QUANTIFICATION PROTOCOL FOR INNOVATIVE FEEDING OF SWINE AND STORING AND SPREADING OF SWINE MANURE

ABRIDGED

Submitted to:

Alberta Environment

and

Alberta Agriculture, Food and Rural Development

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Disclaimer

The following document presents an abridged version of the Innovative Feeding of Swine and Storing and Spreading of Swine Manure protocol prepared for Alberta Environment and Alberta Agriculture, Food and Rural Development which has completed an initial round of technical review. This document has been prepared as a means of supporting a broader stakeholder consultation process. As such, this document should not be used as a quantification protocol.

The full-length version of this protocol is largely based on the *Greenhouse Gas System Pork Protocol: The Innovative Feeding of Swine and Storing and Spreading of Swine Manure (Draft)* dated July 31, 2006. This work was completed under the Pork Technical Working Group (PTWG), a sub-committee of the National Offsets Quantification Team (NOQT). This work represents the culmination of a multi-stakeholder consultation project and reliance on a number of guidance documents.

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1.0 Project and Methodology Scope and Description

This quantification protocol is applicable to the quantification of direct and indirect reductions of greenhouse gas (GHG) emissions resulting from the implementation of two kinds of innovative practices on swine farms. First, the protocol quantifies GHG reductions achieved by feed substituting practices that decrease emissions. In the feeding component of the Pork Protocol, these practices substitute ingredients in the feed to reduce excretion of volatile solids (VS) by increasing energy digestibility and to reduce excretion of nitrogen (N) by optimizing amino acid balance. In the storing and spreading component, these practices substitute the season and frequency of manure spreading to decrease the conversion of VS to CH_4 in storage and to decrease emission of N_2O after spreading. Second, the protocol quantifies reductions associated with pig husbandry practices that increase efficiency by generating less manure per unit of pigs raised. These practices reduce manure excretion by decreasing the feed and/or by decreasing the time needed to raise the pigs under project conditions. **FIGURE 1.1** offers a project element life cycle chart for a typical project.

The Pork Protocol does not prescribe the efficiency-type practices. Rather, this protocol serves as a generic 'recipe' for project proponents to follow in order to meet the measurement, monitoring and GHG quantification requirements. As long as the proponent provides the evidence that less VS and/or N is excreted per unit pig raised, the practice fits within the scope of the Pork Protocol. From both kinds of innovative practices (substitution- and efficiency-type innovations), the total amount of VS and N excreted is decreased, resulting in reduction of CH_4 emission from stored manure and in reduction of N_2O emission from land receiving manure.

The Pork Protocol quantifies emissions reductions on the basis of the pigs raised in the project. Thus, the starting point for all quantification is the number and weight of pigs produced in the project. To calculate the VS and N excretions, the Pork Protocol uses baseline pig performance (supplied by the project proponent or taken from sector-level standards) and baseline manure storage (set as fall emptying for Alberta[1]) and spreading practices. Excretions that would have occurred if the pigs in the project had been raised under these baseline conditions are estimated. Then, the recorded feed and sales information and the documented manure management strategy are used to calculate the project condition excretions and emissions. This approach (1) ensures the functional equivalence of the project with the baseline scenario, (2) eliminates the potential for attributing offsets for decreased numbers of pigs raised, and (3) emphasizes the efficiency objective of the Pork Protocol; namely, to encourage practices that decrease GHG emissions per unit weight of pigs raised. **FIGURE 1.2** offers an element life cycle chart for a typical baseline configuration.

The boundary of the Pork Protocol encompasses the barn where the pigs are raised, the facility where liquid manure is stored, and the land where the liquid manure is spread.

[1] Note – common industry practice for Alberta is fall emptying, indicated in the Statistics Canada Farm Environmental Management Survey (FEMS) 2001.

The project may include a number of sites, and a variety of enterprises, but all project farms will address the activities within the boundary of the Pork Protocol.

FIGURE 1.1: Project Element Life Cycle Chart

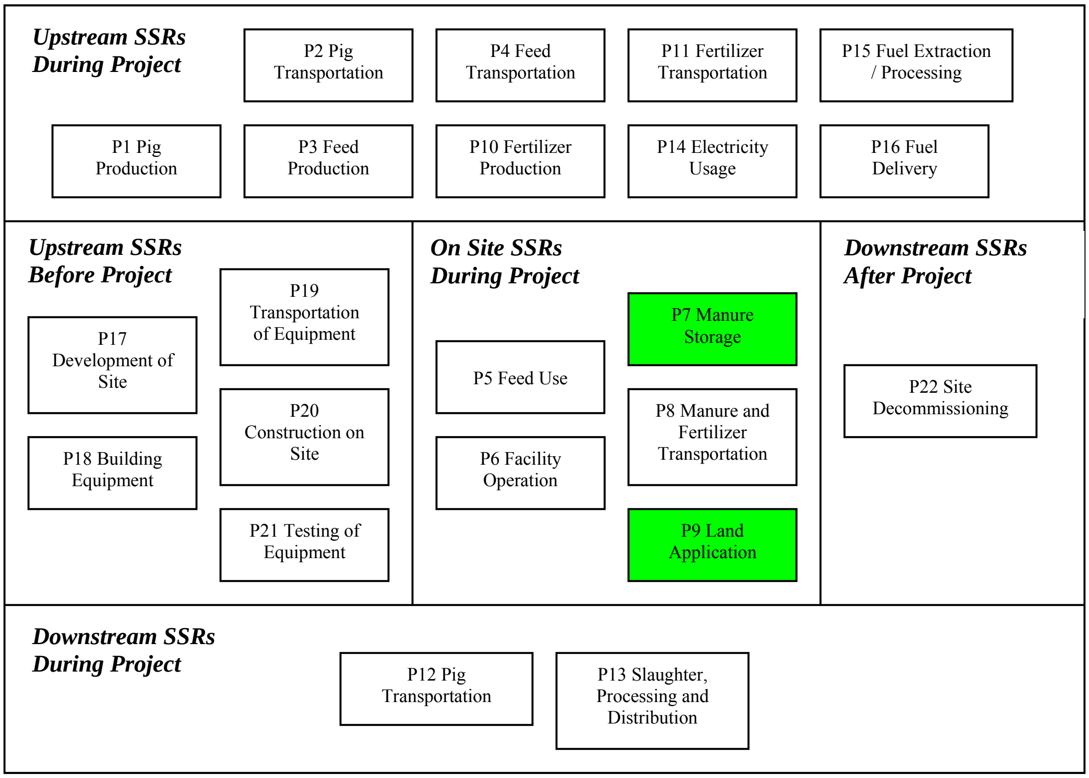
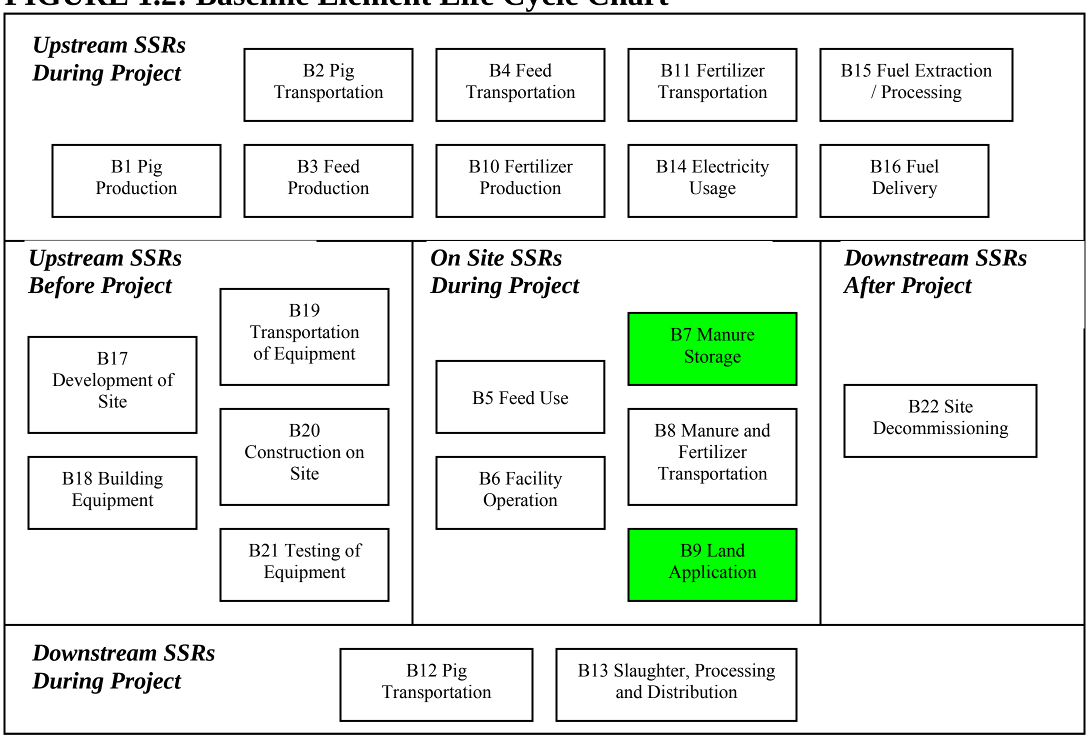


FIGURE 1.2: Baseline Element Life Cycle Chart



To demonstrate that a project meets the requirements under this protocol, the project proponent must supply sufficient evidence to demonstrate that:

1. All farms in the project are currently feeding swine (farrow, farrow to wean, farrow to finish, nursery, feeder operation) as confirmed by an attestation from the project proponent;
2. All farms in the project are currently storing manure for a period of 9 months as confirmed by an attestation from the project proponent;
3. All farms in the project are currently applying manure or custom applying manure to land as confirmed by an attestation from the project proponent;
4. All farms in the project can demonstrate a change in practice in at least one of the Feeding, or Storing and Spreading components of the Pork Protocol. The evidence for change in practice varies with the component of the Pork Protocol:
    - Feeding component — decreased N and/or VS content in the diets and/or decreased feed consumption per unit pigs sold relative to the project-specific or sector-level baseline. Decreased feed consumption per unit pigs raised may be achieved by a range of practices, including, but not limited to:
        - Split-sex or phase feeding;
        - Wet/dry feeders;
        - Improved ventilation/temperature control in the barn;
        - Improved health status of the swine herd;
        - More efficient genetics; or
        - Additives to improve feed efficiency.
    - Storing & Spreading component — change to spring or spring-and-fall emptying and spreading, where the baseline for all projects is set as fall emptying.
5. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

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

1. A project proponent may choose to implement only one component, e.g. practices to reduce methane emissions from manure storage, but they would be required to perform the calculations for the other two components to ensure the net balance of GHG emissions is still positive. This must be shown in the project document;
2. If a farm has both solid and liquid swine manure systems, the feed for pig classes under liquid manure can be split out and applied to the Pork Protocol;

3. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy; and
4. The Pork Protocol promotes a project-specific baseline (based on real historical data), but allows for selection of a sector-level baseline using regional data for feeding (Livestock Feed Requirements Study 2001). All project developers will use an assumed baseline for the storage and spreading component of the Pork Protocol. The Quantification Plan of the Pork Protocol specifies the calculations to be used for each option. Farms that were not operating at the Eligibility Start Date may use their start-up feeding data as a project-specific baseline, or they may choose to use the sector-level feeding baseline to participate in Pork Protocol projects. If applicable, the proponent must indicate and justify why flexibility provisions have been used.

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2.0 Quantification of Identified Sources, Sinks and Reservoirs

Quantification of the reductions, removals and reversals of relevant SSRs for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.4**, below. A These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

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

$$\begin{aligned}\text{Emissions}_{\text{Baseline}} = {} & \text{Emissions}_{\text{Methane}} + \text{Emissions}_{\text{Direct Nitrous Oxide}} \\ & + \text{Emissions}_{\text{Indirect Volatization Nitrous Oxide}} \\ & + \text{Emissions}_{\text{Indirect Leachate Nitrous Oxide}}\end{aligned}$$

$$\begin{aligned}\text{Emissions}_{\text{Project}} = {} & \text{Emissions}_{\text{Methane}} + \text{Emissions}_{\text{Direct Nitrous Oxide}} \\ & + \text{Emissions}_{\text{Indirect Volatization Nitrous Oxide}} \\ & + \text{Emissions}_{\text{Indirect Leachate Nitrous Oxide}}\end{aligned}$$

TABLE 2.1: Quantification Procedures

1.0 Project / Baseline SSR	2. Parameter / Variable	3. Unit
Project SSRs		
P7 Manure Storage	$VS_{Pig\ Class\ i} = FI_{Pig\ Class\ i} * (DM_{Pig\ Class\ i} - Ash_{Pig\ Class\ i}) / 100 * (1 - ED_{Pig\ Class\ i}) / 100$ or $VS_{Pig\ Class\ i} = Population_{Pig\ Class\ i} * Frac\ VS\ Excreted_{Pig\ Class\ i} / 100 * DFI_{Pig\ Class\ i} * Days_{Month}$	
	Volatile Solids Excreted Monthly per Pig Class / $VS_{Pig\ Class\ i}$	Mg
	Total Feed Intake per Month per Pig Class / $FI_{Pig\ Class\ i}$	Mg
	Percentage of Dry Matter in Feed for the Month per Pig Class / $DM_{Pig\ Class\ i}$	%
	Percentage of Ash Content in Feed for the Month per Pig Class / $Ash_{Pig\ Class\ i}$	%
	Energy Digestibility for Feed for the Month per Pig Class / $ED_{Pig\ Class\ i}$	%
	Population of Pigs for the Month per Pig Class / $Population_{Pig\ Class\ i}$	head
	Fraction of Volatile Solids Excreted Due to Feed for the Month per Pig Class / $Frac\ VS\ Excreted_{Pig\ Class\ i}$	%
	Daily Feed Consumption per Pig Class / $DFI_{Pig\ Class\ i}$	Mg / head / d
	Days Month	d
	$VS\ Load = VS_{Monthly\ Total} * SCA$	
	Monthly Loading of Volatile Solids / VS Load	Mg
	Monthly Total of Volatile Excreted Summed across Pig Classes / $VS_{Monthly\ Total}$	Mg
	Storage Characteristic Adjustment Factor / SCA	-
	$VS\ Available = VS\ Load + [VS\ Available_{Last\ Month} - VS\ Converted_{Last\ Month}]$	
	Available Volatile Solids for the Month / VS Available	Mg
	Available Volatile Solids for the Previous Month / $VS\ Available_{Last\ Month}$	Mg
	Volatile Solids Converted to Methane for the Previous Month / $VS\ Converted_{Last\ Month}$	Mg
	$f = \exp [(E_{Activation} * (T_{Average} - T_{Standard})) / (R_{Gas\ Constant} * T_{Average} * T_{Standard})]$	
	Monthly Climate Factor / f	-
	Activation Energy Constant / $E_{Activation}$	cal / mol
	Ideal Gas Constant / $R_{Gas\ Constant}$	cal * ºK / mol
	Standard Temperature	ºK
	Average Monthly Temperature	ºK
	$Emissions_{Methane} = \sum [VS_{Available\ month\ i} * f_{month\ i} * B_o]$	
	$Emissions_{Methane}$	Mg
	Maximum Methane Production Capacity / B_o	-
P9 Land Application	$Nitrogen\ Available_{Pig\ Class\ i} = [(Nitrogen\ in\ Feed_{Pig\ Class\ i} / 100) * Mass\ of\ Feed_{Pig\ Class\ i}] - \{[(Nitrogen\ in\ Pigs\ Sold_{Pig\ Class\ i} / 100) * Mass\ of\ Pigs\ Sold_{Pig\ Class\ i}] - [(Nitrogen\ in\ Pigs\ Purchased_{Pig\ Class\ i} / 100) * Mass\ of\ Pigs\ Purchased_{Pig\ Class\ i}]\}$	
	Nitrogen Available to Volatize from Pig Class i / $Nitrogen\ Available_{Pig\ Class\ i}$	Mg / Event
	Concentration of Nitrogen in Feed for Pig Class i / $Nitrogen\ in\ Feed_{Pig\ Class\ i}$	%
	Mass of Feed for Pig Class i / $Mass\ of\ Feed_{Pig\ Class\ i}$	Mg / Event

	Concentration of Nitrogen in Pigs Sold from Pig Class i / $\text{Nitrogen in Pigs Sold}_{\text{Pig Class i}}$	%
	Mass of Pigs Sold from Pig Class i / $\text{Mass of Pigs Sold}_{\text{Pig Class i}}$	Mg / Event
	Concentration of Nitrogen in Pigs Purchased into Pig Class i / $\text{Nitrogen in Pigs Purchased}_{\text{Pig Class i}}$	%
	Mass of Pigs Purchased from Pig Class i / $\text{Mass of Pigs Purchased}_{\text{Pig Class i}}$	Mg / Event
	$\text{Nitrogen}_{\text{Manure}} = \sum [\text{Nitrogen Available}_{\text{Monthly Total}} * (1 - \text{Volatilization Rate})]$	
	Nitrogen in Manure at Event / $\text{Nitrogen}_{\text{Manure}}$	Mg / Event
	Monthly Total of Nitrogen Available Across Pig Classes / $\text{Nitrogen Available}_{\text{Monthly Total}}$	Mg
	Volatilization Rate	-
	$\text{Emissions}_{\text{Direct Nitrous Oxide}} = \sum [\text{Nitrogen}_{\text{Manure}} * \text{Emission Factor}_{\text{Evap to Precip}} * \text{Ratio Factor}_{\text{Thaw}} * \text{Ratio Factor}_{\text{Season}}]$	
	Direct Emissions of Nitrous Oxide from Manure Spread Across Events / $\text{Emissions}_{\text{Direct Nitrous Oxide}}$	Mg
	Emission Factor Adjusted According to Ratio of Potential Evaporation to Precipitation / $\text{Emission Factor}_{\text{Evap to Precip}}$	-
	Ratio Factor to Correct for Emissions During Snow-Covered Periods / $\text{Ratio Factor}_{\text{Thaw}}$	-
	Ratio Factor to Account for Season of Manure Application / $\text{Ratio Factor}_{\text{Season}}$	-
	$\text{Emissions}_{\text{Indirect Volatilization Nitrous Oxide}} = \sum [\text{Nitrogen Available}_{\text{Monthly Total}} * \text{Volatilization Rate} * \text{Emission Factor}_{\text{Volatilization}}]$	
	Indirect Emissions of Nitrous Oxide from Volatilization and Redeposition of NH_3 and NOx / $\text{Emissions}_{\text{Indirect Volatilization Nitrous Oxide}}$	Mg
	Emission Factor for N_2O from Nitrogen Redeposited after Volatilization / $\text{Emission Factor}_{\text{Volatilization}}$	kg N_20 - N / kg N
	$\text{Emissions}_{\text{Indirect Leachate Nitrous Oxide}} = \sum [\text{Nitrogen}_{\text{Manure}} * \text{Fraction}_{\text{Leachate}} * \text{Emission Factor}_{\text{Leachate}}]$	
	Indirect Emissions of Nitrous Oxide from Volatilization and Leachate / $\text{Emissions}_{\text{Indirect Leachate Nitrous Oxide}}$	Mg
	Fraction of Nitrogen Lost in Leachate / $\text{Fraction}_{\text{Leachate}}$	-
	Emission Factor for N_2O from Leachate / $\text{Emission Factor}_{\text{Leachate}}$	kg N_20 - N / kg N
B7 Manure Storage	$\text{VS}_{\text{Pig Class i}} = \text{FI}_{\text{Pig Class i}} * (\text{DM}_{\text{Pig Class i}} - \text{Ash}_{\text{Pig Class i}}) / 100 * (1 - \text{ED}_{\text{Pig Class i}}) / 100$ or $\text{VS}_{\text{Pig Class i}} = \text{Population}_{\text{Pig Class i}} * \text{Frac VS Excreted}_{\text{Pig Class i}} / 100 * \text{DFI}_{\text{Pig Class i}} * \text{Days}_{\text{Month}}$	
	$\text{VS Load} = \text{VS}_{\text{Monthly Total}} * \text{SCA}$	
	$\text{VS Available} = \text{VS Load} + [\text{VS Available}_{\text{Last Month}} - \text{VS Converted}_{\text{Last Month}}]$	
	$f = \exp [(E_{\text{Activation}} * (T_{\text{Average}} - T_{\text{Standard}})) / (R_{\text{Gas Constant}} * T_{\text{Average}} * T_{\text{Standard}})]$	
	$\text{Emissions}_{\text{Methane}} = \sum [\text{VS}_{\text{Available month i}} * f_{\text{month i}} * B_o]$	
B9 Land Application	$\text{Nitrogen Available}_{\text{Pig Class i}} = [(\text{Nitrogen in Feed}_{\text{Pig Class i}} / 100) * \text{Mass of Feed}_{\text{Pig Class i}}] - \{[(\text{Nitrogen in Pigs Sold}_{\text{Pig Class i}} / 100) * \text{Mass of Pigs Sold}_{\text{Pig Class i}}] - [(\text{Nitrogen in Pigs Purchased}_{\text{Pig Class i}} / 100) * \text{Mass of Pigs Purchased}_{\text{Pig Class i}}]\}$	
	$\text{Nitrogen}_{\text{Manure}} = \sum [\text{Nitrogen Available}_{\text{Monthly Total}} * (1 - \text{Volatilization Rate})]$	
	$\text{Emissions}_{\text{Direct Nitrous Oxide}} = \sum [\text{Nitrogen}_{\text{Manure}} * \text{Emission Factor}_{\text{Evap to Precip}} * \text{Ratio Factor}_{\text{Thaw}} * \text{Ratio Factor}_{\text{Season}}]$	
	$\text{Emissions}_{\text{Indirect Volatilization Nitrous Oxide}} = \sum [\text{Nitrogen Available}_{\text{Monthly Total}} * \text{Volatilization Rate} * \text{Emission Factor}_{\text{Volatilization}}]$	
	$\text{Emissions}_{\text{Indirect Leachate Nitrous Oxide}} = \sum [\text{Nitrogen}_{\text{Manure}} * \text{Fraction}_{\text{Leachate}} * \text{Emission Factor}_{\text{Leachate}}]$	

APPENDIX A: Glossary of New Terms

The following definitions are critical to the appropriate interpretation of this quantification protocol.

Emptying season:	The time of year that the manure storage is agitated and emptied, and the manure applied to cropland. For the purposes of this protocol the baseline is set as fall emptying.
Farrow-to-finish:	A term used to describe a pig farm on which animals complete their entire life cycle, from birth to market.
Farrow-to-wean:	Term used to describe a pig farm on which the main product is a 5-25kg pig. These young pigs, known as 'weaners' are sold off the farrow-to-wean farm to a finishing operation that would grow the weaners from 5-25 kg to an approximate slaughter market weight of 115 kg.
Feeder:	The term for a pig which has reached a total weight of 25 kg or more and is in the final stages of development for a slaughter market. A feeder pig will be marketed at roughly 115 kg.
Feed Efficiency:	For any swine enterprise, feed efficiency is calculated as the total weight of pigs sold divided by the total weight of feed used. In the Pork Protocol, increased feed efficiency (less feed needed to grow the same weight of pigs) is accepted as an indicator of increased energy efficiency.
Feed wastage:	The amount of feed that is wasted by the pigs during the rearing period. Feed wastage usually occurs at the feeding station within the pen area. Feed can be wasted as a result of any number of management practice decisions. For example, if the feeding station is not properly adjusted so that animals have access to excessive quantities of feedstuff, rooting in the feed trough may result in excessive feed wastage, or if the feeders are not properly sized and the animals have to step into the feeder to access the feedstuff high levels of feed wastage can be expected.

Indoor deep pit:	Indoor deep pit barns are constructed with deep basements to store liquid slurry that passes through a slatted floor system on which pigs are housed. Manure is not removed from these barns to an external storage on a regular basis. Manure is removed directly from these barns/manure storage structures when manure is being applied to cropland only. Deep pit barns require constant ventilation of the manure storage under the animals to avoid the build-up of potentially lethal manure gases in the barn.
Nursery:	A pig barn designed to house animals from the time they are weaned (about 5 kg) until they reach a sufficient age and weight (25 kg) to be moved into a finishing barn. Nurseries are specially designed to allow pigs need to develop immune responses before being transferred to a finishing facility.
Outdoor slurry:	Outdoor slurry is used to describe a manure storage structure that is outside of the pig barn. Outdoor slurry containment systems generally consist of two types: a round concrete manure storage structure or a rectangular, earthen storage structure.
Phase feeding:	Phase feeding is a management system where the composition of a finishing ration is altered throughout the finishing growth cycle to reflect the deceased requirement by the animals for crude protein. The result is a lower cost of finishing pigs to market weight as sources of crude protein such as soybean meal tend to be one of the more expensive feed ingredients. Additional benefits include reduced nitrogen output in urine and faeces when animals are fed closer to their crude protein requirement and are not required to pass excess nitrogen through their digestive systems. Flushing excess protein (nitrogen) is costly in metabolic energy and increases the amount of water consumed by finishing pigs, increasing the volume of slurry produced on the farm.
Split sex feeding:	A management practice used to increase the feed efficiency of finishing hogs. Barrows and gilts (male and female feeder hogs) require slightly different mineral, protein and energy levels in their

rations to achieve their genetic potential for efficient growth. By separating males and females (sexing) prior to the animals populating a feeder barn, it is possible to feed a male ration to the barrows and a female ration to the gilts corresponding to the individual needs of the two animal populations in order to achieve a high level of feed conversion efficiency.

Volatile solids: The undigested organic portion of feed that is excreted by pigs as manure and is potentially available for conversion into methane during manure storage through natural microbiological processes. Non-volatile solids include any dirt, ash or other inorganic materials that may be contained in hog feed and cannot be converted to methane.