * EF_{Fuel\ Comb\ CH_4} * GWP_{CH_4}) ; \sum (Vol.\ Fuel * EF_{Fuel\ Ext\ and\ prod\ N_2O} * EF_{Fuel\ Comb\ N_2O} * GWP_{N_2O})$					
	Emissions _{Fert and Lime Dist}	kg of CO ₂ ; kg CH ₄ ; kg N ₂ O	N/A	N/A	N/A	Quantity being calculated
	Incremental Volume of Fuel Consumed to Operate Farm Equipment for Implementation of 4R Plan / Vol. Fuel	L / m ³ / other	Measured	As per fuel volume determination methods provided in Appendix K	Quarterly reconciliation	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small
	Carbon Dioxide Emissions Factor for Extraction and Production of Each Type of Fuel / EF _{Fuel_{Ext and prod}}	kg CO ₂ per L / m ³ / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	CO ₂					
	Carbon Dioxide Emissions Factor for Combustion of Each Type of Fuel / EF Fuel _{Comb CO₂}	kg CO ₂ per L / m ³ / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	CH ₄ Emissions Factor for Extraction and Production of Each Type of Fuel / EF Fuel _{Ext and prod CH₄}	kg CH ₄ per L / m ³ / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Methane Emissions Factor for Combustion of Each Type of Fuel / EF Fuel _{Ext and prod CH₄}	kg CH ₄ per L / m ³ / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Global	Unitless	Estimated	Refer to Carbon	N/A	Must use most

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Warming Potential for Methane / GWP_{CH_4}			Offset Emission Factors Handbook		current factors published in Carbon Offset Emission Factors Handbook
	Nitrous Oxide Emissions Factor for Extraction and Production of Each Type of Fuel / EF $Fuel_{Ext\ and\ prod\ N_2O}$	kg N_2O per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Nitrous Oxide Emissions Factor for Combustion of Each Type of Fuel / EF $Fuel_{Comb\ N_2O}$	kg N_2O per L / m^3 / other	Estimated	Refer to Carbon Offset Emission Factors Handbook	Annual	Must use most current factors published in Carbon Offset Emission Factors Handbook
	Global Warming Potential for Nitrous Oxide / GWP_{N_2O}	Unitless	Estimated	Refer to Carbon Offset Emission Factors Handbook	N/A	Must use most current factors published in Carbon Offset Emission Factors Handbook

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
B8/P8 - Fertilizer and Lime Use	$Emissions_{Manure\ Use, crop\ i} = N_{Manure\ crop\ i} * EF_{ECO} * MolarRatio$					
	Manure Use Emissions – Emissions _{Manure Use, crop i}	kg N ₂ O	N/A	N/A	N/A	Quantity being calculated
	Manure Nitrogen Use per Crop i — N _{Manure crop i}	kg N	Measured	Direct measurement during application	Continuous	Direct measurement is the most accurate method
	Emission Factor Related to Local Soil and Climatic Conditions — EF _{Eco}	kg N ₂ O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation to potential evapotranspiration for the area. ⁱ Also integrates influence of texture, tillage, and topography	Annually	The value associated with EF _{Eco} is to be determined based on the EcoDistrict the farm is located in. The EF _{Eco} value for each EcoDistrict is listed in Appendix A. As per the approach used in Canada's National Inventory Report quantification method. For irrigated fields, use an EF _{Eco} = 0.017
	MolarRatio	unitless	N/A	N/A	N/A	This molar ratio

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
						fraction converts nitrogen to nitrous oxide based on the molecular weight of N ₂ O and N ₂ . MolarRatio = 44/28
B8/P8 -Fertilizer and Lime Use	<i>Emissions_{Other Fert and Lime Use, crop i} = N_{FN crop i} * EF_{ECO} * MolarRatio</i>					
	Other (inorganic fertilizer and crop residue) Fertilizer and Lime Use Emissions - Emissions _{Other Fert and Lime Use, crop i}	kg N ₂ O	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen Fertilizer Use per Crop i — N _{FN crop i}	kg N	Measured	Direct measurement during application	Continuous	Direct measurement is the most accurate method
	Emission Factor Related to	kg N ₂ O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the	Annually	The value associated with EF _{Eco} is to be determined

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Local Soil and Climatic Conditions — EF_{Eco}			ratio of precipitation to potential evapotranspiration for the area ¹ . Also integrates influence of texture, tillage, and topography		based on the EcoDistrict the farm is located in. The EF_{Eco} value for each EcoDistrict is listed in Appendix A. As per the approach used in Canada's National Inventory Report quantification method. For irrigated fields, use an $EF_{Eco} = 0.017$
	MolarRatio	unitless	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2 . MolarRatio = 44/28
B13/P13 - Soil and Crop Dynamics	$Emissions_{Manure\ Soil\ and\ Crop\ Dyn,\ crop\ i} = ((N_{Manure\ crop\ i} * FRAC_m * EF_{VD}) + (N_{Manure\ crop\ i} * FRAC_L * EF_L)) * MolarRatio$					
	Manure Soil and Crop Dynamics Emissions – $Emissions_{Manure\ Soil\ and\ Crop}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Dyn, crop i					
	Manure nitrogen per crop i— N_{Manure}	kg N	Measured	Direct measurement during application	Continuous	Direct measurement is the most accurate method
	Fraction of Manure nitrogen Applied to Soils that Volatizes as $\text{NH}_3\text{-N}$ and $\text{NO}_x\text{-N}$ — FRAC_m	unitless	Estimated	Default factor set at 0.2 for manure	Annually	As per Canada's 2014 National Inventory Report quantification report
	Emission Factor for Nitrous Oxide 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 2014 National Inventory Report quantification report
	Fraction of Nitrogen Lost in Leachate — FRAC_L	kg N	Estimated	Calculated using $0.3247 * \text{P/PE} - 0.00247$, where P/PE is the ratio of precipitation and	Monthly	The $\text{FRAC}_{\text{leach}}$ value for each EcoDistrict within Alberta is listed in Appendix A. As per Canada's

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
				irrigation to potential evapotranspiration for the area		National Inventory Report quantification method. For irrigated fields, use a $FRAC_L = 0.3$
	Emission Factor for Nitrous Oxide from Leachate — EF_L	kg N ₂ O - N / kg N	Default	Default factor set at 0.025 kg N ₂ O - N / kg N	Annually	As per Canada's 2014 National Inventory Report quantification report
	MolarRatio	unitless	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N ₂ O and N ₂ . MolarRatio = 44/28
B13/P13 - Soil and Crop Dynamics	$Emissions_{Other\ Soil\ and\ Crop\ Dyn, crop\ i} = ((N_{res\ crop\ i} * EF_{ECO}) + (N_{VD\ crop\ i} * EF_{VD}) + (N_{L\ crop\ i} * EF_L)) * MolarRatio$					
	Other (inorganic fertilizer and crop residue) Soil and Crop Dynamics Emissions –	kg N ₂ O	N/A	N/A	N/A	Quantity being calculated

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emissions _{Oth} er Soil and Crop Dyn, crop i					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually — N _{res, crop i}	kg N	Calculated	Calculated as per the equation given below	Annually	As per Canada's National Inventory Report quantification process
	Emission Factor Related to Local Soil and Climatic Conditions — EF _{Eco}	kg N ₂ O - N / kg N	Estimated	Calculated using 0.022*P/PE-0.0048, where P/PE is the ratio of precipitation to potential evapotranspiration for the area ⁱ . Also integrates influence of texture, tillage, and topography	Annually	The value associated with EF _{Eco} is to be determined based on the EcoDistrict which the farm is located in. The EF _{Eco} value for each EcoDistrict is listed in Appendix A As per the approach used in Canada's National Inventory Report quantification method. For irrigated fields, use an EF _{Eco} = 0.017

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Emissions of Nitrous Oxide from Volatilization and Re-deposition of NH ₃ and NO _x per Crop i— $N_{VD, crop i}$	kg N	Calculated	Calculated as per the equation given below	Annually	As per Canada's National Inventory Report quantification process
	Emission Factor for Nitrous Oxide from Nitrogen Redeposited after Volatilization — EF_{VD}	kg N ₂ O - N / kg N	Estimated	Default factor set at 0.01 kg N ₂ O - N / kg N	Annually	As per Canada's 2014 National Inventory Report quantification report
	Emissions From Leaching of NO ₂ - N and NO ₃ - N per Crop i— $N_L, crop i$	kg N	Calculated	Calculated as per the equation given below	Annually	As per Canada's National Inventory Report quantification process
	Emission Factor for Nitrous	kg N ₂ O - N / kg N	Default	Default factor set at 0.025 kg N ₂ O - N / kg N	Annually	As per Canada's 2014 National Inventory Report

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Oxide From Leachate — EF_L					quantification report
	MolarRatio	unitless	N/A	N/A	N/A	This molar ratio fraction converts nitrogen to nitrous oxide based on the molecular weight of N_2O and N_2 . MolarRatio = 44/28
B13/P13 - Soil and Crop Dynamics	$N_{res\ crop\ i} = Crop\ Mass_{crop\ i} * (1/ Yield\ Ratio) * FRAC_{renew\ crop\ i} * ((R_{AG\ crop\ i} * N_{AG\ crop\ i}) + (R_{BG\ crop\ i} * N_{BG\ crop\ i}))$					
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per Crop i — $N_{res\ crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Harvested Annual Dry Matter Production for Crop i — $Mass_{crop\ i}$	kg DM	Measured	Direct measurement	Annually	Direct measurement is the most accurate method

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Fraction of Total Dry Matter Production that is Harvested – Yield Ratio	unitless	Estimated	This value is determined using the Table E.1 in Appendix E. The value is from the fifth column (Yield_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
	Fraction of Total Area Under Crop <i>i</i> that is Renewed Annually — $FRAC_{renew\ crop\ i}$	unitless	Estimated	For annual crops $FRAC_{renew} = 1$	Annually	Values calculated based on values published by IPCC. Reference values adjusted periodically as part of internal IPCC review of its methodologies). Value set at one to reflect that only annuals are allowed in project condition
	Ratio of Above-Ground Residues Dry Matter	unitless	Estimated	This value is determined using the Table E.1 in Appendix E. The value is from the	Annually	Values are attained from Holos 2008 methodology (produced by Agriculture and

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	to Harvested Production for Crop i — $R_{AG\ crop\ i}$			sixth column (AG residue_ratio) for the appropriate crop		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 i — $N_{AG\ crop\ i}$	kg nitrogen / kg DM	Estimated	This value is determined using the Table E.1 in Appendix E. 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 i — $R_{BG\ crop\ i}$	unitless	Estimated	This value is determined using the Table E.1 in Appendix E. 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

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
						for Canadian specific conditions
	Nitrogen Content of Below-Ground Residues for Crop i — $N_{BG\ crop\ i}$	kg nitrogen / kg DM	Estimated	This value is determined using the Table E.1 in Appendix E. 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
B13/P13 - Soil and Crop Dynamics	$N_{VD\ crop\ i} = (N_{Fert\ crop\ i} * FRAC_f)$					
	Indirect Emissions of Nitrogen from Volatilization and Re-deposition of NH_3 and NO_x per Crop i — $N_{VD\ crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen	kg N	Estimated	Direct measurement	Annually	Direct measurement is the most accurate

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Fertilizer Use per Crop i — $N_{fert, crop i}$					method
	Fraction of Synthetic Fertilizer Nitrogen Applied to Soils that Volatizes as NH_3^- and NO_x-N — $FRAC_f$	unitless	Estimated	Default factor set at 0.1 for commercial fertilizer	Annually	As per Canada's 2014 National Inventory Report quantification report
$N_{L, crop i} = (N_{Fert, crop i} + N_{res, crop i}) * FRAC_L$						
	Indirect Emissions of Nitrogen from Leaching per Crop i — $N_{L, crop i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic Nitrogen Fertilizer Use per Crop i — $N_{Fert, crop i}$	kg N	Measured	Direct measurement	Continuous	Direct measurement is the most accurate method

Project/Baseline Sources Sinks	Parameter / Variable	Unit	Measured / Estimated	Method	Frequency	Justify Measurement or Estimation and Frequency
	Total Amount of Crop Nitrogen that is Returned to the Cropland Annually per Crop i — $N_{res, crop i}$	kg N	Calculated	Calculated as per the equation above	Annually	As per Canada's National Inventory Report quantification process
	Fraction of Nitrogen Lost in Leachate — $FRAC_L$	unitless	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 $FRAC_{leach}$ value for each EcoDistrict within Alberta is listed in Appendix A. As per Canada's National Inventory Report quantification method. For irrigated fields, use a $FRAC_L = 0.3$

ⁱ - Rochette *et al*, 2008A, Estimation of N₂O emissions from agricultural soils in Canada. II. 1990-2005 Inventory. Canadian Journal of Soil Science. 88: 655-669 and Rochette *et al*, 2008B, Estimation of N₂O emissions from agricultural soils in Canada. I. Development of a country-specific methodology. Canadian Journal of Soil Science. 88: 641-654.

5.0 Documentation

Projects must be supported with data of sufficient quality to fulfill the quantification requirements and be substantiated by records for the purpose of verification to a reasonable level of assurance. Reasonable assurance means the verifier must be able to reach a positive finding on the accuracy and correctness of the GHG assertion.

Based on these requirements, data must be quantifiable, measurable and verifiable using replicable means. That is, an independent verifier should be able to reach the same conclusions using evidence-supported data. The Alberta carbon offset system cannot accept data that is based on attestation.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. Requirements can be found in ESRD's Technical Guidance for Greenhouse Gas Verification at Reasonable Level of Assurance.

5.1 Documents

Documentation in the form of documents and records is a key element to project development. The offset project plan must be specific and detail the documentation requirements for the project. The verification process relies heavily on the quality and availability of documentation and the project plan must be clear on the types of documentation that will be available to the verifier/auditor. Verifiers and auditors will be auditing to a reasonable level of assurance. The project developer will need to provide the verifier/auditor with objective evidence of project implementation. Attestation is not considered objective evidence and will not be accepted. The types of documentation and records required to demonstrate that an offset project meets regulatory and protocol requirements will vary and should be clearly outlined in the offset project plan.

Documents and records are required to be:

- legible, identifiable and traceable;
- centrally located;
- dated;
- easily located (easily searched);
- orderly;
- retained for 7 years after end of the project crediting period; and,
- prevented from loss.

In the case of aggregated projects, the individual farmer and the aggregator must both retain records.

Project developers are required to retain copies of all required records and any additional records needed to support greenhouse gas assertions. The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must 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 verification/audit will be conducted for the project.

Requirements can be found in Technical Guidance for Greenhouse Gas Verification at Reasonable Level of Assurance.

Documents are the instructions or plan on how a certain activity is carried out. Project documents are required to prove eligibility, baseline eligibility and project quantification. Documents include but are not limited to the project plan, procedures, specifications, drawings, regulations, standards, guidelines, etc. Documents may occasionally change or be updated and project developers must use the most current versions. The offset project documents should include a list of records that will be available to demonstrate to verifiers and auditors that offset criteria have been met. The offset project documents should also indicate how the records will be managed (i.e., retention, storage and access).

5.2 Records

Records are required to prove completion of the project as planned. Records include but are not limited to invoices, contracts, metered results, maintenance logs, calculations, databases, photographs, calibration records, farm record sheets, 4R Plans, soil testing results, etc. Records must be retained according to the requirements outlined in Section 5.0 and as indicated in the offset project plan. In the case of an aggregated project, the individual farmer and the aggregator must both retain sufficient records demonstrating that the offset criteria are met. Records must be available and be disclosed to a verifier and/or government auditor upon request.

5.2.1 General Records Requirements

Table 9 outlines the minimum general records needed to support this protocol.

Table 9: General Records Requirements

Record Requirement	Examples of Records	Why Required
Ownership of the farm fields being claimed in the project	<ul style="list-style-type: none"> • Land title certificate for each field being claimed in the project for the first year the field is included; and • Confirmation of annual check against land titles to determine if ownership for the property has changed; and • If ownership has changed, a new land title certificate must be obtained; and • If the project developer leases land for implementation of the project, signed written lease agreement between the land owner(s) and the tenant. If a single lease agreement is used for multiple project years, the agreement must be valid over this time span. 	To confirm land ownership
Right to transact on offset credits	<ul style="list-style-type: none"> • Contract between the project developer and farm operator for the assignment of carbon rights. This must include an agreement to provide access to data needed to quantify the greenhouse gas assertion for the farm enterprise; and • Carbon Transfer Agreements¹ between land owner(s) and the project developer. This agreement may be incorporated into the lease agreement. The contract must be in place before the farm field can be registered in an offset project and must be valid for the project years for which credits are being serialized. 	To confirm the right to transact on offset credits
Confirmation of annual Farm Enterprise Boundary by the Accredited Professional Advisor	<ul style="list-style-type: none"> • Measurement of farm enterprise boundary size using imagery such as satellite data or aerial photos or county maps; • Annual check of additions or removals of land title certificates under the farm enterprise boundary; and • Annual check of additions or removals of land lease agreements between the farm enterprise and other parties. 	To confirm the entire farm enterprise is included in the offset project To confirm that new lands added to the farm enterprise boundary are recorded and appropriately

Record Requirement	Examples of Records	Why Required
		handled according to protocol requirements
Location of the Farm Enterprise included in Project	<ul style="list-style-type: none"> • Legal land location(s) (Alberta Township System and GPS coordinates) of the entire farm enterprise boundary; and • EcoDistrict location(s) within the farm enterprise boundary, determined using the toolⁱⁱ provided by Alberta Agriculture and Rural Development. 	Entire Farm Enterprise Boundary must be included in the project EcoDistrict locations required for emission reductions accounting
Use of Irrigation if applicable	<ul style="list-style-type: none"> • Supporting documentation for water usage on the field by farm operator including two of the following: <ul style="list-style-type: none"> ▪ Water use records; ▪ Photo evidence with GPS time stamp showing equipment used including model information; ▪ Crop insurance records noting use of irrigation; ▪ Air photo or satellite imagery showing pivots; ▪ Alberta Irrigation Program documents; ▪ Detailed farm maps showing coverage of irrigation networks over project fields including type and model numbers for equipment being used; OR • Sign off by the Accredited Professional Advisor who reviewed and collected supporting documentation that confirm the irrigation practice; and • Copy of supporting documentation reviewed by Accredited Professional Advisor. 	Irrigation impacts N ₂ O emissions from agricultural soils. Irrigation status required to properly calculate project emission reductions
Accredited Professional Advisor credentials	<ul style="list-style-type: none"> • Confirmation that the Accredited Professional Advisor has successfully completed the 4R Accredited Professional Advisor training program provided by the Canadian Fertilizer Institute; • Proof of Accredited Professional Advisor's registration as a member of the Alberta Institute of Agrologists; and 	To ensure that the Accredited Professional Advisor has training and credentials required under the protocol

Record Requirement	Examples of Records	Why Required
	<ul style="list-style-type: none"> Confirmation from the AIA Membership Directory (website) that the Accredited Professional Advisor meets the requirements of the Area of Practice Standard for Greenhouse Gas Assessment and Management Practice. The record must be a screen shot or print out of the member directory, showing the name of the individual and include GHG Assessment and Management Practice, and the date the member search was conducted. The date of the search must precede any work conducted by the member on the project. 	
Verifier Training	<ul style="list-style-type: none"> Evidence that the verifier completed the 4R Training program hosted by the Canadian Fertilizer Institute. 	To ensure the verifier understands the requirements of a 4R Plan.

i – A Carbon Transfer Agreement is a legal document between a land owner and project developer, indicating that the project developer is leasing the land from the land owner and has rights to the value of any carbon offsets created during the duration of the lease.

ii - The EcoDistrict must be specified to determine the appropriate factor to quantify N₂O emissions for the field. EcoDistrict maps are available from the Canadian National Soil DataBase.

5.2.2 Baseline Considerations

The baseline N₂O emissions are calculated per mass of crop type produced as the average over the three years prior to project implementation.²⁷ It is not required that the same fields are farmed with a particular crop type in the baseline and project condition, since crops will be rotated. Three years of baseline data are needed for any crop type included in the project (using the conventional baseline approach).

Direct evidence is required to substantiate the mass of nitrogen inputs for each crop type for each of the three years used to derive the baseline emissions of N₂O per mass of crop produced. Records requirements for the conventional baseline are noted in Table 10.

Table 10: Conventional Baseline Records Requirements

Record Requirement	Examples of Records	Why Required
Types of crops grown	<ul style="list-style-type: none"> Farm records indicating the crop type grown for each field in the project; and 	To establish the crop types in the

²⁷ Refer to Section 1.3 and 4.0 for details on flexibility of the 3 years required, and what to do if new crop types are introduced to the project.

Record Requirement	Examples of Records	Why Required
in the three years used to establish the baseline	<ul style="list-style-type: none"> • One of the following: <ul style="list-style-type: none"> ▪ AFSC records, hail insurance records by field; ▪ Signed records from a crop advisor that show the type of crop grown by field; or ▪ Seed purchase receipts. 	baseline and project
Crop mass (by crop) grown for each of the three years used to establish the baseline	<ul style="list-style-type: none"> • Selection of an acceptable crop mass determination method, as provided by the protocol in Appendix I; and • Supporting documentation to accompany the selected acceptable crop mass determination, as described in Table 12. 	For GHG quantification
Mass of nitrogen fertilizer applied by crop type across the full farm in each of the three years used for the baseline	<ul style="list-style-type: none"> • Invoices showing nutrient composition and quantity of fertilizer purchased; and • One of the following: <ul style="list-style-type: none"> ▪ Farm log of fertilizer application masses and dates by field; or ▪ Custom application receipts indicating fertilizer mass and application dates. 	For purposes of preparing the 4R Plan; total mass of nitrogen for GHG quantification
Quantity, composition and application date of manure applied by field for each year in the baseline	<ul style="list-style-type: none"> • Manure Management Plans including either manure analysis or referenced manure nutrient values as outlined in Section 3.1ⁱ; and • One of the following: <ul style="list-style-type: none"> ▪ Farm records indicating the manure applied by field; or ▪ Feedlot records or custom application records indicating the manure applied by field. 	For GHG quantification
Baseline calculation records	<ul style="list-style-type: none"> • Set of baseline calculations signed off by project developer and Accredited Professional Advisor; and • Years used to calculate baseline values; and • Supporting documentation describing baseline quantification, including calculations and factors used; and • If non-consecutive years are chosen for development of conventional baseline for 	Baseline calculations required for project verification

Record Requirement	Examples of Records	Why Required
	a crop (and the crop was grown in unused years), trend data on extreme weather events to demonstrate how the year is excluded will be required.	

i - Manure management plans are a requirement for larger operations in Alberta under the *Agricultural Operation Practices Act*. The plans need to record who manure is sold or given to and where it's being applied and at what rate. Nutrient content of the manure is in the Manure Management Plan as well.

5.2.3 Project Records Requirements

Note that management zones become more detailed with increasing 4R performance levels. Project records will at minimum contain the information provided in Table 11.

Table 11: Project Condition Records Requirements

Record Requirement	Examples of Records	Why Required
Locations and area of each 4R management zone (fields/sub-fields) enrolled in the project ⁱ	<ul style="list-style-type: none"> • EcoDistrict location of each field/management zone determined using the toolⁱⁱ provided by Alberta Agriculture and Rural Development; and • Both of the following: <ul style="list-style-type: none"> ▪ Legal land location (Alberta Township System and GPS coordinates) of each management zone; and ▪ Specific location, area and boundaries of each 4R management zone using satellite data or aerial photos 	<p>Key input to 4R Plan</p> <p>To ensure the fields/subfields are in the same EcoDistrict</p>
Crop type grown for each management zone ⁱⁱⁱ	<ul style="list-style-type: none"> • Farm records indicating the crop type grown for each management zone in the project (including indication of fields that were managed under ineligible crop types such as perennial production or summerfallow for that cropping year); and • One of the following: <ul style="list-style-type: none"> ▪ AFSC records, hail insurance records; or ▪ Signed Accredited Professional Advisor records of field observations for each field in the project. The Accredited Professional Advisor must have reviewed and collected supporting farm records that confirm the types of crops/field activities for that year. These records must be maintained in a format that is readily available for verifiers to inspect. 	<p>Key input to 4R Plan</p> <p>Establish that the crop is grown in the project year</p>
4R practices by management zone	<ul style="list-style-type: none"> • 4R Plan signed by Accredited Professional Advisor showing performance level BMPs applied to all management units <ul style="list-style-type: none"> ▪ 4R Plan detailing source BMPs by management zone, including the composition of fertilizers applied; and ▪ 4R Plan detailing rate BMP by management zone, based on annual soil testing and nutrient application recommendations; and ▪ 4R Plan detailing place BMP by management zone, including % band concentration calculations; and ▪ 4R Plan detailing time BMP by management zone, including fertilizer application dates. 	<p>To confirm that the proper reduction modifier is being applied in GHG emission reduction calculations</p> <p>Ensure the proper BMPs are implemented in each performance level</p>

Available nitrogen

- Accredited Professional Advisor sign off on records outlining soil sampling methodology, sampling dates, sample handling, and location from which samples were collected. This information must be specific to 4R management zones. Soil sampling and nitrogen rate recommendations must be made at the intensity described below:
 - Annual soil testing for each field at the basic 4R implementation level; or
 - Annual soil testing required for each management zone at the intermediate 4R implementation level; or
 - Annual soil testing required for each sub-field management zone at the advanced 4R implementation level; and
- If soil testing cannot be completed for a given year (this is allowed a maximum of once in a crediting period for each farm enterprise/sub-project), the following information is required:
 - Description of extreme soil or climatic soil conditions preventing soil sampling (weather trend data, time stamped photos of soil surface, etc.); and
 - Description of alternate tools used to develop fertilizer recommendations without soil sampling data.
- 4R Plan records indicating anticipated nitrogen release from the previous year's organic soil amendments (e.g., nitrogen release from manure or unharvestable crop remaining in the field from the previous year).

Key input to 4R Plan

<p>Quantity, composition and application date of nitrogen fertilizer applied by crop type included in the project</p>	<ul style="list-style-type: none"> • 4R Plan indicating the recommended quantity and composition of fertilizer for each management zone in the project, based on soil sampling, assessment of nitrogen from manure soil amendments in the previous year, assessment of nitrogen from crop residue remaining from the previous year, yield goal, and field conditions in the previous year (e.g., crop residue from a hail event); and • Invoices showing quantity and composition of fertilizer purchased; and • Reconciled total of purchased nitrogen amounts with amounts applied by crop type and/or remaining in storage (in order to support reconciliation this includes a record of nitrogen amounts applied to crop types declared ineligible under this protocol); and • One of the following: <ul style="list-style-type: none"> ▪ Farm log of fertilizer application dates by management zone (including manure); or ▪ Custom application receipts indicating fertilizer application dates. 	<p>Assess conformance to the 4R Plan</p> <p>Total mass of nitrogen is used for GHG quantification</p>
<p>Soil temperature readings</p>	<p>In cases where fall nitrogen application occurs according to the 4R Plan, the following records are required:</p> <ul style="list-style-type: none"> • Sign off from the Accredited Professional Advisor that the fertilizer application occurred in accordance to the 4R Plan and protocol requirements; and <ul style="list-style-type: none"> ○ Soil temperature readings (at a depth of five centimetres or deeper) showing three consecutive days where the soil is less than 10° Celsius; or ○ Soil temperature calculations (using the equation provided in Section 3.1) showing five consecutive days where the soil temperature is calculated to be less than 10° Celsius. 	<p>To ensure that fall soil applications occur according to requirements of the protocol.</p>

Fertilizer placement equipment	<ul style="list-style-type: none"> • Annual provision of date stamped photos of fertilizer banding or spreading and incorporation equipment; and • Evidence that application equipment was calibrated to the equipment manufacturer’s specifications prior to fertilizer application; and • One of the following: <ul style="list-style-type: none"> ▪ Width of fertilizer openers and spacing to determine the per cent band concentration^{iv}; or ▪ Invoices or a letter from custom fertilizer application that indicates the type of opener and row spacing for each field 	Assess conformance to the 4R Plan
Quantity, composition and application date of manure applied by field	<ul style="list-style-type: none"> • Manure Management Plans including either manure analysis or referenced manure nutrient values as outlined in Section 3.1 above; and • One of the following: <ul style="list-style-type: none"> ▪ Farm records indicating mass of manure applied by field; or ▪ Confined Feeding Operation records or custom application records indicating mass of manure applied by field; and • Laboratory analysis results determining manure nutrient content or reference to appropriate manure nutrient values as outlined in Section 3.1 above. 	Assess conformance to the 4R Plan Total mass of nitrogen is used for GHG quantification
Crop mass by crop type, dry matter basis (for each EcoDistrict and 4R performance level)	<ul style="list-style-type: none"> • Estimation of crop yield at the field level, which is used for evaluating the 4R Plan (not used for GHG quantification); and • If using the conventional baseline or Dynamic Baseline One: <ul style="list-style-type: none"> ▪ Selection of acceptable crop mass determination method used for GHG quantification; and ▪ Supporting documentation according to the selected crop mass determination method in Appendix I (see Table 12); or • If using Dynamic Baseline Two: <ul style="list-style-type: none"> ▪ Calculations showing crop mass data derived from the five-year rolling averages published by Agriculture Financial Services Corporation (AFSC); and ▪ Reference to each crop type (including irrigated or dryland) and crop variety used to calculate project crop yields with AFSC five-year rolling average data; and ▪ AFSC risk area used to calculate project crop yields. 	Field level monitoring is used for evaluating the 4R Plan Crop mass is used for GHG quantification

Additional supporting farm records	<ul style="list-style-type: none"> • Farm records noting any extraordinary situations, such as remaining crop residue related to crop damage from hail, flooding, pest infestations, etc., and • In the case of crop failure: <ul style="list-style-type: none"> ◦ Crop insurance records (if applicable); and/or ◦ Independent agronomist or Accredited Professional Advisor assessment documentation. • Farm records indicating which fields contained crops or management systems ineligible for credit production under this protocol (e.g., summerfallow, grazing, ineligible crops) or had ineligible fertilizers applied which resulted in the ineligibility of the entire crop under this protocol for the year. 	To support proof of 4R Plan implementation or describe variances from the 4R Plan
Confirmation that 4R Plan was conformed to by the farm operator	<ul style="list-style-type: none"> • Annual sign off from the Accredited Professional Advisor that the 4R Plan was conformed to, including fields under ineligible crops or ineligible management (e.g., summerfallow, grazed fields, or use of fertilizers ineligible under the protocol); and • Description of situations where 4R was not conformed to and why. 	Implementation Sign off by Accredited Professional Advisor
Additional field passes	<ul style="list-style-type: none"> • Accredited Professional Advisor analysis of additional equipment passes required per 4R management unit as a result of implementation of the 4R Plan; and <p><i>Method A: Documented Fuel Use Method</i></p> <ul style="list-style-type: none"> • Sale receipts including specification of fuel type; and • Fuel logs and or equipment use logs indicating date and fuel usage associated with additional passes <p><i>Method B: Additional Pass Method</i></p> <ul style="list-style-type: none"> • Area and location (supported with aerial photos or satellite data) of 4R management units receiving additional passes 	Emissions associated with fuel usage from additional passes part of overall project emissions reductions claims

i - It is not required that the same fields are farmed with a particular crop type in the baseline and project condition, since crops will be rotated. However, all fields in the baseline and project must be within the same EcoDistrict.

ii - The EcoDistrict must be specified to determine the appropriate factor to quantify N₂O emissions for the filed. EcoDistrict maps are available from the Canadian National Soil DataBase (NSDB).

iii - There is no need to record different crop varieties.

iv - For specialty crops where the fertilizer application may be separate from seeding equipment, a date-stamped photo of the fertilizer spacing for that field.

v - Manure management plans are a requirement for larger operations in Alberta under the *Agricultural Operation Practices Act*. The Plans need to record who manure is sold or given to and where it's being applied and at what rate. Nutrient content of the manure is in the Manure Management Plan as well.

Table 12: Crop Mass Determination Methods Records Requirements

Record Requirement	Examples of Records	Why Required
Mobile weighing devices	<ul style="list-style-type: none"> • Calibration report demonstrating that equipment has been calibrated to manufacturer specifications, by a qualified third party, prior to harvest; and • A weight log of each load; and • A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day. 	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Fixed scale	<ul style="list-style-type: none"> • Calibration report demonstrating that equipment has been calibrated to manufacturer specifications, by a qualified third party, prior to harvest; and • A weight log of each load; and • A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day. 	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Commercial-scale certified by Industry Canada with accompanying scale tickets (i.e., elevator or grain processors)	<ul style="list-style-type: none"> • Scale tickets for each truck load that specifies load mass and crop type for each load; • Scale tickets that show the truck loads that link to the moisture test; • Scale company and location; and • Moisture determination result from each load in a moisture log. 	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Bin Volume	<ul style="list-style-type: none"> • Copy of method and calculations used to calculate bin volume measurements; and • A third party sign off will be made available reporting the bin is empty and recorded in a bin log before harvest (Accredited Professional Advisor or their representative check); this must include photo, time stamped evidence; and • Bin moisture test result(s) or average for the bin. 	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

5.3 Record Keeping

Projects must be supported with data sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification to a reasonable level of assurance.

In support of this requirement project data must be managed in a manner that substantiates that:

- Emissions and reductions that have been recorded pertain to the offset project;
- All emissions and reductions that should have been recorded have been recorded;
- Emissions and reductions quantification has been recorded appropriately;
- Emissions and reductions have been recorded in the correct reporting period;
- Emissions and reductions have been recorded in the appropriate category; and
- Must have an auditable data management system.

Based on these requirements, data must be quantifiable, measurable and verifiable using replicable means. That is, an independent verifier should be able to reach the same conclusions using evidence-supported data.

The project developer shall establish and apply quality management procedures to manage data and information. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements. Requirements can be found in Technical Guidance for Greenhouse Gas Verification at Reasonable Level of Assurance.

Alberta Environment and Parks requires that project developers maintain appropriate supporting information for the project, including all raw data for the project for a period of seven years after the final year of the project credit period. Where the project developer is different from the party implementing the activity, as in the case of an aggregated project;²⁸ the individual farmer and the aggregator, as well as the Accredited Professional Advisor, must all maintain sufficient records to support the offset project. The project developer (farmer and aggregator) must keep the information listed below and disclose all information to the verifier and/or government auditor upon request. Initial and annual verification records and audit results must also be maintained.

Table 13: Responsibilities for Data Collection and Retention

Entity	Data Collection and Retention Responsibilities
Farm Operator	Work with the Accredited Professional Advisor to develop the 4R Plan and ensure implementation on an annual basis. Perform the BMPs in accordance with the 4R Plan Provide copies of farm records and documentation to the project developer. The farm operator must retain original records.
Project Developer	The project developer has primary responsibility for record keeping and record coordination to support project implementation and due diligence,

²⁸ Alberta Environment and Parks, 2013, Technical Guidance for Offset Project Developers, Version 4.0.

and will be the primary information source for third party verification.

The project developer is required to collect and manage copies of farm records and supporting documentation outlined in the Tables in Section 5.2.2 above.

Accredited Professional Advisor	Review and sign off on baseline calculations in the 4R Plan. Design, conduct annual soil testing and nitrogen recommendations, and sign off on the 4R Plans Ensure the farm enterprise boundary remains constant throughout the project and that all nitrogen inputs and crop mass are accounted for within the farm enterprise boundary Annual sign off that the 4R Plan was implemented.
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In order to support the third party verification and the potential supplemental government audit, the project developer must put in place a system that meets the following criteria:

- All records must be kept in areas that are easily located;
- All records must be legible, dated and revised as needed;
- All records must be maintained in an orderly manner;
- All documents must be retained for seven years after the end of the project crediting period;
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored in two locations to prevent loss of data.

5.4 Site Visits and Verification Requirements

A risk-based sample size of farms visits is required for verification and all farms should be visited at least once over the life of the project. Verifiers will typically request access to records, as well as do physical inspections for equipment practices and other inspections. All farmers participating in an offset project should be prepared to receive a verifier. By having documentation on hand at the farm, such visits will be easily accommodated.

In order to support the third party verification and the potential supplemental government audit, the project developer must put in place a system that meets the criteria in Section 5.3.

Alberta Environment and Parks require that at least one member of the verification team and/or government audit team has taken the 4R training program offered by the Canadian Fertilizer Institute. Evidence that a verifier completed the training must be included in the verification report.

Note: Attestations are not considered sufficient proof that an activity has taken place and do not meet verification requirements.

5.5 Quality Assurance/Quality Control Considerations

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

- Ensuring that the changes to operational procedures continue to function as planned and achieve greenhouse gas reductions;
- Ensuring that the measurement and calculation system and greenhouse gas reduction reporting remains in place and accurate;
- Checking the validity of all data before it is processed, including emission factors, static factors, and acquired data;
- Performing recalculations of quantification procedures to reduce the possibility of mathematical errors;
- Storing the data in its raw form so it can be retrieved for verification;
- Protecting records of data and documentation by keeping both a hard and soft copy of all documents;
- Recording and explaining any adjustment made to raw data in the associated report and files; and
- A contingency plan for potential data loss.

5.6 Liability

Offset projects must be implemented according to the approved protocol and in accordance with government regulations. Alberta Environment and Parks reserves the right to audit offset credits and associated projects submitted to Alberta Environment and Parks for compliance under the Specified Gas Emitters Regulation and may request corrections based on audit findings.

Notwithstanding any agreement between a project developer (aggregator) and the land owner/farmer, the project developer shall not and cannot pass on any regulatory liability for errors in design and/or use of the project developer's data management system.

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APPENDIX A: EcoDistrict Related Factors

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

TABLE A-1: EcoDistrict Related Factors for Alberta

EcoDistrict	Precipitation / Potential Evapotranspiration Ratio (mm/mm)	Fraction of Nitrogen lost in leachate (%)	Emission Factor for Soil (%)
244	0.56	16	0.791
583	0.58	17	0.962
586	0.56	16	0.803
587	0.56	16	0.836
588	0.52	15	0.680
589	0.55	15	0.770
590	0.58	16	0.838
591	0.67	19	1.019
592	0.61	17	0.912
593	0.63	18	0.922
594	0.64	18	0.964
595	0.59	17	0.717
596	0.58	17	0.811
597	0.61	17	0.906
598	0.65	18	0.945
599	0.62	18	0.767
600	0.63	18	0.954
607	0.56	16	0.745
609	0.56	16	0.791
610	0.64	18	0.946
611	0.59	17	0.943
612	0.61	17	0.897
614	0.76	22	1.219
615	0.75	22	1.216
616	0.74	22	1.181
617	0.74	22	1.174
618	0.65	19	1.035
619	0.77	23	1.241
622	0.79	23	1.314
623	0.74	22	1.159
624	0.85	25	1.395
625	0.75	22	1.189
626	0.75	22	1.188
627	0.74	21	1.141
628	0.72	21	1.141
629	0.74	22	1.198
630	0.72	21	1.142
631	0.59	17	0.858
650	0.62	18	0.982
678	0.73	21	1.143

EcoDistrict	Precipitation / Potential Evapotranspiration Ratio (mm/mm)	Fraction of Nitrogen lost in leachate (%)	Emission Factor for Soil (%)
679	0.63	18	1.005
680	0.62	18	0.888
681	0.70	20	1.099
683	0.69	20	0.906
684	0.71	21	1.147
686	0.58	16	0.866
687	0.57	16	0.666
688	0.57	16	0.893
692	0.70	20	1.093
703	0.71	21	1.167
708	0.69	20	1.121
727	0.68	20	0.884
728	0.59	17	0.719
729	0.53	15	0.612
730	0.56	16	0.714
731	0.65	19	1.044
732	0.67	19	1.152
737	0.65	19	0.903
738	0.56	16	0.723
739	0.51	14	0.789
740	0.64	18	0.883
743	0.51	14	0.652
744	0.61	17	0.813
746	0.65	19	0.917
750	0.55	16	0.806
769	0.52	14	0.811
771	0.46	12	0.643
777	0.52	14	0.797
779	0.51	14	0.736
781	0.50	14	0.638
786	0.48	13	0.610
787	0.41	11	0.831
788	0.42	11	0.578
790	0.42	11	0.573
791	0.46	12	0.583
793	0.42	11	0.779
797	0.44	12	0.691
798	0.52	14	0.709
799	0.48	13	0.682
800	0.50	14	0.757
801	0.61	17	0.948
802	0.48	13	0.721
804	0.41	11	0.568

EcoDistrict	Precipitation / Potential Evapotranspiration Ratio (mm/mm)	Fraction of Nitrogen lost in leachate (%)	Emission Factor for Soil (%)
805	0.35	9	0.382
806	0.34	9	0.769
809	0.35	9	0.476
811	0.36	9	0.406
812	0.37	10	1.330
814	0.34	9	0.545
815	0.34	9	0.432
818	0.38	10	0.982
821	0.34	9	0.301
823	0.35	9	1.060
828	0.36	9	0.608
829	0.36	9	1.157
833	0.35	9	0.562
836	0.35	9	0.295
837	0.36	9	0.451
838	0.37	9	0.386
1016	0.61	17	0.904
1017	0.56	16	0.798
1018	0.57	16	0.847
1019	0.58	16	0.832
9593	0.67	19	0.907
9609	0.75	22	1.182
9687	0.60	17	0.857
9787	0.42	11	0.712

APPENDIX B: Accredited Professional Advisor Qualification Requirements

An Accredited Professional Advisor (APA) is a professional with academic training in soil science, crop science, and/or agronomy as they relate to the nutrient management of crops. In addition, they must meet minimum experience requirements. Experience must be relevant to the management of crops and cropping systems of Alberta.

Accredited Professional Advisors working within the context of this protocol as applied in Alberta must meet the following requirements for education, experience, and specific protocol training:

- (1) Pass the requirements and become accredited under the Canadian Fertilizer Institute's 4R training program.
- (2) Meet one of the following sets of requirements:
 - a) A graduate of a four-year Bachelor of Science (or equivalent) degree program:
 - With training in soils and crops and at least two years of relevant experience in crop management; and
 - A Professional Agrologist (P.Ag.) designation and current member of the Alberta Institute of Agrologists (AIA); or
 - b) A graduate of a two-year science based technical diploma program:
 - With training in soils and crops and at least four years of relevant experience in crop management;
 - A Registered Technologist in Agrology (R.T.Ag.) designation and current member of the AIA; and
 - Working under the supervision of a Professional Agrologist, who is an Accredited Professional Advisor.
- (3) Demonstrate confirmation from the AIA that the P.Ag. or R.T.Ag. is authorized to operate under the AIA's Practice Standard for the Greenhouse Gas Assessment and Management Practice Area.
- (4) All the persons with the needed education and work experience, as noted above, would need to demonstrate additional competencies specific to this Protocol:
 - a) In 4R Nutrient Stewardship including the ability to prepare and sign off on 4R Plans under this protocol;
 - b) The ability to calculate and/or verify emission calculations, create and implement soil sampling plans and derive nitrogen recommendations from soil test results, perform post-harvest assessments, and other specific requirements of the Accredited Professional Advisor's role in the protocol; and
 - c) An understanding of the Accredited Professional Advisor's role in adhering to records requirements under the protocol.

The first requirement can be met by successfully challenging the 4R Nutrient Stewardship and the Nitrous Oxide Emission Reduction Protocol exams administered by the Canadian Fertilizer Institute.

APPENDIX C: Learning Objectives of the Accredited Professional Advisor Training Program

Accredited Professional Advisor Learning Objectives for 4R Nutrient Stewardship Implementation

- (1) Define and describe the essential components of sustainable agriculture:
 - a) Understand the balanced approach to setting sustainability goals for a farm enterprise.
 - b) Describe what is meant by site-specific within the context of 4R.
 - c) Understand the requirement for integrated management.
- (2) Know the key scientific principles that need to be considered in developing Right Source, Right Rate, Right Time and Right Place for nutrients:
 - a) Understand interactions among source, rate, time and place decisions.
 - b) Understand the most limiting nutrient concept and how it related to the principle of balanced nutrient supply.
 - c) Know the plant available forms of macro and micro nutrients and how that relates to nutrient source.
 - d) Know the chemical composition of the different sources of nitrogen including the enhanced efficiency products.
 - e) Understand how soil physical and chemical properties constrain nutrient source decisions.
 - f) Recognize the synergisms among nutrient elements and sources.
 - g) Recognize material compatibilities and incompatibilities that need to be considered when handling nutrient sources.
 - h) Recognize the benefits and sensitivities of associate elements in fertilizer and other nutrient sources.
 - i) Understand the impact of non-nutritive elements that may be contained in source material.
 - j) Understand the different approaches to assessing plant nutrient demand.
 - k) Understand the different methods available to assess soil nutrient supply.
 - l) Describe methods for assessing the contribution of all nutrient sources that may need to be considered for a specific field (for example, last year's manure addition).
 - m) Understand the different methods for calculating nitrogen use efficiency.
 - n) Describe the impacts of nutrient additions on the soil resource.
 - o) Understand the law of diminishing returns as it applies to the economics of fertilizer rates and yield response.
 - p) Explain the timing of nutrient uptake by crops.
 - q) Recognize the dynamics of soil nutrient supply.
 - r) Recognize the dynamics of nutrient loss.
 - s) Understand the constraints placed by the logistics of field operations on time of nutrient application.

- t) Consider the root architecture of crops and how differences relate to nutrient placement.
 - u) Understand how placement and soil chemical and biological reactions affect nutrient availability.
 - v) Recognize the interactions between tillage systems and placement and how it impacts nutrient availability.
 - w) Recognize how nutrient availability can vary spatially in a field and between fields and the common techniques to assess and manage it.
 - x) Understand nitrogen cycling in prairie soils and fall and winter conditions and the spring thaw period can affect mineralization, immobilization, nitrification and denitrification and nitrate leaching.
- (3) Understand and be able to implement the 4R planning process on a farm enterprise:
- a) Understand what would be appropriate economic, environmental, and social goals for a farm enterprise enrolled in a project.
 - b) Describe appropriate key performance indicators that would be relevant for a farm enterprise enrolled in a project.
 - c) Know the minimum beneficial management practices required under the Protocol and how they can be incorporated into a 4R Plan.
 - d) Describe the process for continual improvement within a 4R Plan and the 4R planning cycle.

Accredited Professional Advisor Learning Objectives for Protocol Implementation

- (1) Explain how a project under the protocol is structured and provide:
- a) The roles and responsibilities of large final emitters, aggregators, project developers, Accredited Professional Advisors, farmers, verifiers, and the Government of Alberta as the regulator.
 - b) The eligibility requirements for inclusion of a farm and a field within that farm in a project under this protocol.
 - c) The difference requirements for basic, intermediate, and advanced implementation on a field.
 - d) The responsibilities of the Accredited Professional Advisor under the protocol, including records requirement responsibilities under the protocol.
 - e) Know how to create a soil sampling plan for each level of 4R implementation and use soil sampling results to inform nutrient application recommendations under the 4R Plan.
- (2) Be able to perform the N₂O emission calculations independently and know the following:
- a) The sources of greenhouse gases that need to be included in protocol calculations and which can be excluded.
 - b) Appropriate methods for quantifying the included sources.

- c) The difference between direct and indirect N₂O emissions.
 - d) How to select the appropriate factors and coefficient for any eligible combination of nitrogen sources, crops and fields.
 - e) Understand and apply the differences between the historic baseline approach, the dynamic baseline approach, and the dynamic baseline approach with proxy yields.
 - f) Demonstrate how to perform the emission calculations at a field or and at a farm enterprise level.
 - g) Understand the use of the reduction modifier.
 - h) Demonstrate how to convert N₂O to units of carbon dioxide equivalents and crop type units to carbon credits.
- (3) Understand and apply the requirements for data collection and management and the standards that must be met as well as the considerations that must be taken into account at each phase of the project (refer to Section 5 of the protocol for details).

**APPENDIX D: Sample Form for Sign Off by the Accredited Professional
Advisor**

ACCREDITED PROFESSIONAL ADVISOR'S CERTIFICATE/OPINION

TO:

AND TO:

RE: Design and Implementation of the Comprehensive 4-R Nitrogen Stewardship Plan (the 4R Plan) as specified by the Quantification Protocol for Nitrous Oxide Emission Reduction Protocol (the Protocol) Under the Specified Gas Emitters Regulation

AND RE: [Insert name of project] (the Project) Conducted by [name of farmer] (the Farmer)

AND RE: [Insert name of project developer/aggregator] whose program the farmer is enrolled in]

-
1. Capitalized terms used herein and not defined herein shall have the meanings ascribed to such terms in the Protocol.
 2. I, _____, am an Accredited Professional Advisor (Accredited Professional Advisor) who has completed training through [organization] and have been accredited under [name of accreditation program] and have successfully completed supplementary training on the 4R Plan of the Protocol.
 3. I am currently registered as a Professional Agrologist (P.Ag. or Registered Technologist in Agrology (R.T.Ag.) under the Alberta Institute of Agrologists.
 4. I am currently authorized to operate under the Alberta Institute of Agrologists' Practice Standard for the Greenhouse Gas Assessment and Management Practice Area.
 5. As an Accredited Professional Advisor, I have assisted [name of farmer] in the design, development, and correct implementation of a 4R Plan as part of a Protocol offset project for [description of farm and land] for aggregation by [aggregator name] according to all the Accredited Professional Advisor requirements set out in the Protocol to the best of my abilities and in accordance with all applicable professional standards.
 6. I have worked with [name of farmer] to ensure conformance to the 4R plan designed for application under this protocol.
 7. I have reviewed the Project documentation provided to me by the Farmer and, to the best of my knowledge, [I hereby certify/in my opinion]:
 - (a) the baseline calculations contained in the Project documentation are accurate and correct;
 - (b) the conclusions contained in the Project documentation are appropriate and are supported by baseline calculations; and
 - (c) the 4R Plan for the Project was implemented in accordance with the 4R Plan by the Farmer.
 8. In my opinion, based on my review of the Project documentation that I have been provided and my participation in the design of the 4R Plan and my inspections of the implementation of the 4R Plan, the farmer enrolled in this Project has met the requirements specified under the Quantification Protocol for Agricultural Nitrous Oxide Emission Reductions.
 9. I have made or caused to be made such examinations or investigations as are, in my opinion, necessary to make the statements contained herein, and I have furnished this

[certificate/opinion] with the intent that it may be relied upon by the addressees as a basis for the serialization and registration of carbon offset credits for the Project on the Alberta Emission Offset Registry under the Specified Gas Emitters Regulation.

DATED at _____, this _____ day of _____, 20__.

Name of Accredited Professional Advisor

Signature of Accredited Professional Advisor

APPENDIX E: Crop Residue Nitrogen Factors

Table E-1: Crop Residue Factors from Holos Methodology (based on IPCC methods and modified for Canadian conditions and protocol)

Crop	Moisture Content (w/w)	Nitrogen Content of Above-Ground Residues (kg N / kg)	Nitrogen Content of Below-Ground Residues (kg N / kg)	Relative Dry Matter Allocation		
				Fraction of Total Dry Matter Production that is Harvested (unitless)	Ratio of Above-Ground Residue Dry Matter to Harvested Production (unitless)	Ratio of Below-Ground Residue Dry Matter to Harvested Production (unitless)
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	0.1	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
Lentils	0.13	0.010	0.01	0.28	0.52	0.20
Mixed Grains	0.12	0.006	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 HH, Beauchemin KA, Bruinsma Y, Campbell CA, Desjardins RL, Ellert BH, and Smith EG, 2003, The fate of nitrogen in agroecosystems: An illustration using Canadian estimates, *Nutrient Cycling in Agroecosystems* 67:85–102

* If the seed crop is treated like an annual crop and meets the 4R eligibility criteria for the performance level chosen, then a new annual crop is seeded the next year under 4R Plan requirements, it would qualify under the protocol.

APPENDIX F: Sample Calculations

The quantification of reductions achieved by a project is based on actual measurement and monitoring as indicated by the proper application of the 4R Plan. This sample calculation will help guide project developers and verifiers through the 4R implementation requirements and how greenhouse quantification can be performed at the farm level based on mass of nitrogen inputs and mass of crop produced.

Before initiating a project, the project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta carbon offset system. Of particular note:

- 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 farm and project developer records;
- The project may generate emission reduction offsets for a period of eight years unless an extension is granted by Alberta Environment and Parks. Additional credit duration periods require a reassessment of the baseline condition; and,
- Ownership of the emission reduction offsets must be established as indicated by land owner/land lessee agreements.

For this particular sample calculation, we are considering a farm in Alberta, situated on the Highway 2 corridor between Bowden and Wetaskiwin. The sample calculation will describe the step-by-step procedure to estimate emissions from the farm in the year after the 4R Plan was implemented, but the emissions from the baseline year (used for the calculation of reductions) will be given as 0.5350 kg CO₂e per kg canola (no calculations shown).

Sample EcoDistrict

In this illustration, the calculations are shown only for the canola crop type for the farm, for which no manure or any soil nitrogen amendment other than fertilizer is used in the project year.

EcoDistrict 746 (Crossfield to Bowden) — area of annual crops is 148,122 ha or 148.122 km²

- Black/Gray Chernozem, Medium texture, P/PE 0.65, F_{TILL} 0.9106, F_{TOPO} 0.11, no irrigation.
- EF_{Eco} 0.00917 kg N₂O-N kg⁻¹ N (includes tillage, topography, irrigation, and texture), $FRAC_{LEACH}$ 0.19.

EcoDistrict 737 (Bowden to Wetaskiwin) — area of annual crops is 142,352 ha or 142.352 km²

- Black/Gray Chernozem, Medium texture, P/PE 0.65, F_{TILL} 0.9216, F_{TOPO} 0.16, no irrigation.
- EF_{Eco} 0.00903 kg N₂O-N kg⁻¹ N (includes tillage, topography, irrigation, and texture), $FRAC_{LEACH}$ 0.19.

Note: The two EcoDistricts are shown to emphasize the similarity of emission factors within a region encompassing almost 300 km² of annual crops. The values from EcoDistrict 737 will be used to estimate emissions in this sample calculation.

Sample Project

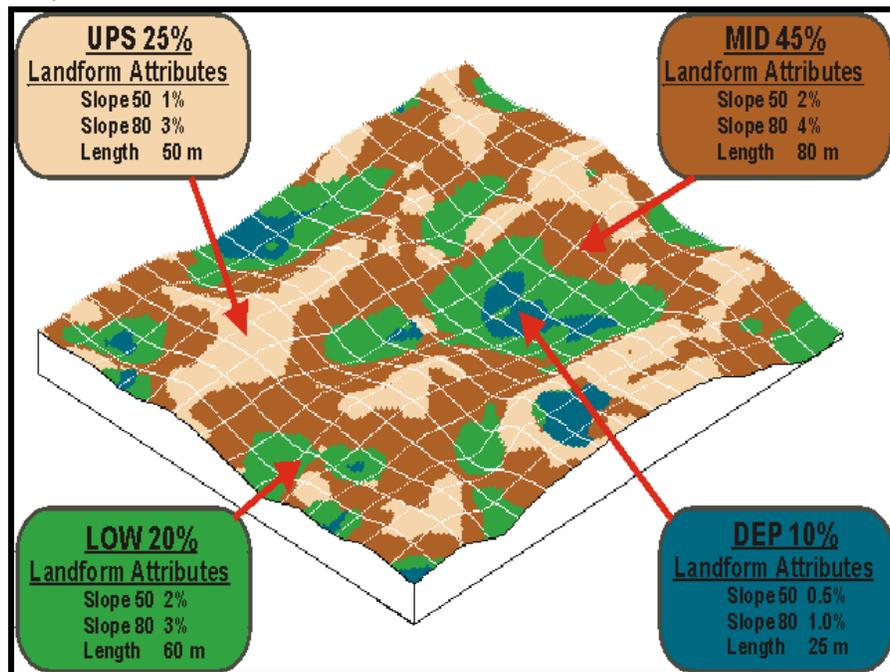
The farm has implemented the intermediate performance level, involving: (1) design and use of the 4R Plan with specific direction for sub-field areas of below and above average yield, as determined by yield monitors in the 4R Plan and implementation; and (2) use of spring-banded instead of fall broadcast application of controlled-release fertilizer.

Step 1 - Identify Sub-Fields for Purposes of 4R Implementation

The 4R Plan specifies the delineation of sub-fields as illustrated in the sample landscape map (Figure F-1). The fields are segmented into management zones as follows:

- Upper Slope (UPS) — generally water shedding and in upper landform positions;
- Mid-Slope (MID) — generally water neutral and in mid-slope landform positions;
- Lower Slope (LOW) — generally water receiving and in lower landform positions; and
- Depression (DEP) — generally undrained areas with ephemeral water accumulations.

Figure F-1: Sample Map of Field Showing Distribution of Landforms on the Case Study Farm (from MacMillan and Pettapiece 2000)²⁹



In this sample project, the 4R Plan identifies 10 canola management zones for below average expected yield and 15 canola zones for above average expected yield (Table F-1).

The characterization of these sub-field segments or above average yield areas for nutrient management, including the guide for testing to support post-harvest assessment, will vary according to the soil water status before seeding. For example, in normal years the UPS and DEP segments would receive nitrogen amendment to support below average yield, while the MID and

²⁹ MacMillan, R.A. and W.W. Pettapiece, 2000, Alberta landforms: Quantitative morphometric descriptions and classification of typical Alberta landforms. Technical Bulletin No. 2000-2E. Research Branch, Agriculture and Agri-Food Canada, Semiarid Prairie Agricultural Research Centre, Swift Current, SK. 118 pp.

LOW segments would be applied with sufficient nitrogen to support above average yield. In dry years the UPS and MID segments would be managed as below average, and the LOW and DEP would be managed as above average. In wet years the LOW and DEP segments would be managed as below average (receiving no nitrogen if water standing), and the MID and UPS would be managed as above average. Further, top-dressing could be considered for UPS in normal years if late spring precipitation provides reasonable potential for sufficient increase in yield to justify the increased expense. The 4R Plan would specify the testing method (sub-field soil sampling, post-harvest nitrogen balance assessment, etc.) to determine the nitrogen status of the soil to provide appropriate application rate recommendation for the below and above average crop management zones. A normal year is considered for this sample calculation.

Step 2 - Report Testing of Soil and Plant Tissue – 4R Implementation

To substantiate the testing, the 4R Plan will tabulate the testing done and the results used to determine the nitrogen application recommendation. The testing plan and lab reports will be retained by the participating farm. The Accredited Professional Advisor will sign off on the 4R Plan to attest to the validity of the testing plan and to the interpretation of the testing results.

To simplify the example, all canola management zones in this project year were sown to wheat in the previous year, and are assigned similar soil nitrogen status. Thus, all below average yield management zones received a total of 12,250 kg N, and all above average yield management zones received a total of 29,250 kg nitrogen for a total mass of applied nitrogen of 41,500 kg (Table F-1).

Table F-1: Mass of Nitrogen Applied for Each Management Zone Sown to Canola in the Project Year of Sample Calculation

	Management Zone	Area (ha)	N Applied (kg N)
Below Average (UPS and DEP)	Canola BA-1	15.0	1,050
	Canola BA-2	16.0	1,120
	Canola BA-3	17.0	1,190
	Canola BA-4	18.0	1,260
	Canola BA-5	17.5	1,225
	Canola BA-6	19.0	1,330
	Canola BA-7	18.5	1,295
	Canola BA-8	20.0	1,400
	Canola BA-9	17.0	1,190
	Canola BA-10	17.0	1,190
	BA Total	175	12,250
Above Average(MID and LOW)	Canola AA-1	22.0	1,980
	Canola AA-2	24.5	2,205
	Canola AA-3	19.0	1,710
	Canola AA-4	20.5	1,845
	Canola AA-5	22.0	1,980
	Canola AA-6	21.5	1,935
	Canola AA-7	23.5	2,115
	Canola AA-8	21.0	1,890
	Canola AA-9	19.0	1,710
	Canola AA-10	22.5	2,025
	Canola AA-11	21.5	1,935
	Canola AA-12	23.5	2,115
	Canola AA-13	24.0	2,160

Canola AA-14	20.0	1,800
Canola AA-15	20.5	1,845
AA Total	325	29,250
Combined Total	500	41,500

Step 3 - Report Crop Type Seeded for Each Crop Management Zone

The crop seeding plan will be included in the 4R Plan signed off by the Accredited Professional Advisor. To substantiate the plan, documentation retained at the farm will include seed purchase (or seed cleaning) receipts and GPS data from seeding equipment.

Step 4 – Obtain Crop Mass for Each Crop Type

In this example, the 4R Plan is implemented at the intermediate performance level and nitrogen application occurs at the management zone level (Table F-1). Within the implementation of the 4R Plan, yield can be reported at each management zone, if yield monitors are used however, in practice the proper calibration of yield monitors for each crop, by each management zone, sub-field or field level, is rarely done.³⁰ For greenhouse gas accounting purposes under this protocol, an acceptable crop mass determination method must be used for the entire crop mass by crop type (see Appendix I). The sign off by the Accredited Professional Advisor will attest to the reasonableness of the crop mass values.

Crop mass and total emissions per unit of crop mass are reported on a dry matter basis. To calculate dry matter, the crop mass data needs to be adjusted for the water content of the crop. See Appendix I for more information on crop moisture testing. The mass of the crop determined in this example for the 500 ha of canola, according to Method No. 1, Mobile Weighing Devices, is 813,150 kg on a dry matter basis.

Step 5 - Calculate Nitrogen Inputs for the Crop Type

Fertilizer

The amount of fertilizer nitrogen applied for each management zone of canola is specified in the 4R Plan and will be signed off by the Accredited Professional Advisor to attest successful application as recommended by source, rate, time and place. The primary evidence to document fertilizer application per management zone will be provided from GPS data from application equipment. The GPS data will be attested by application recommendations from the Accredited Professional Advisor and supported by purchase invoices.

Crop Residues

According to the convention used in Canada's National Inventory Report, the values used to estimate direct and indirect N₂O emissions from crop residues are based on the crop mass for the year of interest. Calculate the amount of crop residue N, above ground and below ground, accumulated in the year of interest for each crop.

Note: In this sample, the calculations will be shown for the field.

³⁰ Yield monitors are not a suitable crop mass determination method for greenhouse gas accounting under this protocol due to the risks of consistent calibration at the field, sub-field or management zone level.

Multiply the average crop mass for the year for each crop using the crop-specific factors from Table E-1, Appendix E. For example, for the sample farm for canola:

$$\begin{aligned}
 N_{\text{res,Canola}} &= \text{Crop Mass}_{\text{Canola}} * (1/\text{Yield Ratio}) * \text{Frac}_{\text{renew}} * ((R_{\text{AG Canola}} * N_{\text{AG Canola}}) + (R_{\text{BG Canola}} * N_{\text{BG Canola}})) \\
 &= 813,150 \text{ kg DM} * 1/0.26 * 1/1 * ((0.60 * 0.008 \text{ kg N kg}^{-1}\text{DM}) + (0.15 * 0.01 \text{ kg N kg}^{-1}\text{DM})) \\
 &= 19,703.25 \text{ kg N}
 \end{aligned}$$

Manure: No manure is applied on this sample farm for the project year of interest. If manure were used on the farm, average manure nitrogen spread on each crop in the year of interest would be included as a source of nitrogen for the crop. That is, according to the convention used in Canada's National Inventory Report, it is assumed that all manure nitrogen is available in the year of application.

Step 6 - Calculate Direct Nitrous Oxide Emissions from Manure and Other Fertilizer and Lime Use (Under P8 Fertilizer and Lime Use)

Direct Emissions from Fertilizer and Manure

Calculate direct N₂O emissions for each crop type in the year of interest by multiplying the amount of fertilizer and manure nitrogen applied to the crop by the emission factor for the soil (EF_{Eco}). The EF_{Eco} value is provided as the EcoDistrict-specific factor for EcoDistrict 737 which integrates the average for the EcoDistrict of factors including F_{TOPO}, F_{TILL}, F_{IRRI}, and F_{TEXT}.

$$\begin{aligned}
 \text{Emissions}_{\text{Manure Use, Canola}} &= N_{\text{Manure Canola}} * \text{EF}_{\text{Eco}} * 44/28 \\
 &= 0 \text{ kg N} * 0.00903 \text{ kg N}_2\text{O-N kg}^{-1} \text{ N} * 44/28 \\
 &= 0 \text{ kg N}_2\text{O}
 \end{aligned}$$

Note: No manure was used on this farm and as a result there are zero emissions. Nevertheless, the equation is shown for illustration purposes.

Direct Emissions from Synthetic Fertilizer and Lime Use

Calculate direct N₂O emissions for each crop type in the year of interest by multiplying the amount of fertilizer nitrogen applied to the crop by the emission factor for the soil (EF_{Eco}). The EF_{Eco} value is provided as the EcoDistrict-specific factor for EcoDistrict 737 which integrates the average for the EcoDistrict of factors including F_{TOPO}, F_{TILL}, F_{IRRI}, and F_{TEXT}.

$$\begin{aligned}
 \text{Emissions}_{\text{Synthetic Fert and Lime Use, Canola}} &= N_{\text{FN Canola}} * \text{EF}_{\text{Eco}} * 44/28 \\
 &= 41,500 \text{ kg N} * 0.00903 \text{ kg N}_2\text{O-N kg}^{-1} \text{ N} * 44/28 \\
 &= 588.89 \text{ kg N}_2\text{O}
 \end{aligned}$$

Step 7 - Calculate Direct and Indirect Emissions from Soil and Crop Dynamics (Under P13 Soil and Crop Dynamics)

Total Indirect Emissions from Manure Soil and Crop Dynamics

Calculate the total indirect N₂O - N emissions for each crop type from manure in the year of interest. Calculate indirect N₂O - N emissions from volatilization for the crop type by multiplying the indirect emissions of nitrogen from volatilization and re-deposition of NH₃ and NO_x by the emission factor for volatilized nitrogen (EF_{VD}). The values for EF_{VD} are constant across Canada.

Calculate indirect N₂O - N emissions from leaching for the crop type by multiplying the manure nitrogen by the fraction of nitrogen lost in leachate (FRAC_L) and the emissions factor for N₂O from leachate (EF_L). The values for FRAC_L are calculated for each EcoDistrict in Canada, and are provided in Table A-1, Appendix A. The value for EF_L is constant across Canada, and currently is set as 0.025 kg N₂O-N kg N.

Sum the indirect emissions from volatilization and leaching and then multiply the total by 44/28 to convert to N₂O emissions.

$$\begin{aligned}
 \text{Emissions}_{\text{Manure Soil and Crop}} &= ((N_{\text{Man Canola}} * \text{FRAC}_m * \text{EF}_{\text{VD}}) + (N_{\text{Man Canola}} + \text{FRAC}_L * \text{EF}_L)) \\
 \text{Dyn, Canola} & * 44/28 \\
 &= ((0 \text{ kg} * 0.2 * 0.01) + (0 \text{ kg} * 0.19 * 0.025)) * 44/28 \\
 &= 0 \text{ kg N}_2\text{O}
 \end{aligned}$$

Note: No manure was used on this farm and as a result there are zero emissions. Nevertheless, the equation is shown for illustration purposes.

Total Direct and Indirect Emissions from Synthetic Fertilizer Soil and Crop Dynamics

Calculate direct N₂O - N crop residue emissions for each crop type in the year of interest by multiplying the amount of crop residue nitrogen accumulated from the crop by the emission factor for the soil (EF_{ECO}).

$$\begin{aligned}
 \text{N}_2\text{O-N}_{\text{res, Canola}} &= N_{\text{res canola}} * \text{EF}_{\text{ECO}} \\
 &= 19,703.25 \text{ kg N} * 0.00903 \text{ kg N}_2\text{O-N kg}^{-1} \text{ N} \\
 &= 177.920 \text{ kg N}_2\text{O} - \text{N}
 \end{aligned}$$

Calculate the kg of nitrogen from volatilization and re-deposition of NH₃ and NO_x.

$$\begin{aligned}
 \text{N}_{\text{VD Canola}} &= (N_{\text{Fert Canola}} * \text{FRAC}_f) \\
 &= (41,500 \text{ kg N} * 0.1) \\
 &= 4,150 \text{ kg N}
 \end{aligned}$$

Volatilization Emissions from Crop Residue

By convention of IPCC, crop residues are not included in the calculation of indirect N₂O emissions from volatilization.

Calculate the kg of nitrogen from leaching of NO₂ and NO₃ NH₃.

$$\begin{aligned}
 \text{N}_{\text{L Canola}} &= (N_{\text{Fert Canola}} + N_{\text{Res Canola}}) * \text{FRAC}_L \\
 &= (41,500 \text{ kg N} + 19,703.25 \text{ kg N}) * 0.19 \\
 &= 11,628.618 \text{ kg N}
 \end{aligned}$$

Calculate indirect N₂O - N emissions from volatilization for the crop type in the year of interest by multiplying the kg of nitrogen from volatilization and re-deposition of NH₃ and NO_x by the emission factor for volatilized nitrogen (EF_{VD}). The values for EF_{VD} are constant across Canada.

Calculate indirect N₂O - N emissions from leaching for the crop type in the year of interest by multiplying the kg of nitrogen from leaching by the emission factor for leached nitrogen (EF_L). The values for FRAC_L are calculated for each EcoDistrict in Canada, and are provided in Table A-1, Appendix A. The value for EF_L is constant across Canada, and currently is set as 0.025 kg N₂O-N kg N.

Calculate total Direct and Indirect Emissions from Synthetic Inorganic Fertilizer Soil and Crop Dynamics by summing the direct N₂O - N emissions from crop residue, indirect N₂O - N emissions from volatilization and indirect N₂O - N emissions from leaching for each crop management zone in the year of interest. Multiply the total by 44/28 to convert to N₂O emissions.

$$\begin{aligned}
 \text{Emissions}_{\text{Synthetic Soil and Crop Dyn, Canola}} &= ((N_{\text{res canola}} * EF_{\text{ECO}}) + (N_{\text{VD canola}} * EF_{\text{VD}}) + (N_{\text{Lcanola}} * EF_{\text{L}})) * 44/28 \\
 &= ((177.920 \text{ kg N}_2\text{O} - \text{N}) + (4,150 \text{ kg N} * 0.01 \text{ Kg N}_2\text{O-N} / \text{kg N}) + (11,628.618 \text{ kg N} * 0.025 \text{ Kg N}_2\text{O-N} / \text{kg N})) * 44/28 \\
 &= (177.920 \text{ kg N}_2\text{O} - \text{N} + 41.5 \text{ Kg N}_2\text{O-N} + 290.715 \text{ Kg N}_2\text{O-N}) * 44/28 \\
 &= 801.64 \text{ kg N}_2\text{O}
 \end{aligned}$$

Step 8 – Total Nitrous Oxide Emissions for Crop Type

Total N₂O emissions for each crop type in the year of interest are calculated by summing the direct and indirect N₂O emissions under SS P8 Fertilizer and Lime Use and P13 Soil and Crop Dynamics.

$$\begin{aligned}
 \text{Total N}_2\text{O Emissions} &= \text{Emissions}_{\text{Fert and Lime Use Canola}} + \text{Emission}_{\text{Soil Crop Dyn Canola}} \\
 &= 588.885 \text{ kg N}_2\text{O} + 801.641 \text{ kg N}_2\text{O} \\
 &= 1,390.526 \text{ kg N}_2\text{O}
 \end{aligned}$$

Convert to Total CO₂e Emissions for Crop Type

To convert total N₂O emissions to total emissions on a carbon dioxide equivalent (CO₂e) basis, multiply the N₂O emissions by the global warming potential. Refer to the Carbon Offset Emission Factors Handbook for global warming potential values.

$$\begin{aligned}
 \text{CO}_2\text{e}_{\text{Canola}} &= 1,390.536 \text{ kg N}_2\text{O} * 310 \text{ kg CO}_2\text{e kg}^{-1} \text{ N}_2\text{O} \\
 &= 431,063.06 \text{ kg CO}_2\text{e} \\
 &= 431.060 \text{ Mg CO}_2\text{e or } 431.060 \text{ tCO}_2\text{e}
 \end{aligned}$$

Step 9 - Determine Total CO₂e Emissions Intensity for Crop Type in the Project Year on a Dry Matter Basis (to Determine Emissions Intensity)

To express emissions on a dry matter basis for the crop type in this project year, apply the reduction modifier corresponding to the performance level implemented on the farm and divide by the crop mass (DM) reported for the crop management zone.

$$\begin{aligned}
 \text{Emissions Intensity}_{\text{Project Canola}} &= (\text{Emissions}_{\text{Fert and Lime Use Canola}} + \text{Emission}_{\text{Soil Crop Dyn Canola}}) * \\
 &\quad \text{RM}_{\text{PL}} / \text{Crop Mass}_{\text{Project Canola}} \\
 &= (431,063.060 \text{ kg CO}_2\text{e} * 0.75) / 813,150 \text{ kg} \\
 &= 0.3976 \text{ kg CO}_2\text{e kg}^{-1} \text{ canola}
 \end{aligned}$$

In the case of the sample farm, the intermediate level is implemented so a reduction modifier (F_{INT}) of 0.75 is used.

Note: In some instances, implementation of the 4R Plan will involve extra fuel consumption for field operations (for example, if split applications of fertilizer are used). Any difference in baseline and project fuel consumption will need to be quantified and added to the project emissions. In this

project there were no added emissions associated with on-site fertilizer and lime distribution. However, if there were added emissions associated with fertilizer and lime distribution these emissions would have to be added to the total emissions from SS P8 Fertilizer and Lime Use and P13 Soil and Crop Dynamics after the reduction modifier is applied, but before total project emissions are divided by the crop mass in the project (See Section 4.1.1 for full equation).

Step 10 - Calculate Total CO₂e Reductions for the Crop Type on a Dry Matter Basis

To express reductions per kg crop produced for the crop type on a dry matter basis, subtract the emissions calculated on a dry matter basis for the project year for the crop type from the emissions calculated on a dry matter basis for the crop type in the baseline period. Reductions are calculated on the basis of a unit of dry matter production to provide functional equivalence between baseline period and project year.

Note: The emissions calculated for the baseline period for this sample farm are 0.5350 kg CO₂e kg⁻¹ canola.

$$\begin{aligned}
 \text{Emission Reduction}_{\text{Canola}} &= (\text{Emissions Intensity}_{\text{Baseline Canola}} - \text{Emissions Intensity}_{\text{Project}}) * \text{Crop Mass}_{\text{Project Canola}} \\
 &= (0.5350 \text{ kg CO}_2\text{e kg}^{-1} \text{ canola} - 0.3976 \text{ kg CO}_2\text{e kg}^{-1} \text{ Canola}) * 813,150 \text{ kg canola} \\
 &= 111,726.81 \text{ kg CO}_2\text{e} \\
 &= 111.73 \text{ Mg CO}_2\text{e or } 111.73 \text{ tCO}_2\text{e}
 \end{aligned}$$

Calculating Emission Reductions for a Full Farm Across Crops, EcoDistricts and/or Performance Levels

Emission reductions should be calculated by crop for each performance level and EcoDistrict separately following the methodology presented in Section 4.1 above and demonstrated in this appendix. In order to calculate the total emission reductions for a farm the sum of the emission reductions by crop for each performance level and EcoDistrict is taken. For example, if the farm given in the example above employed 4R nutrient management on its canola in EcoDistricts 746 and 737 at the intermediate performance level and applied 4R nutrient management on its winter wheat grown in EcoDistrict 737 at both the basic and intermediate performance levels the emission reductions for each combination of crop, performance level and EcoDistrict would be calculated separately and then summed to get the total emission reductions for the farm. Table F-2 illustrates this process.

Table F-2: Calculated Emission Reductions by Crop, Performance Level and EcoDistrict

Crop	Performance Level	EcoDistrict	Emission Reductions (tCO ₂ e)
Canola	Intermediate	746	122.35
Canola	Intermediate	737	111.73
Winter Wheat	Basic	737	120.50
Winter Wheat	Intermediate	737	130.75
Total Emission Reductions for the Farm			485.33

APPENDIX G: Impact of the Project Activity on Downstream Crop-Related Emissions

A study was commissioned by Saskatchewan Environment to assess the impact on crop transportation and handling GHG emissions due to possible increases in grain/oilseed production as a result of implementation of the Protocol. Cecil Nagy at the Department of Bioresource Policy, Business and Economics at the University of Saskatchewan conducted the analysis.

Methods

To conduct the analysis, crop district data from Statistics Canada and Saskatchewan Agriculture and Food (crop production (tonnes) for 14 crops produced in Saskatchewan and area seeded (ha) for those crops) were used for the base production levels. Mr. Nagy was asked to assess the impact on downstream handling/transportation emissions from changes in production (tonnes) by soil zone for yield increases from 5 per cent to 30 per cent using the five-year average yield and seeded area as the base data for each crop district. Mr. Nagy assessed emission sources from truck, rail and lake transportation along with grain handling for each of the areas, in relation to major terminals for grain/oilseed collection.

The estimate of the change in downstream GHG emissions is the sum of the tonne-kilometres by mode of transportation times the GHG emission coefficient for the mode of transportation plus GHG from handling facilities for the amount of crop shipped to a domestic or export destination. The change in production by crop, times the share of production going to the domestic or export market, times the share to each market destination, given the mode(s) of transportation involved, times the total kilometres by mode, times the GHG coefficient, results in the transportation emissions.

The GHG from grain handling is estimated as the amount of grain handled for export or domestic markets times the number of times the grain is handled. For grain shipped by train it is times four and for truck transport it is times two. The coefficients used to estimate GHG emissions are presented in Table G-1 below. The grain handling coefficient is estimated as the amount of electricity needed to move the grain to storage, turn the grain once and load the grain onto trucks or rail cars. Estimates of the amount of electricity needed are 1.27 KWh per tonne using electric motors typically used in a grain terminal (Kenkel, 2008). The emission coefficient for electricity generation in Saskatchewan (2008 estimate) from Environment Canada is 710 g CO₂e per KWh which gives an estimate of 0.90 kg CO₂e per tonne of grain.

Table G-1: GHG Coefficients for Transport and Handling

Mode	Coefficient	Units
Train ¹	16.98	kg CO ₂ e / 1000 tonne-Km
Truck ²	88.6	kg CO ₂ e /1000 tonne-Km
Lake ¹	10	kg CO ₂ e /1000 tonne-Km
Elevator ³	0.90	kg CO ₂ e / tonne

The Environmental Footprint of Surface Freight Transportation, Lawson Economics Research Inc., 2007

Estimate from the Draft Intermodal Protocol.

Dr. Nagy's estimate from Environment Canada electricity coefficient and electricity use estimate.

Results and Conclusions

The analysis and subsequent review by the technical working group for the protocol, determined that even with a 30% increase in yield, the impact on the project reductions would be less than material. Table G-2 shows the emissions on a per hectare basis of varying increases in yield.

Table G-2: GHG Emissions from Adoption of the Protocol (CO₂e tonnes per hectare) Five-Year Production Averages*

	5%	10%	15%	20%	25%	30%
Brown	0.0040	0.0080	0.0120	0.0160	0.0201	0.0241
Dark Brown	0.0040	0.0080	0.0120	0.0160	0.0201	0.0244
Thin Black	0.0037	0.0074	0.0112	0.0149	0.0186	0.0225
Thick Black	0.0040	0.0080	0.0120	0.0160	0.0200	0.0241
Gray	0.0045	0.0091	0.0136	0.0182	0.0227	0.0274

*Estimated as the seeded hectares to crops for which the protocol would be adopted.

Based on these results, the technical working group deemed the impact immaterial and the exclusion of the crop transportation/handling emissions from the quantification to be justified. The approach used in analyzing the downstream emission impacts was conservative due to the following two factors:

- (1) It is highly unlikely that growers would see a 30% increase in yields as a result of implementing the 4R Nutrient Plan; modest yield increases are more likely (5 to 7% increases) due to more efficient use of nitrogen; and,
- (2) The analysis assumes that the yield increases of, for example 30%, would have to occur consistently for all crops in the district, and further, the adoption of the Protocol on 100% of all the seeded acres in the soil zones within the district.

Based on the analysis, the technical working group felt confident that the downstream emissions sources could be excluded.

References

Canadian Grain Commission. 2012. Canadian Grain Exports and Exports of Canadian Grain & Wheat Flour, Canadian Grain Commission.

Kenkel, P. 2008. Grain Handling and Storage Costs in Country Elevators. Department of Agricultural Economics, Oklahoma State University. P 11.

Statistics Canada. 2012. Table 404-0021 Rail transportation, origin and destination of commodities, annual.

APPENDIX H: Dynamic Baseline Quantification Approaches

One of the two approaches given below may be used to quantify the estimated emission reductions achieved by the project without the need for consideration of historical parameters. Both of these approaches use a dynamic baseline approaches quantify the emissions that likely would have occurred in the project year, had the 4R Plan not been implemented. Under both approaches, the dynamic baseline is recalculated each year using the estimated project emissions and the conservative reduction modifier as inputs.

Using a dynamic baseline allows project developers who do not have sufficient data or data of appropriate quality for the three-year conventional baseline for farms to participate on a go forward basis. To account for increased uncertainty associated with decreased availability of on-farm baseline data, dynamic baseline approaches have a discount factor applied to calculated project emissions. In order to be eligible for use of a dynamic baseline, projects must also provide proof that nitrogen application rates have not exceeded recommendations for each crop. To provide this assurance, Accredited Professional Advisors will use a variety of information sources such as soil testing reports, field history, current crop, soil amendments from the previous year, and historic knowledge of regional soils and cropping systems to ensure reasonable and conservative nitrogen fertilizer rate recommendations. These requirements are currently built into the body of the protocol and associated records requirements. Once a baseline approach is chosen, project developers cannot switch between the conventional and dynamic baseline approaches. In Dynamic Baseline One, crop mass for the current project year is determined by the acceptable yield methods outlined in Appendix I. Dynamic Baseline One has a five per cent discount factor applied to it. In Dynamic Baseline Two default crop mass data is derived from the five-year rolling averages published by Agriculture Financial Services Corporation. Dynamic Baseline Two has a 10 per cent discount factor applied to it.

In the case of catastrophic crop failure (owing to drought, frost, hail, weed infestation, etc.), the total mass of crop produced may be decreased to the extent that project emissions per mass of crop exceed baseline emissions. In this event, the fields/crops would be excluded from credit production under this protocol for that year.

If the Dynamic Baseline One approach has been employed, project developers cannot switch back to the Dynamic Baseline Two. Users of Dynamic Baseline Two must switch to use of Dynamic Baseline One within two years (see Section 1.3). Both dynamic baseline approaches are conservative in the sense that they result in fewer credits being generated, on average, than when a conventional baseline is used. Dynamic Baseline Two is the most conservative approach with the application of a 10% discount factor.

The basis for applying a dynamic baseline approach in this protocol is justified by other accepted protocols in the Alberta offset system where measurement or estimation of variables in the project condition (for example, wind projects where electricity produced, or conservation cropping where volume of carbon dioxide sequestered or land fill gas projects where volume of landfill gas collected) are used for estimating emissions that would have occurred in the baseline condition.

A dynamic baseline is favoured over a conventional, historic baseline approach in many protocols because the business-as-usual externalities that cannot be otherwise controlled are removed from consideration. The most significant externalities in this Protocol are related to growing conditions and weather related events. Changes in growing conditions from year to year are not relevant under a dynamic baseline approach because both the baseline and the project emissions are calculated from measurements and estimates from the same year.

Dynamic Baseline One - Quantification Approach

Calculate the total baseline CO₂e emissions for each crop type (t CO₂e), using the present years data, following the steps outlined in Section 4.11 of the Protocol and shown in the sample calculation provided in Appendix F. Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and each performance level on the farm. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are then summed across the analytical units to derive the GHG claim for the farm. Note that emissions associated with manure application are considered to be consistent in the baseline and project condition, so no emission reductions are applied to manure nitrogen application in the dynamic baseline.

$$\begin{aligned} \text{Emission Reduction} &= [\sum_{\text{EcoDistrict } j} \sum_{\text{4R management level } k} (\text{Emissions Reduction}_{\text{crop } i})] - \text{Emissions}_{\text{Fert and Lime Dist}} \\ \text{Emissions Reduction}_{\text{crop } i} &= \text{DF} * [\sum_{\text{crop } i} [\text{Emissions}_{\text{Other Fert and Lime Use, } i} + \text{Emissions}_{\text{Other Soil Crop Dyn, } i}] * (1 - \text{RM}_{\text{PL}})] * \text{GWP}_{\text{N}_2\text{O}} \\ \text{Discount Factor (DF)} &= 0.95 \text{ (5\% discount factor) for Dynamic Baseline One} \\ \text{Other factors} &= \text{See Section 4.1.1} \end{aligned}$$

Dynamic Baseline Two - (Default Crop Mass) Quantification Approach

With application of a 10 per cent discount factor, the Dynamic Baseline Two quantification approach is more conservative in terms of the number of credits generated in comparison to both the conventional baseline and the Dynamic Baseline One approach. The difference between this approach and the Dynamic Baseline One is that five-year average yields published by the Agriculture Financial Services Corporation (AFSC) of Alberta are used as a proxy for crop mass values from the farm. Crop yields from this source are organized by crop type and AFSC risk area.³¹ The appropriate regional risk area shapefile can be obtained from Alberta Agriculture and Rural Development. Dynamic Baseline Two can be used for a maximum of two years. After the two year maximum, project developers using Dynamic Baseline Two must switch to Dynamic Baseline One.

The quantification approach for Dynamic Baseline Two is as follows:

- (1) Obtain the appropriate shapefile for AFSC risk zones from ARD and develop rule set for allocating EcoDistricts to risk zones.
- (2) Multiply the five-year average yield for the EcoDistrict by risk zone by the area cropped to determine the crop mass.

For example, using a five-year average yield of 1600 kg/ha, for canola grown on 500 ha of land the calculation would be as follows:

$$\begin{aligned} \text{Crop Mass}_{\text{crop}} &= \text{Five-year average Yield}_{\text{crop } i} * \text{Cropped Area} \\ &= 1600 \text{ kg/ha} * 500 \text{ ha} \\ &= 800,000 \text{ kg of canola} \end{aligned}$$

³¹ Five-year rolling averages for yield by risk management zone are published annually by Agriculture Financial Services Corporation.

Calculate the total baseline CO₂e emissions for each crop type (tCO₂e), using the present years nitrogen input data and the crop mass value calculated above. Total emission reductions associated with the project are the sum of the emissions reductions calculated for each crop type within each EcoDistrict and at each performance level on farms. Separate calculations must be made for areas where EcoDistricts differ, and also where 4R management levels differ. Reductions are then summed across the analytical units to derive the GHG claim for the farm.

Emission Reduction	$[\sum_{\text{EcoDistrict } j} \sum_{\text{4R management level } k} (\text{Emissions Reduction}_{\text{crop } i})] - \text{Emissions}_{\text{Fert and Lime Dist}}$
Emissions Reduction _{crop i}	$[\text{DF} * \sum_{\text{crop } i} [\text{Emissions}_{\text{Other Fert and Lime Use, } i} + \text{Emissions}_{\text{Other Soil Crop Dyn, } i} * (1 - \text{RM}_{\text{PL}})]] * \text{GWP}_{\text{N}_2\text{O}}$
Discount Factor (DF)	0.90 (10% discount factor) for Dynamic Baseline Two
Other factors	See Section 4.1.1

APPENDIX I: Acceptable Crop Mass Determination Methods

On Alberta farms, a number of different methods for measuring crop mass are currently being used. Proper and frequent calibration from a practical standpoint is difficult to achieve given the urgency of fall harvest operations. This variability creates a challenge for project developers and verifiers. In a protocol validation study conducted over the summer of 2013, the evidence to support the reported crop masses was insufficient to meet the requirements of this protocol. For example, many farms did not use weigh wagons or their weigh wagons were not properly calibrated.

To mitigate this risk for this protocol, acceptable crop mass determination methods are listed below. The verifier does not need to test the materiality of the crop mass measurements, only ensure that the following procedures were followed and the necessary documentation collected. The farmer will keep a moisture log and it will be made available, showing moisture test reports (date, time, crop and measurement). The farmer will also maintain crop mass logs. All crop mass determinations will be conducted at harvest, before being fed.

The following Acceptable Crop Mass Determination Methods can be applied in the protocol:

(1) Mobile Weighing Devices

- A load cell(s) used on a mobile weighing device shall be calibrated to manufacturer specifications, by a qualified third party, prior to harvest;
- A calibration report will be made available to the verifier to assess the proper procedures are followed; and
- A log of masses for each load shall be maintained.³²
- A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day.

(2) Fixed Scale

- The scale will be demonstrated to be properly calibrated and maintained, by a qualified third party, prior to harvest;
- A calibration report will be made available to the verifier to assess proper procedures are followed; and
- A log of masses and moisture for each load shall be maintained.³³
- A log of crop moisture readings shall be maintained. In order to calculate an average crop moisture content, it is required that for each crop type, a minimum of three crop moisture tests are taken from each field per day.

(3) Commercial Scale Certified by Industry Canada with accompanying Scale Tickets (i.e., elevator or grain processors)

- Scale tickets can be presented that show the truck loads that link to the moisture logs listed above as well as the scale company and location.

(4) Storage Volume Measurement

³² In the event the weight log is less than the project claim, the weight log shall prevail.

³³ In the event the weight log is less than the project claim, the weight log shall prevail.

- The following sources can be used to calculate the bin volume dimensions and crop mass (dry matter basis, according to moisture logs above):
 - Agriculture and Rural Development. March 2002. Round Bin Volume Calculator.
 - Saskatchewan Crop Insurance Corporation. Interactive Bin Calculator.
 - Manitoba Agricultural Services Corporation. MASC Insurance Calculators.
- All crop at harvest needs to go into an empty bin, meaning crop mass at harvest needs to be segregated from any existing crop from the year before;
- A third party sign off will be made available reporting the bin is empty and recorded in a Bin Log before harvest (checked by Accredited Professional Advisor), which must include photo and time-stamped evidence; and
- The bin log and moisture log will be made available to the verifier upon request.

Any project developer using these options must have a QA/QC system in place to identify and reduce fraud and other unwanted incorrect claims.

References

Agriculture and Rural Development. March 2002. Round Bin Volume Calculator.

Manitoba Agricultural Services Corporation. MASC Insurance Calculators.

Saskatchewan Crop Insurance Corporation. Interactive Bin Calculator.

APPENDIX J: The 4R Practices

Canada’s fertilizer industry has a vested interest in managing products to protect the environment and has developed an approach to nutrient management which provides farmers with a variety of science-based beneficial management practices (BMPs) to ensure the right source of fertilizer is applied at the right rate, right time and right place. Examples of Beneficial Management Practices to mitigate these risks include the following:

Table J-1: The 4R Practices

Practice	Examples
Right Source: Using the right product to meet crop needs	<ul style="list-style-type: none"> • Ammonium-based formulations • Slow/controlled release fertilizers • Inhibitors • Stabilized nitrogen
Right Rate: Matching the right amount of fertilizer to crop needs	<ul style="list-style-type: none"> • Soil Testing • Yield Goal Analysis • Crop Removal Balance • Nutrient Management Planning • Plant Tissue Analysis • Applicator Calibration • Crop Scouting • Record Keeping • Variable Rate Technology
Right Time: Making nutrients available when crops need them	<ul style="list-style-type: none"> • Application Timing • Controlled Release Technologies • Inhibitors • Fertilizer Product Choice
Right Place: Keep nutrients where crops can use them	<ul style="list-style-type: none"> • Application Method • Incorporation of Fertilizer • Buffer Strips • Conservation Tillage • Cover Cropping • On-Farm Fertilizer Storage

APPENDIX K: Additional Fuel Pass Method

The Accredited Professional Advisor will assess and document nitrogen fertilizer application practices prior to project implementation as part of developing the initial 4R Plan. As part of this assessment, the Accredited Professional Advisor will establish and document the number of field passes typically used by the grower for nitrogen fertilizer application prior to project implementation.

Each year of the project, the Accredited Professional Advisor will assess the nitrogen application practices relative to the baseline. Any increased GHG emissions from additional nitrogen application passes relative to the baseline will be calculated and subtracted from the GHG assertion for the farm. Two methods for accounting for additional passes are available as outlined below.

Method A: Documented Fuel Use Method

This method can be used when there is sufficient documented evidence of the farm fuel used in the additional passes to apply nitrogen fertilizer to accurately calculate the additional GHGs released by the operation. Documentation may include fuel use logs and/or equipment use logs that can be clearly traced to the additional operations. Documented evidence of additional fuel usage must apply specifically to field use (excluding road use and personal vehicles). The method is as follows:

- Document which fields received additional passes.
- Document the fuel type, volume of fuel used in the additional passes, and the method used to calculate fuel use.
- Multiply the total volume of fuel used by the emission factors provided in Table 8 of the protocol.
- Subtract the GHG value in kgCO₂e from the GHG offset assertion for the farm, as described in Section 4.1.1 of the Protocol.

Method B: Additional Pass Method

This method is based on the number of additional passes used rather than direct estimate of fuel consumption. To be conservative, the default value of 5.23 litres per hectare (band fertilizer with coulters), which is four to six times higher fuel use than the other methods, will be used in all cases under Method B, regardless of the type of equipment used (see Table K-1). Under this methodology it is assumed that diesel fuel is used. An additional 10 per cent fuel usage is added to ensure conservativeness of the estimate resulting from this scenario.

Vol. Fuel	=	$1.10 * \text{Fuel Use}_{\text{diesel}} * \sum_{\text{Mgmt unit } I} [\text{Pass}_{\text{area } I} * \text{Pass}_{\text{quantity } I}]$
Vol. Fuel	=	Volume of diesel fuel used during extra field passes
1.10	=	10 per cent increase in total fuel usage for conservativeness
Fuel Use _{diesel}	=	Fuel usage factor (diesel) for each extra pass. Value set at 5.23 litres of diesel per hectare
Mgmt unit I	=	Index number for management units which received extra field passes as a result of 4R Plan implementation
Pass _{area}	=	Area that received extra field passes
Pass _{quantity}	=	Number of extra passes on each field

- Document which fields received additional passes.
- Document the area of each field that received additional passes.
- Multiply the area of each field by the number of additional passes.

- Sum the additional pass hectares from all fields to get the total pass-hectares for the farm.
- Multiply the total pass hectares for the farm by the default fuel use factor of 5.23 litres of fuel per hectare. Multiply this value by the total number of hectares which received extra passes on the farm. This will result in a calculation of extra L of fuel used in the project condition. Add an extra 10 per cent fuel usage (multiply by 1.10).
- Multiply the total volume of fuel used by the emission factors provided in Table 8 of the protocol.
- Subtract the GHG value in kgCO₂e from the GHG offset assertion for the farm, as described in Section 4.1.1 of the Protocol.

Example Calculations

Prior to project implementation, a grower with 1000 hectares of cereals and oilseeds applies all fertilizer nitrogen at time of seeding. As part of his improved practices under his 4R Plan, he switches from a one to a two pass system by applying 75% of his recommended nitrogen rate on his wheat fields at time of seeding and in crop banding the remaining 25% post emergent. In Year 1 of the project he follows this practice on 400 hectares of wheat with the remainder of his cropped area in a one-pass system.

Method A

Total fuel consumption for the second pass was calculated from fuel logs at 750 litres. 750 litres of fuel will therefore be used for calculation of Emissions_{Fert and Lime Dist} with the quantification methodology provided in Table 8.

Method B

Calculating additional hectare-passes

$$400 \text{ ha} \times 1 = 400 \text{ ha-pass}$$

Calculating the fuel usage from the additional pass

$$400 \text{ ha-pass} \times 5.23 \text{ L fuel per hectare} = 2092 \text{ L of extra fuel used}$$

$$2092 \text{ L of extra fuel} \times 1.10 = 2301.20 \text{ L of extra fuel (diesel)}$$

2301.20 L of diesel fuel will therefore be used for calculation of Emissions_{Fert and Lime Dist} emissions with the quantification methodology provided in Table 8.

Justification and Recommendation for the Additional GHG Pass Coefficient

Mr. Lawrence Papworth, at the Alberta Agriculture and Rural Development AgTech Centre, developed a chart on possible post emergent fertilizer application methods. Lawrence indicated a coultter would have to be used to band granular, liquid or anhydrous NH₃ and the main power use is the draft of the coultter, which means that fuel use would be the same for all of them. Knife openers could be used to band fertilizer in row crops but it isn't common. Lawrence added the high clearance sprayer option because they are quite common on farms. Producers can use sprayers that apply micronutrients on post emergent specialty crops. The values in the chart are based on operating power units efficiently.

Table K-1: Fuel Usage Calculations for a Variety of Additional Pass Methods

Type of Operation	Fuel Use (gallons/acre)	Fuel Use (litres/acre)	Fuel Use (litres/hectare)
Spreading granular fertilizer	0.16	0.60	1.48
Dribble liquid fertilizer	0.16	0.61	1.50
Band fertilizer with coulters	0.56	2.11	5.23
Broadcast or dribble liquid fertilizer (high	0.11	0.42	1.03

References

Iowa State University. 2005. Ag Decision Maker: Fuel Required for Field Operations. File A3-27.

Government of Saskatchewan. 2015. 2014-15 Farm Machinery Custom and Rental Rate Guide.

National Sustainable Agriculture Information Service. 2007. Conserving Fuel on the Farm.

Virginia State University. 2014. Predicting Tractor Diesel Fuel Consumption. Publication 442-073.e