QUANTIFICATION PROTOCOL FOR MECHANICAL PULP SLUDGE UTILIZATION PROJECTS RELATED TO AGRICULTURAL APPLICATION

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1.0 Project and Methodology Scope and Description

The opportunities for generating carbon offsets with this protocol arise mainly from the direct and indirect reduction of atmospheric greenhouse gases (GHG) through the application of mechanical pulp mill sludge on agricultural land as opposed to previous practices of drying, incinerating or landfilling the waste material. This quantification protocol is written for the Mechanical Pulp Mill Sludge Utilization project developer. Some familiarity with, or general understanding of the generation of sludge in the mill process and agricultural practices is expected.

1.1 Protocol Scope and Description

Mechanical pulp sludge is traditionally a discarded by-product produced during the production of pulp and paper. The carbon offsets from this protocol will be based on the quantification of increased carbon stocks and decreased GHG's resulting from the application of pulp sludge to agricultural land as opposed to its drying, incineration or placement in a landfill. Sludge application significantly increases crop yields and residues on agricultural land thus subsequently increasing the below ground carbon reservoir. The soil carbon reservoir stores and accumulates carbon rather than releasing greenhouse gases to the atmosphere.

This protocol can theoretically be applied to all mechanical pulp mills spreading sludge on all agricultural land and crop types across the province. This protocol can be used as a generic template for proponents to follow to meet the measurement, monitoring, and GHG quantification requirements. Due to the nature of the protocol two baseline approaches are required to quantify the baseline condition. Regardless of historical sludge disposal practices associated with a mechanical pulp mill facility, this protocol will apply an ***adjusted baseline approach*** which accounts for adoption levels of land application of mechanical sludge in Alberta, adjusted based on historical land application activity levels from mills currently operating in the Alberta. This value has been set at 53% based on the adoption levels from five years of historical operational data from three mills operating in Alberta. This value will be applied to all projects applying this protocol (see Appendix C for more interpretation). Due to the complexity and variability of farming and cropping systems, a comparison approach has been adopted for the quantification of reductions achieved through increased soil organic carbon. The comparison approach uses actual measurements of parameters from a control group to compare with the project. **FIGURE 1.1** and **FIGURE 1.2** describe typical project and baseline conditions as a flow diagram, respectively.

For consistency with other Alberta Offset System protocols this protocol does not explicitly assign ownership, but instead states the minimum data collection requirements in order to adequately quantify the net GHG benefit of the project activity. It is therefore up to each project proponent to provide proof of ownership of all offsets claimed at the time of third party verification or upon request by Alberta Environment (e.g. through contracts with land owners and/or other participants).

Protocol Approach:
This protocol provides guidance for project proponents with respect to quantifying reductions from the utilization of mechanical pulp sludge for agricultural application. The protocol quantification approach is based on tonnes of sludge applied to agricultural land which would have been landfilled or dried and incinerated in the baseline condition. The baseline approach utilizes project specific data from pulp mill facilities in Alberta to determine the baseline emissions that would have occurred had sludge not been applied to agricultural land. Business as usual practices for sludge handling in Alberta includes landfilling, drying, and incineration.

Further reductions in GHG's are achieved by increased soil carbon storage as a result of sludge application. This document offers two quantification methods for quantifying increased soil carbon storage, allowing users to select a simple or advanced approach. This flexibility allows users to maximize the GHG emission reductions quantified based on data availability and budget. The simple approach requires less accurate data measurements and monitoring but in return utilizes more conservative quantification approaches, therefore yielding less GHG emission reductions, while the advanced approach requires a more accurate and detailed measurement and monitoring approach but allows users to maximize the GHG emission reductions quantified.

The development of this quantification protocol included review of the following existing GHG quantification and guidance documents:

1) ISO 14064-2:2006 Specification with Guidance at the Project Level for Quantification, Monitoring and Reporting of GHG Emission Reductions or Removal Enhancements
2) Environment Canada's National Inventory Report 1990-2004 Greenhouse Gas Sources and Sinks in Canada – Annex 13 – Emission Factors
3) Environment Canada's National Inventory Report 1990-2004 Greenhouse Gas Sources and Sinks in Canada – Annex 3 – Additional Methodologies – A3.6 Methodology for Waste
4) NCASI 2005 – Calculation Tools for Estimating Greenhouse Gas Emissions From Wood Product Facilities – Version 1.0
5) 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 5: Waste – Chapter 5 – Incineration and Open Burning Waste
6) 2006 IPCC Guidelines for National Greenhouse Gas Inventories – Volume 4: Agriculture, Forestry and Other Land Use – Chapter 5 – Cropland
7) 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4: Agriculture, Forestry and Other Land Use – Chapter 11 – N_20 Emissions from Managed Soils, and CO_2 Emissions from Lime and Urea Application
8) Agriculture and Agri-Food Canada, 2006 – Draft Document – Tillage System Default Coefficient Protocol – Technical Background Document
9) Environment Canada's Draft Guide to Quantification Methodologies and Protocols (March 2006)
10) Canada's Offset System for Greenhouse Gases – Guide to Protocol Developers – August 2008 (Draft)

11) Alberta Environment's Approved Quantification Protocol for Tillage System Management (February 2008 – Version 1.3)
12) Alberta Environment's Offset Credit Project Guidance Document – February 2008
13) Alberta Environment's Offset System Protocol Development Guidance Document (October 2008)

These documents may be reviewed to provide further information and additional detail pertaining to this protocol. This protocol is focused on emissions avoidance and increased soil carbon storage resulting from land application of mechanical pulp sludge; other protocols will cover other aspects of carbon offsets for the mill, and could be used in conjunction with this protocol.

Figure 1.1. Process Flow Diagram for the Project Condition – Agricultural Sludge Utilization

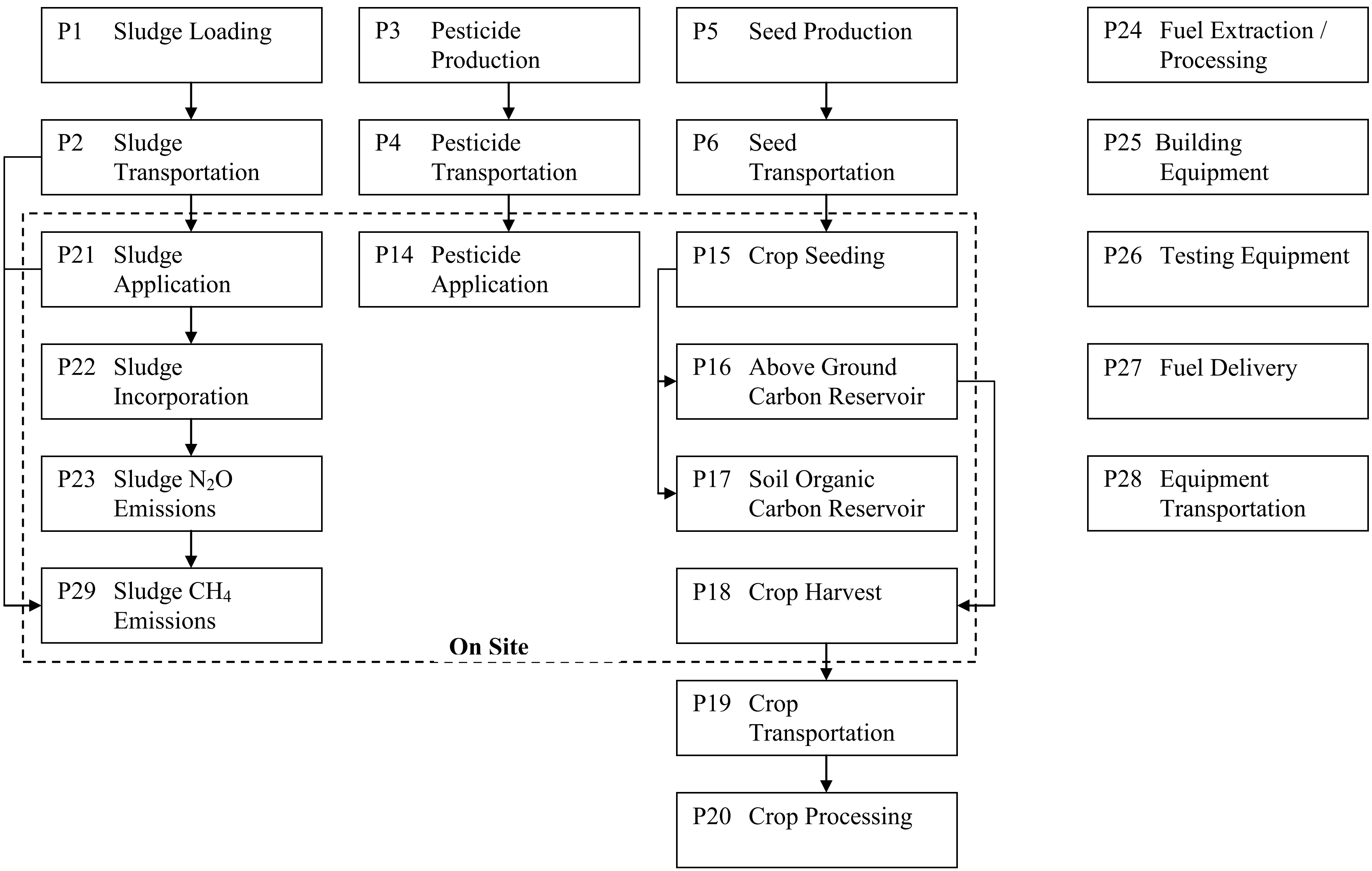
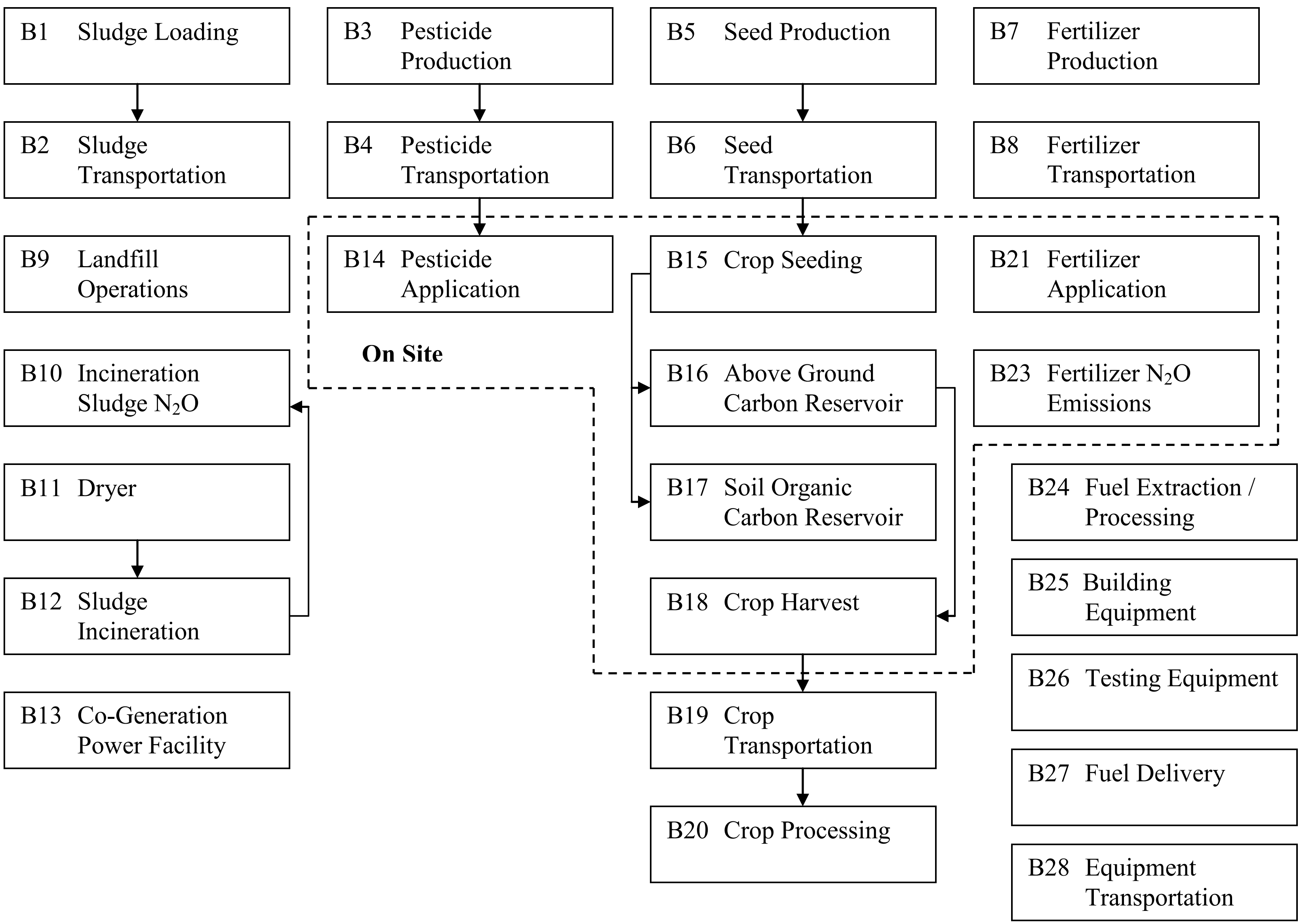


Figure 1.2. Process Flow Diagram for the Baseline Condition – Agricultural Sludge Utilization.



Protocol Applicability:
This protocol is applicable to all mechanical pulp mills in Alberta that are producing sludge and applying it according to the established guidelines (Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999)).

In order for a project to gain carbon offsets under this protocol, the project proponent must demonstrate that it meets the protocol requirements and produce sufficient evidence to indicate that:

1. The sludge was stored, spread and incorporated in the approved method described in the Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999) and this protocol as confirmed by affirmation from the project developer and farm records. Requirements include:
    a. Sludge is applied and incorporated on the specified parcel of land only once during a 5 year period (minimum credit period) and a maximum of twice during a 8 year credit period.
    b. Mechanical pulp sludge should be stockpiled in a manner that prevents methane production and contamination of any surface watercourses and groundwater. Prescriptive measures include:
        i. Sludge should only be stockpiled on site when necessary and land applied as soon as possible.
        ii. Maximum stockpile height of 1.5 meters to allow aeration.
        iii. The stockpile should not be located on land which has a slope greater than 9%.
        iv. Not more than a quantity sufficient for one application of sludge should be stored at a designated application area at any time.
    c. Any method of spreading sludge that results in an even application to soil may be used.
        i. Conventional tractor pulled manure spreaders and truck mounted spreaders which have an auger type flinger at the back to dispense the sludge are recommended.
        ii. Following the contours of the land to minimize soil disturbance is also recommended.
        iii. Whenever possible, mechanical pulp sludge should be incorporated into the soil within 72 hours after it is spread so as to prevent nutrient losses and/or methane production. Roto-tillers or tandem (double) discs are the most useful implements for incorporation.

2. The project must meet sludge land application guidelines established under the Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999). Sludge should not be spread on:
    a. Organic soil
    b. Soil with a C:N ratio greater than 40:1

c. Soil which has an EC greater than 6 dS/m
d. Soil which has a SAR greater than 8
e. An area where the slope exceeds 15%
f. Soil in low lying areas that have saturated soil conditions for more than six consecutive weeks so as to prevent conditions conducive for methane production
g. An area where the seasonally high water table is within 1.5 meters of the soil surface

The recommended distance from residences or watercourses on land with 0 to 3% slopes is 15 meters, 30 meters on land with 3 to 9% slopes and 50 meters on land with 9 to 15% slopes.

3. The quantification of reductions achieved by increased soil organic carbon **for all projects commenced after 2010 are based on actual comparison measurements and monitoring** as indicated by the proper application of this protocol using approved control groups representing business as usual farming and cropping practices.
    a. A control strip is to be established in each representative parcel of land designated for sludge application. Ideally the control strip will be located in the middle of the land area and be a minimum of 10 meters wide and run the entire length of the area to account for landscape variability. **No sludge should be applied in the control strip.**

4. The minimum number of samples was taken as indicated in this protocol. The number of samples required may increase with increased variability in landscape topography and should be assessed by qualified personnel. All sample locations should be geo referenced and data quality management procedures followed.

5. The quantification of reductions achieved between 2002 and 2010 are based on calculations provided in the simple quantification approach and approved data sources (see Section 2.5.2 – of this protocol).

6. The project must meet the requirements for offset eligibility as specified in the applicable regulation and guidance documents for the Alberta Offset System (Specified Gas Emitters Regulation – Offset Credit Project Guidance Document 2008). [Of particular note:

    a. [Ownership of the emission reduction offsets must be established as indicated by facility records;]
    b. [Baseline emissions must be real, quantifiable and verifiable.]

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

1. This protocol applies to the reduction of atmospheric GHG's by land application of sludge and avoided emissions from no longer drying, incinerating or landfilling sludge. This protocol can be combined with other protocols where multiple projects are undertaken by the pulp mill to reduce overall GHG emissions.

2. The protocol offers two options for quantifying the soil organic carbon emission reductions.

    a. Advanced Approach – requires a higher level of rigor for measurements and monitoring (and associated cost), which may allow eligible projects to deliver greater GHG credits to the market than the simple approach.
    b. Simple Approach – requires the use of established data sources such as soil inventory and data maps, the Alberta Soil Information Viewer, and previous sampling data to establish background soil organic carbon and bulk density information and incorporates a discount factor into the quantification.

    These two approaches are allowed in order to provide flexibility. They balance the level of detail in monitoring requirements with the degree of conservativeness in various calculations to ensure that GHG emission reductions quantified under each approach are comparable from the standpoint of quality and verifiability. If applicable, the proponent must indicate and justify why flexibility provisions have been used.

3. Site specific emission factors may be substituted for the generic emission factors used in this protocol document. Emission factors must be verifiable and/or obtained from a credible reference.

1.2 Glossary of New Terms:

Affected Greenhouse Gas Source, Sink or Reservoir	GHG source, sink or reservoir influenced by a project activity, through changes in market demand or supply for associated products or services, or through physical displacement. An affected GHG source, sink or reservoir is generally off the project site (ANSI/ISO/ASQ E14064-2:2006(E)).
Carbon Sequestration:	The process of increasing the carbon stored in a reservoir other than the atmosphere.

Carbon Stock:	The quantity of carbon held within a reservoir at a specified time, expressed in units of mass.
Control Strip	A parcel of land (minimum 10 m wide) which is sampled as the standard or baseline and compared with an area treated with sludge.
Controlled Greenhouse Gas Source, Sink or Reservoir	GHG source, sink or reservoir whose operation is under the direction and influence of the greenhouse gas project proponent through financial, policy, management or other instruments. A controlled GHG source, sink or reservoir is generally on the project site (ANSI/ISO/ASQ E14064-2:2006(E)).
Credit Period	The protocol credit period applies over an 8 year period during which the sludge is applied and incorporated once at the beginning of the credit period and again at year 5 as indicated in the Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land (Alberta Environmental Protection 1999).
Functional Equivalence:	The project and the baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (such as tonnes of sludge disposed, mass of beef produced, land area cropped, energy use/per unit of product) for comparison between the project and baseline activity (refer to the Project Guidance Document for the Alberta Offset System for more information).
Related Greenhouse Gas Source, Sink or Reservoir	GHG source, sink or reservoir that has material or energy flows into, out of, or within the project. A related GHG source, sink or reservoir is generally upstream or downstream from the project, and can be either on or off the project site. It may also include activities related to design, construction and decommissioning of the site (ANSI/ISO/ASQ E14064-2:2006(E)).
Reservoir:	A physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a greenhouse gas removed from the atmosphere by a greenhouse gas sink or a greenhouse gas captured from a greenhouse gas source. Examples of reservoirs include trees, soil, oil and gas reservoirs, and oceans.

Pulp Sludge: A traditionally discarded by-product created by the operations of mechanical pulp mills. Mechanical pulp sludge consists primarily of water, wood fiber, biomass, and residual process and wastewater treatment chemicals (mainly nutrients such as nitrogen and phosphorus). Sludge improves the nutrient status and physical properties of soil resulting in enhanced plant growth.

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

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

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

The emissions produced for the project will differ due to variations in sludge application rates and properties, farm management and cropping practices, climatic conditions, and soil chemical and physical properties. A measurement comparison approach of affected carbon reservoirs will establish the additional carbon stored by the project.

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

Figure 2.1. Project Element Life Cycle Chart – Agricultural Sludge Utilization

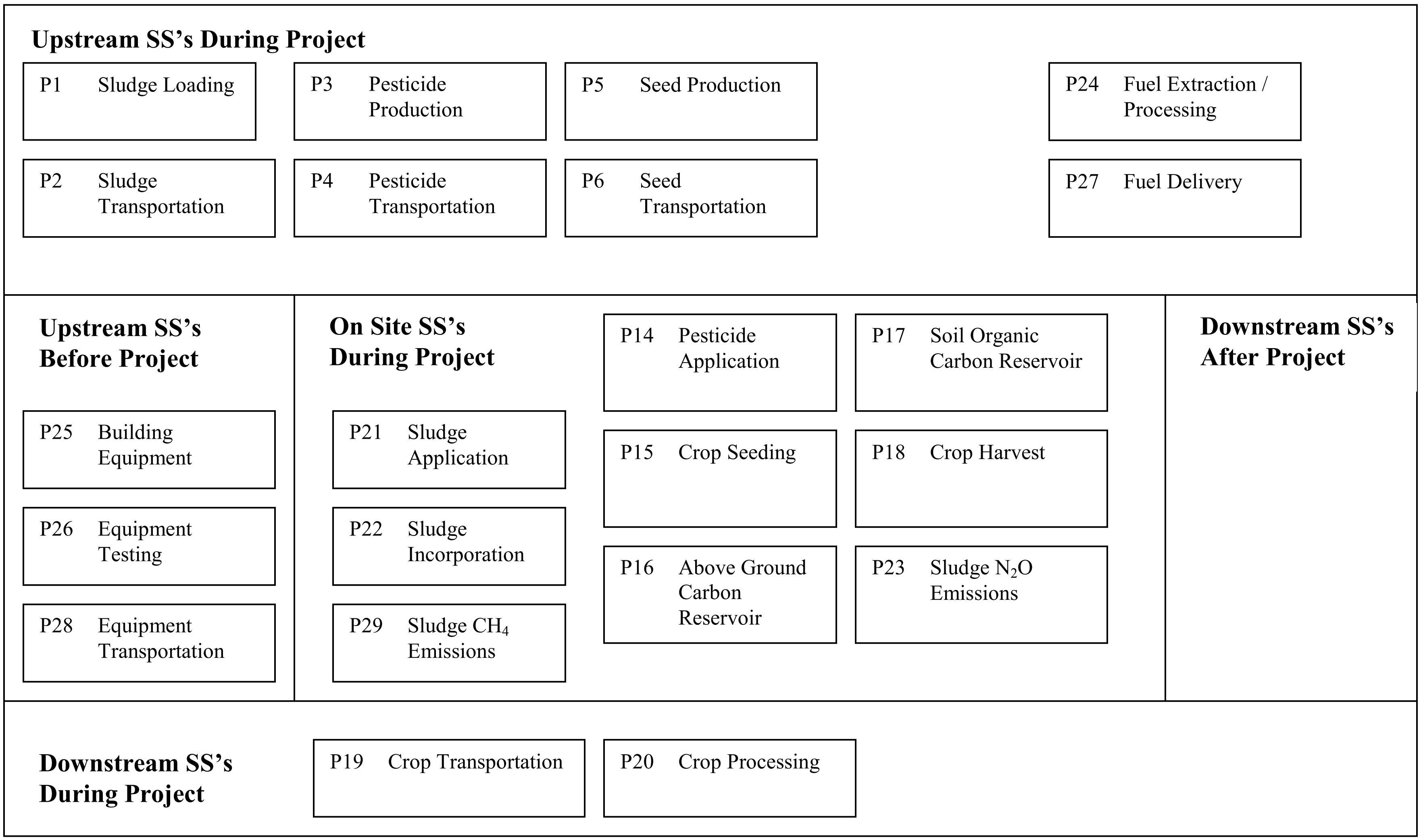


Table 2.1. Project SS's for Agricultural Sludge Application

SS	Description	Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Sludge Loading	Sludge will be loaded from bunkers into trucks for delivery to the site. The related energy inputs for fuelling this equipment are captured under this SS, for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment and the number of loads would be used to evaluate functional equivalence with baseline condition.	Related
P2 Sludge Transportation	Sludge will be hauled to the site by truck. Distance travelled and number of loads will be tracked to evaluate the project equivalent emissions.	Related
P3 Pesticide Production	Pesticide production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be evaluated for the project equivalent.	Related
P4 Pesticide Transportation	Pesticide may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used evaluate the project equivalent emissions.	Related
P5 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 evaluated for the project equivalent.	Related
P6 Seed Transportation	Seed may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the project equivalent emissions.	Related
P24 Fuel Extraction / Processing	Each of the fossil fuels used throughout the on-site component of the project will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P27 Fuel Delivery	Each of the fuels used throughout the on site component of the project will need to be transported. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling stations as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Project Operation		
P14 Pesticide Application	Emissions associated with spreading pesticides. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
P21 Sludge Application	Sludge would be distributed on the field to achieve a uniform application rate. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
P22 Sludge Incorporation	Sludge would be incorporated after application using farm equipment. The related energy inputs for fuelling this equipment would be based on type of equipment used, application rate, and area covered.	Controlled

P23 Sludge N_2O Emissions	N_2O -N emissions from nitrogen in the sludge after land application and incorporation. It is important to track the amount of nitrogen emitted after application and in subsequent years to compare with synthetic fertilizers.	Controlled
P29 Sludge CH_4 Emissions	CH_4 emissions from pulp sludge during transportation, temporary storage on site and after application during anaerobic conditions. The maximum amount of methane that could be produced under these conditions needs to be quantified.	Controlled
P 15 Crop Seeding	Seed would need to be distributed on the field. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
P16 Above Ground Carbon Reservoir	Carbon will accumulate in the above ground biomass from sequestration in plant tissue. The extent of this accumulation would need to be tracked and compared to untreated areas to determine the extent of above ground carbon sequestration.	Controlled
P17 Soil Organic Carbon Reservoir	Carbon will be added to the soil through addition of carbon in the sludge matrix. Carbon will also accumulate in the below ground organic materials as a result of root biomass development and crop decomposition. The soil carbon content prior to and after sludge addition would need to be tracked to a depth of 30 cm to determine changes as a result of sludge application.	Controlled
P18 Crop Harvest	Crops would need to be harvested and transported from the field to storage. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
Downstream SS's during Project Operation		
P19 Crop Transportation	Crops would need to be transported from storage to the market. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Related
P20 Crop Processing	Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the baseline condition.	Related
Other		
P25 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. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
P26 Equipment testing	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
P28 Equipment Transportation	Equipment built off site and the materials to build equipment on site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

2.2 Identification of Baseline

The baseline is the most appropriate and best estimate of GHG emissions and removals that would have occurred in the absence of the project. In this protocol, identification of the baseline condition is presented in two ways. The emissions produced at baseline will differ for each project due to variations in sludge disposal methods, farm management and cropping practices, climatic conditions, and soil chemical and physical properties. A comparison based approach utilizing a representative control group will establish the baseline soil condition and historical site specific data will be used to establish the baseline landfill, drying and incineration emissions with an adjusted baseline used to account for industry land application adoption levels. **TABLE 2.2** identifies all possible baseline approaches and provides justification for the selected baseline scenarios.

Table 2.2. Identification of Possible Baseline Quantification Approaches

Baseline Options	Description	Static / Dynamic Baseline	Accept or Reject and Justify
Historic Benchmark	Typically site-specific and can be constructed to reflect reductions in a base period (such as the average emissions of the previous three years).	Dynamic	Reject: Site specific historical data is available to determine a baseline period for evaluation however does not account for the current adoption level of mechanical sludge land application.
Performance Standard	Assumes the typical emissions profile for the industry or sector is a reasonable representation of the baseline.	Dynamic	Reject: Each mechanical mill operator has different processes and operating procedures thus an industry baseline is not reasonable.
Comparison Based	Actual measurements of parameters from a control group to compare with the project.	Dynamic	Accept: Actual measurements produce the most accurate and reliable results and can not be discounted by variability.
Projection Based	Projections of reductions in the future can use a variety of techniques, from simple straight line growth assumptions to complex models.	Dynamic	Reject: There are too many variables that would need to be input into a model such as soil type, landscape variability, climate factors, crop species, farming and management practices, etc.
Adjusted Baseline	Takes into account current practice levels of a particular project and specified that the same baseline is used for all projects of a certain type, regardless of historical practices.	Dynamic	Accept: Based on historical operational data provided from 3 mechanical pulp mills over a baseline period of 5 years it was possible to quantify the industry based adoption level of land application.

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

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the baseline SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.3.**

Figure 2.2. Baseline Element Life Cycle Chart – Agricultural Sludge Utilization

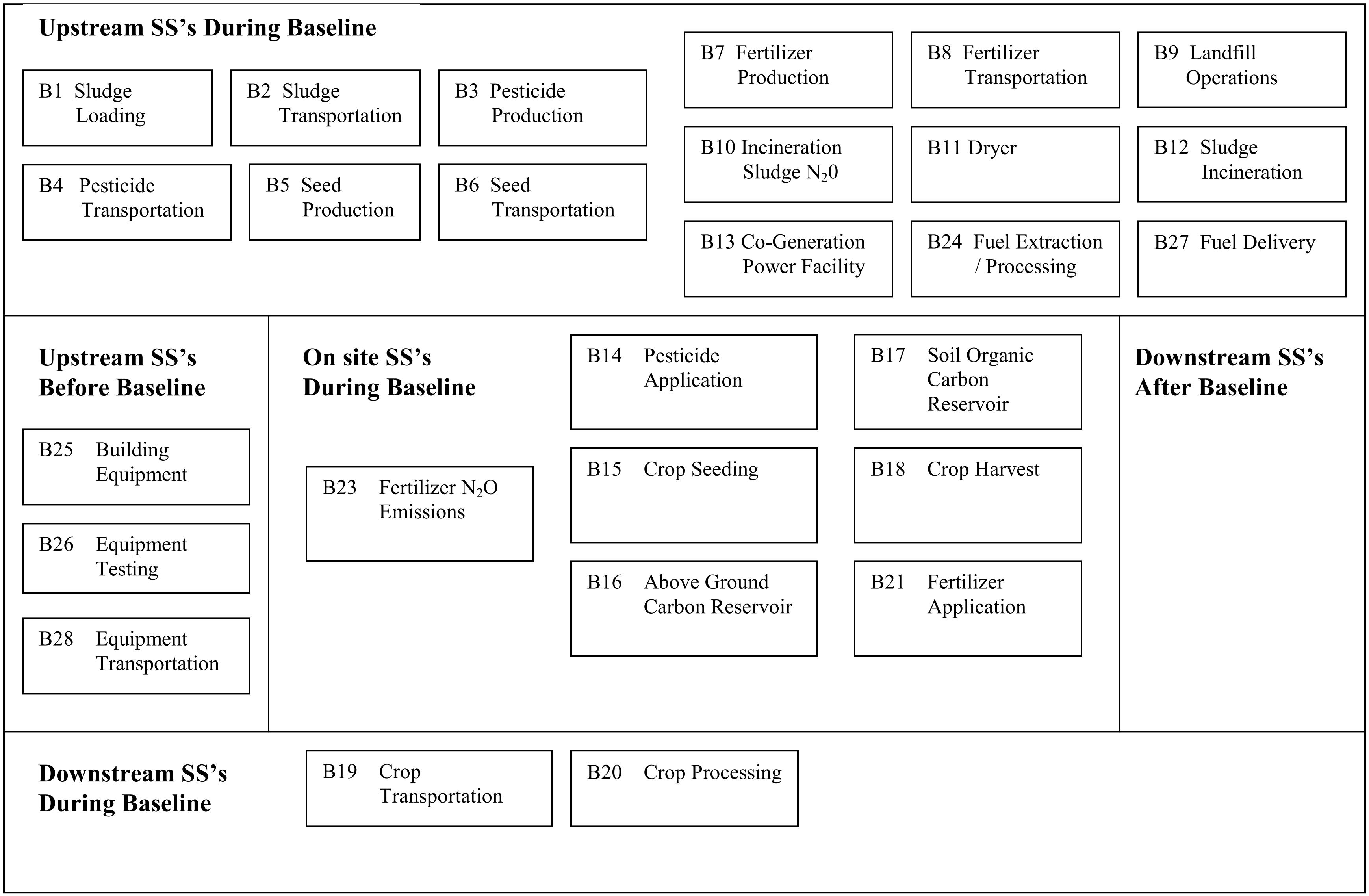


Table 2.3. Baseline SS's for Agricultural Sludge Applications.

SS	Description	Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Sludge Loading	Sludge will be loaded from bunkers into trucks for delivery to the landfill or incineration site. The related energy inputs for fuelling this equipment are captured under this SS, for the purpose of calculating the resulting greenhouse gas emissions. Type of equipment and the number of loads would be used to evaluate functional equivalence with project condition.	Related
B2 Sludge Transportation	Sludge may be transported to a landfill or incineration unit. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the baseline emissions.	Related
B3 Pesticide Production	Pesticide production may include several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be evaluated for the baseline equivalent.	Related
B4 Pesticide Transportation	Pesticide may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used for the calculation.	Related
B5 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 evaluated for the baseline equivalent.	Related
B6 Seed Transportation	Seed may be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate baseline emissions.	Related
B7 Fertilizer Production	Fertilizer production may have energy requirements such as natural gas, diesel and electricity. Quantities and types for each of the energy requirements would be used to determine baseline emissions.	Related
B8 Fertilizer Transportation	Fertilizer may need to be transported to the site by truck. The related energy inputs for fuel will be used to calculate the resulting greenhouse gas emissions. Number of loads and distance travelled will be used to evaluate the baseline equivalent emissions.	Related
B9 Landfill Operations	Sludge may be disposed of in a landfill. Quantities and types for each of the energy inputs and outputs (CH_4) would be tracked to calculate baseline emissions. The length of time used for the quantification would be equivalent to the credit period of 5 years.	Related
B10 Incineration Sludge N_2O Emissions	N_2O emissions from baseline scenarios of landfilling, incineration or burning would need to be quantified. Assuming complete combustion during incineration, N_2O emissions would be calculated using the procedures described in Canada's 2004 National Greenhouse Gas Inventory.	Related
B11 Dryer	Sludge is sometimes dried prior to incineration in a dryer which requires natural gas for operation. The type and amount of fuel used and the number of hours of operation will be tracked to evaluate the baseline condition.	Related

B12 Sludge Incineration	Sludge may be disposed through incineration. To calculate the baseline emissions, the amount of CO_2 emitted after complete combustion of sludge in the incinerator would be calculated as well as the quantities and types of each of the energy inputs required for the operation and maintenance of the incinerator.	Related
B13 Co-Generation Power Facility	Sludge may be disposed through transportation and delivery to a co-generation power facility. Greenhouse gas emissions occur that are associated with the operation and maintenance of the facility. Quantities of emissions would be estimated to evaluate total greenhouse gas emissions.	Related
B24 Fuel Extraction / Processing	Each of the fossil fuels used throughout baseline operations will need to be sourced and processed. This will allow for the calculation of the greenhouse gas emissions from various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B27 Fuel Delivery	Each of the fuels used throughout the baseline operations will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling stations as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Baseline Operation		
B23 Fertilizer N_2O Emissions	Annual direct N_2O -N emissions from synthetic nitrogen fertilizer applied to soils, (kg N yr^{-1}) would need to be quantified on an annual basis for the duration of the credit period (5 years – or prior to reapplication of sludge).	Related
B14 Pesticide Application	Emissions associated with spreading pesticide. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
B21 Fertilizer Application	Fertilizer would be distributed on the field to achieve a uniform application rate. Type of equipment used and the area covered would be used to evaluate emissions from this activity.	Controlled
B15 Crop Seeding	Seed would need to be distributed on the field. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
B16 Above Ground Carbon Reservoir	Carbon will accumulate in the above ground biomass from sequestration in plant tissue. Yield from the produced crop would be measured and carbon content would be estimated based on previous research to evaluate above ground carbon accumulation. The extent of this accumulation would need to be tracked to determine the extent of above ground carbon sequestration under baseline conditions.	Controlled
B17 Soil Organic Carbon Reservoir	Carbon will be added to the soil through addition of carbon in the sludge matrix. Carbon will also accumulate in the below ground organic materials as a result of root biomass development and crop decomposition. The soil carbon content prior to sludge addition will be measured to a depth of 30 cm to determine the baseline condition.	Controlled
B18 Crop Harvest	Crops would need to be harvested and transported from the field to storage. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Controlled
Downstream SS's during Baseline Operation		
B19 Crop Transportation	Crops would need to be transported from storage to the market. Type of equipment, number of loads and distance travelled would be used to evaluate fuel requirements and equivalent emissions.	Related

B20 Crop Processing	Input of materials and energy used in the crop processing would be tracked to evaluate functional equivalence with the project condition.	Related
Other		
B25 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. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels and electricity used to power equipment for the extraction of the raw materials, processing, fabricating and assembly.	Related
B26 Equipment testing	Equipment may need to be tested to ensure that it is operational. This may result in running the equipment using fossil fuels in order to ensure that the equipment runs properly. These activities will result in greenhouse gas emissions associated with the combustion of fossil fuels and the use of electricity.	Related
B28 Equipment Transportation	Equipment built off site and the materials to build equipment on site, will all need to be delivered to the site. Transportation may be completed by train, truck, by some combination or even by courier. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels to power the equipment delivering the equipment to the site.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in the Canada's Offset System for Greenhouse Gases – Guide for Protocol Developers (August 2008 – Draft Version) and American National Standard – Greenhouse Gases Part 2 – Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements (ANSI/ISO/ASQ E14064-2, 2006). The justification for the exclusion or conditions upon which SS's may be excluded is provided. All other SS's listed previously are included. This information is summarized in **TABLE 2.4**.

Table 2.4. Comparisons of SS's for Agricultural Sludge Applications.

SS	Baseline (C,R,A)	Project (C,R,A)	Include or Exclude from Quantification	Justification for Exclusion
Upstream SS's				
B1 Sludge Loading	Related	N/A	Exclude	Excluded as the emissions from loading sludge are functionally equivalent in the project and baseline condition (i.e., the same amount of sludge is loaded for landfilling or incineration and for land application).
P1 Sludge Loading	N/A	Related	Exclude	
B2 Sludge Transportation	Related	N/A	Include	N/A
P2 Sludge Transportation	N/A	Related	Include	N/A
B3 Pesticide Production	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practices are covered under proposed greenhouse gas regulations. Further, the baseline and project conditions are functionally equivalent.
P3 Pesticide Production	N/A	Related	Exclude	
B4 Pesticide Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
P4 Pesticide Transportation	N/A	Related	Exclude	
B5 Seed Production	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practices are covered under proposed greenhouse gas regulations. Further, the baseline and project conditions are functionally equivalent.
P5 Seed Production	N/A	Related	Exclude	
B6 Seed Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible and likely functionally equivalent to the baseline scenario.
P6 Seed Transportation	N/A	Related	Exclude	
B7 Fertilizer Production	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emission from these practices are covered under proposed greenhouse gas regulations.
B8 Fertilizer Transportation	Related	N/A	Exclude	Excluded as the emissions from transportation are negligible.
B9 Landfill Operations	Related	N/A	Include	N/A
B10 Incineration Sludge N_2O	Related	N/A	Include	N/A
B11 Dryer	Related	N/A	Include	N/A

B12 Sludge Incineration	Related	N/A	Include	N/A
B13 Co-Generation Power Facility	Related	N/A	Exclude	Excluded as these SS's are subject to separate greenhouse gas regulations under which reporting and claiming carbon offsets is not under the control of the mechanical sludge producer.
B24 Fuel Extraction / Processing	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practices are covered under proposed greenhouse gas regulations.. Further, emissions from fuel extraction and processing are likely functionally equivalent in the project condition as the baseline scenario.
P24 Fuel Extraction / Processing	N/A	Related	Exclude	
B27 Fuel Delivery	Related	N/A	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practices are covered under proposed greenhouse gas regulations.
P27 Fuel Delivery	N/A	Related	Exclude	
Onsite SS's				
B23 Fertilizer N_2O Emissions	Related	N/A	Exclude	Excluded as emissions from this SS are negligible in comparison to the overall emission reductions proposed in this protocol (See Appendix B).
P23 Sludge N_2O Emissions	N/A	Controlled	Exclude	
P29 Sludge CH_4 Emissions	N/A	Controlled	Exclude	Excluded as emissions from this SS are negligible in comparison to the overall emission reductions proposed in this protocol (See Appendix B).
B14 Pesticide Application	N/A	Controlled	Exclude	Excluded as the emissions from application are negligible and likely functionally equivalent to the baseline scenario.
P14 Pesticide Application	Controlled	N/A	Exclude	
B21 Fertilizer Application	Controlled	N/A	Exclude	Excluded as emissions from fertilizer application over the 5 year credit allocation period are likely functionally equivalent or higher than sludge application and incorporation (i.e., fertilizer would be applied 5 times during the credit allocation period and although sludge application and incorporation may require more initial energy inputs, it is only required once during the same period).
P21 Sludge Application	N/A	Controlled	Exclude	
P22 Sludge Incorporation	N/A	Controlled	Exclude	
B15 Crop Seeding	Controlled	N/A	Exclude	Excluded as the emissions from crop seeding are likely functionally equivalent to the baseline scenario.
P15 Crop Seeding	N/A	Controlled	Exclude	
B16 Above Ground Carbon Reservoir	Controlled	N/A	Excluded	Excluded as the amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. Annual crops which are harvested each year therefore there is no long-term storage of carbon in biomass (IPCC 2006 Guidelines for Agricultural Land).
P16 Above Ground Carbon Reservoir	N/A	Controlled	Excluded	

B17 Soil Organic Carbon Reservoir	Controlled	N/A	Include	N/A
P17 Soil Organic Carbon Reservoir	N/A	Controlled	Include	
B18 Crop Harvest	Controlled	N/A	Exclude	Excluded as the emissions from crop harvesting are likely functionally equivalent to the baseline scenario.
P18 Crop Harvest	N/A	Controlled	Exclude	
Downstream SS's				
B19 Crop Transportation	Controlled	N/A	Exclude	Excluded as the emissions from crop transportation are negligible and likely functionally equivalent to the baseline scenario.
P19 Crop Transportation	N/A	Controlled	Exclude	
B20 Crop Processing	Controlled	N/A	Exclude	Excluded as the emissions from crop processing are likely functionally equivalent to the baseline scenario.
P20 Crop Processing	N/A	Controlled	Exclude	
Other				
B25 Building Equipment	Related	N/A	Exclude	Emissions from building equipment are not material given the long project life, and the minimal building equipment typically required.
P25 Building Equipment	N/A	Related	Exclude	
B26 Equipment Testing	Related	N/A	Exclude	Emissions from testing of equipment are not material given the minimal testing of equipment typically required.
P26 Equipment Testing	N/A	Related	Exclude	
B28 Equipment Transportation	Related	N/A	Exclude	Emissions from transportation of equipment are not material given the minimal transportation of equipment that would be required.
P28 Equipment Transportation	N/A	Related	Exclude	

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

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined below. Methods for quantifying baseline conditions are outlined in **TABLE 2.5**. A listing of relevant emission factors and example calculations are provided in **Appendices A, B and C**. Carbon sequestration or soil organic carbon can be calculated using either the simple or advanced quantification approach (**TABLES 2.6 and 2.7**). A **reversal coefficient** will be calculated as set out in this protocol to account for changes in practice that may occur during the credit period that could result in the release of sequestered carbon. These calculation methodologies serve to complete the following equations for calculating the emission reductions from the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Adjusted Baseline}^{1} * [\text{Emissions}_{\text{Landfill Operations}} + \text{Emissions}_{\text{Dryer}} + \text{Emissions}_{\text{Incineration}} + \text{Emissions}_{\text{Incineration Sludge N20}} + \text{Emissions}_{\text{Sludge Transportation}} + (-\text{Emissions}_{\text{Soil Carbon}})]$$

$$\text{Emissions}_{\text{Project}} = \text{Emissions}_{\text{Sludge Transportation}} + (-\text{Emissions}_{\text{Soil Carbon}})$$

Where:

Emission $_{\text{Baseline}}$ = sum of emissions under the baseline condition

Emissions $_{\text{Landfill Operations}}$ = Emissions under B9 Landfill Operations
Emissions $_{\text{Dryer}}$ = Emissions under B11 Dryer
Emissions $_{\text{Incineration}}$ = Emissions under B12 Incineration
Emissions $_{\text{Incineration Sludge N20}}$ = Emissions under B10 Incineration Sludge N_20
Emissions $_{\text{Sludge Transportation}}$ = Emissions under SS B2 Sludge Transportation
Emissions $_{\text{Soil Carbon}}$ = SS B17 Soil Organic Carbon Reservoir (Quantified using Simple or Advanced Approach)

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[1] Note – the adjusted baseline value is a 53% discount from the baseline emissions. This amount is based on five years of sludge land application data (1996 to 2001) from three mills operating in Alberta and represents the amount of sludge being land applied in Alberta at that time (Appendix B).

Emissions $_{Project}$ = sum of emissions under the project condition

Emissions $_{Sludge\ Transportation}$ = Emissions under SS P2 Sludge Transportation

Emissions $_{Soil\ Carbon}$ = SS P17 Soil Organic Carbon Reservoir (Quantified using Simple or Advanced Approach)

Total Reversal Coefficient (Mg C) = Credit Period (8 yrs) * Area Treated (ha) * 0.59 Mg CO_{2e} ha^{-1} yr^{-1} (Appendix B).

Table 2.5. Baseline Quantification Procedures – Agricultural Sludge Utilization

Baseline SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured or Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
$t\ CO_{2e}/yr = Gi * (1\ t\ CH_4/1000\ kg\ CH_4) * 21\ kg\ CO_{2e} / 1\ kg\ CH_4$ Where: $Gi = Mi * k * Lo * \exp^{(-k*ti)}$ and $Lo = MCF * DOC * DOC_F * F(16/12) * (1000\ kg\ CH_4/t\ CH_4)$ (IPCC/OECD/IEA, 1997)							
B9 Landfill Operations (Calculated for a 5 to 8 year credit period)	Gi = generation rate	kg CH_4/yr	Estimated	Scholl Canyon model (IPCC / Environment Canada guidelines)	N/A	Annual	Quantity being calculated
	Mi = mass of wet sludge	Mg	Measured	Direct measurement of amount of sludge going to landfill	N/A	Continuous	May be measured when loaded or delivered to site
	k = CH_4 generation rate	CH_4/yr	Estimated	NCASI, 2003 default = 0.03/yr	N/A	N/A	Default value for k based on NCASI (2003) report
	Ti = age of landfill	Years	Measured	Age of sludge diverted from landfill	N/A	Continuous	CH_4 generated over credit period
	Lo = generation	kg CH_4/t sludge	Estimated	IPCC/Environment Canada	N/A	Continuous	Represents amount of CH_4
	MCF = CH_4 correction	0.8	Estimated	IPCC/Environment Canada	N/A	Continuous	Correction factor accounts for difference between managed/unmanaged sites
	DOC=degradable organic fraction	0.3 t C/ t sludge	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Represents the amount of degradable organic carbon in wood waste
	DOC_F	0.5	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Fraction of DOC dissimilated
	F=fraction of CH_4 in landfill gas	F=0.4 to 0.6	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Value of 0.5 was chosen
$t\ CO_{2e}$ = BDT sludge * % carbon * 44 t • mol CO_2 / 12 t • mol C (assuming complete combustion) $t\ N_20 = t_{sludge} * (t\ N_2 / t_{sludge}) * (44\ t \bullet mol\ N_20 / 28\ t \bullet mol\ N_2) * 310\ kg\ CO_{2e} / 1\ kg\ N_20$							
B12 Incineration	BDT sludge	Mg dry sludge	Measured	Direct measurement of sludge produced	N/A	Continuous	Mill records of produced sludge
	% Carbon	Mg C/Mg dry sludge	Measured	Analysis by total combustion and infrared detection	N/A	Continuous or with process	Determine carbon content of sludge incinerated
	CO_2 equivalent	44/12	Measured	Stoichiometric factor to convert Mg carbon to CO2	N/A	Continuous	Factor to convert carbon to CO_2
B10 Incineration N_20 Emissions	N_2O emissions	t N_2O	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Periodic	Amount of N in sludge converted to N_2O by stoichiometric factor to convert N to N_2O

Table 2.5. (Concluded) Baseline Quantification Procedures – Agricultural Sludge Utilization

Project and Baseline SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured or Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
Dryer Natural Gas Usage t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet sludge * m^3 / 0.03723 Gj * 1.902 kg CO_{2e} / m^3 * Mg $CO_{2\,e}$ /1000 kg $CO_{2\,e}$ Dryer CH_4 emissions t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet * m^3 / 0.03723 Gj * 0.000037 kg CO_{2e} / m^3 * 21 kg CO2e / 1 kg CH4 Dryer NO_x emissions t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet * m^3 / 0.03723 Gj * 0.000033 kg CO_{2e} / m^3 * 310 kg CO_{2e} / 1 kg N_20							
B11 Dryer	Wet sludge	Mg wet	Measured	Direct measurement of amount of sludge to dryer	N/A	Continuous	Determined from historical site specific data sources
	Natural gas usage	Gj/Mg wet	Measured	Metered gas usage to dryer	N/A	Annual	Natural gas usage for dryer
	Conversion of Gj to m^3 equivalent	0.03723 m^3	Estimated	Natural Resources Canada, issues table (1998-1999)	N/A	Continuous	Factor to convert Gj natural gas to m^3
	GHG emission factor for CO_2	1.902 kg CO_2e /m^3	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Factor to convert m^3 natural gas used in flash dryer to CO_2 equivalent
	GHG emission factor for CH_4	0.000037 kg CO_{2e} / m^3	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Factor to convert m^3 natural gas used in flash dryer to CH_4 equivalent
	GHG emission factor for NO_x	0.000033 kg CO_{2e} / m^3	Estimated	Environment Canada Greenhouse Gas Inventory, 2004	N/A	Continuous	Factor to convert m^3 natural gas used in flash dryer to NOx equivalent
g CO_{2e} = (L fuel * 2.66 kg CO_2/L) + ((L fuel * 0.00015 kg CH_4/L) * 21 kg CO_{2e} / 1 kg CH_4) + (L fuel * 0.00008 kg N_20/L) * 310 kg CO_{2e} / 1 kg N_20) or g CO_{2e} = (km * 33.6 L/100 km * 2.66 kg CO_2/L) + ((km * 33.6 L/100 km * 0.000015 kg CH_4/L) * 21 kg CO_{2e} / 1 kg CH_4) + (km * 33.6 L/100 km * 0.00008 kg N_20/L) * 310 kg CO_{2e} / 1 kg N_20)							
P2/B2 Sludge Transportation	Combustion emission factor for fuel	g CO_{2e} /L	Measured	Use data from Canada's GHG Inventory for Heavy Duty Diesel Vehicle	N/A	Annually	Use truck haul records of haul distance, running hours, or actual fuel records

2.5.1.1 Advanced Quantification Approach for Sequestration

The advanced quantification approach utilizes the **comparison based approach** for quantifying baseline soil conditions. The quantification of reductions achieved by increased soil organic carbon for **all new** projects are based on actual comparison measurements and monitoring as indicated by the proper application of this protocol using approved control groups representing business as usual farming and cropping practices.

Project proponents are required to establish a control strip in each representative parcel of land designated for sludge application. Ideally the control strip will be located in the middle of the land area and be a minimum of 10 meters wide and run the entire length of the area to account for landscape variability. **No sludge should be applied in the control strip.**

The advanced approach requires a higher level of rigor for measurements and monitoring therefore estimated emissions are based on more accurate data and **no discount factor** is required. All soil (control and treatment) is to be sampled at the end of the credit period (5 to 8 years) to determine soil organic carbon content and bulk density. Farming and cropping practices remain the same between the control and treatment areas therefore any differences in soil organic carbon can be attributed to the addition of sludge. A reversal emission coefficient is applied to the quantification to account for GHG losses due to decomposition and volatilization over time. The recommended sampling scheme is shown in **Figure 2.3.** The quantification methods are described in **TABLE 2.6.**

Emissions from soil organic carbon sequestration can be calculated using the following equation:

$$\textbf{Emissions}_{\textbf{Soil Carbon}} = (\textbf{t } CO_{2e}/\textbf{ha}) = \textbf{SOC\%/100 * bulk density (kg/m}^3\textbf{) * sample depth (m) * 10 000 m}^2\textbf{/ha * 1 t/1000kg * (44 t•mol } CO_2\textbf{/ 12 t•mol C)}$$

If there is a change in practice that occurs during the credit period that could result in the release of carbon removed, there is a requirement to quantify not only the impact of not storing any new carbon in the current year, but the impact of losing previously sequestered carbon due to a change in management practice. This is done according to the following equation (**Appendix B**):

Total Reversal Coefficient = Credit Period (8 yrs) * Area Treated (ha) * 0.59 Mg $\mathbf{CO_{2e}\ ha^{-1}\ yr^{-1}}$ **(Appendix B)**

The total reversal coefficient is subsequently subtracted from the overall Emission Reductions.

$$\text{Emission Reduction Advanced Approach} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}} - \text{Total Reversal Coefficient}$$

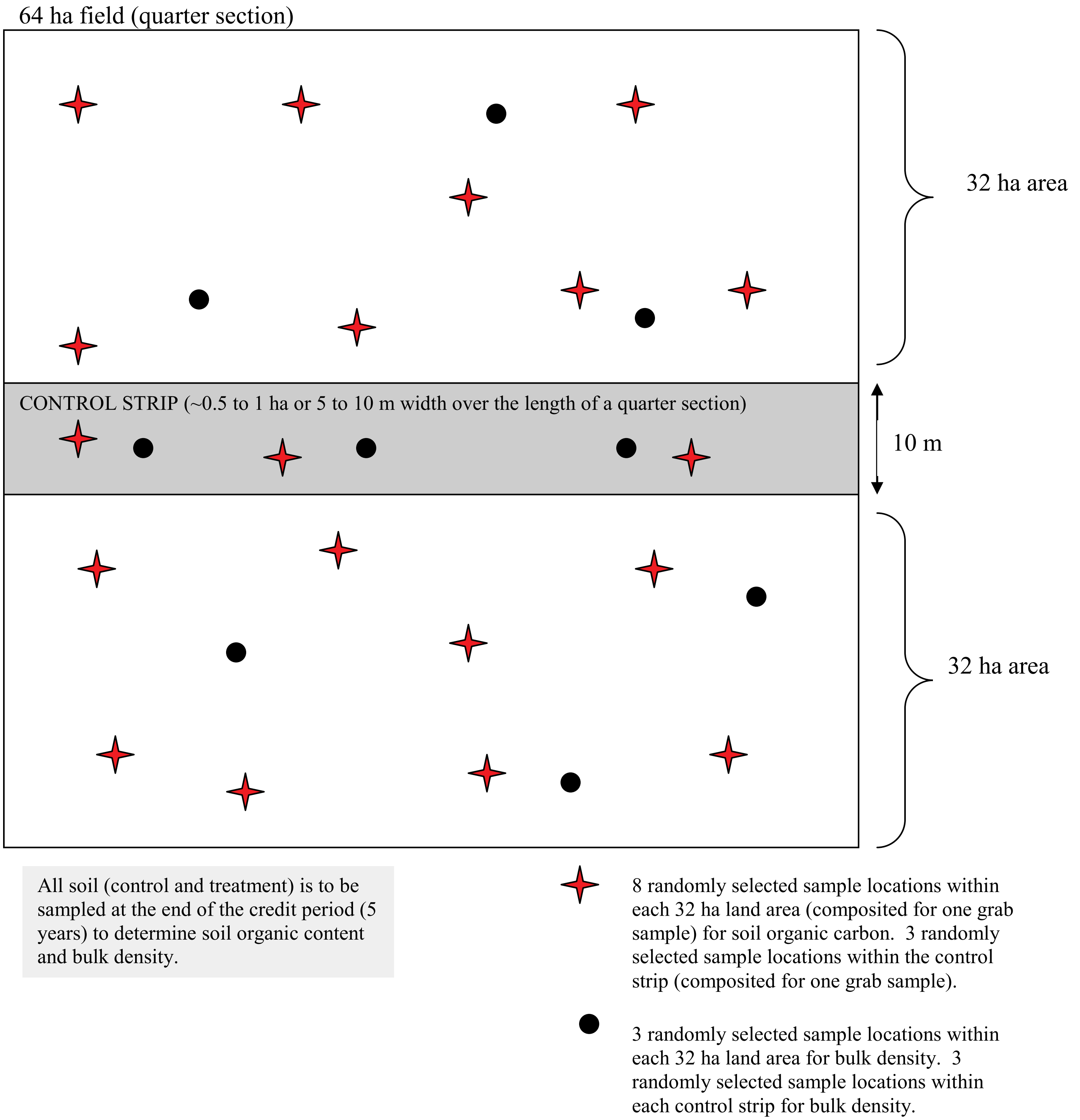

Figure 2.3. Diagram representing optimum sampling conditions. For land units of irregular shapes, modifications to this plan may be necessary however, the basic elements of the sampling scheme described should be maintained.

Table 2.6. Advanced Quantification Procedures – Agricultural Sludge Utilization

Project SS's							
Project/ Baseline	**Parameter/ Variable**	**Unit**	**Measured/ Estimated**	**Method**	**Sample Size**	**Frequency**	**Justify Measurement or Estimation or Frequency**
Soil organic carbon reservoir (t C/ha) = SOC%/100 * bulk density (kg/m^3) * sample depth (m) *10000 m^2/ha * 1 t/1000kg t CO_{2e} = t C/ha * Area (ha) * 44t•mol CO_2/12 t•mol C							
P17 Soil Organic Carbon Reservoir (Emission reductions from soil carbon addition and accumulations, Mg CO_2e/ha/yr)	Soil bulk density	kg/m^3	Measured using core sample of known volume and dry weight	Collect samples to a depth of 30 cm, using bulk density sampler and dry to constant weight	Sample minimum of 3, GPS referenced sample locations in each 32 ha area to confirm bulk density at end of credit period	At the end of each credit allocation period	Representative sample to account for variability in receiving soil characteristics
	Soil organic carbon	%	Measured	Using soil from bulk density sample measure SOC by total carbon by LECO furnace (Leco Corporation, 1993)	Minimum 8 randomly selected, GPS referenced sample locations within each 32 ha treatment area composited for one grab sample	At the end of each credit allocation period	For calculation of soil organic carbon content in sludge treated area
	Area treated	ha	Measured	Field survey or map	N/A	Initial survey of treated area	For determination of total credit
B17 Soil Organic Carbon Reservoir (Emission reductions from soil carbon addition and accumulations, Mg CO_2e/ha/yr)	Soil bulk density	kg/m^3	Measured using core sample of known volume and dry weight	Collect samples to a depth of 30 cm, using bulk density sampler and dry to constant weight	Minimum of 3 randomly selected, GPS referenced, individual sample locations within each control strip to confirm baseline bulk density	At the end of each credit allocation period	Representative sample to account for variability in receiving soil characteristics
	Soil organic carbon	%	Measured	Using soil from bulk density sample measure SOC by total carbon by LECO furnace (Leco Corporation, 1993)	Minimum of 3 randomly selected, GPS referenced sample locations within each control strip and composited for one grab sample	At the end of each credit allocation period	For calculation of soil organic carbon content area to be treated with sludge
	Area treated	ha	Measured	Field survey or map	N/A	Initial survey of treated area	For determination of total credit

2.5.1.2 Simple Quantification Approach for Sequestration

An alternative way for calculating or estimating the carbon offsets from land application of mechanical pulp mill sludge is summarized in **TABLE 2.7**. The simple quantification method outlined in **TABLE 2.7** can be applied to areas where no control strip has been established for comparison measurements. The simple approach requires the use of established data sources such as soil inventory and data maps and the Alberta Soil Information Viewer and/or previous sampling data for background soil organic carbon and bulk density information and incorporates a discount factor into the quantification. A range of soil carbon and bulk density data for soil regions in northern Alberta can be found in Appendix A, along with a list of references for use by project proponents to determine soil carbon and bulk density data. Further research will be required to extrapolate this quantification method to other regions of the province and country.

No actual measurements are required for quantification with the simple approach, therefore to ensure a conservative emission reduction when using the simplified approach a discount factor of **0.55** is incorporated into the quantification. The discount factor can be decreased with appropriate information provided for verification (**Appendix B**). A reversal coefficient is not required as no carbon sequestration is being quantified; only carbon inputs to the soil are considered when using this approach. Appropriate time and date stamped operational records are required to verify the amount of sludge hauled and applied to each designated parcel of land. An approximation of carbon in the final soil mix can be obtained as follows (Example quantification provided in **Appendix C**):

<u>Baseline (t carbon/ha in upper 30 cm of soil)</u>

t soil carbon = bulk density * depth * (%Carbon/100) * area
Note: This may need to be quantified in more than one step depending on the change with depth in soil organic carbon content and bulk density.

<u>Project (t carbon/ha in upper 30 cm of soil)</u>

t soil carbon mix = Sludge (t/ha) + Organic soil (t/ha) + Mineral soil (t/ha)

Where: Soil (t/ha) = soil depth (cm) * bulk density (g/cm^3)* area
Soil depth = incorporation depth (cm) – sludge depth (cm)
Sludge (t/ha) = application rate (t $_{\text{dry sludge}}$/ha)

Carbon content of final mix (t Carbon/t mix) = **((Sludge * Sludge $_{\%\ \text{carbon}}$) / t mix) + ((Soil * Soil $_{\%\ \text{carbon}}$) / t mix)**

t C/ha = (t Carbon/t mix) * t mix

Emission Reduction Simple Approach = **Baseline (t C/ha) – Project (t C/ha) * 0.55 discount factor**

Table 2.7. Simple Quantification Procedures – Agricultural Sludge Utilization.

Project/ Baseline	Parameter/ Variable	Unit	Measured/ Estimated	Method	Sample Size	Frequency	Justify Measurement or Estimation or Frequency
Emission Reduction t CO_{2e} = Baseline (t C/ha) – Project (t C/ha) * 0.55 discount * 44t•mol CO_2/12 t•mol C							
P17 Soil Organic Carbon Reservoir	Sludge application rate	Mg/ha	Measured	Operational records	N/A	Continuous	Rate of application determines carbon loading
	Sludge wet bulk density	Wet Mg/m^3	Measured	Operational records	N/A	Continuous or to reflect process change	Wet bulk density and moisture content of applied sludge to determine application rate
	Sludge moisture content	% solids	Measured	Operational records	N/A		
	Sludge carbon content	% Carbon	Measured	Operational records	N/A		Carbon content of dry sludge to calculate applied carbon equivalent
	Soil bulk density	kg/m^3	Estimated	Estimation from published soil survey data (Appendix A)	N/A	Check for updates or site specific measurements	Soil bulk density information related to established soil series
	Soil carbon content	% carbon	Estimated	Estimation from published soil survey data (Appendix A)	N/A	Check for updates or site specific measurements	Carbon content information related to soil survey data
	Soil/sludge mix depth	m	Estimated	Calculate using concentration x mass relations	N/A	Continuous	Calculate based on 30 cm depth for comparison to baseline condition (30 cm depth)
t Carbon = bulk density (kg/m^3) * depth * (%C/100) * area (ha) * 44t•mol CO_2/12 t•mol C							
B17 Soil Organic Carbon Reservoir	Soil bulk density	kg/m^3	Estimated	Estimation from published soil survey data (Appendix A)	N/A	Check for updates or site specific measurements	Soil bulk density information related to established soil series
	Soil carbon content	% carbon	Estimated	Estimation from published soil survey data (Appendix A)	N/A	Check for updates or site specific measurements	Carbon content information related to soil survey data
	Soil depth	m	Estimated	Calculate using concentration x mass relations	N/A	Continuous	Calculate based on 30 cm depth for comparison

2.6 Management of Data Quality

Since this protocol is a measurement based comparison approach, data quality management must include field measurements, and data from the sampling and related analytical work. Procedures will be established for measurements completed and sampling and analytical techniques for the baseline and project scenarios.

2.6.1 Record Keeping

Generators that distribute mechanical pulp sludge for the purposes of land application are to document and retain the following information for a minimum of 10 years:

a) Name, address, and phone number of the land owner, company, or individual using the sludge.
b) Legal land description of all areas of sludge application.
c) Quantity of sludge issued to each user.
d) Sample location, timing and name of qualified individuals conducting the sampling program.
e) Written logs of all field measurements and observations.
f) Electronic files of all raw and calculated data.
g) Blanks, duplicates, and internal standard tracking for all analytical data.
h) All records to be available for review and audit.

2.6.2 Quality Assurance/Quality Control Practices

a) Establish minimum experience standards for personnel conducting field measurements, sampling and analysis (**Appendix B**).

- Collection, analyses of samples and reporting should be conducted by qualified personnel in accordance with the following documents:
  - i. *Soil Sampling and Methods of Analysis*, Carter, M. (ed.), Lewis Publishers, 1993, Bocca Raton, Florida.
  - ii. *Standards and Guidelines for the Land Application of Mechanical Pulp Mill Sludge to Agricultural Land,* Alberta Environmental Protection, 1999.

b) A qualified professional is required to sign off on the field work completed to ensure quality work has been completed with due diligence.
c) Check data integrity of field measurements by performing random checks.
d) Confirm estimated data with confirming measurements.
e) Maintain database of analytical standards and unknowns.
f) Recalculate data to ensure no mathematical errors have been made.

Appendix A. Conversion and Emission Factors Used

P2/B2 Fuel Use – Sludge Transportation

$Emissions_{Sludge\ Transportation}$ = (L fuel * 2.66 kg CO_2/L) + ((L fuel * 0.00015 kg CH_4/L) * 21 kg CO_{2e} / 1 kg CH_4) + ((L fuel * 0.00008 kg N_2O/L) * 310 kg CO_{2e} / 1 kg N_20) = g CO_2 equivalent

kg CO_2 / L fuel used = 2.66
kg CH_4 / L fuel used = 0.00015
kg N_2O / L fuel used = 0.00008

or

$Emissions_{Sludge\ Transportation}$ = (km * 33.6 L/100km * 2.66 kg CO_2/L) + ((km * 33.6 L/100km * 0.00015 kg CH_4/L) * 21 kg CO_{2e} / 1 kg CH_4) + ((km * 33.6 L/100km * 0.00008 kg N_2O/L) * 310 kg CO_{2e} / 1 kg N_20) = g CO_2 equivalent

Diesel heavy truck = 33.6 L / 100 km

Greenhouse Gas Potential
CO_{2e} = N_2O x 310 kg CO_{2e} / 1 kg N_20
CO_{2e} = CH_4 x 21 kg CO_{2e} / 1 kg CH_4

Source:
National Inventory Report, 1990-2005, Greenhouse Gas Sources and Sinks in Canada. *(A12.1.4 Mobile Combustion – Table A12-7 – Uncontrolled Heavy Duty Diesel Vehicles)* Environment Canada, May 2008. http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/tdm-toc_eng.cfm

Fuel Economy factors (Heavy Duty Truck - Diesel) (*Canada's Climate Change Voluntary Challenge and Registry (VCR) – 2003)*

B9 Landfill Emissions

CH_4 emissions from landfilling pulp sludge are calculated using the Scholl Canyon Model (IPCC/OECD/IEA, 1997) which is used to estimate methane generation from landfills using the 1st order decay equation,

$$Gi = Mi * k * Lo * exp^{(-k*ti)}$$

Where:
- Gi = generation rate (kg CH_4/yr)
- Mi = mass of sludge (Mt)
- k = CH_4 generation constant (0.03/yr)
- Lo= CH_4 generation potential (kg CH_4/t sludge)
- Ti = age of material in landfill (years)

$Lo = MCF * DOC * DOC_F * F(16/12) * (1000\ kg\ CH_4/t\ CH_4)$

Where: $MCF = CH_4$ correction factor (0.8)
DOC = degradable organic carbon (0.3)
DOC_F = fraction of DOC dissimilated (0.5)
F = fraction of CH_4 in landfill gas (0.5)
16/12 = stoicheometric factor to convert CH_4 to carbon

$Lo = 0.8 * 0.3 * 0.5 * 0.5 (16/12) * 1000 = 80\ kg\ CH_4 / t$ sludge

MCF= CH_4 correction factor (fraction = 0.8 (IPCC/OECD/IEA, 1997))
DOC = degradable organic carbon (t C/t sludge = 0.3 (fraction of waste that is wood)
DOC_F =fraction of degradable organic carbon dissimilated = 0.5 (IPCC/OECD/IEA, 1997)
F = fraction of CH_4 in landfill gas = 0.5

The fraction of degradable organic carbon represents the amount of organic carbon that is accessible to biochemical decomposition, therefore assuming 100% wood composition the DOC value = 0.3

B12 Incineration
Assuming complete combustion, carbon is converted to CO_2

$CO_{2\,e}$ = BDT sludge * % carbon * 44 t • mol CO_2 / 12 t• mol C

Canada's Greenhouse Gas Inventory, 2004, Environment Canada

B10 Incineration N_20 Emissions
Assuming complete combustion, all nitrogen contained in the sludge gets converted to N_20

CO_{2e} from N_20 = t_{sludge} * ($t\ N_2$ / t_{sludge}) * (44 t • mol N_20 / 28 t • mol N_2) * 310 kg CO_{2e} / 1 kg N_20

Canada's Greenhouse Gas Inventory, 2004, Environment Canada (IPCC/OECD/IEA 1997)

B11 Dryer – Natural Gas Usage

Dryer Natural Gas Usage t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet sludge * m^3 / 0.03723 Gj * 1.902 kg CO_{2e} / m^3 * Mg $CO_{2\,e}$ /1000 kg $CO_{2\,e}$

Dryer CH_4 emissions t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet sludge * m^3 / 0.03723 Gj * 0.000037 kg CH_4 / m^3 * 21 kg $CO_{2\,e}$ / 1 kg CH_4

Dryer N_20 emissions t $CO_{2\,e}$ = Mg wet sludge * Gj/Mg wet * m^3 / 0.03723 Gj * 0.000033 kg N_20 / m^3 * 310 kg CO_{2e} / 1 kg N_20

Energy content of Natural Gas = 0.03723 GJ/m^3 (National Inventory Report (1990-2004 - Greenhouse Gas Sources and Sinks in Canada))

Emission Factor CO_2e = 1.902 kg CO_2e/m^3 of natural gas (National Inventory Report (1990-2004 - Greenhouse Gas Sources and Sinks in Canada))

Emission Factor CH_4 = 0.000037 kg CH_4 / m^3 of natural gas (National Inventory Report, 1990-2005 – A12.1 Fuel Combustion – Table A12-1: Emission Factors for Natural Gas and NGLs).

Emission Factor N_20 = 0.000033 kg N_20 / m^3 of natural gas (National Inventory Report, 1990-2005 – A12.1 Fuel Combustion – Table A12-1: Emission Factors for Natural Gas and NGLs).

National Inventory Report, 1990-2005, Greenhouse Gas Sources and Sinks in Canada. *(A12.1 Fuel Combustion – Table A12-1: Emission Factors for Natural Gas and NGLs)* Environment Canada, May 2008. http://www.ec.gc.ca/pdb/ghg/inventory_report/ 2006_report/tdm-toc_eng.cfm

Canadian GHG Challenge Registry Guide to Entity and Facility Based Reporting, Version 4.0, February 2005. *Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Product Facilities (Prepared for ICFPA by NCASI 2005)).*

Table A1. Soil Organic Carbon and Bulk Density Values

Soil Group	Horizon*	Organic Carbon (%)**	Bulk Density (Mg/m3)**
Dark Gray and Dark Gray Wooded	Ap B	3.5 to 12.0 0.5 to 2.0	0.60 to 1.0 0.90 to 1.4
Gray Wooded	Ap B	1.5 to 6.0 0.2 to 1.2	0.60 to 1.0 0.90 to 1.4

* Ap – defined as upper 15 cm of soil and representative of zone of incorporation
B – Defined as 15 to 30 cm of soil representing mineral zone below Ap (could include portions of Ae, AB and B horizons)
** Values based on data generated from field research trials resulting from sampling associated with operational sludge spreading programs in the vicinity of Whitecourt, Slave Lake and published soil survey data.

Alternative resources for estimating organic carbon content and bulk density:

Dumanski, J., Macyk, T.M, Veauvy, C.F, and J.D. Lindsay. 1972. Soil survey and land evaluation of the Hinton-Edson area, Alberta. Alberta Institute of Pedology Report No. S-72-31. 1972.

Wynnyk, A., Lindsay, J.D., and W. Odynsky. 1969. Soil survey of the Whitecourt and Barrhead area. Alberta Soil Survey Report No. 27, 1969.

Kyearsgaard, A. 1972. Soil survey of the Tawatinaw map sheet (83-I). Alberta Institute of Pedology Report No. S-72-29. 1972.

Pedocan Land Evaluation Ltd. 1993. Soil series information for reclamation planning in Alberta. Alberta Conservation and Reclamation Council Report No. RRTAC 93-7. ISBN 0-7732-6041-2.

Alberta Agriculture and Rural Development. 2008. Agricultural Region of Alberta Soil Inventory Database (AGRASID 3.0) http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag3252?opendocument

Appendix B. Technical Background Information

1.0 Development of the Discount Factor for the Simple Quantification Approach

The 0.55 discount factor for use in the simple quantification approach was determined based on the following:

Monitoring and quantification procedures prescribed for the simple quantification approach are designed to err on the conservative side in order to not over-estimate GHG emission reductions. A 55% discount factor applied to the carbon value of the simple quantification approach (Section 2.5.1.2) aims to account for the variability in bulk density and soil organic carbon content estimations. The organic carbon values provided in Table A1 for the Ap horizon vary by 70% and the bulk density values vary by 40%. The midpoint between the ranges in variation in organic matter content and bulk density is 55% and was chosen to represent the variation. As a result the discount factor was set at 0.55.

The discount factor could be decreased if appropriate historical documentation of actual measurement data could be presented to reassure verifiers that the variability in bulk density and organic carbon contents are less than the conservative values used for developing this discount factor.

2.0 Nitrous Oxide Quantifications – Land Application

Nitrous oxide (N_2O) is produced naturally in soils through the processes of nitrification and denitrification. Nitrification is the aerobic microbial oxidation of ammonium to nitrate, and denitrification is the anaerobic microbial reduction of nitrate to nitrogen gas (N_2). Nitrous oxide is a gaseous intermediate in the reaction sequence of denitrification and a by-product of nitrification that leaks from microbial cells into the soil and ultimately into the atmosphere. One of the main controlling factors in this reaction is the availability of inorganic N in the soil (IPCC 2006). The following methodology estimates N_20 emissions using human-induced net N additions to soils (e.g., synthetic or organic fertilizers, pulp sludge). The emissions of N_20 that result from anthropogenic N inputs or N mineralization occur through both a direct pathway (i.e., directly from the soils to which the N is added/released), and through two indirect pathways: i) following volatilization of NH_3 and NO_x from managed soils and the subsequent redeposition of these gases and their products NH_4^+ and NO_3^- to soils and waters; and ii) after leaching and runoff of N, mainly as NO_3^- from managed pathways.

The Tier 1 IPCC (2006) methodologies were used to quantify the direct and indirect N_20 emissions from the project and baseline condition, for the purpose of determining if it is acceptable to exclude N_20 emissions from the quantifications using the most conservative approach. The Tier 1 methodologies do not take into account different land cover, soil type, climatic conditions, or management practices. For simplicity, N from crop residues was omitted from these quantifications due to the variability in farming practices and crop types within the region, however the addition of this step would not increase the overall emission enough to change the results.

$$N_20\text{- } N = (N_20_{direct}\text{-}N + N_20_{indirect}\text{-}N) * (44 \text{ t} \bullet \text{mol } N_20 / 28 \text{ t} \bullet \text{mol } N_2)$$

Where:

N_20_{direct}-N = [F_{SN} + F_{ON}] * EF_1

F_{SN} = annual amount of synthetic fertilizer N applied to soil, kg N yr^{-1}
F_{ON} = annual amount of pulp sludge N applied to soil, kg N yr^{-1}
EF_1 = emission factor for N_20 emissions from N inputs, (0.01 kg N_20-N (kg N input)$^{-1}$)

$N_20_{indirect}$-N = N_20_{ATD}-N + N_20_L-N
Where:
N_20_{ATD}-N = [F_{SN} * $Frac_{GASF}$] + [F_{ON} * $Frac_{GASM}$] * EF_4
N_20_{ATD}-N = annual amount of N_20-N produced from atmospheric deposition of N volatilized from managed soils kg N_20-N yr-1
F_{SN} = annual amount of synthetic fertilizer N applied to soil, kg N yr^{-1}
F_{ON} = annual amount of pulp sludge N applied to soil, kg N yr^{-1}
$Frac_{GASF}$ = fraction of synthetic fertilizer N that volatilizes as NH_3 and NO_x, (0.10 kg N volatilized (kg N applied)$^{-1}$)
$Frac_{GASM}$ = fraction of pulp sludge N that volatilizes as NH_3 and NO_x (0.20 kg N volatilized (kg N applied)$^{-1}$)
EF_4 = emission factor for N_20 emissions from atmospheric deposition of N on soils and water surfaces (0.01 kg N-N_20 (kg NH_3–N + NO_x-N volatilized)$^{-1}$)

N_20_L-N = (F_{SN} + F_{ON} + F_{SOM}) * $Frac_{LEACH}$ * EF_5
N_20_L-N = annual amount of N_20-N produced from leaching and runoff of N additions to managed soils, kg N yr^{-1}
$Frac_{LEACH}$ = fraction of all N added to/mineralized in managed soils that is lost through leaching and runoff, (0.30 kg N (kg N additions)$^{-1}$)
EF_5 = emission factor for N_20 emissions from N leaching and runoff, (0.0075 kg N_20-N (kg N leached)$^{-1}$).
F_{SOM} = annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter as a result of changes to land use or management in regions where leaching/runoff occurs, kg N yr^{-1}

> Note: $F_{SOM} = \Sigma_{LU} [(\Delta C_{Mineral, LU} * 1/R) * 1000]$, where = average loss of soil carbon for each land use (LU) type, in tonnes C, 1/R = C:N ratio of soil organic matter. This factor involves specific information regarding soil organic carbon stock changes, stock change factors for management regimes and organic carbon additions, and the land area of the stratum being estimated. All land in the stratum requires common biophysical conditions (i.e., climate and soil type) and management history over the inventory time period. Although, this information is variable and site specific, based on initial quantifications it is not expected to significantly increase the quantity of N_20 emissions and can therefore be considered negligible and immaterial to these quantifications.

Using this approach to quantify N_20 emissions it was determined that the overall emissions from nitrous oxide were less than 5% of the overall emissions quantified in the project and thus were immaterial and excluded from the quantifications. See the example quantification below.

Table B-1. Assumptions for Example Quantification:

Fertilizer	Sludge Parameters	Trucking	Receiving Soil Properties		
Application Rate = 50 kg N /ha (Applied 5 times over 5 year credit period)	Carbon Content = 45% Nitrogen Content = 2%	Haul Distance = 100 km	**Depth**	**Db (kg/m3)**	**% Carbon**
	Application Rate = 50 t/ha (Applied 1 time over 5 year credit period)	35 t Truck Capacity	0-15 cm	0.9	3.29
		33.6 L/100km	15-30 cm	1.35	1.06

BASELINE N_20-N =
$[F_{SN} * EF_1] + [F_{SN} * Frac_{GASF} * EF_4)] + [F_{SN} * Frac_{LEACH} * EF_5] * 44/28$
= [50 kg N/ha * 0.01 kg N_20-N (kg N input)$^{-1}$] + [50 kg N/ha * 0.10 kg N volatilized (kg N applied)$^{-1}$ * 0.01 kg N-N_20 (kg NH_3–N + NO_x-N volatilized)$^{-1}$] + [50 kg N/ha * 0.30 kg N (kg N additions)$^{-1}$ * 0.0075 kg N_20-N (kg N leached)$^{-1}$]
= (0.5 kg N_20-N + 0.05 kg N_20 -N + 0.1125 kg N_20-N) * 44/28
= 0.6625 kg N_20-N * 44/28
Baseline N_20 emissions = 1.04 kg N_20 ha^{-1} yr^{-1}
1.04 kg N_20 ha^{-1} yr^{-1} * 310 kg CO_{2e} / 1 kg N_20 * (1 t / 1000 kg) * 5 applications over 5 year credit period = 1.61 t CO_{2e} / ha

PROJECT N_20-N =
$[F_{ON} * EF_1] + [F_{ON} * Frac_{GASM} * EF_4)] + [F_{ON} * Frac_{LEACH} * EF_5] * 44/28$
= [1000 kg N/ha * 0.01 kg N_20-N (kg N input)$^{-1}$] + [1000 kg N/ha * 0.20 kg N volatilized (kg N applied)$^{-1}$ * 0.01 kg N-N_20 (kg NH_3–N + NO_x-N volatilized)$^{-1}$] + [1000 kg N/ha * 0.30 kg N (kg N additions)$^{-1}$ * 0.0075 kg N_20-N (kg N leached)$^{-1}$]
= (10 kg N_20-N + 2 kg N_20 -N + 2.25 kg N_20-N) * 44/28
= 14.25 kg N_20-N * 44/28
Project N_20 emissions = 22.39 kg N_20 ha^{-1} yr^{-1}
22.39 kg N_20 ha^{-1} yr^{-1} * 310 kg CO_{2e} / 1 kg N_20 * (1 t / 1000 kg) * 1 application over 5 year credit period = 6.94 t CO_{2e} / ha

Overall N_20 Emissions = (Baseline N_20-N) – (Project N_20-N)
= 1.61 t CO_{2e} /ha – 6.94 t CO_{2e} /ha = - 5.33 t CO_{2e} /ha
Table B-2. Project and Baseline Emissions Associated with Mechanical Pulp Sludge Land Application over a 5 year period (without applying the discount factor)

		t CO_2e / 50 t/ha application	
		Landfill	Incineration
Baseline	B9 Landfill Operations	78	-
	B11 Flash dryer	-	72
	B12 Incineration	-	117
	B2 Sludge Transportation	0.044	-
	B23 Fertilizer N_20	1.61	1.61
	B17 SOC Reservoir	-201	-201
	Σ Emissions Baseline	-121.96	-10.34
Project	P17 SOC Reservoir	-279	-279
	P23 Sludge N_20	6.94	6.94
	P2 Sludge Transportation	0.44	0.44
	Σ Emissions Project	-271.62	-271.62
Baseline - Project		**149.66**	**261.28**

Since the overall N_20 emissions using the conservative Tier 1 IPCC (2006) methodologies are less than 5% of the total emissions for the project ([5.28 t CO_{2e} /ha] / [149.66 t CO_{2e} /ha] * 100% = 3.5%) the emissions can be excluded from the quantification.

3.0 Methane Gas Quantifications – Land Application

B_o values

The maximum methane-producing capacity of the sludge (B_o) has not been specifically determined. The theoretical default value for B_o of wastewater is 0.25 kg CH_4/kg BOD (IPCC 1996). Other sludges from kraft pulp mills have been tested and it was determined that the methane producing capacity ranged between 0.1 and 0.25 m^3 CH_4/kg volatile solids (Felske and Jenson, Personal Communication 2009).

MCFs

Methane conversion factors (MCFs) are determined for a specific waste management system and represent the degree to which B_o is achieved. The amount of methane generated by a specific waste management system is affected by the extent of anaerobic conditions present, the temperature of the system, and the retention time of organic material in the system. No MCFs specifically apply to pulp sludge however default methane conversion factors (MCFs) are provided in IPCC (2006) guidelines for different manure management systems and by annual average temperatures. MCF values are determined by temperature and manure management systems. The mean annual temperature of the Parkland region in Alberta is less than 10°C and the closest manure management system to land application of pulp sludge would be Pasture/Range/Paddock where the manure from pasture and range grazing animals is allowed to lie as deposited, and is not managed. The MCF under these conditions is 1%. Since the sludge is incorporated the MCF is likely higher than 1% (Table 10.17, V4:Ch10, IPCC 2006), therefore to ensure conservativeness a MCF of 5% was applied to the pulp sludge.

Total %C (Volatile Solids)	B_o	MCF	Application Rate
45%	0.25 m^3 CH_4/kg VS	5%	50 t/ha

The potential amount of methane that could be produced under the right conditions from transportation, storage and land application of sludge can thus be calculated.

Using a conservative approach:
50 t/ha * 1000 kg/t * 45% VS
= 22 500 kg VS/ha
22 500 kg VS/ha * 0.25 m^3 CH_4/kg VS * 5 %
= 218.25 m^3 CH_4/ha
218.25 m^3 CH_4/ha * 0.00068 t/ m^3 * 21 CO_{2e}
= 4.02 t CO_{2e}/ha

This indicates that even if 5% of the maximum methane-producing capacity of the sludge was emitted the amount would be immaterial in terms of the overall emission reductions ([4.02 t CO_{2e}/ha] / [149.66 t CO_{2e} /ha] * 100% = 2.7 %) and thus methane emissions can be excluded from the overall quantification.

4.0 SOC Reversal Quantifications

To increase the assurance that an offset has been created, the proponent must address the chance that a change in practice might occur during the credit period that could result in the release of carbon removed by applying a reversal using a reversal factor set out in the protocol. Previous work has assumed that the effect of reversing a practice change on soil organic carbon (SOC) is of the same magnitude but is the negative value of the effect of practice change (McConkey et al. 2007).

The requirement is to quantify not only the impact of not storing any new carbon in the current year, but also the impact of losing previously sequestered carbon due to a change in management practice. The principle of equal but opposite effects must also be applied to previously stored carbon. As such, the amount of previously stored carbon that would be lost by practicing Full-Till for one year would be equal to the amount of carbon gained from practicing No-Till for one year, assuming that the previous practice in the project was No-Till.

In order to calculate the reversal coefficients for SOC change, one must first calculate the net coefficients for positive tillage change. This is done by using the raw 5 year linear SOC coefficients from Table B1, to represent the number of years in the credit period and the area (ha) being treated.

Table B1. Effective Raw Linear Coefficients used to predict soil organic carbon change from tillage practice change for Specified Years after Practice Change.

Region	Tillage System Change	5 yr (Mg C ha^{-1} yr^{-1})	5 yr (Mg CO_2 ha^{-1} yr^{-1})	10 yr (Mg C ha^{-1} yr^{-1})	10 yr (Mg CO_2 ha^{-1} yr^{-1})
Parkland	FT to NT	0.17	0.63	0.16	0.59
	NT to FT	-0.17	-0.63	-0.16	-0.59

Source: Haak et al. 2006

Total Reversal Coefficient
(5 year Credit Period) = Yrs * ha * 0.63 Mg CO_{2e} ha^{-1} yr^{-1}
(8 to 10 year Credit Period) = Yrs * ha * 0.59 Mg CO_{2e} ha^{-1} yr^{-1}

Example:
Area of field treated = 100 ha
Credit Period = 5 years

Total Reversal Coefficient = 5 yr * 100 ha * 0.63 Mg CO_{2e} ha^{-1} yr^{-1}
= 320 Mg CO_{2e}

5.0 Adjusted Baseline

An industry wide adjusted baseline was determined by evaluating the total amount of sludge produced compared to the total amount of sludge applied to agriculture land for three mechanical pulp mills from 1996 to 2001.

	Sludge Produced (Bone Dry t)							Sludge Land Applied (Bone Dry t)						
Mill	1996	1997	1998	1999	2000	2001	96-01	1996	1997	1998	1999	2000	2001	96-01
1	13769	15423	15607	15789	18354	20441	***99383***	8909	10530	12305	10669	12136	11987	***66536***
2	11353	22144	20310	25394	20075	14499	***113775***	0	914	0	0	5590	13596	***20100***
3	11778	11430	15655	15205	22647	18757	***95472***	5786	6905	12613	11208	20792	18187	***75490***
	Total Sludge Produced (t)						***308630***	**Total Sludge Applied (t)**						***162126***

Sector Adjusted Baseline (1996 - 2001)

$$\text{Adjusted Baseline}_{\text{sector adjusted}} = \frac{\Sigma \text{ total applied}_{1996\text{-}2001}}{\Sigma \text{ total produced}_{1996\text{-}2001}}$$

$$= \mathbf{0.53}$$

6.0 Professional Qualifications

Minimum experience standards for personnel conducting field measurements, sampling and analysis can be determined at the discretion of the professional signing off on the project. A qualified professional consists of any individual belonging to an accredited professional organization or a person with 10 or more years of relevant experience in soils. It is the responsibility of the professional to ensure that an appropriate number of field samples were collected using appropriate methods and handled according to laboratory requirements.

7.0 References

Haak, D., with Soil Management Technical Working Group for Canada's GHG Offset System. 2006. Tillage System Default Coefficient Protocol based on Canada's Offset System for Greenhouse Gases Technical Background Document (DRAFT), 72 pp.

IPCC 2006. Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. National Greenhouse Gas Inventories Programme. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

McConkey, B., D. Angers, M. Bentham, M. Boehm, T. Brierley, D. Cerkowniak, C. Liang, P. Collas, H. de Gooijer, R. Desjardins, S. Gameda, B. Grant, T. Huffman, J. Hutchinson, L. Hill, P. Krug, C. Monreal, T. Martin, G. Patterson, P. Rochette, W. Smith, B. VandenBygaart, X. Vergé, D. Worth. 2007. Canadian Agricultural Greenhouse Gas Monitoring Accounting and Reporting System (CanAG-MARS): Methodology and greenhouse gas estimates for agricultural land in the LULUCF sector for NIR 2006, 138 pp.

National Inventory Report, 1990-2005, Greenhouse Gas Sources and Sinks in Canada. *(A12.1.4 Mobile Combustion – Table 12-7 – Uncontrolled Heavy Duty Diesel Vehicles)* Environment Canada, May 2008. http://www.ec.gc.ca/pdb/ghg/inventory_report/ 2006_report/tdm-toc_eng.cfm

Canadian GHG Challenge Registry Guide to Entity and Facility Based Reporting, Version 4.0, February 2005. *Calculation Tools for Estimating Greenhouse Gas Emissions from Wood Product Facilities (Prepared for ICFPA by NCASI 2005)).*

Appendix C. Example Calculation for Simple Quantification Method

Baseline (t carbon/ha in upper 30 cm of soil)

Organic (10 cm)
Dbd = 0.9 g/cm^3
%C = 3.29

Mineral (20 cm)
Dbd = 1.35 g/cm^3
%C = 1.06

30 cm

<u>Organic</u>
10 000m^2 * 100cm/1m * 100cm/1m * 10cm * 0.9g/cm^3 * 3.29 gC/100g soil * 1kg/1000g * 1 tC/1000kgC = 29.6 t C/ha

<u>Mineral</u>
10 000m^2 * 100cm/1m * 100cm/1m * 20cm * 1.35g/cm^3 * 1.06 gC/100g soil * 1kg/1000g * 1 tC/1000kgC = 28.6 t C/ha

Total 30 cm = 29.6 + 28.6 = 58 t C/ha

58 t C/ha * 44 t • mol CO_2 / 12 t • mol C * 0.50 discount factor = 106 t CO_{2e} in SOC reservoir

Project (t carbon/ha in upper 30 cm of soil after addition of 50 t dry sludge/ha)

Organic (10 cm) / Sludge (3.5 cm) / Mineral (16.5 cm) Mix
Organic Dbd = 0.9 g/cm^3
%C organic = 3.29

Mineral
Dbd = 1.35 g/cm^3
%C = 1.06

30 cm sludge/organic/mineral mix

<u>Depth of sludge at 50 t/ha</u>
50 t dry * 100 t wet/30 t dry * 1 m^3/0.48t wet * 1 ha/10 000m^2 * 100cm/1m = 3.5 cm

<u>Total Weight of 30 cm Mix (Sludge = 50 t)</u>
Organic - 10 000m^2 * 100cm/1m * 100cm/1m * 10cm * 0.09g/cm^3 * 1kg/1000g * 1 tC/1000kg C = 900 t C / ha
Mineral - 10 000m^2 * 100cm/1m * 100cm/1m * 16.5cm * 1.35g/cm^3 * 1kg/1000g * 1 tC/1000kg C = 2275 t C / ha

Total 30 cm Mix = 50 +900 + 2275 = 3225 t C / ha

<u>t C/ha/30 cm mix =</u>

$$\frac{(\text{t sludge} * \%\,C/100)}{\text{t 30 cm mix}} + \frac{(\text{t organic} * \%\,C/100)}{\text{t 30 cm mix}} + \frac{(\text{t mineral} * \%\,C/100)}{\text{t 30 cm mix}} * \text{t Mix}$$

= (50*(45/100)/3225) + (900*(3.29/100)/3225) + (2275*(1.06/100)/3325 * 3225

= 76 t C/ha /30 cm mix

76 t C/ha * 44 t • mol CO_2 / 12 t • mol C * 0.50 discount factor = 139 t CO_{2e} in SOC reservoir

Emission Reduction = (Baseline – Project) * 0.5 discount factor
Emission Reduction = 106 t CO_{2e} /ha – 139 t CO_{2e} /ha = -33 t CO_{2e} /ha