

Protocol for Reducing Fertilizer Nitrous Oxide Emissions in Canadian Agricultural Croplands

NERP v2.5

November 5, 2025

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1. Glossary of Terms/Abbreviations

Accredited Professional Advisor (APA)	For the purposes of this protocol the APA has successfully completed the 4R Training Program offered by Fertilizer Canada (see Appendix G for full list of qualifications)[1]
Additionality	Project activities that are above and beyond "business as usual" operation, exceed the baseline characterization and are not mandated by regulation.
Ammonium-based Fertilizer	Any fertilizer which releases more than two-thirds of its N in the ammonium form.
Band Application	Fertilizer placed in a concentrated sub-surface row, where fertilizer row is not spread more than 30 per cent of the row laterally.
Baseline Emissions	Business as usual GHG emission assessment against which GHG remissions from a specific GHG reduction activity are measured.
Best Management Practices	Integrated sets of fertilizer management practices, customized annually to specific crop demands and field conditions, which have been shown to reduce GHG emissions
Carbon Dioxide (CO_2)	The GHG consisting of a single carbon atom and two oxygen atoms.
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. For the dynamic baseline the metric is identical since the accounting is done in the cropping year using the same N rate and crop yield.
Conservation Tillage	According to the NIR, tillage practices that minimize soil disturbance – namely no till and reduced till.
Controlled Release Fertilizer Product	A fertilizer in which nutrient release is delayed after application, or which extends nutrient availability to the plant significantly longer than a reference 'rapidly available nutrient fertilizer' such as ammonium nitrate or urea, by employing a physical barrier, coating, or other mechanism. Controlled release fertilizer products available today include products such as polymer-coated urea products. (AAPFCO aligned).
CO_2 Equivalent (CO_2e)	The quantity of a given GHG multiplied by its 100-year GWP. This is the standard unit for comparing the degree of warming which can be caused by different GHGs.
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 3.2. The crop year is accounted from harvest of previous crop to harvest of current crop.
Denitrification	The conversion of nitrate to N gas (dinitrogen and various nitrogen oxides (NOx), including N_2O) by soil denitrifying microbes under depleted oxygen conditions.
Direct Emissions	GHG emissions from sources that are owned or controlled by the reporting entity.
Drier Soils	Drier soils are soils that are in an EcoDistrict with a Precipitation/Potential Evapotranspiration ratio (P/PE) of less than 1.0.
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.

[1] https://fertilizercanada.ca/our-focus/stewardship/4r-certification/#:~:text=The%204R%20Certification%20program%20evaluates,%26%20nutrient%20application%2C%20and%20documentation.

Emission Factor (EF)	A unique value for determining an amount of a GHG emitted for a given quantity of activity data (e.g. metric tons of CO_2e emitted per barrel of fossil fuel burned).
EF_{ECO}	The base Ecodistrict emission factor adjusted for tillage system and irrigation management (see table A-2 in Appendix)
Emission Reduction	Baseline GHG emissions minus project GHG emissions, measured in CO_2 equivalent.
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.
Fossil Fuel	A fuel such as coal, oil and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
Greenhouse Gas (GHG)	All gases that contribute to the atmospheric greenhouse effect including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF6), hydrofluorocarbons (HFCs) or perfluorocarbons (PFCs).
GHG Reservoir	A physical unit or component of the biosphere, geosphere, or hydrosphere with the capability to store or accumulate a GHG that has been removed from the atmosphere by a GHG sink or a GHG captured from a GHG source.
GHG Sink	A physical unit or process that removes a GHG from the atmosphere.
GHG Source	A physical unit or process that releases a GHG into the atmosphere.
Global Warming Potential (GWP)	The ratio of radiative forcing (degree of warming to the atmosphere) that would result from the emission of one unit of a given GHG compared to one unit of CO_2 over a defined period (e.g. 100 years). GWPs for this protocol are defined by the regulation.
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 (summer fallow) or herbicides (chem fallow).
Farm Enterprise	All lands and crops under the control of the farmer.
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.
Fossil Fuel	A fuel such as coal, oil and natural gas, produced by the decomposition of ancient (fossilized) plants and animals.
High Moisture/High Risk	Where existing soil moisture conditions combined with normal or predicted rainfall during the growing season can be expected to result in leaching, runoff, or saturated soil in more than one-fourth of the field area
Indirect Emissions	GHG emissions that occur at a location other than where the reduction activity is implemented and/or at sources not owned or controlled by project participants.
Management Zone	For the purposes of 4R Plan implementation (and not GHG accounting), a sub-field unit of a crop that is managed differently from other management zones within the same field. (see Table 1).
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: EFeco tables in this document vary by EcoDistrict for irrigated soils.
Nitrification	The microbial transformation of ammonium (NH_4+) forms of N in a two-stage process to nitrite (NO_2-) and then to nitrate (NO_3-), as accomplished by nitrifying microbes, respectively.
Nitrification Inhibitor	An additive to ammonium-based fertilizers that inhibits soil bacteria from converting ammonium (NH_4+) to nitrite (NO_2-). This effectively keeps the N in ammonium form for a longer period, slowing down conversion to nitrate reducing

	potential N_2O emissions arising from both nitrification and denitrification processes.
Nitrogen Use Efficiency (NUE)	An estimate or measure of the proportion of added inorganic or organic nitrogen taken up by a crop in the year of application. Direct measurement of NUE requires sophisticated isotopic techniques using N-15 as a tracer. Various proxy techniques are available that allow relative comparisons of NUE across fields, years, and crops. For more information on the various approaches to estimating NUE see Congreves et al. (2021).
Olympic Average	A truncated mean, where the highest and lowest values in a dataset are excluded before averaging the remaining values.
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_2O emission processes.
Professional Agrologist (P.Ag.) or Certified Crop Advisor	Professional Agrologists are regulated members with the agrologist associations in the provinces. Certified Crop Advisors are members of the CCA.
Project Emissions	Actual GHG emissions that occur within the GHG Assessment Boundary due to project activities. Project emissions are calculated at a minimum on an annual, ex post basis.
Project Developer	The entity that undertakes a GHG project.
Real-time Crop Sensors	Sensor attached to a N fertilizer applicator used in-crop to assess the crop N status (greenness) and determine whether additional N 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 agrologist associations in the respective provinces.
Reporting Period	The specific time of project operation for which the Project Developer has calculated and reported emission reductions and is seeking verification and issuance of credits.
Sink	Any process, activity or mechanism that removes GHG from the atmosphere and stores it in a reservoir.
Split Apply	Implies that N will be applied in either two or more applications in the growing season (e.g., spring and/or early summer) to synchronize supply with a crop's ability to use that N.
Spring Application	Spring application, for the purposes of this protocol, refers to application of fertilizer after thaw and before or at seeding.
Urea-Ammonium Nitrate (UAN)	A N 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.
Urease Inhibitor	A substance that inhibits the hydrolytic action of the urease enzyme on urea. The temporary delay in the hydrolysis of urea can reduce ammonia volatilization losses. (AAPFCO aligned).
Variable Rate Application	A method of automatically varying the rate of a crop input based on a prescription map, generated through soil testing or plant data liken yield/NDVI. 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.
Verification	The process used to ensure that a given Project Developer's GHG emissions or emission reductions have met the minimum quality standard and complied with the particular program's rules, procedures and protocols for calculating and reporting GHG emissions and emission reductions.

Verifier	An individual or organization that is accredited under ISO 14065 by a member of the International Accreditation Forum in Canada or the United States according to an ISO 17011 program.
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.

Intent of this Document

This document outlines a methodology to quantify and commodify on-farm reductions in nitrous oxide (N_2O) emissions attributable to inorganic and organic nitrogen applications on Canadian agricultural soils used for annual field crops.

Fertilizer nitrogen (N) application to annual crops results in soil N_2O emissions – a potent greenhouse gas (GHG) with a global warming potential (GWP) that is 265 to 298 times stronger than that of CO_2 over a 100-year timeframe. As a result, many scientific, industry and public policy efforts have focused on ways to reduce these emissions, driven by interest to reduce emissions as part of reaching Net Zero climate targets. Application of N from synthetic fertilizer, biological fixation, livestock manure-derived sources, and crop residues are important sources of N inputs that need to be taken into consideration for crop production and N_2O emission pathways. Fertilizer-derived N, like any form of soil mineral N[2] (or free or soluble N), is subject to emission as N_2O either from nitrification/denitrification pathways in the soil, losses through leaching of nitrate, and/or volatilization and redeposition of ammonia gas.

Integrated sets of fertilizer management practices, customized annually to specific crop demands and field conditions, have been shown to reduce these GHG emissions (Young et al., 2021)[3]. These best management practices (BMPs) are designed to manage applied N sources in a comprehensive way to reduce overall N_2O emissions associated with N fertilizer application. The BMPs are integrated into a 4R (Right Source at the Right Rate, Right Time, and Right Place ®) Nitrogen Stewardship Plan, hereinafter called a '4R Plan', which synchronizes the availability of N with the requirements of the specific crop, minimizing the emissions of N_2O. This is discussed in further detail in Section 5.

Application of this protocol, designed to minimize these N_2O emission pathways through the implementation of the BMPs in a 4R Plan, results in:

- Optimization of the crop response per unit of added N; and

[2] Mineral N refers to NH_4+ (ammonium), NO_3- (nitrate) or NO_2- (nitrite).

[3] Young, M.D., G.H. Ros, and W. de Vries. 2021. Impacts of agronomic measures on crop, soil, and environmental indicators: A review and synthesis of meta-analysis. Agriculture, Ecosystems & Environment 319: 107551. doi: 10.1016/j.agee.2021.107551.

- 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 N_2O (through NH_3 volatilization/deposition or loss to the system through leaching and runoff).

This represents a risk-based approach, informed by over 50 years of peer-reviewed research on the effects that specific management practices have on the biological processes that lead to N losses in North American cropping systems. A 4R Plan is designed to address the risk of N losses by promoting comprehensive N management across the 4Rs to achieve the above two outcomes. (See Table 1 and Appendix D for more information on the BMPs.)

Fertilizer Canada is sponsoring this flexible, science-based methodological protocol adapted from both the Alberta[4] and Ontario-Quebec (ON-QUE) GHG protocol efforts. It is written for professionals with experience and expertise in 4R Nutrient Stewardship, agronomy, and emission reduction project quantification and implementation. Under this protocol, these professionals are expected to work closely with farmers to implement the 4R management system on the ground. Furthermore, this document builds on 18 years of scientific research in Canada, while also integrating feedback from practitioners to ensure that it is both evidence-based and pragmatic.

Fertilizer Canada is making this protocol available to those stakeholders who wish to undertake N management projects in Canada, whether those be voluntary carbon credits, Scope 3 value chain reductions (as defined by the Greenhouse Gas Protocol Corporate Standard and Science Based Targets Initiative) or improving carbon intensity (CI) scores for crop feedstocks for initiatives like Canada's Clean Fuel Regulation (CFR).

2.1 Causality and/or Additionality Justification

For voluntary carbon credit programs, the requirements are usually outlined within the context of the Standard or Registry (e.g., Verra, Climate Action Reserve, Gold Standard, etc.). Typically, these require quality conditions, such as ensuring the credits meet the following quality criteria:

- **Additional –** beyond business as usual/common industry practice with a valid and defensible baseline and not required by law.
- **Measurable, Quantifiable** – following ISO 14064:2, consensus and review of agreed upon best available science and supplemented with primary farm activity data. The protocol has gone through this process and accounts for all 7 GHGs and relevant sources/sinks. The protocol will be reassessed every 3-5 years to ensure conformance with latest science.
- **Permanent –** must protect against carbon reversals in sequestration projects and for a certain 'liability period'. Note: no sequestration occurs in this protocol.

[4] https://open.alberta.ca/publications/9781460125502

- **Leakage –** account for shifting of land uses/activities outside the boundary of the project, due to the project activity. This has been accounted for using ISO14064:2.

- **Consistent Metrics (Functionally Equivalent) –** same level of quantity or service occurs between baseline and project; here, it is crop for crop. Baseline and project must be aligned on the same unit of output; here, this means comparing the same crop type in both scenarios.

- **Clearly Owned –** demonstrate clear ownership; preferably through a unitized reduction that can be tracked on a registry.

- **Verifiable –** the carbon accounting and tracking process must be clear, defensible, and evidence-based to prove to a third-party verifier that all the above requirements have been met.

This protocol has been built on well-proven processes following best practice guidance and the ISO 14064:2 Standard. Six principles govern the quantification process in the Standard – relevance, completeness, consistency, accuracy, conservativeness and transparency[5]. The implementation of, and ensuring adherence to, the conservativeness principle is extremely important and is frequently a matter of balance between the others (e.g., between accuracy and conservativeness, or accuracy and relevance), and therefore almost always involves compromise. It is applied as a risk-based approach where gaps in peer reviewed science exist, or uncertain data sources are used. Coming to consensus through well-managed, science-informed and robust peer review with experts, applying conservative approaches can be used to round out the quantification. It is important to strive to underestimate baseline emissions. In this manner, the conservativeness principle serves as a moderator to accuracy.

For Scope 3 programs, the focus is on 'causality' rather than additionality (i.e., did the Scope 3 program participants cause the practice change to occur), meaning business as usual or common practice thresholds do not come into play. The regulatory requirement still applies, but when using this protocol, the project developer and downstream partners cause the practice changes and the Scope 3 emissions reduction benefits in the following ways:

- **Cash Incentives –** project developer pays farmers to implement the N_2O-reducing 4R N Management practices that result in the emissions benefit.

- **Agronomic Training –** project developer offers one-on-one agronomic support for practice implementation for farmers who are enrolled in the N Management Project.

[5] The principles can be considered this way in the context of quantification: **Relevance –** select GHG sources and sinks, emission factors and formulae appropriate to the environmental integrity of the protocol; **Completeness –** consider all relevant GHG emissions and removals. Relevant information used to support decisions made in the quantification process should be transparently documented; **Consistency –** to ensure meaningful comparison of GHG-related information, in particular, like emissions need to be compared in baseline and project scenarios and expressed on a similar quality of goods or services basis ('Functional equivalence"); **Accuracy –** reduce bias and uncertainties as far as practical - rely on IPCC and National Inventory methods as much as possible; **Conservativeness –** conservative assumptions, values and procedures are used to ensure that GHG emission reductions or removal enhancements are not over-estimated; **Transparency –** present your calculations, assumptions and decisions in a clear, upfront manner that facilitates review by reviewers, interested parties, verifiers – ultimately Program Operators will accept the protocols.

- **Measurement, Reporting and Verification (MRV) Enablement –** project developer establishes an internal process to manage the data collection, evidence, monitoring and reporting processes to quantify the emissions benefits.
- **Procurement Clauses –** this is where production practices are outlined in the procurement agreement by the buyer, where a potential premium is applied.

There is little distinction between the mechanics of a carbon credit or Scope 3 program, but the latter will have more flexibility on the quantification methodology, depending on the program.

It is important to note that this protocol has been tested under voluntary carbon credit and Scope 3 programs resulting in successful third-party verified assets by multiple companies in Canada to date[6]. It has also been applied to estimate lower CI crop pathways for Canada's CFR program; however, its use for this purpose has not been formally tested yet, since CFR crop CI pathways won't be available until 2026.

3. Nitrogen Management Project Description

Projects that commit and switch to emission reduction activities following an integrated set of Best Management Practices (BMPs) for annual cropping systems in Canada can reduce nitrous oxide (N_2O) emissions under this protocol. These BMPs are designed to manage applied Nitrogen (N) sources in a comprehensive way to reduce overall N_2O emissions associated with N fertilizer application. The BMPs are integrated into a 4R Plan. Implementing the entire 4R Plan at a selected performance level (i.e., basic, intermediate, or advanced) is designed to reduce N_2O emissions in cropping systems in Canada. Since a 4R Plan represents a practice change activity that goes beyond business as usual (i.e., additional) and is not required by law, it can generate emission reductions and create assets that can be monetized under various voluntary carbon programs. Projects that implement individual elements of the BMPs within a given performance level are not eligible to generate emission reductions using this protocol. This protocol is designed and fine-tuned for an integrated N_2O reduction outcome across the practices[7].

Implementing a 4R Plan, as outlined in this protocol, results in applied N being used more efficiently by agricultural crops. Furthermore, implementing the 4Rs together across fields, considering the local conditions of the fields (i.e., residual N, moisture, crop N demand, and topographical variability), generates real reductions of N_2O emissions from agricultural cropping systems.

This protocol is written for professionals with experience and expertise in agronomy and emission reduction project quantification and implementation. The protocol requires agricultural professionals to assist in designing and implementing the 4R Plan with the grower. These professionals must be

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[6] See the Nutrien-Maple Leaf Scope 3 project on the VIVID Impact Registry here.

[7] Note – there may be multiple performance levels implemented on farm, depending on the crop and the growers 4R Plan.

trained and accredited to apply this protocol and to sign off on 4R Plans. This protocol requires planning and commitment to implement a 4R Plan.

More details on the Accredited Professional Advisor (APA) and the accreditation program are provided in Section 3.3 and Appendix G. Typically, project developers will work with each farm to design the program, and an APA is required to draft and sign off on a 4R Plan for each farm. The project developer will aggregate multiple farms together into a project, depending on the requirements of the voluntary program.

3.1 Protocol Scope

The scope of this protocol is limited to quantifying on-farm reductions of emissions from N sources and any additional fuel use associated with the management of synthetic fertilizer, manure fertilizers, and crop residues. GHG emission reductions associated with carbon sequestration in the soil and off-site emissions reductions affected by the manufacture and distribution of N fertilizers are excluded. 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 and actively managed on farm[8].

Emission Reduction Activity

In this protocol, N_2O emissions from agricultural soils are quantified using Canada's National Emissions Inventory Tier II methodology as outlined in the National Inventory Report (NIR) submitted to the UN Framework Convention on Climate Change. The quantification of direct and indirect N_2O emissions from more sophisticated use of fertilizer utilizes the published emission equations and factors from the methodology in Canada's National Inventory Report. This Tier II level of quantification is performed on an EcoDistrict basis, which accounts for variables associated with soil type, texture, topography and climate (Liang et al., 2021). To determine the appropriate EcoDistrict for the farm, maps including digital EcoDistrict shapefiles, are available on the Agriculture and Agri-Food Canada National Soil Database (NSDB) and the National Ecological Framework for Canada can be used.

The quantified emission reductions from implementing the 4Rs are based on Reduction Modifiers (RMs). These RMs are applied to the NIR-calculated emissions for a particular performance level of practice suites. The RMs are conservative, science-based coefficients for estimating the synergistic effects of the 4R practices on lowering N_2O emissions per unit of crop produced (the functional unit for comparing baseline and project emissions). Table 1 describes the 4R practice suites, at different levels of site specificity (performance) and the corresponding RMs for soils in Canada[9]. Project emissions (Canada's NIR Tier II method) are multiplied by the RM to provide an adjusted value for N_2O emissions impacted by 4R management, expressed in CO_2 equivalent (CO_2e). This adjusted project

[8] Implementing the protocol will result in reduced applications of N fertilizer per unit crop grown relative to baseline conditions. It is conservative to exclude upstream emission reductions. However, under a Scope 3 program, stakeholders may wish to include these upstream benefits. It will depend on the rules of the voluntary program.

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

emissions value is a conservative estimate of the lower emissions achieved under an integrated set of 4R BMP's. Reductions are calculated as the difference between the project and baseline emissions.

Not only does this protocol align with the latest NIR methodology for quantifying N_2O emissions, (Liang et al., 2021), but it also incorporates the most up-to-date science, 4R practice tables, and RMs developed as part of the ON-QUE Protocol Adaption Process for the California-Western Climate Initiative linked markets (2016-2018). The Climate Action Reserve (CAR) team, along with Viresco Solutions conducted a scientific review and update on the N management protocols from Fall 2017 to Spring 2018. Practice experts started the adaptation process with the ON 4R Designation Working Group's draft 4R BMP Framework for Basic, Intermediate and Advanced Performance Levels. The Ontario Agricultural Business Association, researchers, and practitioners from across the country, participated in the adaption process. Dr. David Burton (Dalhousie University) was commissioned to conduct a literature review on updated 4R Science, progressing the 2008 era practices and evidence in the Alberta NERP[10]. Two teams of 4R agronomic and N_2O experts (East and West) took the 4R BMP drafts, assessed relevancy from the NERP perspective, and modified regional BMP tables were produced. The 4R science teams gathered in Toronto in January 2018, and, in a facilitated process of Expert Review and Input, reached consensus on the BMP suites and RMs. The process followed the ISO 14064:2 guidelines on use of expert opinion and was informed by a compilation of evidence-based N_2O science in the peer-reviewed literature. Further updates were made in October 2025 during an in-person meeting in Ottawa hosted and facilitated by Fertilizer Canada. The workshop followed a similarly rigorous process as the previous meetings, and incorporated the latest 4R BMP Guidelines released by Fertilizer Canada in September 2025. All materials and workshop consensus reports are available upon request from Fertilizer Canada[11]. These documents provide justification for the selection of BMPs and the updated RMs. The updated BMP tables have been incorporated into Table 1 below to reflect the latest consensus on 4R management.

The updated RMs are included in Table 1. These RMs are informed by the best available science and have conservatively assigned reduction modifiers for Basic, Intermediate, and Advanced performance levels of BMPs for annual crops.

Table 1: Overview of the 4R Practice Performance Levels for Different Crops in Canada[12]

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
Spring Seeded Cereals and Oilseeds Western Canada					
Basic	Ammonium based NPS sources (MAP, DAP, APP. AS) allowed for fall or spring	Optimize N Rate by: • Setting field-specific N rates accounting for realistic yield goals • Account for all fertilizer N and available N from	• Apply fertilizer N in spring before or at seeding; or • Apply fertilizer N in fall after soil cools (below 10°C for 3	• Apply in subsurface bands/injection • Surface application in season allowed	0.85 (15% reduction)

[10] Burton, D., and Land Resources Consulting Services (2018). A review of the recent scientific literature documenting the impact of 4R management on N_2O emissions relevant to the Canadian Context. Prepared for Fertilizer Canada as part of the ON-QUE Protocol Adaption Process. Dalhousie University.

[11] https://fertilizercanada.ca/our-focus/stewardship/4r-designation/

[12] For a description of the foundational scientific documents supporting this table, please see Appendix J.

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
		previous legume crops in total application • Apply N using annual soil testing and/or N balance • Rates based on provincial guidelines (as a reference) • Account for annual weather variations	consecutive days and not before Oct. 10); or • Split application between fall after soil cools and spring before or at seeding or in season (at most 1/3 of N applied) • UAN not eligible for fall application	(at most 1/3 of the N)	
Intermediate	Same as Basic, plus use of enhanced efficiency fertilizers in high moisture, high risk situations[13]: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Optimize N Rate by The same as Basic, plus: • Apply N according to sub-field zones using qualitative estimates of field variability (landscape position, soil variability) • OR if EEF is applied uniformly across the entire field, no rate adjustments are required • Where used, adjust rates to account for enhanced efficiency sources (e.g. NI, NI/UI)	Same as Basic	• Apply in subsurface bands/injection • Broadcast application utilizing double inhibitors (NI and UI)	0.75 (25% reduction)
Advanced	Same as Basic, plus, use of enhanced efficiency fertilizers in all situations: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Optimize rate by • The same as Basic and Intermediate but setting subfield zones and applying specific N rates according to quantified field variability using digitized zone maps, zone soil sampling, remote sensing (advanced variable rate) • Complement with in-season crop monitoring	Same as above, only no fall application allowed.	Same as Intermediate	0.65 (35% reduction)
Potato – Irrigated Prairie					
Basic	Ammonium based NPS sources (MAP, DAP, APP. AS) allowed for fall or spring	• Apply based on N balance or provincial guidelines for attainable yield • Set field specific rates based on previous N response history and soil types • Adjust for variety following provincial guidelines	• Split N between before or at planting and one or more in-season applications (1/3 or more of applied N) • No N application on frozen soil and/or snow-covered ground	• Broadcast and incorporate within 24 hours using tillage to a minimum depth of 2 inches • OR apply via fertigation • Consider using enhanced efficiency fertilizer in	0.85 (15% reduction)

13 Where existing soil moisture conditions combined with normal or predicted rainfall during the growing season can be expected to result in leaching, runoff, or saturated soil in more than one-fourth of the field area

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
				cases where incorporation is not possible following surface application	
Intermediate	Same as Basic, plus use of enhanced efficiency fertilizers accounting for at least 33% of total N budget: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Optimize rate by • The same as Basic but adjusting N rates based on estimates of residual N in combination with estimates of other soil supply sources (mineralization, previous pulse or other legume crops) • Soil test each field every year using georeferenced (GPS) soil tests (Drier Regions) • Develop an N rate strategy based on well-developed field management zones, adjusting N rates according to estimates of field variability	Same as Basic, plus • Include one or more in-season fertigation applications	Same as Basic, plus • Surface apply in-season application(s) using an appropriate EEF	0.8 (20% reduction)
Advanced	Same as Intermediate, plus use of enhanced efficiency fertilizers accounting for at least 70% of the total N budget: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Same as Intermediate plus, • Apply N according to quantified field variability using digitized soil maps (advanced variable rate) • Set subfield management zone N rates using a recognized N calculator or recommendation system that accounts for realistic yield goal, soil N supply characteristics, previous legume crops, and previous manure applications as well as annual weather variations • Soil test one or more management zones in each field every year using georeferenced (GPS) soil tests. • Adjust N application based on in-season and/or post-season N monitoring using technologies such as crop sensors, satellite or aerial imagery, crop N demand modelling, field scouting, and petiole testing	Same as above, only no fall application allowed.	Same as Intermediate, plus: • Apply initial application of primary N source in subsurface bands/injection. • For in-season application, surface apply primary N using an appropriate EEF followed by immediate hilling. • If using fertigation, apply N according to crop needs as determined by petiole testing (or other validated assessment approach) and with corresponding reduction of N before planting	0.7 (30% reduction)
Corn, No Manure Eastern Canada [14]					

[14] For fields receiving Manure, use the Manure BMPs outlined below in the Manure Application section of this Table. There is only a basic level of implementation due to the challenges associated with precise manure rate, time, place determinations.

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
Basic	• For spring or in-crop applications, any N fertilizer with guaranteed analysis • For fall application, only ammoniated phosphate sources (MAP, DAP, APP	Optimize Rate by: • Setting field specific N rates considering field-specific yield history and soil types in relation to yield potential of other fields on farm and in region • Account for all fertilizer N and available N from previous legume crops in total application • Apply based on N balance or provincial guidelines (e.g. OMAFRA Corn N calculator) • Consider probabilities for weather variations when setting rates	• Apply fertilizer N in spring before or at seeding • No N application (fertilizer or manure) on frozen soil and/or snow-covered ground • Note: N from NP sources allowed for all	• Apply in subsurface bands/injection • Side-band at seeding • If broadcasting urea or UAN, incorporate within 24 hours	0.85 (15% reduction)
Intermediate	Same as Basic, plus use of enhanced efficiency fertilizers accounting for at least 33% of total N budget and targeted to high moisture, high risk situations: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Same as Basic, plus: • Set zone rather than field N rates	Same as basic, except no ammoniated phosphate fall-applied	Same as Basic, plus: • Broadcast and incorporate within 24 hours; or • Surface application using NI and UI	0.75 (25% reduction)
Advanced	Same as Intermediate, plus use of enhanced efficiency fertilizers accounting for at least 70 % of total N application, targeted to all situations, except high risk: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Same as Intermediate, plus: • Variable rate based on digitized zone maps • In-field sensors of plant-available N • In-season crop monitoring • In-season or post-season assessment of N supply	Same as Intermediate, plus: • Split application in-season (at least 1/3 of N as side dress)	Same as Intermediate, plus: • Surface application limited to in-season using surface banded with NI and UI	0.65 (35% reduction)
Winter Wheat, No Manure Eastern Canada[14]					
Basic	Any N fertilizer with guaranteed analysis	• Apply N based on N balance or OMAFRA guidelines • Set field scale N rates using a recognized N calculator or recommendation system that accounts for realistic yield and protein goals, soil N supply characteristics, previous legume	• Apply primary N source as soon as practical in spring • No N application on frozen soil and/or snow-covered ground • Note: N from NP sources (MAP, DAP APP) allowed for fall at P rate	• Surface apply primary N source in spring. • Broadcast granular fertilizer and topdress liquid (UAN) using streamer nozzles or dribble	0.85 (15% reduction)

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
		crops, and previous manure applications. • Consider probabilities for weather variations when setting rates		banding equipment.	
Intermediate	Same as Basic, plus, enhanced efficiency fertilizers make up at least 33 per cent of total N application, targeted to high moisture, high risk situations: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR) *Or* • Use nitrate sources (AN, CAN, CN) where main risk is ammonia volatilization	Same as Basic, plus: • Develop sub-field management zones based on qualitative assessment of field variability such as observed landscape position and soil variability • Set management zone N rates using a recognized N calculator or recommendation system that accounts for realistic yield and protein goals, soil N supply characteristics, previous legume crops, and previous manure applications.	Same as Basic, plus: • Apply required N as topdress in the spring, as close as practical to Feekes 5 or Zadoks 30 growth stage	Same as Basic, plus: • Broadcast granular EEF forms of urea or use nitrate-based products	0.75 (25% reduction)
Advanced	Same as Intermediate, plus enhanced efficiency fertilizers make up at least 70 per cent of total N application, targeted to all situations, except high risk: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	Same as Intermediate, plus: • Develop sub-field management zones based on quantitative analysis of field variability	Same as Intermediate, plus: • Split apply N using a combination of spring top dress as soon as practical and a second spring application by Feekes 7 or Zadoks 32 growth stage	Same as Intermediate, plus: • Apply UAN treated with a UI or UI/NI in season using dribble banding equipment or streamer nozzles.	0.65 (35% reduction)
Table and Processing Potato – Rain Fed Canada					
Basic	Ammonium based NPS sources (MAP, DAP, APP. AS) allowed for fall or spring	• Apply based on N balance or provincial guidelines for attainable yield • Set field specific rates based on previous N response history and soil types • Adjust for variety following provincial guidelines	• Apply N in spring before or at seeding • No N application on frozen soil and/or snow-covered ground	• For spring application, broadcast and incorporate within 24 hours using tillage to a minimum depth of 2 inches • Consider using enhanced efficiency fertilizers in cases where incorporation is not possible following surface application	N/A (no reduction, business as usual)
Intermediate	Same as Basic, plus use of enhanced efficiency fertilizers accounting for	Same as Basic, plus: • Develop sub-field management zones	Same as Basic, plus:	Same as Basic, plus: • Apply Primary N source at or	0.85

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
	at least 33 per cent of total N budget targeted to high moisture, high risk situations: • NIs or, • Double inhibitors (NI and Urease inhibitors (UI) or, • Controlled release (CR)	based on qualitative assessment of field variability such as observed landscape position and soil variability • Set subfield management zone N rates using a recognized N calculator or recommendation system that accounts for realistic yield goal, soil N supply characteristics, previous legume crops, and previous manure applications as well as annual weather variations. • Soil test one or more management zones in each field every year using georeferenced (GPS) soil tests	• Apply nitrogen in spring at seeding (not before).	before seeding using subsurface bands/injection	(15% reduction)
Advanced	Same as Intermediate	Same as Intermediate, plus: • Develop sub-field management zones based on quantitative analysis of field variability • Apply N using digitized/automated prescriptions for predetermined management zones. • Monitor N in-season using technologies such as crop sensors, satellite or UAV imagery, crop nitrogen demand modelling, field scouting, and/or petiole testing.	Same as Intermediate, plus: • Split primary nitrogen sources between an initial application at seeding using EEFs and one or more in-season application. • For in-season application, apply immediately prior to hilling	Same as Intermediate, plus: • Apply initial application of primary N source in subsurface bands/injection • Surface apply in-season application(s) using an appropriate EEF, followed by immediate hilling	0.75 (25% reduction)
***Manure Application*[15]**					
Basic	• Available N content of manure is estimated from analysis or table values, and determined in the context of application timing and method • Any N fertilizer with guaranteed analysis • Ammonium based NP sources (MAP,	• Total N application rate accounts for all fertilizer N and available N from applied manure and previous legume crops • Apply based on N balance or provincial guidelines • Set field specific N rates for corn considering field specific yield history and soil types in relation to yield	• Fall manure delayed until after soil has cooled (10 degrees for 3 consecutive days and not before Oct. 10); target most manure application to spring • Apply fertilizer N in spring before or at seeding, or as side dress	• If injecting or banding liquid manure, apply a nitrification inhibitor (NI) • Broadcast and incorporate within 24 hours	0.85 (15% reduction)

[15] The suite of BMPs for Manure Application attempt to capture the regulatory requirements across the provinces; however, they differ regarding mandatory manure regulations. The APA needs to consider the provincial level requirements in this context when laying out the 4R Plan.

Level	Right Source	Right Rate	Right Time	Right Place	Reduction Modifier
	DAP, APP) allowed for fall	potential of other fields on farm and in region • Consider supplementing with synthetic N to ensure manure P is not overapplied • Consider probabilities for weather variations when setting rates	• No N application (fertilizer or manure) on frozen soil and/or snow-covered ground • Note: N from NP sources allowed for fall		
Pulses					
Basic	• Use inoculation (unless already adequate population in soil) to avoid adding N fertiliser • Ammonium based NP sources (MAP, DAP, APP) allowed for fall	• In season application of N allowed in cases of nodulation failure • N rate not to exceed crop removal tables or provincial recommendations	• Only apply N in season *Note: N from NP sources allowed for fall*	• Surface application in season	N/A

The GHGs considered in this methodological protocol are listed in Table 2.

Table 2: Relevant GHGs Applicable for this Protocol

GHG	Formula	Applicable to Project	Global Warming Potential (GWP) applied in the most recent NIR)
Carbon Dioxide	CO_2	Yes	1
Nitrous Oxide	N_2O	Yes	Refer to latest NIR as per Table 8
Methane – non-fossil	CH_4	Yes	Refer to latest NIR as per Table 8
Methane – fossil	CH_4	Yes	Refer to latest NIR as per Table 8

3.2 Protocol Applicability

This protocol is applicable to any farm in Canada practicing enhanced N management through the implementation of a 4R Plan, as described. Projects must be able to provide sufficient records to demonstrate practices implemented and the emission reductions being claimed under a particular program are accurate. This may include third-party verification, depending on the program design requirements. As a result, this protocol relies on the proper documentation of field practices and requires that dated farm records and similar evidence of practices be retained by the farm operator or project developer to substantiate the claim of the reductions. Supporting evidence for all emission reductions claims are to be made available to any third-party assurance provider and/or any reviewer from the project developer upon request. See Section 7 for minimum record requirements. To apply this protocol, the project developer must document proper application and demonstrate adherence to

the following requirements (unless otherwise allowed by a flexibility mechanism that has been documented and verified):

1) Evidence that an Accredited Professional Advisor (APA)-approved 4R Plan has been implemented on each farm, including:

    - The farm must be enrolled with the APA as having a 4R Plan with spatial files for each field included in the quantification; and,

    - Crops/fields not meeting protocol requirements need to have the yields and fertilizer applied to these fields removed from quantification and cannot contribute to quantification of the project's emission reductions for that year. These omitted data points should be tracked and reported on.

2) The emission reduction quantification is calculated on a mass basis using N inputs and crop mass per crop type across fields enrolled in the project. Quantification is calculated according to the following:

    - At the individual field level[16] (See flexibility mechanisms for approaches to quantification where an EcoDistrict boundary splits a field); 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.

3) Emission Reductions can be quantified by applying two types of baselines to compare to the project emissions: A 3-year average conventional baseline or one of two dynamic baseline options, which are calculated every year (refer to Section 4 for more information).

4) Only crops harvested for seed or biomass annually are eligible for participation. Annual crop types need to be the same in the baseline and project to ensure equivalency in residue N accounting (including irrigated crops in the baseline and project). See Appendix B for equivalent comparisons.

5) Burning of crop residue on a field makes that field ineligible for the year under this protocol. Annual forages grown for silage or baling are eligible.

6) A farm where fields are receiving manure, manure products or any N source with guaranteed analysis and registered as a fertilizer are eligible to participate under this protocol, but all other N sources are currently excluded from eligibility. If a crop receives an ineligible fertilizer, fields receiving the ineligible fertilizer must be excluded from quantification for the year, but the N content applied should be tracked and reported under the protocol. The APA must confirm the N content of the ineligible source.

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[16] The allows for quantification to accommodate fields at different levels (B,I,A). It is quite common for growers to use for more advanced performance on canola and wheat but not barley.

7) If using a 3-year conventional baseline approach, crops produced under irrigation in the baseline are also under irrigation in the project for the duration of the project[17].

8) If using a 3-year conventional baseline, N_2O emissions are based on the average 3 crop-type years prior to implementation of the 4R Plan. If a farm experiences a devastating baseline 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 adjacent crop year. 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 GHG emission reductions.

9) 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.

10) For the conventional baseline or Dynamic Baseline one approaches, when catastrophic crop failure occurs (i.e., owing to drought, frost, hail, weed infestation, etc.) that results in 50% or less crop yield from average, 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 project developer can either:

    - Exclude the fields/crops from the mass-based accounting for that year; or
    - Substitute in a five-year Olympic average[18] yield value from published provincial crop insurance agencies to apply a conservative average estimate.

    Any implications of N remaining in the soil due to crop loss must be addressed in the following year's 4R Plan and confirmed by soil test results/N balance calculation reviewed by an APA when determining the right rate.

11) Crop mass is required for emission quantification using the methods described in this protocol. See acceptable methods outlined in Table 12.

This protocol provides some flexibility to the above applicability conditions – presented in Section 3.4 below. This recognizes that farm cropping systems vary in levels of technology deployment and voluntary programs may vary in their rules and requirements.

3.3 Accredited Professional Advisor (APA)

An APA is a professional with academic training and experience in soil science, crop science, and/or agronomy as well as more specific knowledge of greenhouse gas management and accounting at the farm level. See Appendix G for a description of APA qualification requirements.

[17] Not relevant with dynamic baseline although proof of irrigation required in the cropping (vintage) year due to the difference in emission factors

[18] Olympic average – a truncated mean, where the highest and lowest values in a dataset are excluded before averaging the remaining values.

An APA needs to work with the grower to develop a 4R Plan. Oversight after the fact to assess implementation is also a role of the APA. Project developers (or aggregators) are required to work with the farms committed to implementing the project activities under the supervision of an APA to develop, implement, and provide evidence of implementation of the 4R Plan for their farm enterprise over the crediting period. Farms are not anticipated to start and stop implementation of the project activities over the crediting period, but annual updates to their 4R Plan are required.

An APA is required to:

1) Review and sign off on the baseline condition and calculations established by the farm and/or 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 (i.e., summer fallow or ineligible crops), and attesting to the accuracy of calculations based on the documentation. See Section 4 for a description of the baseline.

2) Sign off on the 4R Plan for each participating farm. This plan will address all farmed fields and crops under the control of the farm, and designate the performance level of all fields to be included in the quantification. The APA ensures that all N inputs and crop mass are accounted for. The details of the design of the 4R Plan are provided in Section 5.

3) Provide sign off that the 4R Plan was implemented as designed for each participating farm. It is expected that N recommendations from annual soil testing or post-harvest N balance calculations will form the basis for the following year's 4R Plan[19]. 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 APA will comply with provincial legislation and professional designations. It is the responsibility of the individual professional to ensure that their activities as an APA are not contrary to the regulatory protocol in the province(s) in which they practice.

Note: The APA sign off is not a formal validation or verification for the emission reduction project. Based on the situation, needs, and requirements, independent third-party verification is initiated by the project developer for all emissions reductions registered in the Nitrogen Management Project.

3.4 Flexibility Mechanisms

Flexibility in applying this protocol is provided in the following ways and needs to be outlined in the project documentation. Implementation of each flexibility mechanism described in the project documentation is to be independently verified:

1) One of two alternative dynamic baseline approaches (as opposed to the conventional baseline) may be employed by calculating the expected project emissions from the estimated baseline

[19] The APA is responsible for approving the soil sampling procedures for the particular protocol performance level (Basic, Intermediate, and Advanced).

emissions and the application of the reduction modifiers outlined in Table 1. See Appendix C for details on the application of the dynamic baseline approaches.

2) The project may exclude on-site fertilizer and lime distribution (see Table 6) from quantification where it can be demonstrated that no increased fuel uses from 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 (i.e., 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.

3) If a field spans multiple EcoDistricts, projects have the option of treating such fields as occurring within a single EcoDistrict, provided that they calculate GHG emission reductions for the field using the set of EcoDistrict values[20] that produce the more conservative estimate. All sets of calculations using each applicable EcoDistrict will need to be maintained to demonstrate the conservativeness of the chosen EcoDistrict.

4) Combine-mounted yield monitors can be used under the following flexibility conditions.

    a. Yield monitors are calibrated before harvest (following manufacturer's specifications)[21]. If there is no record of calibration, then a logbook by field could be sufficient if photographed with a date stamp. In addition, calibration must be performed for each crop type.

    b. Yield monitors are used with a two-factor, conservative attribution method:

        - Use Yield monitor data (field level) to attribute farm level measurements of crop mass or volume approaches;
        - For crop mass or volume approaches, use either scales, bins, or grain tank volumes and relate these to the yield monitor data, indicating which method;
        - Capture the yield monitor data and record-correlated yield measurements by field in logbooks/printouts or some other means;
        - If using newer self-calibrating combines with load cells, this is acceptable but will require proof for each crop type;
        - Use records from Crop Insurance Agencies.[22]

    c. Two methods of determining yield from the above list are required (with records). The project developer will demonstrate the most conservative outputs were chosen between the methods.

[20] This can be easily assessed by reviewing the EF_{ECO} factors in Appendix A for the two EcoDistricts that would give the lowest emission reduction estimate.
[21] It's best practice to apply data smoothing procedures to clean the yield monitor data, post-harvest, prior to using in quantification.
[22] Crop Insurance Agencies conduct audits of reported yields. This data is used for commercial terms and so assurance processes are adequate.

d. The APA is required to confirm all applications of this flexibility mechanism to generate yield data.

5) Crop Moisture Contents: In the event a farm is unable to measure crop moisture directly for a volume of crop, safe storage moisture levels as reported by government agencies can assumed[23].

6) Soil Testing and N Balance: To determine optimal rate of N application to a crop, either annual soil testing or N balance calculations reviewed by an APA are allowed. Provincial guidelines are used as a reference for crops and if the project is going to exceed the guideline by more than 10%, the agronomic professional will provide professional judgement. This approach also provides greater flexibility at a lower cost and was embraced by 4R Scientists in the science review and update of the 4R tables during the ON-QUE Climate Action Reserve protocol process (as detailed in Table 1).[24]

4. Baseline Condition

Three types of baseline conditions are allowed under this protocol: (1) a static historic benchmark baseline (conventional baseline); or (2) one of two types of dynamic baseline approaches. The quantification approach for the conventional baseline method is presented in Section 6.1.1. The quantification approach for dynamic baselines 1 and 2 is presented in Appendix C.

Under the conventional baseline condition, a 3-year average of GHG emissions per unit crop produced is quantified for each crop type based on historic N_2O emissions and fertilizer activities, prior to implementation of the 4R Plan. This provides an average rate of N_2O by crop type being fertilized based on the average over the three years prior to project implementation[25]. Comparable metrics between the baseline and the project condition are achieved by calculating emissions per mass of crop produced.

Under the dynamic baseline approaches, the project emissions reductions are calculated by applying the appropriate reduction modifiers (RMs) (for the 4R Plan implementation level of the field) to the estimated N_2O emissions of the current crop year. Under both approaches, the dynamic baseline is recalculated each year using the estimated project emissions and the conservative RM as inputs. It relies on the 4R Plan for each field, accounting for the effect of Source, Time and Place BMPs on N_2O emissions, through the RMs. N rate must be optimized according to the 4R Plan level. The dynamic nature of this approach (calculated each year) means that the N rate and the Yield are the same in the baseline and the project. Since determining the optimal rate relies on current assessments of external/internal variables down to the field and crop level, this method aligns better with the flexible

[23] For example, see here.
[24] Burton, D., and Land Resources Consulting Services. 2018. A review of the recent scientific literature documenting the impact of 4R management on N_2O emissions relevant to the Canadian Context. Prepared for Fertilizer Canada as part of the ON-QUE Protocol Adaption Process. Unpublished.

[25] If a farm experiences a devastating year that results in 50 per cent less crop yield (from an Olympic average), that year must be removed from the three-year average baseline and replaced with another crop year.

N management planning put forward under this methodology. In other words, the need to consider variables like: weather/expected moisture; crop type being planned and crop yield goals; previous crop N and residue (N credits); soil fertility sampling for residual N; balancing fertilizer cost for expected crop yield (including stabilizer use), can all be captured in a dynamic way moving forward as the Project progresses. This removes the overriding variables that are introduced when historical management is fixed, such as variability in weather conditions, increased yield goal setting as agronomic management improves over time and other management imperatives that have changed from the historic period.

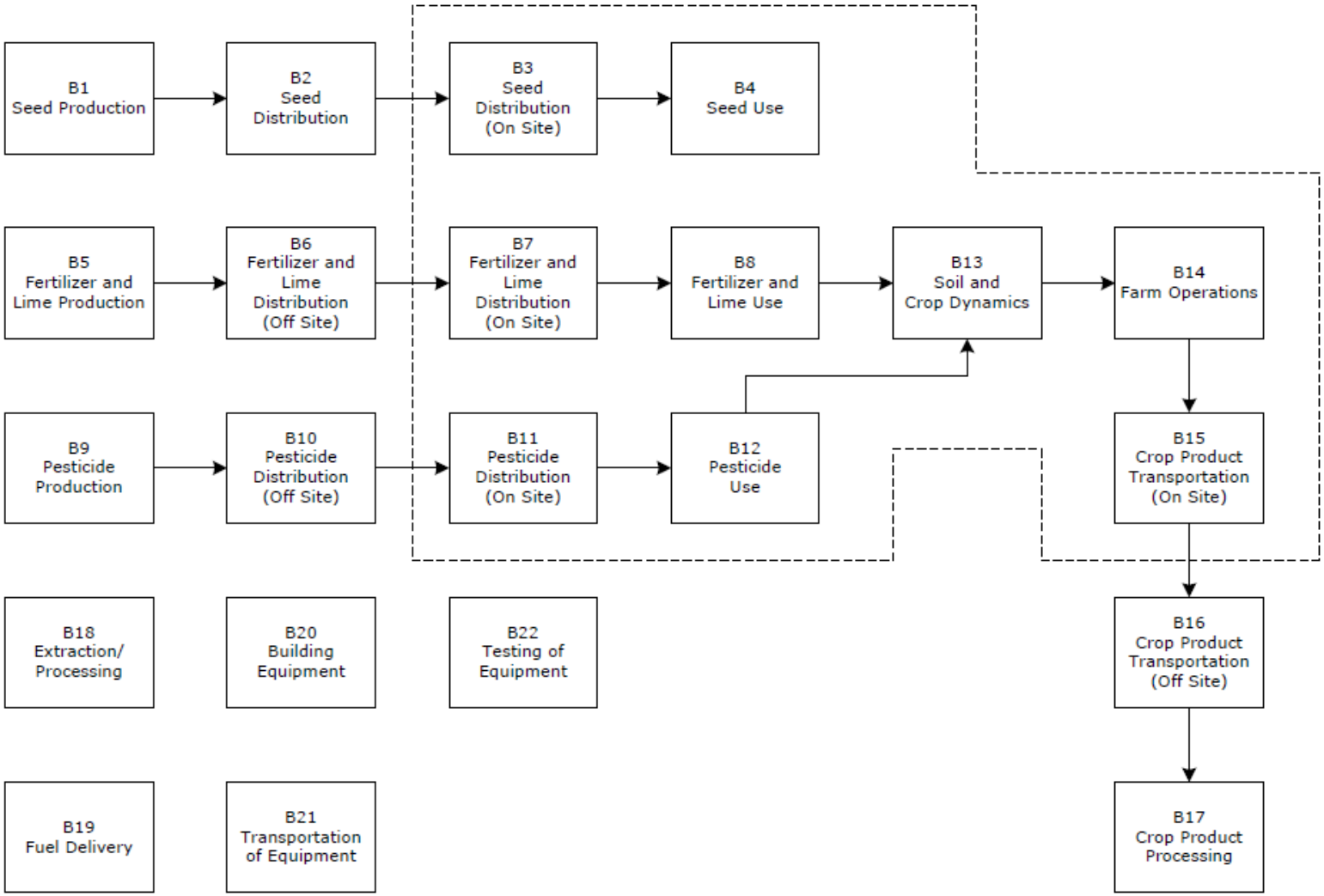
Dynamic Baseline One uses measured crop mass from farms (using one of the acceptable crop mass determination methods in Table 12 or by applying a flexibility mechanism 2 outlined above). Dynamic Baseline Two uses conservative five-year average default yields for crop risk zones across the provinces. These values are published annually by crop insurance agencies in each province. As an additional measure of conservativeness, dynamic baseline two applies a 10% discount factor.

The comparable metric for calculating emission reductions between baseline and project conditions is achieved by expressing emissions on mass of crop produced basis (functional unit). 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.

4.1 Baseline Condition Process Flow Diagram

Figure 1 presents the process and material flow for the baseline condition. The GHG assessment boundary is delineated by the dotted line around the relevant sources and sinks in the diagram.

Figure 1: Process Flow Diagram for Baseline Condition



4.2 Identification of Baseline Sources and Sinks

The identification of sources and sinks in the baseline condition is based on guidance from the ISO 14064-2: Specification with guidance at the project level for quantification, monitoring and reporting of GHG emission reductions or removal enhancements (International Organization for Standardization). Sources and sinks are determined to be either controlled, related or affected by the project activity 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, relevant stakeholders, national GHG 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 Condition Sources and Sinks

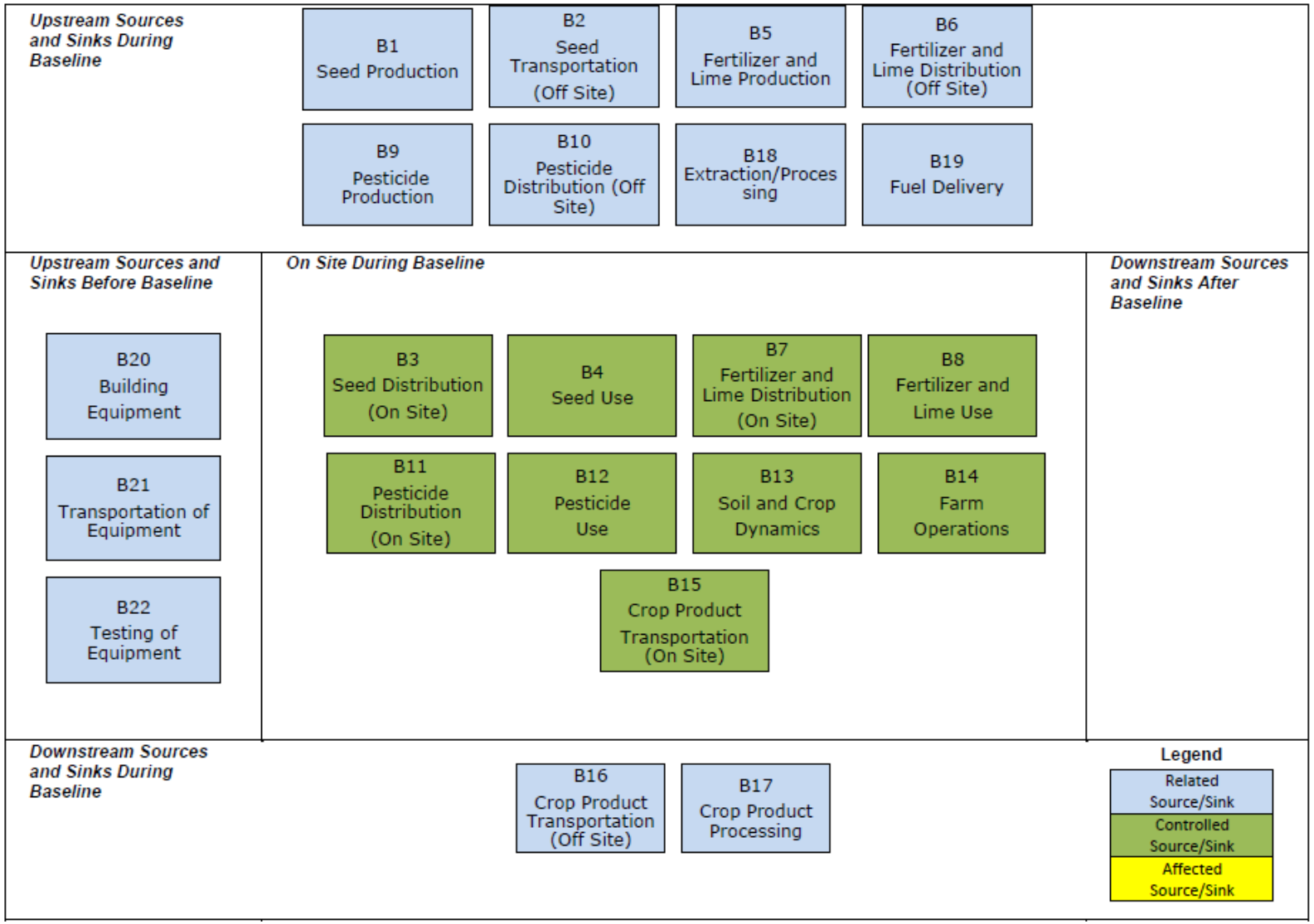


Table 3: Identification of Baseline Sources and Sinks

Sources and Sinks	Description	Type
Upstream Sources and Sinks During Baseline Operation		
B1 - Seed Production	Seed production may include several energy inputs such as natural gas, diesel, and electricity. Quantities and types of energy inputs are evaluated.	Related
B2 - Seed Transportation (Off-Site)	Seeds may be transported off-site by truck or train. Energy inputs for fuel are captured to calculate GHG emissions based on loads and distance.	Related
B5 - Fertilizer and Lime Production	Fertilizer and lime production require energy inputs such as natural gas, diesel, and electricity. Comparable metrics are calculated for GHG analysis.	Related
B6 - Fertilizer and Lime Distribution (Off-Site)	Fertilizer and lime are transported to the project site by truck or train. Energy inputs are evaluated for calculating GHG emissions.	Related
B9 - Pesticide Production	Pesticide production uses natural gas, diesel, and electricity. Quantities and energy types are analysed for GHG impact.	Related
B10 - Pesticide Distribution (Off-Site)	Pesticides are transported by truck or train, and the energy used in transportation is evaluated for GHG emissions.	Related
B18 - Fuel Extraction and Processing	Fuels are sourced, processed, and refined. The total volume and fuel types used are tracked for GHG emissions related to production and refinement.	Related
B19 - Fuel Delivery	Fuels needed for on-site project activities are transported via truck, rail, or pipeline, leading to emissions.	Related
On Site Sources and Sinks During Baseline Operation		
B3 - Seed Distribution (On-Site)	Seed is transported to storage and the field. The energy inputs for transportation are captured for GHG emissions calculations.	Controlled
B4 - Seed Use	Emissions associated with the embedded energy and materials in seeds are tracked and compared to the project condition.	Controlled
B7 - Fertilizer and Lime Distribution (On-Site)	Fertilizer and lime are transported to the field, and energy inputs are tracked for calculating GHG emissions.	Controlled
B8 - Fertilizer and Lime Use	The use of fertilizers and lime, including timing, composition, and concentration, is tracked to calculate emissions.	Controlled
B11 - Pesticide Distribution (On-Site)	Pesticides are transported from storage to the field. Energy inputs for transportation are captured to calculate GHG emissions based on loads and distance.	Controlled
B12 - Pesticide Use	Emissions related to the use of pesticides, including timing, composition, concentration, and volume of pesticides applied, are tracked for GHG impact.	Controlled
B13 - Soil Crop Dynamics	Flows of materials and energy that comprise the cycling of soil and plant organic N, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as N_2O.	Controlled
B14 - Farm Operations	GHG emissions from farm operation activities, including running vehicles and equipment. Energy inputs for farm maintenance are tracked for emissions evaluation.	Controlled
B15 - Crop Product Transportation (On-Site)	Transportation of harvested crops from the field to storage. Energy inputs for transportation are captured for GHG emissions calculations.	Controlled

Downstream SS During Baseline Operation		
B16 - Crop Product Transportation (Off-Site)	Transportation of crops from storage to the market via truck or train. Energy inputs for this process are tracked for GHG emissions evaluation.	Related
B17 - Crop Product Processing	Processing the harvested crops. Inputs of materials and energy used for processing are tracked for GHG emissions.	Related
Other		
B20 - Building Equipment	Equipment for the project may be built either on-site or off-site. GHG emissions associated with materials, processing, and assembly are tracked.	Related
B21 - Transportation of Equipment	Equipment transportation to the project site, either by truck, train, or courier. Energy inputs for transportation are included in the GHG evaluation.	Related
B22 - Testing of Equipment	Equipment testing may involve burning fuels to ensure proper functionality. GHG emissions are tracked based on fuel use during testing.	Related

5. Project Condition

The project condition, also called the 4R Plan, takes forms of N into account, in particular inorganic (synthetic) fertilizers applied to a particular crop to calculate direct and indirect N_2O emissions. Emission reductions are calculated on a crop-by-crop basis, known as crop types, in a given year for eligible fields.

The development and deployment of the 4R Plan is a practice change at the farm level and represents an additional or new activity designed to control the risk of N_2O emissions.

The 4R Plan enables this practice change through:

1) A comprehensive and professionally developed 4R Plan to account for all sources of N applied at each farm/field to address 4R management of N applicable essentially to all farmers; and

2) Providing greater assurance around N use for all farmers including those that had sophisticated N practices during the baseline period. Farmers that were already undertaking annual testing/N balance calculations or variable rate application would not achieve emission reductions without the protocol of all the BMPs in a 4R Plan (i.e., there can be no assurance that N_2O reductions are achieved without assurance that all 4Rs are addressed).

The 4R Plan, with the associated BMPs required for each performance level, is implemented to achieve a reduction of N_2O emissions in the project as compared to the baseline condition. As the performance level increases from Basic to Intermediate to Advanced, the 4R Plan must address more precisely the field variability through the development of more sophisticated suites of BMPs. The greater the performance level, the more potential there is for emission reductions as shown by a larger reduction modifier (RM) (Table 1) anchored to the optimal rate determination to ensure that synthetic N is not overapplied.

A number of resources to describe application of 4R principles are available[26] to support project implementation. Provincial crop and nutrient management guidelines, such as the Alberta Nutrient Management Planning Guide[27] can be used as a reference for technical elements of the 4R Plan such as assessing fields on site or remotely, soil sampling and testing, and calculating fertilizer requirements. The various elements of the 4R Plan and the technical methods pertinent to nutrient management are also integrated in the Fertilizer Canada training provided to APAs.

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

[26] IPNI. 2016. 4R Plant Nutrition Manual. Available at https://plantnutrition.ca/research/4r-plant-nutrition-manual/; SPRPN. 2022. Furthering 4R Nutrient Stewardship. Issue Brief 03. Scientific Panel on Responsible Plant Nutrition, Paris, France. : 10. https://www.sprpn.org/post/furthering-4r-nutrient-stewardship.

[27] Alberta Agriculture and Rural Development, 2008, Alberta's Nutrient Management Planning Guide. https://open.alberta.ca/publications/7086752

Basic Performance Level

The 4R Plan at the basic performance level will:

- Be implemented at a scale of whole fields;
- Track and use all legal land locations, shape files, and/or remote sensing to determine field locations and field size;
- Require annual soil testing/N balance assessments for each field to optimize rate of N;
- Describe field-scale sampling and annual soil testing of nitrate-N remaining in the soil from the previous year to derive fertilizer rate requirements for the upcoming crop year or use a N balance assessment by an APA[28];
- Incorporate anticipated N release from the previous year's organic soil amendments if applicable (e.g., N release from manure, legumes 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 one of the crop mass determination methods or flexibility mechanisms will be used for the emission reduction quantification; and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 7.1 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 APA's professional judgement.
- Identify and track management zones by using shapefiles, field imagery or remote sensing to determine field location and field size, and to delineate management zones;
- Require annual soil testing or N balance estimates for each field management zone to determine optimal rate;
- Describe sub-field sampling and annual soil testing of N remaining in the soil at the management zone level from the previous year; or apply an N balance assessment to derive fertilizer rate requirements for the upcoming crop year;

[28] For a description of acceptable soil sampling best practices see the Introduction to 4R Course (Fertilizer Canada) or Alberta Agriculture and Rural Development, Alberta's Nutrient Management Planning Guide.

- Incorporate anticipated N release from the previous year's organic soil amendments (e.g., N release from manure, legumes 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 the emission reduction quantification and may include use of satellite imagery for mapping acres, equipment with acres counters (must have sectional controls implanted); and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 7.1 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 soil map considering relevant soil attributes.
- Use GPS coordinates and digital imagery to determine field location and field size.
- Track and describe sub-field sampling and annual soil testing of N, or a post-harvest N balance 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;
- Incorporate anticipated N release from the previous year's organic soil amendments (e.g., N release from manure, legumes 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 subfield management zone; and
- List the data to be recorded to document activities specified in the 4R Plan (see Section 7.1 for sample data sources).

In years where an ineligible organic fertilizer is used, the remaining N available from these ineligible sources must also be addressed by the APA and incorporated into the following year's N rate recommendations. The 4R Plan will calculate the proportion of N inputs recovered in the harvested crop and determine optimal rate for the next cropping year.

5.1 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 APA. Electronic signatures are eligible as long as all required information for the APA is listed.

The 4R Plan to be implemented on the project farm's fields shall be signed by the farmer committing to the activities over the crediting period and stamped by the APA. The 4R Plan shall describe the activities to be implemented, provide the rationale for determining these activities, and specify the data to be collected to document completion of these activities.

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 for program review. The work of the APA supports the review being conducted by the verifier but does not replace it as these are two independent processes.

Soil Sampling/N Balance Assessments

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 APA. The APA will use annual soil test results from soil sampling programs to inform nutrient recommendations for each management zone in the 4R Plan. Alternatively, if applying an N Balance Assessment or other methods to optimize N rate, the APA will ensure that the method is available to the verifier and the annual soil sampling conforms to the plan.

Fertilizer

The 4R Plan must include a report on the quantity, timing, placement, and type of fertilizer N applied for each crop type. Proper placement of the fertilizer (i.e., seed bed utilization requirements) and the resolution of the supporting documentation will vary with the selected performance level (depending on the area of the management zone). The APA should identify applicable records and documentation that will support fertilizer use in the 4R Plan.

Crop Residues

Calculating the amount of crop residue N, above ground and below ground, for each crop type is a required N input in this protocol. This estimate is derived from default look-up tables provide in Appendix B of this protocol. Crop mass is the basis for deriving this N 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 N input calculations will need to be addressed in the 4R Plan. For example, the amount of N removed in these events should be treated as crop mass and using default or measured N 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
Crop-Specific Factors	kg N/kg dry matter	From Table B-1 (see Appendix B) Ratio of above-ground residue dry matter to harvested production (AGresidue_ratio) N content of above-ground residues (AGresidue_n_conc) Ratio of below-ground residue dry matter to harvested production (BGresidue_ratio), N content of below-ground residues (BGresidue_N_conc)

Manure Soil Amendments

If manure is used on the farm, the N_2O quantification method of Canada's National Inventory Report assumes that all manure N is available in the year of application. Manure is the only organic soil amendment applicable for quantification under this protocol. Project documentation should include but not limited to:

- 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 N 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 Canada 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 can be used to determine manure nutrient content. Alternatively, manure production and nutrient content tables from the reports published by the provincial organizations could 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 will be available from the confined feeding operation.

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 APA via the 4R Plan, and the project developer/aggregator.

Fertilizer Nitrogen Placement

For the prairie provinces of Western Canada, the 4R Plan anticipates 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% of the row laterally. In Eastern Canada, optimum placement depends on crop and timing, as advised by the APA.

The general equation to be applied for estimating fertilizer spread as % of the row is:

% Band Concentration =	Width of Spread/Fertilizer Opener Spacing * 100

Where:

- Width of Spread is determined by the type of opener (Table 5).
- 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, 29]											
	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[ii]	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 flow, etc. Some openers give less than 2.5 cm spread (e.g., double disc).

ii – Fertilizer concentration refers to the width of spread of fertilizer and seed relative to the row spacing. For example, a 7.5 cm spread with a 15 cm row spacing is 50 per cent seed bed utilization (7.5/15 x 100 = 50%). If the same rate of fertilizer is applied with a 7.5 cm spread and a 30 cm row spacing, the concentration of fertilizer in the seed row is doubled (7.5/30 x 100 = 25% concentration). Some openers spread seed and fertilizer vertically, and this approach cannot be applied to these spreaders.

Fall Applied Fertilizers

In drier regions, where annual precipitation is less than 100% or 1:1, of potential evapotranspiration, the 4R Plan allows for some fall application of fertilizers for spring-seeded crops, so long as the temperature of the soil is less than 10 degrees 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 publicly available

[29] The width of spread of fertilizer and seed depends on the type of opener, soil type and moisture content.

weather station data (daily high temperature) can be used to predict soil temperature using the equation below[30]. Daily high temperatures for five consecutive days must result in soil temperatures below 10 degrees Celsius using the following equation in order to support appropriate fall application of fertilizers:

Soil temperature =	0.6287t + 0.3339

Where:

- t = Air temperature in degrees Celsius (daily high)

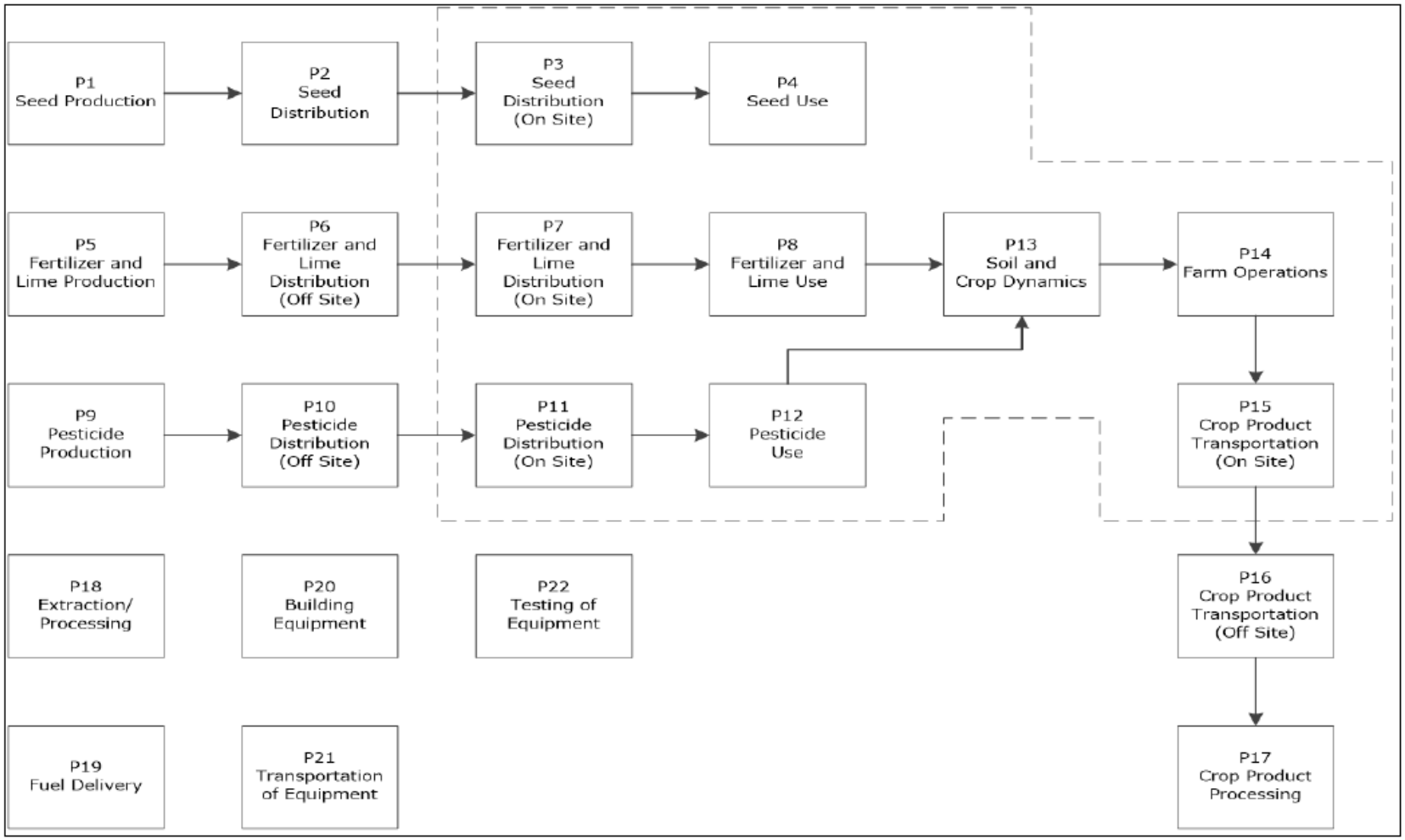
Temperature data can be obtained from the AgroClimatic Information Service maintained by Government of Canada. The APA must ensure that this is well documented in the 4R Plan.

5.2 Project Condition Process Flow Diagram

Figure 3 presents the process and material flow for the project condition. The GHG assessment boundary is delineated by the dotted line around the relevant sources and sinks in the diagram.

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

Figure 3: Process Flow Diagram for the Project Condition



5.3 Identification of Project Sources and Sinks

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

Project sources and sinks were identified by reviewing the relevant process flow diagrams, consulting with technical experts, relevant stakeholders, national GHG inventory scientists and reviewing good practice guidance. 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 condition 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

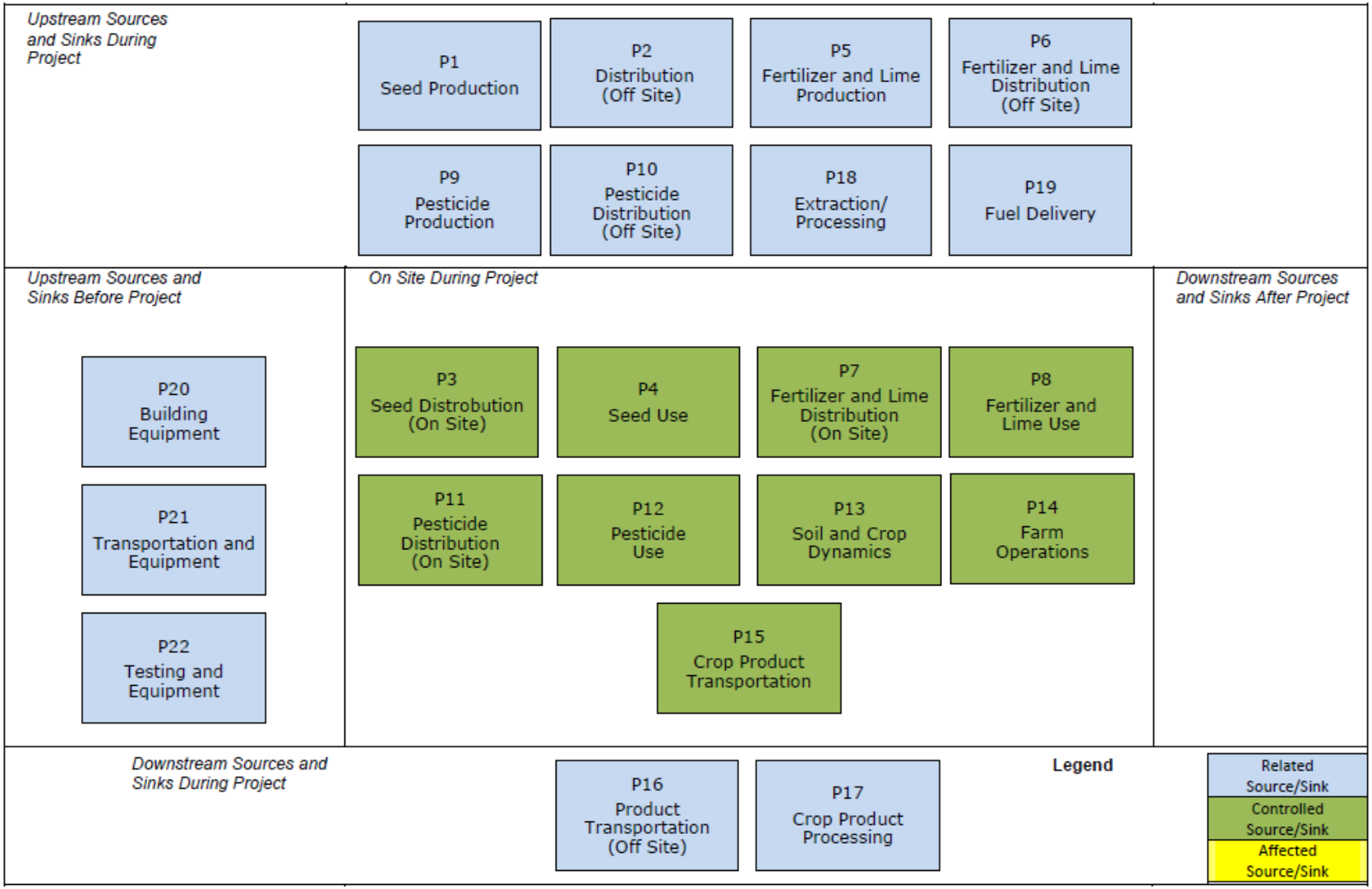


Table 6: Identification of Project Condition Sources and Sinks

Source/Sink	Description	Controlled, Related, or Affected
Upstream Sources and Sinks During Project Operation		
P1 – Seed Production	Seed production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated to evaluate 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 fueling 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 fueling this equipment are captured under this source/sink, for the purposes of calculating the resulting GHG 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 fueling 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
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 GHGs.	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 fueling this equipment are captured under this source, for the purposes of calculating the resulting GHG 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 increased fossil fuel consumption on farm due to split application of fertilizer or increased monitoring requirements. The related energy inputs for fueling this equipment are captured under this source, for the purposes of calculating the	Controlled

	resulting GHG emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	
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 fueling this equipment are captured under this source, for the purposes of calculating the resulting GHG emissions. Type of equipment, number of loads and distance travelled would be used to ensure comparable metrics with the baseline condition.	Controlled
P12 – Pesticide Use	Emissions associated with the use of the pesticide. Timing, composition, concentration and volume of pesticide 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 organic N, including deposition in plant tissue, decomposition of crop residues, stabilization in organic matter and emission as N_2O.	Controlled
P14 – Farm Operations	GHG 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 fueling this equipment are captured under this source, for the purposes of calculating the resulting GHG 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	Crops would need to be transported from storage to the market by truck, barge and/or train. The related energy inputs for fueling this equipment are captured under this source, for the purposes of calculating the resulting GHG 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 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. GHG 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. GHG 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 to ensure that the equipment runs properly. These activities will result in GHG emissions associated with the combustion of fossil fuels and the use of electricity.	Related

6. Quantification

Baseline and project conditions were assessed against each other to determine the quantification scope for the emissions reductions under this protocol. Sources and sinks are either included or excluded depending how they are impacted by the project activity. Where included, these are the relevant sources/sinks to quantify. Sources that are not expected to materially change between baseline and project conditions are excluded from quantification. This consistency between the baseline and project condition GHG emissions serves to justify the exclusion of these emission sources for projects being implemented under this protocol.

Project developers must assess included emission sources for their specific project. If assumptions are not valid for a specific project, the associated emissions must be quantified and documented in the planning and reporting mechanisms for the particular voluntary program.

All sources and sinks are identified in Table 3 (baseline) and Table 6 (project), and are listed and assessed in Table 7 below. Each source and sink are listed as included or excluded with justification to identify those that are relevant for quantification.

Table 7: Comparison of Sources/Sinks Required for Quantification

SSR	Source Description	GHG	Relevant to Baseline (B) or Project (P)	Included or Excluded	Justification/Explanation
1	Emissions from the energy inputs (such as natural gas, diesel and electricity) needed for seed production.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded because seed production is not impacted by the project activity and emissions are not anticipated to change between the baseline and project conditions.
2	Emissions from the energy inputs needed to transport seed to the project site.	CO2 CH4 N_2O	B, P	Excluded	Excluded since the amount of seed transported is likely to be the same between baseline and project and therefore emissions would be functionally equivalent.
3	Emissions from the energy inputs needed to transport seed on site.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as the emissions from seed transportation should not change materially between the baseline and project conditions.
4	Emissions from the use of seeds such as energy and material inputs.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as the emissions from seed use should not change materially between the baseline and project conditions.
5	Emissions from the production of fertilizer and lime. This may include several material and energy inputs such as natural gas, diesel and electricity.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as fertilizer and lime production will either not change materially from the baseline to project condition or fertilizer production will decrease in the project condition (in which case excluding emissions would be conservative).
6	Emissions resulting from the transport of fertilizer and lime to the project site by truck.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as emissions from transportation are likely equivalent in the baseline and project conditions since the amount of fertilizer and lime distributed is not anticipated to change.
7	Emissions associated with transporting fertilizer and lime from storage to the field.	CO_2 N_2O CH_4	B, P	Included	The implementation of 4R Plans may result in increased fossil fuel consumption on the farm due to split applications or increased monitoring requirements. The related energy inputs for fueling this equipment are captured under this source, for the purposes of calculating the resulting GHG emissions. Type of equipment,

					number of loads and distance travelled are important for comparing baseline to project condition.
8	Emissions from the use of fertilizer and lime. Timing, composition, concentration, placement and volume need to be tracked.	N_2O CO_2	B, P	Included	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.
9	Emissions from the material and energy inputs (e.g. natural gas, diesel and electricity) needed to produce pesticide.	CO_2 N_2O CH_4	B, P	Excluded	Excluded since pesticide production should not materially change between the baseline and project conditions.
10	Emissions from the energy inputs needed to transport pesticide to the farm by truck and/or train.	CO_2 N_2O CH_4	B, P	Excluded	Excluded as the emissions from transportation should not materially change between the baseline and project conditions.
11	Emissions from the transport of pesticide from storage to the field.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as the emissions from transportation from storage to the field should not materially change between the baseline and project conditions.
12	Emissions associated with the use of pesticide.	CO_2 N_2O	B, P	Excluded	Excluded as the emissions from pesticide use should not materially change between the baseline and project conditions.
13	Emissions from the cycling of soil and plant N, including deposition in plant tissue, decomposition of crop residues and stabilization in organic matter.	CO_2 N_2O	B, P	Included	Included as the emissions associated with soil crop dynamics will be materially different between the baseline and project and therefore must be quantified.
14	Emissions from the operation and maintenance of the farm facility and related equipment.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as the emissions from farm operations should not change materially between the baseline and project conditions.
15	Emissions from harvesting and transporting crops from field to storage.	CO_2 CH_4 N_2O	B, P	Excluded	Excluded as the emissions from crop harvesting and transportation should not change materially between the baseline and project conditions.
16	Emissions from transporting the crop product from storage to the market.	CO_2 N_2O CH_4	B, P	Excluded	Excluded as the emissions from transportation are negligible and should not materially change between the baseline and project condition.
17	Emissions associated with the inputs, materials and energy involved in crop product processing.	CO_2 N_2O CH_4	B, P	Excluded	Excluded as the emissions from crop product processing should not materially change between the baseline and project conditions.

18	Emissions from fuel extraction and processing for each of the fuels used throughout the project.	CO_2 N_2O CH_4	B, P	Excluded	Excluded as emissions from fossil fuel consumption will be equivalent or higher in the baseline condition. Therefore, it is conservative to exclude them.
19	Emissions associated with the delivery of each fuel used in the on-site component of the project.	CO_2 N_2O CH_4	B, P	Excluded	Excluded as emissions from fuel use should not materially change between the baseline and project condition.
20	Emissions associated with equipment building. This includes all components of the storage, handling, processing, combustion, air quality control, system control and safety systems. Emissions are 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.	CO_2 N_2O CH_4	B, P	Excluded	Emissions from building equipment are not material for the baseline condition given the minimal building equipment typically required.
21	Emissions from the delivery of equipment to the project site.	CO_2 N_2O CH_4	B, P	Excluded	Emissions from transportation of equipment are not material given the long project life and the minimal transportation of equipment typically required
22	Emissions associated with testing equipment to ensure it is operational (e.g. combustion of fossil fuels and/or the use of electricity).	CO_2 N_2O CH_4	B, P	Excluded	Emissions from testing of equipment are not material for the baseline condition given the minimal testing of equipment typically required.

Note: As part of the development of the protocol, an analysis of the downstream crop transportation/processing sources was conducted by an expert to determine if an increase in crop yields because of the project activity would increase these sources. The analysis found that even with a 30 per cent increase in yield as a result of implementing a 4R Plan, the impact on downstream crop transportation and handling emissions is immaterial (de minimus) to the overall project reduction (analysis available upon request).

6.1 Quantification Methodology

This protocol quantifies direct and indirect N_2O 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 N_2O emissions are corrected for the predominant soil type, the representative topography and the climate for the farm.

Emission reduction quantification is calculated on a mass basis using N inputs and crop mass per crop type, based on an analytical unit defined by a field in the same EcoDistrict and 4R Performance level. The project developer will quantify emission reductions in their entirety for each analytical unit and then sum the reductions across the entire participating farms/fields to obtain the emission reduction claim for that year.

The direct and indirect emissions of N_2O from soil are calculated according to N inputs from synthetic fertilizer, manure, and crop residue decomposition per crop type[31]. The N_2O emission calculations are based on the total mass of N per crop type divided by the total crop mass for each particular crop. This results in N_2O emissions per crop mass. Since the baseline represents the N management practices in place before implementation of the 4R Plan, the baseline emission calculations only account for mass of N added per crop type. This means that for the baseline condition only the mass of N inputs and yield per crop type need to be documented. N inputs from both inorganic (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 N_2O in the project involves accounting for N inputs and meeting all specified requirements for time, place, rate and source of fertilizer for the performance level being used, with documented evidence of practice change.

Projects using the conventional 3-year average baseline must account for incremental increases in GHG emissions associated with differences in the N fertilizer application practices between baseline and project (i.e. increased fossil fuel use). The APA will assess and document N fertilizer application practices prior to project implementation as part of developing the initial 4R Plan. As part of this assessment, the APA will establish and document the number of field passes used by the grower for N fertilizer application prior to project implementation.

Each year of the project, the APA will assess the N application practices relative to the baseline. Any increased emissions from additional N application passes relative to the baseline will be calculated and subtracted from the net GHG Statement for the farm. The methods for accounting for additional passes are explained with examples in Appendix E.

[31] Fields which receive organic fertilizers other than manure or crop residue must be included in the 4R Plan, but those fields are ineligible to generate emission reductions for the year in which they are used.

6.1.1 Quantification Approach

Quantification of the relevant sources and sinks for each of the GHGs are to be completed using the methods outlined in Table 8. These calculation methods serve to calculate 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. Reductions are summed across the analytical units to derive the emission reduction claim for the farm for the year. The calculations sequence for each crop type, using the conventional baseline approach, is as follows:

The CO_2e emissions in the baseline and project conditions are calculated using functional units of kilograms (kg) CO_2e per kg of crop produced on a dry matter basis. In the equations, the crop type will be referred to as crop i, representing that each project (farm) may consist of a number of crops.

1) The baseline condition (in this case, the conventional baseline) is expressed for each crop type as the three-year average kg CO_2e per kg of crop produced, or if applying one of the dynamic baselines, a one-year calculation of the kg CO_2e per kg of crop produced for each crop type (see (see Appendix C for a description of dynamic baseline quantification).

2) 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.

3) The sum of emissions from synthetic N fertilizer and crop residue (kg CO_2e 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 (see Table 1) for Basic level of application for manure).

4) The CO_2e reduction for each project crop type is calculated as the difference between the baseline emissions intensity and project emissions intensity (as calculated in Step 3 above) (kg CO_2e per kg crop produced).

5) To derive the total emission reductions (kg CO_2e) for each crop type, multiply the reduction in Step 4 above by the total mass of crop produced (kg crop produced) in the project.

6) If applicable, emissions reductions from multiple crop types are summed.

7) If applicable, emissions reductions from crops in each 4R management level and each EcoDistrict are summed.

8) Emissions from additional fuel use are subtracted from the above result to calculate total project emission reductions (see Appendix E for more information on quantification of additional fuel use).

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 ensure the GHG statement is conservative, emission reductions cannot be generated for reducing the number of field passes during the project.

6.1.2 Eligible Emission Reductions

Eligible emission reductions are calculated from a comparison of project and baseline emissions for all sources and sinks (SS) according to the three high-level equations below.

Equation 1:

Eligible Net Emission Reductions =	$[\sum EcoDistrict_j \sum 4R_{Management\ Level\ k} \sum Crop\ i\ (Emissions\ Intensity_{Baseline} - Emissions\ Intensity_{Project}) * Crop\ Mass_{Project}] - Emissions_{Fertilizer\ and\ Lime\ Dist}$

Where emission reductions are:

- $EcoDistrict_j$ = Index number for tracking EcoDistrict types
- $4R_{Management\ Level\ k}$ = Index number for tracking 4R management performance levels, within an EcoDistrict
- Crop i = Index number for tracking crop types within an EcoDistrict and within a performance level
- $Emissions\ Intensity_{Baseline}$ = Sum of the emissions under the baseline condition divided by baseline crop mass (equation 2)
- $Emissions\ Intensity_{Project}$ = Sum of the emissions under the project condition divided by project crop mass (equation 3)
- $Crop\ Mass_{Project}$ = Dry basis project crop mass for crop i
- $Emissions_{Fertilizer\ and\ Lime\ Dist}$ = Incremental emissions under SS P7 Fertilizer and Lime Distribution (on-site)
- Emission reductions are reported in tonne CO_2e

Where baseline emissions are calculated according to the following:

Equation 2:

$Emissions\ Intensity_{Baseline}$ =	$[\sum Crop\ i\ [(Emissions_{Manure\ Use} + Emissions_{Manure\ Soil\ Crop\ Dyn,\ i} + Emissions_{Urea} + Emissions_{Other\ Fert\ and\ Lime\ Use,\ Crop\ i} + Emission_{\ Other\ Fert\ Soil\ Crop\ Dyn,\ Crop\ i}) / Crop\ Mass_{Baseline\ i}] * GWP_{N2O}$

Baseline emissions sources include the following:

$Emissions\ Intensity_{Baseline}$	=	Sum of emissions under the baseline condition divided by baseline crop mass
	=	Crop i index number for tracking crop types within an EcoDistrict and within a performance level, may also be at field level (field i)
	+	Emissions from manure under SS P8/B8 Fertilizer and Lime Use
	+	Emissions from manure under SS P13/B13 Soil Crop Dynamics Emissions from Urea SS B8/P8 CO_2

+ Emissions from Urea SS B8/P8 CO_2, as applicable

+ Emissions from inorganic fertilizer and crop residues under SS P7 Fertilizer and Lime Use

+ Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics

/ Crop Mass determined in the baseline for all crops based on a three-year average, adjusted to a dry matter basis (conventional approach); see below for Dynamic Baseline Approach.

* GWP_{N_20} Global warming potential value for N_2O

Where project emissions are calculated according to the following:

Equation 3:

Emissions Intensity$_{Project}$ =	$[\sum$Crop i $[Emissions_{Manure\ Use} + Emissions_{Manure\ Soil\ Crop\ Dyn,\ i} + Emissions_{Urea} + ((Emissions_{Other\ Fert\ and\ Lime\ Use,\ Crop\ i} + Emissions_{Other\ Fert\ Soil\ Crop\ Dyn,\ Crop\ i}) * RM_{PL}) / Crop\ Mass_{Project\ i}] * GWP_{N2O}$

Project emissions sources include the following:

Emissions Intensity$_{Project}$

= Sum of emissions under the project condition divided by project crop mass

= Crop i index number for tracking crop types within an EcoDistrict and within a performance level, may also be at field level (field i)

+ Emissions from manure under SS P8/B8 Fertilizer and Lime Use

+ Emissions from manure under SS P13/B13 Soil Crop Dynamics Emissions from Urea SS B8/P8 CO_2

+ Emissions from Urea SS B8/P8 CO_2, as applicable

+ Emissions from inorganic fertilizer and crop residues under SS P7 Fertilizer and Lime Use

+ Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics

* RM_{PL} emission reduction modifier of 0.85 and 0.75 and 0.65, which corresponds to the implementation of Basic, Intermediate and Advanced 4R Plans, respectively for annual crops

/ Crop Mass determined in the project for all crops based adjusted to a dry matter basis.

* GWP_{N_20} Global warming potential value for N_2O

The dynamic baseline approach (introduced in Section 3.4 and further explained in Section 4) can be applied in this protocol. See Appendix C for equations required under the dynamic baseline approaches.

The following calculation can be used to calculate crop mass on a dry matter basis[32]:

Crop Mass$_{\text{Dry Matter Basis}}$ =	Wet Mass$_{\text{sample}}$ x %DM

Where:

- %DM = (Dry Mass$_{\text{sample}}$ / Wet Mass$_{\text{sample}}$) x 100%
- %DM = Percent dry matter of the crop
- Wet Mass$_{\text{sample}}$ = Wet mass, or harvest mass, of the bin sample used collected to determine bin moisture content
- Dry Mass$_{\text{sample}}$ = Mass of the bin sample used to determine bin moisture content after it has been dried

All quantification calculations in Table 8 using crop mass values must be conducted on a dry matter basis.

Emission reductions are reported in tonne CO_2e. Applicable equations may need to apply the GWP for the gas as well as the unit conversion below:

0.001 =	**Conversion factor, kilograms to tonnes**	**$tCO_2e/kgCO_2e$**

Emission factors for fuels can be found in the latest edition of the National Emissions Inventory Report for Canada (NIR). Applicable GWP values from the latest IPCC Assessment Report are displayed in Table 2. It may be that a particular voluntary program specifies its own GWP values so those can be used instead.

[32] 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: NERP Quantification Factors[33]

Includes each parameter, the method parameters are determined and the justification (if applicable). All variables used to calculate emissions reduction in the project are outlined in the following table.

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_2O	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 E	Quarterly reconciliation	Frequency of reconciliation provides for reasonable diligence given that the magnitude of project emissions is expected to be small
	CO_2 Emissions Factor for Extraction and Production of Each Type of Fuel/$EF_{FuelExt\ and\ prod\ CO_2}$	kg CO_2 per L / m^3 / other	Estimated	Refer to Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada.
	CO_2 Emissions Factor for Combustion of Each Type of Fuel/EF $Fuel_{Comb\ CO_2}$	kg CO_2 per L / m^3 / other	Estimated	Refer to Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada.
	CH_4 Emissions Factor for Extraction and Production of Each Type of Fuel/$EF_{FuelExt\ and\ prod\ CH_4}$	kg CH_4 per L / m^3 / other	Estimated	Refer to Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada.
	CH_4 Emissions Factor for combustion of Each Type of Fuel/$EF_{FuelExt\ and\ Prod\ CH_4}$	kg CH_4 per L / m^3 / other	Estimated	Refer to Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada
	GWP for CH_4/GWP_{CH_4}	Unitless	Estimated	Refer to Canada's NIR Report	N/A	Must use most current factors published in the latest NIR Report for Canada
	N_2O Emissions Factor for Extraction and Production of Each Type of Fuel/$EF_{FuelExt\ and\ Prod\ N_2O}$	kg N_2O per L /m^3 / other	Estimated	Refer to Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada

[33] Note – the above quantification is based on growing season emissions as per the National Emissions Inventory methodology. It does not apply the RF for full growing season emissions (1/0.63) in the NIR, similar to the Alberta NERP v 2.1.

	N_2O 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 Canada's NIR Report	Annual	Must use most current factors published in the latest NIR Report for Canada
	GWP for N_2O/GWP_{N_2O}	Unitless	Estimated	Refer to Canada's NIR Report	N/A	Use most current factors published in the latest NIR Report for Canada
B8/P8 - Fertilizer and Lime Use (manure)	$Emissions_{Manure\ Use,\ Crop\ i} = N_{Manure\ Crop\ i} * (EF_{ECO} * RF_NS_{k=ON,\ m} * RF_CS_m *) * MolarRatio$					
	Manure Use Emissions – $Emissions_{Manure\ Use,\ crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Manure N 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_2O - N / kg N	Estimated	Calculated using e(0.00558*P7.701) where P is the long term mean precipitation from May 1 to October 31 for EcoDistrict i. Also integrates influence of texture, tillage, and topography. Refer to Canada's NIR report.	Annually	Use the EF_{ECO} for the EcoDistrict the farm is located in, which is adjusted for the tillage situation and irrigation management. The EF_{ECO} value for each EcoDistrict is listed in Appendix A
	Ratio factor for organic N source k=ON in cropping system m – $RF_NS_{k=ON,\ m}$	Unitless	Estimated	For organic N sources use factor 0.84	Annually	Use most current factors published in the latest NIR Report for Canada
	Ratio factor for cropping system (annual or perennial) – RF_CS_m	Unitless	Estimated	For annual cropping systems use factor 1.0	Annually	Use most current factors published in the latest NIR Report for Canada
	MolarRatio	Unitless	N/A	MolarRatio = 44/28	N/A	This molar ratio fraction converts N to N_2O based on the molecular weight of N_2O and N_2
B8/P8 - Fertilizer and Lime Use (direct N_2O from synthetic N)	$Emissions_{Other\ Fert\ and\ Lime\ Use,\ Crop\ i} = N_{FN\ Crop\ i} * (EF_{ECO} * RF_CS_m) * MolarRatio$					
	Other (inorganic fertilizer and crop residue) Fertilizer and Lime Use Emissions – $Emissions_{Other\ Fert\ and\ Lime\ Use,\ Crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Synthetic N 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 Local Soil and Climatic Conditions – EF_{ECO}	kg N_2O - N / kg N	Estimated	Calculated using e(0.00558*P7.701) where P is the long term mean precipitation from May 1 to October 31 for EcoDistrict i.	Annually	Use the EF_{ECO} for the EcoDistrict the farm is located in, which is adjusted for the tillage situation and irrigation management.

				Also integrates influence of texture, tillage, and topography. Refer to Canada's NIR report		The EF_{ECO} value for each EcoDistrict is listed in Appendix A
	Ratio factor for cropping system (annual or perennial) – RF_CS_m	Unitless	Estimated	For annual cropping systems use factor 1.00	Annually	Use most current factors published in the latest NIR Report for Canada
	MolarRatio	Unitless	N/A	MolarRatio = 44/28	N/A	This molar ratio fraction converts N to N_2O based on the molecular weight of N_2O and N_2
B8/P8 – Fertilizer and Lime Use (urea CO_2)	Urea CO_2 Emission = $\sum (M_{Urea,\,i} \times EF_{Urea}) * MolarRatio$					
	Annual C emissions from urea application CO_2 Emission	tonne CO_2e	N/A	N/A	Annually	Quantity being calculated
	Annual amount of urea fertilization $M_{Urea,\,i}$	tonne Urea	Measured	Direct measurement during application	Annually	Direct measurement is the most accurate method
	Emission factor EF_{Urea}	tonne C / tonne Urea	Estimated	Emission factor of 0.20	N/A	As per Canada's latest National Inventory Report quantification method
	MolarRatio	tonne CO_2 / tonne C	N/A	MolarRatio = 44/12	N/A	This molar ratio fraction converts carbon (C) to CO_2 based on the molecular weight of CO_2 and C
B13/P13 – Soil and Crop Dynamics (indirect N20 from manure)	$Emissions_{Manure\ Soil\ and\ Crop\ Dyn,\ Crop\ i} = ((N_{Manure\ Crop\ i} * FRAC_m * EF_{VD}) + (N_{Manure\ Crop\ i} * FRAC_L * EF_L)) * MolarRatio$					
	Manure Soil and Crop Dynamics Emissions – $Emissions_{Manure\ Soil\ and\ Crop\ Dyn,\ Crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Manure N per crop i – $N_{Manure\ Crop\ i}$	kg N	Measured	Direct measurement during application	Continuous	Direct measurement is the most accurate method
	Fraction of Manure N Applied to Soils that Volatizes as NH_3-N and NOx-N – $FRAC_m$	Unitless	Estimated	Default factor for dairy 0.11 and swine 0.13. Default factor set at 0.21 for manure other than dairy and swine.	Annually	As per Canada's latest National Inventory Report quantification method
	Emission Factor for N_2O from N Redeposited after Volatilization – EF_{VD}	kg N_2O - N / kg N	Estimated	Default factor set at 0.005 kg N_2O - N / kg N	Annually	As per Canada's latest National Inventory Report quantification method
	Fraction of N Lost in Leachate – $FRAC_L$	kg N	Estimated	Calculated using based on a relationship of precipitation and	Monthly	The $FRAC_{Leach}$ value for each EcoDistrict within Canada is listed in Appendix A. As per Canada's National Inventory Report

				irrigation to potential evapotranspiration for the area		quantification method. For irrigated fields, use a $FRAC_L$ = 0.3
	Emission Factor for N_2O from Leachate – EF_L	kg N_2O - N / kg N	Default	Default factor set at 0.0075 kg N_2O - N / kg N	Annually	As per Canada's latest National Inventory Report quantification method
	MolarRatio	Unitless	N/A	MolarRatio = 44/28	N/A	This molar ratio fraction converts N to N_2O based on the molecular weight of N_2O and N_2
B13/P13 - Soil and Crop Dynamics (N_2O from crop residue)	$Emissions_{Other\ Soil\ and\ Crop\ Dyn,\ Crop\ i} = ((N_{Res\ crop\ i} * EF_{ECO} * RF_NS_{k=ON,\ m} * RF_CS_m) + (N_{VD\ Crop\ i} * EF_{VD}) + (NL_{Crop\ i} * EF_L)) * MolarRatio$					
	Other (inorganic fertilizer and crop residue) Soil and Crop Dynamics Emissions – $Emissions_{Other\ Soil\ and\ Crop\ Dyn,\ Crop\ i}$	kg N_2O	N/A	N/A	N/A	Quantity being calculated
	Total Amount of Crop N that is Returned to the Cropland Annually – $N_{Res,\ Crop\ i}$	kg N	Calculated	Calculated as per the equation given below	Annually	Calculated as per the equation given below
	Emission Factor Related to Local Soil and Climatic Conditions – EF_{ECO}	kg N_2O - N / kg N	Estimated	Calculated using e(0.00558*P7.701) where P is the long term mean precipitation from May 1 to October 31 for EcoDistrict i. Also integrates influence of texture, tillage, and topography. Refer to Canada's NIR report.	Annually	Use the EF_{ECO} for the EcoDistrict the farm is located in, which is adjusted for the tillage situation and irrigation management. The EF_{ECO} value for each EcoDistrict is listed in Appendix A
	Ratio factor for organic N source k=ON in cropping system m – $RF_NS_{k=ON,\ m}$	Unitless	Estimated	For crop residue in annual cropping systems use 0.84	Annually	As per Canada's latest National Inventory Report quantification method
	Ratio factor for cropping system (annual or perennial) – RF_CS_m	Unitless	Estimated	For annual cropping systems use factor 1.00	Annually	As per Canada's latest National Inventory Report quantification method
	Emissions of N_2O from Volatilization and Re-deposition of NH_3 and NOx per Crop i – $N_{VD\ Crop\ i}$	kg N	Calculated	Calculated as per the equation given below	Annually	Calculated as per the equation given below
	Emission Factor for N_2O from N Redeposited after Volatilization – EF_{VD}	kg N_2O - N / kg N	Estimated	Default factor set at 0.005 kg N_2O - N / kg N	Annually	As per Canada's latest National Inventory Report quantification method
	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	Calculated as per the equation given below
	Emission Factor for N_2O From Leachate – EF_L	kg N_2O - N / kg N	Default	Default factor set at 0.0075 kg N_2O - N / kg N	Annually	As per Canada's latest National Inventory Report quantification method

	MolarRatio	Unitless	N/A	MolarRatio = 44/28	N/A	This molar ratio fraction converts N to N_2O based on the molecular weight of N_2O and N_2
B13/P13 - Soil and Crop Dynamics (crop residue N input to cropland)	$N_{Res\ Crop\ i}$ = Crop $Mass_{Cop\ i}$ * (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 N 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 – Crop $Mass_{Crop\ i}$	kg DM	Measured	Direct measurement	Annually	Direct measurement is the most accurate method
	Fraction of Total Dry Matter Production that is Harvested – Yield Ratio	Unitless	Estimated	This value is determined using the Table B.1 in Appendix B: Crop Residue Nitrogen Factors. 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 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 to Harvested Production for Crop i – $R_{AG\ Crop\ i}$	Unitless	Estimated	This value is determined using Table B.1 in Appendix B: Crop Residue Nitrogen Factors. The value is from the sixth column (AG residue_ratio) for the appropriate crop	Annually	Values are attained from Holos 2008 methodology (produced by Agriculture and Agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions
	N Content of Above- Ground Residues for Crop i – $N_{AG\ Crop\ i}$	kg N / kg DM	Estimated	This value is determined using Table B.1 in Appendix B: Crop Residue Nitrogen Factors. 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 Table B.1 in Appendix B: Crop Residue Nitrogen Factors. The value is from the seventh column (BGresidue_ratio) for the appropriate crop	Annually	Values are attained from Holos 2008 methodology (produced by Agriculture and Agri-food Canada) which is based on IPCC methodology but has been modified to account for Canadian specific conditions

	N Content of Below- Ground Residues for Crop i – $N_{BG\ Crop\ i}$	kg N / kg DM	Estimated	This value is determined using Table B.1 in Appendix B: Crop Residue Nitrogen Factors. 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 (indirect N_2O from fertilizer)	$N_{VD\ Crop\ i} = (N_{Fert\ Crop\ i} * FRAC_F)$					
	Indirect Emissions of N from Volatilization and Re-deposition of NH_3 and NOx per Crop i – $N_{VD\ Crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic N Fertilizer Use per Crop i – $N_{Fert\ crop\ i}$	kg N	Estimated	Direct measurement	Annually	Direct measurement is the most accurate method
	Fraction of Synthetic Fertilizer N Applied to Soils that Volatizes as NH_3- and NOx-N – $FRAC_F$	Unitless	Estimated	Default factor set at 0.06 for commercial fertilizer	Annually	As per Canada's latest National Inventory Report quantification method
	$N_{L\ Crop\ i} = (N_{Fert\ Crop\ i} + N_{Res,\ Crop\ i}) * FRAC_L$					
	Indirect Emissions of N from Leaching per Crop i – $N_{L\ Crop\ i}$	kg N	N/A	N/A	N/A	Quantity being calculated
	Synthetic N Fertilizer Use per Crop i– $N_{Fert\ Crop\ i}$	kg N	Measured	Direct measurement	Continuous	Direct measurement is the most accurate method
	Total Amount of Crop N 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 latest National Inventory Report quantification method
	Fraction of N Lost in Leachate – $FRAC_L$	Unitless	Estimated	Calculated using based on a relationship of precipitation and irrigation to potential evapotranspiration for the area	Monthly	The $FRAC_{Leach}$ value for each EcoDistrict within Canada is listed in Appendix A. As per Canada's National Inventory Report quantification method. For irrigated fields, use a $FRAC_L = 0.3$

7. Data and Evidence Management

Documentation (farm data, documents and records) is a key element to project development, verification, and meeting Nitrogen Management project requirements under this protocol. The types of document and records required to demonstrate that an emission reduction project meets the protocol requirements can vary by project, and by voluntary program. There are multiple aspects to the data and evidence needed to support the projects – guidance is provided by this protocol and the accounting basis of ISO 14064 process-based standards. For projects, it is necessary to collect:

- **Primary farm activity data –** the data collected from the project/farm to calculate the GHG reductions according to Table 8 along with default factors provided for calculations (measurement and monitoring); and
- **Supporting evidence that activities have occurred –** either farm-level or third-party source documentation – this evidence becomes part of the monitoring and reporting providing "Positive Proof" that activities occurred. This facilitates verification.

It is the project developer's responsibility to ensure they are meeting all requirements and clearly document how they meet the voluntary program requirements in the project documentation, supported by any data management systems (sometimes called MMRV – measuring, monitoring, reporting and verification).

The verification process relies heavily on the quality and availability of documentation to support each emission reduction. Projects are verified to meet requirements of the particular voluntary program so objective evidence of project implementation is required to make an emission reduction claim. Reasonable assurance means the verifier is able to reach a positive finding on the accuracy and correctness of the GHG Statement of Reductions/Removals.

To support any potential verification, the project needs to meet the following criteria (see Appendix I for sample monitoring plan):

- All records must be kept in areas that are easily located;
- All records must be legible and dated;
- All records must be maintained in an orderly manner;
- All documents must be retained in accordance with regulatory requirements (if required);
- Electronic and paper documentation are both satisfactory; and
- Copies of records should be stored to prevent loss of data.

The project developer shall establish and apply quality management procedures to manage data and information. Best practice is to have written procedures for each measurement task outlining responsibility, review, timing and record location. The greater the rigour of a management system for the data, the more efficient the verification process can be conducted for the project.

7.1 Documents

Documentation in the form of documents and records is a key element to project development. Documents are required to demonstrate that a project meets program criteria, eligibility, baseline eligibility and project emission reduction quantification requirements. Examples of documents include the 4R Plan(s), established procedures, specifications, drawings, regulations, standards, guidelines, training certificates etc. These documents must include a list of records available to a reviewer that demonstrate the voluntary program criteria have been met. The project documents should also indicate how the records will be managed (i.e., retention, storage and access).

Documents may be stand-alone or interdependent but must be complete. Documents may be subject to change or periodic update. The project developer must be able to demonstrate that the relevant version of a document is being used.

The project planning documents must be specific and detail the documentation requirements for the particular program. 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. The project developer will need to provide a reviewer with objective evidence of project implementation.

Documents and records are required to be:

- Legible, identifiable and traceable;
- Centrally located;
- Dated;
- Easily located (easily searched); and
- Orderly and prevented from loss.

7.2 Records

Records/evidence 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, components of the 4R Plans, and soil testing/N balance results. Where the project developer is different from the person or entity implementing the activity, both must maintain sufficient records to support the project and any emission reduction claims. If the project developer or farm and/or farmed fields ownership changes, sufficient records must be provided to the new owner to support any previous claims. Table 9 outlines the minimum general records needed to support this protocol.

7.2.1 General Records Requirements

Table 9: General Records Requirements

Record Requirement	Examples of Records	Why Required
Right to Transact on Emission Reductions	• Contract between the project developer/aggregator and farm operator for the assignment of the emission reduction rights. This includes agreement to provide access to data needed to quantify the GHG statement for the farm	To confirm the right to transact on the voluntary program outcomes
Locations of the Farm Included in Project	• Legal land location(s) (Township System and additional boundary file or central GPS coordinates) within the farm • EcoDistrict location(s) within the farm enterprise boundary	Farm Boundary must be included in the project management system EcoDistrict locations required for emission reductions accounting
Use of Irrigation if Applicable	• Supporting documentation for water usage on the field by farm operator including two of the following: o Water use records o Photo evidence with GPS time stamp showing equipment used including model information o Crop insurance records noting use of irrigation o Air photo or satellite imagery showing pivots o Provincial Irrigation Program documents o Detailed farm maps showing coverage of irrigation networks over project fields including type and model numbers for equipment being used • OR o Sign off by the APA who reviewed and collected supporting documentation that confirm the irrigation practice o Copy of supporting documentation reviewed by the APA	Irrigation impacts N_2O emissions from agricultural soils Irrigation status required to properly calculate project emission reductions
APA credentials	• Confirmation that the APA has successfully completed the Fertilizer Canada 4R Nutrient Stewardship Courses (1-3) and NERP course (APA Certificate)	To ensure that the participants of this protocol have training and credentials required

7.2.2 Baseline Considerations

The baseline N_2O emissions are calculated per mass of crop type produced as the average over the three years prior to project implementation (conventional baseline)[34]. 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).

[34] Refer to Sections 3.4 and 6.1 for details on flexibility of the 3 years required and what to do if new crop types are introduced to the project.

Direct evidence is required to substantiate the mass of N inputs for each crop type for each of the three years used to derive the baseline emissions of N_2O 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 in the Three Years Used to Establish the Baseline	Farm records indicating the crop type grown for each field in the project; one of the following: • Crop Insurance records, hail insurance records by field • Signed records from a crop advisor • Seed purchase receipts	To establish the crop types in the baseline and project
Crop Mass (by Crop) Grown for Each of the Three Years Used to Establish the Baseline	• Selection of one of the acceptable crop mass determination methods, or flexibility mechanisms as provided in the protocol • Supporting documentation for the selected crop mass determination method	For GHG quantification
Mass of N Fertilizer Applied by Crop Type Across the Eligible Fields in Each of the Three Years Used for the Baseline	• Invoices showing nutrient composition and quantity of fertilizer purchased • Farm log of fertilizer application masses and dates • Custom application receipts	For purposes of preparing the 4R Plan and GHG quantification
Quantity, Composition, and Application Date of Manure Applied by Field for Each Year in the Baseline	Manure Management Plans, including manure analysis or referenced manure nutrient values as outlined in Section 5.1. One of the following: • Farm records indicating the manure applied by field. • Custom application receipts.	For GHG quantification
Baseline Calculation Records	• Set of baseline calculations signed off by the project developer and APA • Years used to calculate baseline values • Supporting documentation describing baseline quantification, including calculations and factors used • If non-consecutive years are chosen for development of conventional baseline for a crop (and the crop was grown in un-used years), trend data on extreme weather events to demonstrate how the year is excluded will be required	Baseline calculations required for project verification

i - Custom manure applicators or operators who apply, transfer or receive more than 500 tonnes of manure per year should keep records for a minimum of five years and must conduct soil tests. For more information, see related Manure management guidelines and legislation and Manure Management Record Keeping Regulations published by provinces.

7.2.3 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]	• EcoDistrict location of each field/management zone determined using the tool[ii] provided by the provincial and federal government • Legal land location (Township System) with boundary file and central GPS coordinates • Specific location, area, and boundaries of each 4R management zone using satellite or aerial photos	Key input to the 4R Plan to ensure fields/sub-fields are in the same EcoDistrict
Crop Type Grown for Each Management Zone[iii]	• Farm records indicating the crop type grown for each management zone in the project • Crop insurance agency hail insurance records • Signed APA records of field observations	Key input for 4R Plan to establish the crop grown in the project year
4R Practices by Management Zone	• 4R Plan signed by the APA showing BMPs applied to all management units • 4R Plan detailing source BMPs by management zone • 4R Plan detailing time BMP by zone, including fertilizer application dates	To confirm proper BMPs are applied, and the reduction modifier is being applied in GHG emission reduction calculations
Available N	• APA sign off on records outlining soil sampling methodology and N rate recommendations per management zone • Annual soil testing for N application rates based on 4R levels (Basic, Intermediate, or Advanced) • Description of alternate tools if soil testing cannot be completed	Key input to the 4R Plan for N application and soil management recommendations
Quantity, Composition, and Application Date of N Fertilizer Applied by Crop Type Included in the Project	• 4R Plan indicating the recommended quantity and composition of fertilizer • Invoices showing quantity and composition of fertilizer purchased • Reconciled total N applied per crop type	To assess conformance to the 4R Plan and for GHG quantification
Soil Temperature Readings	• Soil temperature readings for fall N applications according to the 4R Plan, taken for five consecutive days when soil temperature is calculated to be less than 10°C	To ensure fall soil applications occur under the correct conditions required by the protocol
Fertilizer Placement Equipment	• Annual provision of date-stamped photos of fertilizer banding or spreading equipment • Evidence of calibration to equipment manufacturer's specifications One of the following: • Width of fertilizer openers and spacing to determine the percent band concentration[iv], or • Invoices or a letter from custom fertilizer application that indicates the type of opener and row spacing for each field	To assess conformance to the 4R Plan, ensuring equipment is aligned with 4R recommendations

Quantity, Composition, and Application Date of Manure Applied by Field	• Manure management records including nutrient analysis or referenced nutrient values • Signed off records by the APA confirming N content of applied manure	For GHG quantification of N from manure application
Crop Mass by Crop Type, Dry Matter Basis (for Each EcoDistrict and 4R Performance Level)	• Estimation of crop yield at field level for evaluating the 4R Plan • Supporting documentation for selected crop mass determination method • Crop insurance agency data for yields and risk assessment	Crop mass used for GHG quantification and evaluating the 4R Plan
Additional Supporting Farm Records	• Farm records noting extraordinary situations (crop damage, flooding, infestations, etc.) • Listing of ineligible fields or subfields in the Aggregated Project Reporting Sheet (APRS)	To support proof of 4R Plan implementation and describe variances
Confirmation that 4R Plan was Conformed to by the Farm Operator	• Annual sign off by the APA that the 4R Plan was conformed to, including fields under ineligible crops or management practices	Implementation sign off by the APA
Additional Field Passes	• Analysis by the APA of additional equipment passes per 4R management unit (as a result of the 4R Plan) • Sale receipts indicating fuel type • Field logs for additional passes with satellite data	Emissions associated with fuel usage from additional passes as part of 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.

ii - The EcoDistrict must be specified to determine the appropriate factor to quantify N_2O 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 records are a requirement for larger operations in some provinces like Alberta under the *Agricultural Operation Practices Act*. The records need to document who manure is sold or given to and where it's being applied and at what rate. Nutrient content of the manure is required as well.

Table 12: Crop Mass Determination Methods Records Requirements

See Appendix F for greater details regarding crop mass determination record requirements

Record Requirement	Examples of Records	Why Required
Mobile Weighing Devices	• Calibration report (digital printouts) showing equipment was calibrated by a qualified third party before harvest • Weight log of each load[35] • Crop moisture log (minimum 3 tests per crop type/day) • A log of crop moisture readings shall be maintained. 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

[35] In the event the weight log is less than the project claim, the weight log shall prevail.

Fixed Scale	• Calibration report showing equipment calibration by a qualified third party • Weight log of each load[36] • Crop moisture log (minimum three tests per crop type/day) • A log of crop moisture readings shall be maintained. 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 Scale Tickets)	• Scale tickets specifying load mass and crop type • Moisture determination result linked to each load in a moisture log	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Bin Volume	• Method and calculations used for bin volume measurements • Third-party sign off before harvest • Bin moisture test results or average for the bin • Crop must be segregated by bin	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations
Flexibility Mechanism 4: Combine-Mounted Yield Monitors	• Calibration report or evidence of yield monitor calibration for each crop type • If no calibration report, then photograph of logbook by field, date stamped • Apply the 2-Factor conservative attribution method, with justification (see Flexibility Mechanism 4) • Safe bin storage moisture levels sufficient. Adjust by DM values in Appendix B.	To determine crop mass on a dry matter basis for mass-based GHG reduction calculations

7.3 Record Keeping

Projects must be supported with data of sufficient quality to fulfil the quantification requirements and be substantiated by records.

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 project;
- All emissions and reductions that should have been recorded have been recorded;
- Emissions and reductions quantification has been recorded appropriately and counted once;
- Emissions and reductions have been recorded in the correct reporting period;
- Emissions and reductions have been recorded in the appropriate category; and
- An auditable data management system.

[36] In the event the weight log is less than the project claim, the weight log shall prevail.

Based on these requirements, data must be quantifiable, measurable and verifiable using replicable means. That is, any independent reviewer 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. A sample monitoring plan is provided in Appendix I for reference. Written procedures must be established for each measurement task outlining responsibility, timing and record location requirements.

Where the project developer is different from the party implementing the activity, as in the case of an aggregated project; the individual farmer and the aggregator, must all maintain sufficient records to support the project. The project developer (farmer and aggregator) must keep the information listed below and disclose all information to the verifier and/or government regulator upon request.

Table 13: Responsibilities for Data Collection and Retention

Entity	Data Collection and Retention Responsibilities
Farm Operator	• Work with the APA to develop the 4R Plan and commit to annual implementation during the crediting period • Perform BMPs according to the 4R Plan • Provide farm records and documentation to the project developer/aggregator. Retain original records
Project Developer/Aggregator	• Responsible for record-keeping, record coordination, and due diligence to support project implementation • Primary source for third-party verification and government reviews • Collect and manage copies of farm records and supporting documentation
Accredited Professional Advisor (APA)	• Review and sign off on baseline conditions and calculations in the 4R Plan • Oversee/review annual soil testing or N balance calculations, provide N recommendations, and sign off on 4R Plans • Ensure farm boundaries and N inputs/crop mass are accurately accounted for • Annual sign off on 4R Plan implementation

To support the third-party verification and any government review, 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.

7.4 Site Visits

A risk-based sample size of farms site visits is required for verification, per the Standard for Validation, Verification and Audit, and all farms should be visited at least once over the life of the project. Verifiers will do physical inspections for equipment practices and other inspections. All farmers participating in a project should be prepared to receive a verifier. By having documentation on hand at the farm, such visits will be easily accommodated.

7.5 Quality Assurance/Quality Control (QA/QC) Considerations

QA/QC procedures are applied to ensure that all measurements and calculations have been made correctly. Project developers remain responsible for clearly providing evidence and information that support their emission reduction project meet all rules and requirements of the system, regulation, and protocol. QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly.

Some standard QA/QC procedures 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 electronic 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.

7.6 Quality Principles

The following are requirements for all Nitrogen Management Projects:

- **Do No Harm:** No social or environmental harm to the people, communities, and ecosystems. Projects must adhere to legal designations of land, protected areas, conservation easements, and any restrictions already in place associated with land use, land-use change and forestry.

- **Legal & Carbon Rights:** The necessary legal and contractual authority is in place to claim carbon impacts.

- **Real, Measurable, & Verifiable Impact:** Emissions reductions and removals are quantified using rigorous, transparent, and verifiable methodologies that produce

consistent results over time. Additional independent verification may be required based on that size and materiality of each program.

- **Integrity & Permanence:** Climate benefits associated with any quantified impacts remain in place throughout the duration of the project's time period (i.e., have not been released back into the atmosphere).
- **Proper Risk Mitigation:** Risk levels associated with a loss of permanence are matched to long term monitoring plans, conservative issuance, and proper buffer reserves that maintain program integrity in case of reversals.
- **Avoid Double Counting:** Safeguards are in place to transparently track, report, and minimize the risk of double counting.
- **Meets Project Developer's Eligibility & Quality Requirements for Inset:** Clearly link the project developer's actions with the associated impact guidance laid out in the Standard document of project developer or have taken the proper steps of requesting and receiving an exception for any scenarios not addressed in this document.

7.7 Supplier Engagement

Additionality (Applicable for the Offset Projects Only)

Demonstrating additionality is required for allocating a claim to project developer.

To allocate any climate claim to project developer, the project must demonstrate that the project scenario provides additional climate benefits over the business-as-usual scenario.

Required additionality categories are:

- **Regulatory:** Interventions must not be adopted due to regulatory or policy requirements.
- **Common Practice:** Interventions must not be common practice (>20 per cent implementation) in geographic sourcing region.
- **New practice:** Interventions must be new practices to the operation for at least the past three years.

Causality (Applicable for the Scope 3 Emission Reduction Program Only)

Demonstrating causality is required for attributing a claim to project developer.

To attribute 100% of a project's claims allocation to project developer, the project must demonstrate that they have substantively contributed to or enabled the intervention and the resulting benefits (material role in the occurrence of the intervention). At a minimum, the project must achieve a Right to

Claim by securing an attestation from the supplier that enrollment in Nitrogen Management Project has caused the adoption of project interventions.

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APPENDIX B: Crop Residue Nitrogen Factors

Table B-1: Crop Residue Factors from Alberta NERP (v2.1)

Based on Holos 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	0.01	0.26	0.60	0.15
Chickpeas	0.13	0.018	0.01	0.29	0.51	0.20
Coloured/White/Faba Beans	0.13	0.010	0.01	0.46	0.34	0.20
Dry Peas	0.13	0.018	0.01	0.29	0.51	0.20
Flaxseed	0.08	0.007	0.01	0.26	0.60	0.15
Fodder Corn	0.70	0.013	0.007	0.72	0.08	0.20
Grain Corn (shelled)	0.15	0.005	0.007	0.47	0.38	0.15
Hay and Forage Seed*	0.13	0.015	0.013	0.12	0.48	0.40
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

* 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 C: 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 approach to 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 be eligible for use of a dynamic baseline, projects must also provide proof that N application rates have not exceeded recommendations for each crop. To provide this assurance, APAs 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 N 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 Table 12 of the protocol. 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 to account for increased uncertainty associated with decreased availability of primary on-farm data. If the Dynamic Baseline One approach has been employed, project developers cannot switch back to the Dynamic Baseline Two. Dynamic Baseline Two is the most conservative approach with the application of a 10 per cent discount factor.

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. If a force majeure causes a season's yield to drop below 50% of the farm's average production history, the project developer can either:

- Exclude the fields/crops from the mass-based accounting for that year; or
- Substitute in a five-year Olympic average[37] yield value from published provincial crop insurance agencies to apply a conservative average estimate.

[37] Olympic average – a truncated mean, where the highest and lowest values in a dataset are excluded before averaging the remaining values.

Note: Any implications of N remaining in the soil due to crop loss must be addressed in the following year's 4R Plan and confirmed by soil test results/N balance calculation reviewed by an APA when determining the right rate.

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 CO_2 sequestered or landfill 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 baseline emissions for each crop type (tCO_2e) using the present years data. 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 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 N application in the dynamic baseline.

Emission Reduction = $[\sum_{\text{EcoDistrict j}} \sum_{\text{4R management level k}} (\text{Emissions Reduction}_{\text{Crop i}})] - \text{Emissions}_{\text{Fert and Lime Dist}}$

Where:

- EcoDistrict_j = Index number for tracking EcoDistrict types
- 4RManagement Level k = Index number for tracking 4R management performance levels, within an EcoDistrict
- $\text{Emissions Reduction}_{\text{Crop i}} = [\sum_{\text{crop i}} [\text{Emissions}_{\text{Other Fert and Lime Use, i}} + \text{Emissions}_{\text{Other Soil Crop Dyn, i}}] * (1\text{-}RM_{PL}) * GWP_{N20}$
- $\text{Emissions}_{\text{Other Fert and Lime Use}}$ = Emissions from inorganic fertilizer and crop residues under SS P7 Fertilizer and Lime Use
- $\text{Emissions}_{\text{Other Soil Crop Dyn}}$ = Emissions from inorganic fertilizer and crop residues under SS P13/B13 Soil Crop Dynamics
- Crop i = Index number for tracking crop types within an EcoDistrict and within a performance level
- $\text{Emissions}_{\text{Fertilizer and Lime Dist}}$ = Incremental emissions under SS P7 Fertilizer and Lime Distribution (on-site)

- RM_{PL} = emission reduction modifier of 0.85 and 0.75 and 0.65, which corresponds to the implementation of Basic, Intermediate and Advanced 4R Plans, respectively for annual crops
- GWP_{N_20} = Global warming potential value for N_2O
- Emission reductions are reported in tonne CO_2e

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 crop insurance agencies in each province are used as a proxy for crop mass values from the farm. Crop yields from this source are organized by crop type and crop risk area[1].

The quantification approach for Dynamic Baseline Two is as follows:

9) Obtain the information and develop rule set for allocating EcoDdistricts to risk zones; and

10) 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 1,600 kg/ha, for canola grown on 500 ha of land the calculation would be as follows:

Crop Mass$_{Crop}$	**= Five-year average Yield$_{Crop\ i}$ * Cropped Area** = 1,600 kg/ha * 500 ha = 800,000 kg of canola

Calculate the baseline emissions for each crop type (tCO_2e), using the present years N 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 where 4R management levels differ. Reductions are then summed across the analytical units to derive the GHG claim for the farm.

Emission Reduction =	$[\sum_{EcoDistrict\ j} \sum_{4R\ management\ level\ k} (Emissions\ Reduction_{Crop\ i})] - Emissions_{Fert\ and\ Lime\ Dist}$

Where:

- $Emissions\ Reduction_{Crop\ i} = DF * [\sum_{Crop\ i} [Emissions_{Other\ Fert\ and\ Lime\ Use,\ i} + Emissions_{Other\ Soil\ Crop\ Dyn,\ i}] * (1-RM_{PL}) * GWP_{N20}$

- Discount Factor (DF) = 0.90 (10% discount factor) for Dynamic Baseline Two
- Other Factors = See Dynamic Baseline 1 equation above

APPENDIX E: Additional Fuel Pass Method

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

Each year of the project, the APA will assess the N application practices relative to the baseline. Any increased GHG emissions from additional N application passes relative to the baseline will be calculated and subtracted from the GHG Statement 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 N 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; and
- Subtract the GHG value in $kgCO_2e$ from the GHG Statement for the farm, as described in Section 5.1.1 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. See Table E-1 for fuel use values for common operation types for additional pass methods. 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, must be used when the method is unknown. 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 =	$1.10 * \text{Fuel Use}_{\text{Diesel}} * \sum_{\text{Mgmt unit } l} [\text{Pass}_{\text{Area } l} * \text{Pass}_{\text{Quantity } l}]$

- Where:

- Vol. Fuel = Volume of diesel fuel used during extra field passes
- 1.10 = 10% 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 l = 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; and
- Subtract the GHG value in kg CO_2e from the GHG Statement for the farm, as described in Section 5.1.1.

Example Calculations

Prior to project implementation, a grower with 1,000 hectares of cereals and oilseeds applies all fertilizer N 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 per cent of his recommended N rate on his wheat fields at time of seeding and in crop banding the remaining 25 per cent 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 EmissionsFert and Lime Dist with the quantification methodology provided in Table 8.

Method B

Calculating additional hectare-passes

400 ha X 1 = 400 ha-pass

Calculating the fuel usage from the additional pass

400 ha-pass x operation type fuel use (L fuel per hectare) = 400 ha-pass x 5.23 L fuel per hectare = 2,092 L of extra fuel used

2,092 L of extra fuel x 1.10 = 2,301.20 L of extra fuel (diesel)

2,301.20 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 coulter would have to be used to band granular, liquid or anhydrous NH_3 and the main power use is the draft of the coulter, 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 E-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 Clearance Sprayer)	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

Appendix F: Acceptable Crop Mass Determination Methods

On Canadian farms, several different methods for measuring crop mass are currently being used. Proper and frequent calibration from a practical standpoint is difficult to achieve given 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:

11) 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;
- A log of masses for each load shall be maintained[2]; 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. As per flexibility mechanism 5, in the event a farm is unable to measure crop moisture directly for a volume of crop, safe storage moisture levels as reported by government agencies can assumed

12) 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;
- A log of masses and moisture for each load shall be maintained[3]; 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.

13) 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.

14) Storage Volume Measurement

- 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 an APA), which must include photo and time-stamped evidence; and
- The bin log and moisture log will be made available to the verifier upon request.

15) Combine-Mounted Yield Monitors can be used under the following flexibility conditions:

- Yield monitors are calibrated before harvest (following manufacturer's specifications see Table 10 and Appendix G); if there is no record of calibration then a logbook by field could be sufficient if photographed with a date stamp. In addition, calibration must be performed for each crop type;
- Yield monitors are used with a two-factor, conservative attribution method;
- Use Yield monitor data (field level) to attribute farm level measurements of crop mass or volume approaches;
- For crop mass or volume approaches, use either scales, bins, or grain tank volumes and relate these to the Yield Monitor data, indicating which method;
- Capture the yield monitor data and record-correlated yield measurements by field, in logbooks/printouts or some other means;
- If using newer self-calibrating combines with load cells, this is acceptable but will require proof for each crop type;

- Use records from Crop Insurance Agencies[4];
- Two methods of determining yield from the above are required (with records). The project developer will demonstrate the most conservative outputs were chosen between the methods; and
- The APA is required to confirm under seal, all applications of this flexibility mechanism to generate yield data.

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 G: Accredited Professional Advisor Qualification Requirements

An Accredited Professional Advisor (APA) is a professional with academic training and experience in soil science, crop science and/or agronomy as well as more specific knowledge of greenhouse gas management and accounting at the farm level.

PART A – Post Secondary Education and Experience

APAs working within the context of this protocol must meet one of the following sets of education and experience requirements:

1B: 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; or

2B: 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.

PART B – Recognized Professional Designation

The professional requirement is met by individuals who currently hold one of the following recognized professional designations:

1A: A Certified Crop Advisor (CCA) or Certified Professional Agronomist (CPAg) designation through the American Society of Agronomy; or

2A: A Professional Agrologist (PAg) or Technical Agrologist (TAg, RTAg, TechAg etc.) designation through an agrology institute in one or more Canadian provinces.

NOTE: The roles and duties of the APA under this protocol would generally fall within the definition of the practice of agrology as understood within the Canadian regulatory protocol for professionals. The profession of agrology is regulated at the provincial level. Several provinces regulate agrology as a right to title while others regulate it as a right to practice.

Provinces (Ontario, for example) may impose additional certification or training requirements on individuals developing nutrient management plans for farms producing or receiving manure.

It is the responsibility of the individual professional to ensure that their activities as an APA are not contrary to the regulatory framework in the province(s) in which they practice.

PART C – Protocol Specific Designations, Knowledge, and Skills

All the persons with the needed education, work experience, and professional designations noted above, also need to demonstrate additional competencies specific to this protocol including:

1C: The ability to prepare and sign off on 4R Nutrient Stewardship Plans as required under this protocol;

2C: The ability to calculate and/or verify emission calculations, create and implement soil sampling plans and derive N recommendation from soil test results, perform post-harvest assessments and other specific requirements of the APA's role in the protocol; and

3C: An understanding of the APA's role in adhering to record requirements under the protocol as they relate to the independent verification and audit process.

Requirement 1C is met by holding a current certificate as a 4R Designated Agronomist under Fertilizer Canada's 4R Designation Program. Obtaining the 4R Designated Agronomist credential is achieved by first completing the three-part 4R training course on the Fertilizer Canada eLearning site, and successfully challenging the module exams OR for CCAs, obtaining the 4R NMS specialty certification by challenging the appropriate regional 4R NMS exam. The second step in obtaining the 4R Designated Agronomist certificate is to complete and submit the agronomist attestation form to Fertilizer Canada.

Requirements 2C and 3C are met by successfully completing the APA training available through Fertilizer Canada's eLearning site. Once the APA training has been completed and the APA exams successfully challenged Fertilizer Canada will provide the individual with and APA certificate good for 5 years from the date of issue.

Appendix I: Sample Monitoring Plan

Table K-1: Location

SSR identifier or name	B8/P8 Fertilizer and Lime Use (On-site) and B13/P13 Soil Crop Dynamics
Data parameter	Location of fields participating in the program. Used to identify location-specific factors used in quantification approach (EcoDistrict)
Estimation, modeling, measurement or calculation approaches	Measured and recorded for each farm through equipment generated field boundaries (GIS spatial extent of the cropped area); confirmed through legal land description documentation
Data Recording (electronic or paper)	Electronic
Data unit	Coordinates (geospatial extent) of participating fields
Sources/Origin	Recorded for each farm
Monitoring frequency	Annually
Description and justification of monitoring method	Using digitalized field boundaries gives an accurate method for geospatial extent. Furthermore, the data is cross-checked based on legal land description for accuracy.
Uncertainty	Low level of uncertainty due to relative accuracy of legal land descriptions and geospatial coordinates
Provide the details for any deviations from methodology including the justification and rationale	This method complies with the guidelines outlined in Section 7 of the protocol

Table K-2: Crop Type

SSR identifier or name	B8/P8 Fertilizer and Lime Use (On-site) and B13/P13 Soil Crop Dynamics
Data parameter	Crops grown for each field (basic level)
Estimation, modeling, measurement or calculation approaches	Record based on the Agriculture Management Tool crop plan, seeding and harvest records, satellite imagery, crop Insurance records, Ag Canada annual crop inventory, crop advisor records, APA records or seed purchase receipts
Data Recording (electronic or paper)	Both

Data unit	Crop type
Sources/Origin	Recorded for each eligible field on enrolled farms.
Monitoring frequency	Annually
Description and justification of monitoring method	This is the most accurate and practical method of measuring this parameter. Furthermore, the data is supported by appropriate evidence to verify its accuracy.
Uncertainty	There is a low level of uncertainty associated with the above parameters (crop type) due to the possibility of misrepresentation of the data/information. However, this uncertainty is greatly reduced by cross-comparison with the information found in the required supporting documentation
Provide the details for any deviations from methodology including the justification and rationale	This method complies with the guidelines outlined in Section 7 of the protocol

Table K-3: Additional Fuel Usage

SSR identifier or name	B7/P7 Fertilizer and Lime Distribution (On-Site)
Data parameter	Any additional fuel used to carry out the 4R plan and the fuel type (gasoline or diesel)
Estimation, modeling, measurement or calculation approaches	Estimation for each greenhouse gas
Data Recording (electronic or paper)	Electronic
Data unit	MJ or L
Sources/Origin	Recorded for each farm
Monitoring frequency	Monthly
Description and justification of monitoring method	Monthly record for activities occurred in the field
Uncertainty	Estimate of fuel usage including specification of fuel type from equipment records; and fuel logs and or digital equipment use logs indicating date and fuel usage associated with additional passes (if applicable), therefore low uncertainty.
Provide the details for any deviations from methodology	This method complies with the guidelines outlined in Section 7 of the protocol

including the justification and rationale	

Table K-4: Applied Nitrogen

SSR identifier or name	B8/P8 Fertilizer and Lime Use (On-site)
Data parameter	Quantity of N applied to the field as synthetic fertilizer or manure.
Estimation, modeling, measurement or calculation approaches	Measured under the project condition. Applied fertilizer rates are collected by zone or field (as applied data through farm machinery) where data is digitally encoded with GPS coordinates
Data Recording (electronic or paper)	Electronic
Data unit	kg of N
Sources/Origin	Measured and recorded for each field
Monitoring frequency	Annually
Description and justification of monitoring method	This is the most accurate method of measuring this parameter assuming that staff are correctly trained, and equipment is correctly maintained
Uncertainty	There is a low level of uncertainty associated with the above parameters due to the APA developing the soil testing and tissue testing sampling plan. Accredited labs are used to analyze the soil samples with reported uncertainties in the 0.001per cent range
Provide the details for any deviations from methodology including the justification and rationale.	This method complies with the guidelines outlined in Section 7 of the protocol

Table K-5: N Rate Justification

SSR identifier or name	B8/P8 Fertilizer and Lime Use (On-site)
Data parameter	Justification of N applied based on soil test, N balance calculation, expert judgement (by APA) or any other method used
Estimation, modeling, measurement or calculation approaches	Measured under the project condition – soil testing will be conducted at a soil testing lab with a quality control/quality assurance program. Nutrient recommendations will be made, with a corresponding justification for N applied
Data Recording (electronic or paper)	Both

Data unit	kg of N
Sources/Origin	Measured and recorded for each field
Monitoring frequency	Annually
Description and justification of monitoring method	This is the most accurate method of measuring this parameter assuming that staff are correctly trained, and equipment is correctly maintained
Uncertainty	There is a low level of uncertainty associated with the above parameters due to the APA developing the soil testing and tissue testing sampling plan. Accredited labs are used to analyze the soil samples with reported uncertainties in the 0.001per cent range
Provide the details for any deviations from methodology including the justification and rationale	This method complies with the guidelines outlined in Section 7 of the protocol

Table K-6: Yield

SSR identifier or name	B13/P13 Soil Crop Dynamics
Data parameter	Yield for each field/ crop combination on a dry matter basis.
Estimation, modeling, measurement or calculation approaches	Measured using the approved yield methods in the protocol, in addition to yield monitors for GHG accounting, as detailed in Table 12. Estimation of yield may be completed for participants with data completeness issues and may only be used for post-harvest assessment, not for GHG accounting
Data Recording (electronic or paper)	Both
Data unit	tonnes of dry matter (DM)
Sources/Origin	Measured and recorded for each field
Monitoring frequency	Annually
Description and justification of monitoring method	The justification for using all the yield data types included within this project is outlined in Section 7. Briefly, the use of acceptable crop mass determination methods meets the protocol requirements, and the use of yield monitors requires the use of a discount factor of 10 per cent, to ensure conservativeness and accuracy in the quantification approach
Uncertainty	Uncertainty in yield is greater under yield monitors than for acceptable crop mass determination methods. In areas where data has a high uncertainty, has poor quality or is incomplete, yield data is not used within the GHG accounting approach, to ensure conservativeness

Provide the details for any deviations from methodology including the justification and rationale	The justification for using all the yield data types described is detailed above and within Table 12. This method complies with the guidelines outlined in Section 7 of the protocol

Appendix J: Scientific Evidence for the Impact of 4R Management on N_2O Emissions Relevant to a Canadian Context

NERP Science Review Paper; Burton, 2018. A review of the recent scientific literature documenting the impact of 4R management on N_2O emissions relevant to a Canadian context. Prepared for Fertilizer Canada; Summary: Review of scientific literature available for 4R management, focusing on the specific Canadian context (soil type, climate, N_2O emissions), N source effects on N_2O emissions, influence of timing on N_2O emissions, influence of placement on N_2O emissions, impact of fertilizer application rate on N_2O emissions and non 4R factors that impact N_2O emissions including soil type, irrigation or drainage, tillage and crop rotation.

NERP Science Panel Workshop Presentation; Summary: Presentation to provide context of NERP to Consultation group and review the ISO 14064-2 carbon accounting principles and standard requirements to experts.

Fertilizer Management Coefficient Workshop Report 2018 02 01; Summary: Document outlines the process of the Science Review process, and primary outcomes of the consultation process. Details regarding the science review participants, meeting agenda, polling results and meeting minutes can be found.

Western Canada Expert Panel; Summary: Presentation used for discussion and review of the BMP Tables created for Western Canada.

Applied Ecology Drever et al., 2021 Supplementary Materials; Summary: Supplementary Materials for the Natural Climate Solutions for Canada peer-review paper (document #15). This paper used the 2018 Science Review process outcomes to determine the potential greenhouse gas mitigation from the 4R Nutrient Stewardship Approach.

Scientific development and consensus document in the ON-QUE Adapted NERP Fertilizer Protocol Project 2018; Relevant Excerpts; "For each level of adoption, we multiplied direct N_2O emissions from fertilizer and manure by a reduction modifier based on the expert opinion of 12 Canadian scientists convened by Fertilizer Canada in 2018" & "Finally, for the advanced 4R level, emissions reduction modifiers were 0.70 and 0.65 in western Canada for irrigated potato and other crops, respectively."

Scientific development and consensus of the reduction modifiers: Climate Check, 2009, Decision Paper for Nitrous Oxide Emission Reduction Protocol, prepared for Climate Change Central and Fertilizer Canada.

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