Recommendations to Estimate Swine Nutrient Production in the Phase 6 Watershed Model

DRAFT REPORT

Report to the Agricultural Modeling Subcommittee and Agricultural Workgroup

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Report generation

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Swine Data Report

Background
Quantification of swine industry characteristics is important for Chesapeake Bay Modeling advancement. The purpose of this report is to provide current and historical perspective on the swine industry in regards to manure nutrient generation.

Although independently owned and operated pig farms still exist, the swine industry in the Chesapeake Bay Watershed falls largely into the following categorical units common to modern integrated swine production systems.

> **Sow Farms** - A unit that maintains a sow herd for the purpose of producing pigs. Depending on the stage of the reproductive cycle, sows are housed in barns specific for breeding and gestation or farrowing (birthing), all at a common farm location.
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> Once bred, sows will be fed for a gestation period of 114 days. Shortly before her due date the sow is moved from the gestation barn to a room within the farrowing barn. The rooms are filled in a grouped system so that a newly filled room contains sows that are all due to farrow within the same 1-7 day period. This allows nursing sows in that group to all be weaned at the same time. The weaned piglets (approximately 12 to 15 pounds body weight each) are moved to an off-site nursery farm, while the sows are moved as a group back to the breeding/gestation barn where they are bred again. Wean age is typically about 21 days and sows will breed again about 5 days after weaning. Multiple farrowing rooms exist in modern facilities so that a new room can be used each week. After weaning and removal of the sows and the litter the room is washed and disinfected so another group of sows can move into the room. Thus the gestation and farrowing barns each operate with an internal rotation. Although there is variation due to age, body condition, genetics, etc., sows typically weigh 450 to 500 pounds each. Since younger and lighter females are included in these manure production estimates an average weight of 450 pounds should be used in modeling activities involving sow farms.
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> Young females that have not yet produced a litter are called gilts. A supply of gilts is necessary for sow farms in order to replace dead sows or sows culled (removed) from the herd for poor reproductive performance. Prior to introduction to the sow farm, gilts may be located at separate units called Isolation Barns or gilt development units. Sow farms will contain only a limited number of boars due to widespread adoption of artificial insemination using semen from off-site boar studs. The boars on sow farms are utilized as 'teaser' animals in order to detect 'standing heat' in sows at which time the sow is artificially inseminated by a farm technician. The ratio of sows to gilts is approximately 10:1. The ratio of sows to teaser boars is 100:1 or greater.
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> For modeling activities, gilts and boars housed within a sow unit should simply be included as a member of the sow herd. For gilt isolation barns or gilt development units that have separate manure storage, gilts may be considered finisher hogs (defined later in this report) since body size and feed rations are similar. Justification for this inclusion of gilts into the finisher category is based on the fact that there are not a large number of gilt isolation barns or gilt development units or

animal numbers housed in this manner. Future modeling considerations may be given to a separate gilt isolation barn or gilt development unit category.

Boar Studs
There are few farms in the watershed that house only boars. These facilities exist to supply semen to sow farms. Because ejaculates from boars typically contain many more sperm cells than are needed to impregnate a single sow, semen is diluted to create multiple artificial insemination doses. Thus, semen from a small number of boars will service all the sows on a number of sow farms.

Nursery Farms
Weaned pigs are typically moved from the sow farm to an off-site facility called a nursery farm. Some older farms maintain on-site nursery facilities at the sow farms, but the industry is largely moving away from this practice for herd health reasons. Nursery buildings allow specialized and focused management for young pigs. Buildings designed specifically for lower weight animals also allows for efficient growth and economics. These facilities house young swine for approximately seven weeks, so at the age of ten weeks the animals are called feeder pigs and are moved to a finisher farm, weighing 50 to 60 pounds each.

Finisher Farms
Feeder pigs are brought to the finisher farm where they will grow until they are 'finished', meaning they are grown to market weights of approximately 270 pounds. Once they reach this weight they are called market hogs and moved to the processing plant.

Both nursery and finisher farms operate in an all-in-all-out manner. This means that an entire building is populated at the same time and that all animals are removed at the same time. After the building is emptied, washing and disinfection occur prior to repopulation. Both types of barns are often constructed in very similar manners from site to site. Companies with multiple site management and efficient production have driven these common housing standards.

Wean-Finish Farms
Wean-finish farms combine both the Nursery and Finishing phases of production into one barn. Pigs weighing 12 to 15 pounds are moved in after weaning and transportation from sow farms and are moved out at market weights of approximately 270 pounds. Thus, the pig remains in the same pen from weaning to market. Corporate farms owned and operated by Smithfield Hog Production Division in Virginia are wean-finish.

Nutrient Balances
Sow farms contain enough sows that produce large enough litters to supply pigs to a number of nursery and finisher farms. For this reason there are far fewer sow farms compared to other units of production. However, sow farms may be higher in Animal Units and, depending on the farm's land base, may need to export manure nutrients. Swine manure is mostly liquid and very low in solid content. Therefore, exported swine manure is usually delivered to nearby neighbors and lands. It is not economically feasible to export swine nutrients more than a few miles or out of the watershed.

Nursery and finisher units are often within a balance between nutrient generation and on-site farm crop nutrient needs. Indeed, many farmers benefit by installing nursery or finisher barns, the manure from which supplement crop nutrient needs. This decreases commercial fertilizer purchases for that farm.

Feed Management

Feed management at swine farms greatly impacts nutrient generation. It is in the best interest of these farms to utilize feed ration formulations that closely match the nutrient requirements of the animals. Swine within various stages of production (e.g., nursery or finisher) receive rations specifically balanced to meet their nutritional requirements as they grow in a system called "phase feeding". For example, finisher hogs may receive feed containing 18% crude protein from 45 to 90 pounds body weight, 16% crude protein from 90 to 135 pounds body weight, 15% crude protein from 135 to 180 pounds body weight, 14% from 180 to 225 pounds body weight, and 13% crude protein from 225 to 270 pounds body weight. Additionally, nutrient requirements of gilts and barrows (castrated males) differ so many farms will feed the animals in separate pens or barns, allowing consumption of different diets in a system called "split-sex feeding". By formulating diets that closely match amino acid (building blocks of protein) requirements nitrogen excretion is minimized.

Phytase Utilization

Phosphorus excretion is also minimized by feeding diets that closely match the animal's phosphorous requirements and also through the utilization of phytase. Phytase is a commercially available enzyme that allows monogastric animals, like the pig, to efficiently digest phosphorus-containing molecules found in most grains. Adoption by swine integrators and widespread utilization of phytase technology has greatly decreased the need for inorganic phosphorus addition to swine diets, and has decreased by more than 20% the amount of phosphorus excreted into the environment each year.

Adoption of phytase utilization as a Best Management Practice began in the late 1990s. Personal communications with feed mill management and agency personnel that assisted with securing grants to fund adoption technology indicate that in both Pennsylvania and Virginia, phytase utilization began in 1998. By 2000-2001 phytase was used in 100% of swine diets fabricated by Wenger Feeds (Rheems, PA), including both sow and growing pig rations. In Virginia, Carroll's Foods (now Smithfield Hog Production Division) initiated swine phytase utilization in 1998. As communicated by Dr. Allen Harper, former Swine Specialist with Virginia Cooperative Extension, pigs fed with phytase supplemented diets excreted 21% less phosphorus resulting in an estimated annual phosphorus excretion reduction of 158,000 pounds in Virginia. Similar phytase utilization occurred by most watershed feed mills by 2002.

Manure Management

Industry standards not only exist for housing design, but are common for manure storage as well. In the Northern watershed area, most modern nursery and finisher farms have deep pit manure storage that is under the floor of the swine barn. This system means that the barns can be constructed with minimal land footprint

requirements. Sow farms may also have under-floor deep pit storage. Manure from deep pits is removed directly from the barns and applied to land.

Some sow farms and some older finisher sites have external open-air manure storage. These storage facilities are designed in a variety of manners, with most modern outdoor construction in the form of lined earthen basins or concrete structures. In northern areas of the watershed these facilities are simply outdoor manure storage basins. In southern watershed regions many outdoor manure facilities operate as true lagoons. In these systems, pens within barns are typically over shallow manure pits and are routinely emptied into large outdoor lagoons for storage. Many of these systems contain both a primary stage and secondary stage manure lagoon. When pits in barns are emptied, manure flows into the primary lagoon. There, solids within the manure settle to the bottom. As the level of liquid rises in the first stage lagoon, it flows through a pipe to the second stage lagoon. The contents of the second stage lagoon can be used to refill manure pits within the barns and/or spray-irrigated on adjacent farmland. Liquid from the second stage storage is expected to be very low in nutrient and solid contents since settled solids in the first stage will hold high concentrations of nutrients, especially phosphorus, in that storage area. While second stage liquid is irrigated to farmland on a routine basis, first stage solids can be retained in storage for years before removal is necessary. Lagoon systems can be considered a form of manure treatment since nutrients are removed and held for long periods. Other types of alternative manure treatments are not common with swine manure.

The following manure storage types are considered for this report:

1. Deep pit, underfloor manure storage
2. Outdoor storage basins (earthen or concrete)
3. Lagoons, including first and second stage treatments

Methodology

Several sources were utilized to assure that current data were available for this report. Country View Family Farms, in Pennsylvania, and Smithfield Hog Production Division, in Virginia, cooperated to provide manure analyses from many of their farms. Manure analyses that were older than 14 months were not considered. Technicians were also employed through contract to visit a number of farms to collect manure samples. Samples were sent to laboratories at either Clemson University or Penn State University for analyses. Both Country View Family Farms and Smithfield Hog Production Division also provided animal weights and farm inventories that were paired with manure analyses data. A third source was historic data provided from several reputable sources. Producer information was removed from data for confidentiality.

The committee made several determinations based on industry standards and professional judgment that helped to shape the recommendations found in this report.

- Gilts and boars were included in sow farm data. Gilts are are often housed with sows and the number of boars on sow farms is limited to those needed for heat detection. Future addition of these animal groups to the model, by inclusion of gilt isolation or development units and boar studs should be considered.

- Sows with litters are counted as sows. Even though nursing litters are with sows within the farrowing barns of sow farms, the piglets receive little or no supplemental feed nutrients and the manure production of the litter is a very small fraction of that produced by the sow.
- Wean-Finish farms are not considered in this report. This type of production barn is less common than the multiple site nursery and finisher systems. There simply was not enough data available to create a separate category for this type of farm. The recommendation for this type of facility is to adjust animal weight accordingly to entry and exit weights, and to utilize actual farm manure samples. If manure samples are not available then finishing farm nutrient values should be used. The corresponding finishing animals represent far greater weights, feed consumption and residence time at these facilities. Future addition of this type of farm to the model should be considered.
- Weights reported represent the average weight of animals during the time they populate the specific phase of production. Adding entry and exit animal weights, and dividing that sum by two was used to determine average weights.
- Lagoon systems found in Virginia often contain both a Primary and Secondary manure lagoon. Manure nutrient data for lagoon systems is provided for both of these lagoons as well as a total average.
- Because this report was developed under time and resource constraints the data set from which conclusions are drawn is not perfect. Much data originates from only a few cooperative integrated companies. While the data from the farms within these large integrated systems is quite representative of the large number of animals managed within the company's systems, differences may be expected with other integrated systems due to variation in such factors as genetics, or feed regimens. Nonetheless, the judgment of this professional panel is that the variation noted here would not be great. We feel that this data set is a fair representation of the industry given the collection constraints noted above. Future endeavors should include larger data sets from a more diverse set of operations.

Data

The following tables reflect averages determined from data provided through sources noted in the introduction of this report.

Table 1. Summary of swine production phases and weights considered categorically for this report.

Phase of Production	Average Animal Weight (lbs)	Typical Weight Range (lbs)
Sows (includes gilts and boars)	450	400-500
Nursery	34.99	13.30 - 56.68
Finisher	163.85	56.68 - 272.74

Table 2. Summary of swine manure content for manure storage categories of this report.

Manure Storage Type	TKN (lbs/1000 gal)	P2O5 (lbs/1000 gal)	K2O (lbs/1000 gal)
Sow with Outdoor or Underfloor Storage (non-lagoon)	29.80	12.13	17.82
Nursery	14.34	18.72	8.85
Finisher	26.22	20.65	27.93
Growing Pig Lagoon Primary Storage (2.4% solids)	2.72	7.52	5.72
Growing Pig Lagoon Secondary Storage (0.19% solids)	0.43	1.71	0.57

Table 3. Wean pig weights over a four-year period.

	Number of Farms in Data Set (n)	Total Wean Pigs Considered for Data	Range		Average Piglet Wean Weight (lbs) Exit Sow Farm
			Minimum Individual Farm Weighted Average Weight (lbs)	Maximum Individual Farm Weighted Average Weight (lbs)	
2015	11	920,691	12.78	14.12	13.52
2014	11	848,566	12.28	13.98	13.31
2013	11	709,057	13.03	13.79	13.25
2012	11	679,901	12.51	13.82	13.12
Four year Average		789,554			13.30

Table 4. Weights for Nursery Swine Barns.

	Number of Farms in Data Set (n)	Total Wean Pigs Considered for Data	Average Wean Pig Weight (lbs) Entry to Nursery	Total Feeder Pigs Considered for Data	Range		Average Feeder Pig Weight (lbs) Exit Nursery	During this Phase Average Feeder Pig Weight (lbs)
					Minimum Individual Farm Weighted Average Weight (lbs)	Maximum Individual Farm Weighted Average Weight (lbs)		
2015	13	920,691	13.52	474,406	51.89	59.92	57.28	35.40
2014	12	848,566	13.31	390,945	45.97	61.57	54.90	34.10
2013	10	709,057	13.25	366,786	52.64	60.74	55.49	34.38
2012	10	679,901	13.12	309,908	54.89	63.56	59.05	36.09
Four year Average		789,554	13.30	385,511			56.68	34.99

Table 5. Weights for Finisher Swine Barns.

	Number of Farms in Data Set (n)	Total Feeder Pigs Considered for Data	Range		Weighted Average Feeder Pig Weight (lbs) Entry to Finisher	Total Finisher Pigs Considered for Data	Range		Weighted Average Finish Pig Weight (lbs) Exit Finisher	During this Phase Average Finish Pig Weight (lbs)
			Minimum Individual Farm Weighted Average Weight (lbs)	Maximum Individual Farm Weighted Average Weight (lbs)			Minimum Individual Farm Weighted Average Weight (lbs)	Maximum Individual Farm Weighted Average Weight (lbs)		
2015	36	212,639	47.14	61.59	55.70	212,639	255.46	295.19	274.66	165.18
2014	31	169,042	41.82	58.74	53.35	169,042	248.99	294.89	270.20	161.92
2013	32	197,513	49.09	61.50	55.79	197,413	263.99	296.01	275.91	165.85
2012	30	190,929	49.17	63.53	54.58	190,929	255.69	285.77	270.17	162.46
Four year Average		192,531			54.86	192,506			272.74	163.85

Table 6. Nursery[1] manure nutrient content.

	Number of Farms in Data Set	Average Nutrient per Gallon (lbs/1000 gal)				Average Nutrient per Pound of Animal per year (lbs/lb animal/yr)[2]			
		NH4	TKN	P2O5	K2O	NH4	TKN	P2O5	K2O
PA only Averages	16 for NH4; 17 for other nutrients	16.34	20.74	10.19	19.58	0.0622	0.0798	0.0358	0.0755
VA only Averages	17 for all nutrients	3.67	7.20	1.19	7.90	0.0292	0.0586	0.0097	0.0642
Combined Average (both states)	19 for NH4; 20 for other nutrients	14.34	18.72	8.85	17.83	0.0564	0.0763	0.0315	0.0736

[1]Nursery pigs begin this phase of production when wean pigs weighing 12 to 15 pounds enter the barn and exit after about seven weeks as Feeder pigs weighing 50-60 pounds and enter a finisher barn.

[2]A weight of 34.99 pounds is used for calculations and represents the average weight of pigs during this stage of production (entry and exit animal weights added and sum then divided by two) as determined from data available for this report.

Table 7. Finisher[1] manure nutrient content.

	Number of Farms in Data Nutrient Set	Average Nutrient per Gallon (lbs/1000 gal)				Number of Farms Providing Inventory Data	Average Nutrient per Pound of Animal per year (lbs/lb animal/yr)[2]			
		NH4	TKN	P2O5	K2O		NH4	TKN	P2O5	K2O
PA only Averages	29	26.65	35.95	29.55	35.98	29	0.0236	0.0316	0.0285	0.0316
VA only Averages	14	3.94	6.07	2.21	11.27	10	0.0041	0.0062	0.0017	0.0132
Combined Average (both states)	43	19.26	26.22	20.65	27.93	39	0.0186	0.0251	0.0216	0.0269

[1]Finisher pigs begin the finisher phase of production weighing approximately 50 to 60 pounds and are marketed at weights of approximately 270 pounds. Average finisher pig weight is approximately 165 pounds.
[2]A weight of 163.85 pounds is used for calculations and represents the average weight of pigs during this stage of production (entry and exit animal weights added and sum then divided by two) as determined from data available for this report.

Table 8. Sow Farm[1] manure nutrient content for farms with outdoor storage basins and deep pit under-floor storage in Pennsylvania.

	Number of Farms in Data Nutrient Set	Average Nutrient per Gallon (lbs/1000 gal)				Average Nutrient per Pound of Animal per year (lbs/lb animal/yr)[1]			
		NH4	TKN	P2O5	K2O	NH4	TKN	P2O5	K2O
PA only Average[2]	11	20.62	29.80	12.13	17.82	0.0751	0.1096	0.0475	0.0613

[1]Sow Farms include sows and a relatively smaller number of boars and gilts. The average animal weight on sow farms is routinely considered to be 450 pounds.
[2]No nutrient data was received from VA for this non-lagoon type of outdoor storage.

Table 9. Wean to Finish and Finisher Farm[1] lagoon storage manure nutrient content in Virginia.

	Number of Samples in Data Set[2]	Average Nutrient Content (lbs/1000 gallons)								% Solids
		NH4	N	TKN	P205	K2O	Ca	Mg	Na	
Primary Only	51	4.80	2.72	7.52	5.72	10.14	2.48	1.47	2.06	2.40
Secondary Only	23	1.28	0.43	1.71	0.57	5.88	0.42	0.17	1.22	0.19
Combined Primary and Secondary	74[2]	3.70	2.01	5.72	4.12	8.82	1.84	1.07	1.80	1.71

[1]Wean to finish farms grow pigs from 12 to 15 pounds to a weight of approximately 270 pounds. Finish farms grow pigs from 50 to 60 pounds to approximately 270 pounds.
[2]Some data originated from the same farms that contain both primary and secondary storage lagoons. Thus these farms contributed multiple manure samples.

Historic Data

Historic data of swine analysis was gathered from two sources. First, a report generated by the Virginia Department of Conservation and Recreation, Soil and Water Conservation Division's Nutrient Management Program's Animal Waste Coordinator (Bobby Long included manure analysis summaries for storage facilities listed as either 'Mixed' or 'Lagoon'. The number of samples or source was not included with this data. Designation of production phase was not indicated with this data.

The second historic manure analysis data source was the Penn State Agricultural Analytical Service Laboratory. The data set was purged of data that did not fit criteria of this report and some data from known research projects was removed. However, the remaining data possibly contained samples analyzed from non-commercial swine sources as part of other research endeavors. Data was separated into either 'Sow' or 'Non-sow' categories. Sow categories include some farms listed in the data set as 'Farrow-to-Feeder', meaning that Nursery phases of production may be included within the sample. A second summary is presented for categories that included 'Nursery', 'Grow-Finish', 'Finisher' and 'Other'. Two manure samples from Maryland were included in this data. All farms listed with a Pennsylvania location were kept. Some of these farms are surely not located within the Chesapeake Bay watershed, however swine industry demographics would indicate that the majority of samples come from within the watershed.

Data form both sources are summarized below.

Table 10. Historic non-lagoon swine manure analysis data from Virginia.

Historic Non-lagoon Swine Manure Nutrient Values (Virginia)					
Year	TKN (lbs/1000 gal)	NH-4 (lbs/1000 gal)	P205 (lbs/1000 gal)	K20 (lbs/1000 gal)	% Solids
1990	88.20	88.20	58.42	69.76	3.30
1991					
1992	133.90	94.24	82.86	54.63	2.34
1993	171.89	113.76	116.84	73.85	5.21
1994	164.84	118.64	147.33	75.56	5.35
2001	154.39	117.96	193.21	106.62	6.93
2002	113.40	75.78	34.07	58.97	2.69
2003	71.98	46.06	19.70	45.86	2.00
2004	104.36	63.59	33.52	55.28	2.51
2005	134.42	94.57	25.93	78.73	2.88
2006	110.99	71.57	35.12	59.36	3.69
2007	107.41	71.19	32.33	69.01	2.98
2008	108.94	77.37	24.60	60.30	2.85
2009	101.31	74.94	34.10	64.53	7.91
2010	93.33	68.35	17.17	42.99	1.80
2011	109.98	76.67	22.48	57.32	2.94
2012	81.18	60.37	14.26	54.96	1.14
2013	56.38	136.00	56.52	0.00	5.22
2014	118.65	67.31	37.12	52.56	3.11
2015	63.14	48.23	8.47	46.00	0.79

Figure 1. Plot of non-lagoon manure analysis Total Nitrogen and Phosphorus values for Virginia.

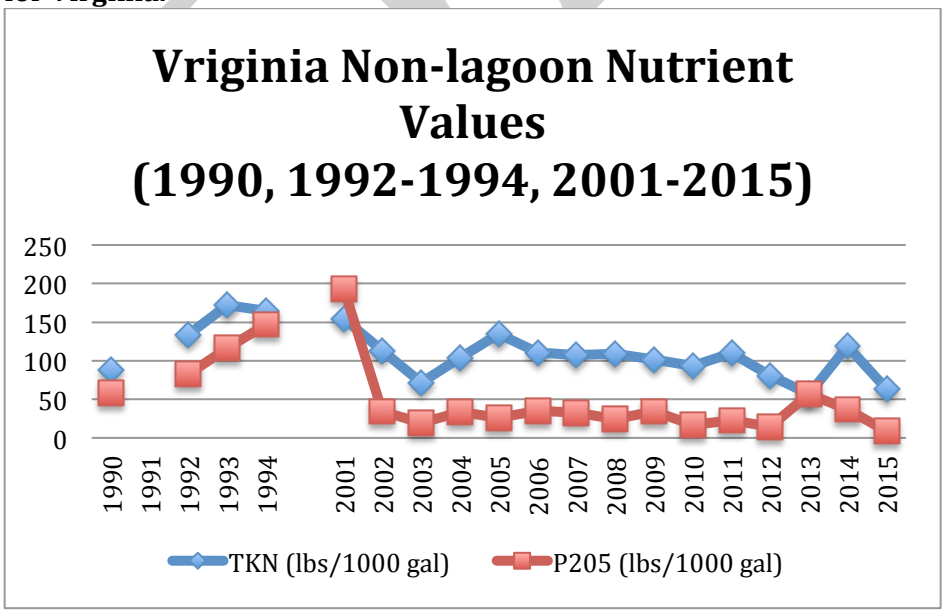


Table 11. Historic lagoon swine manure analysis data from Virginia.

Historic Lagoon Swine Manure Nutrient Values (Virginia)					
Year	TKN (lbs/1000 gal)	NH-4 (lbs/1000 gal)	P205 (lbs/1000 gal)	K20 (lbs/1000 gal)	% Solids
1990	56.92	32.98	130.77	13.18	0.72
1991	81.65	48.58	52.79	37.32	2.76
1992	86.74	49.50	57.71	40.95	2.88
1993	23.19	11.84	12.84	15.26	0.34
1994	20.02	12.80	7.71	18.60	0.04
2001	24.63	19.78	5.13	59.50	0.70
2002	34.57	25.19	6.75	47.31	0.93
2003	28.11	22.56	4.94	40.06	0.55
2004	29.04	23.85	4.35	39.89	0.50
2005	30.19	23.95	4.90	42.20	0.77
2006	31.61	23.56	7.52	41.81	0.75
2007	29.15	20.73	4.80	39.55	0.56
2008	24.63	18.39	3.40	39.69	0.55
2009	28.80	20.47	7.01	45.69	1.01
2010	25.33	17.69	6.24	35.04	0.79
2011	32.96	20.82	9.75	41.18	1.22
2012	23.25	18.73	2.43	44.06	0.49
2013	33.65	23.25	10.10	45.31	0.99
2014	32.27	17.69	4.30	37.12	0.87
2015	29.84	20.82	3.02	42.26	0.54

Figure 2. Plot of lagoon manure analysis Total Nitrogen and Phosphorus values for Virginia.

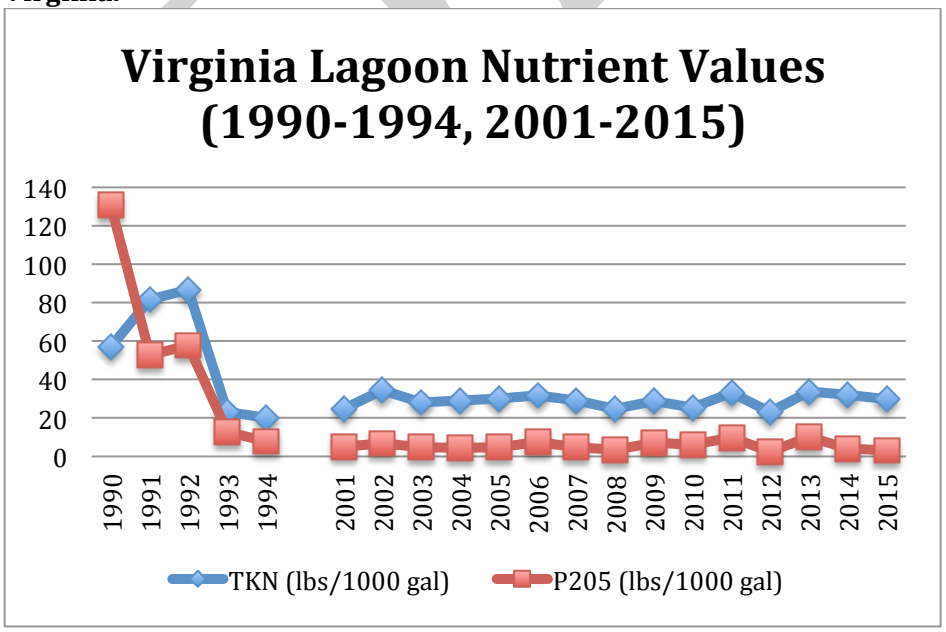


Table 12. Historic sow farm nutrient values from Pennsylvania (all data post-phytase).

Historic Sow Farm Data (Penn State AASL)						
	Number of Samples in the Year	TKN (lb/1000 gal)	NH4 (lb/1000 gal)	P2O5 (lb/1000 gal)	K2O (lb/1000 gal)	% solids
2003	13	23.31	19.54	7.15	13.57	2.46
2004	2	12.78	10.01	2.44	7.94	1.02
2005	3	14.67	14.52	1.19	9.20	0.63
2006	3	8.76	7.40	1.92	7.78	0.74
2007	7	15.74	10.15	9.16	8.82	2.04
2008	0					
2009	1	11.57	8.36	0.74	6.73	0.45
2010	25	26.95	15.86	8.61	12.25	2.55
2011	25	21.57	15.30	4.74	9.29	2.24
2012	52	24.31	17.51	4.49	12.66	1.59
2013	14	30.71	19.84	5.17	17.03	2.16
2014	24	30.34	17.68	8.30	16.79	2.13
2015	11	26.61	16.39	5.46	14.07	1.88
2016	16	26.02	16.25	4.66	16.23	1.95

Figure 3. Plot of sow farm manure analysis Total Nitrogen and Phosphorus values for Pennsylvania (all data post-phytase).

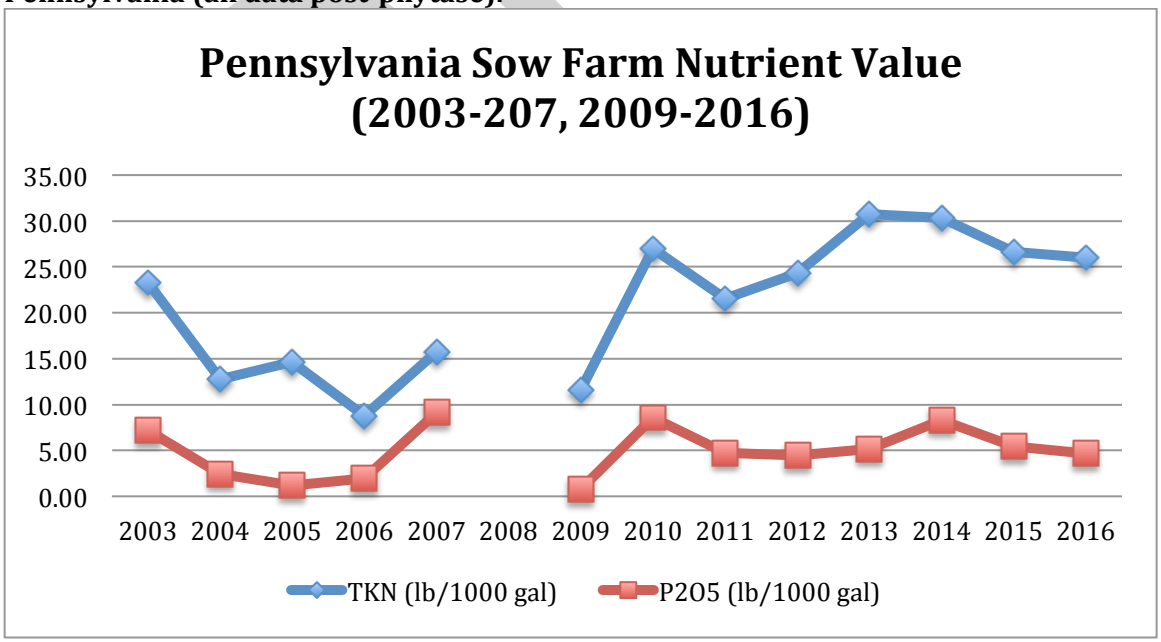
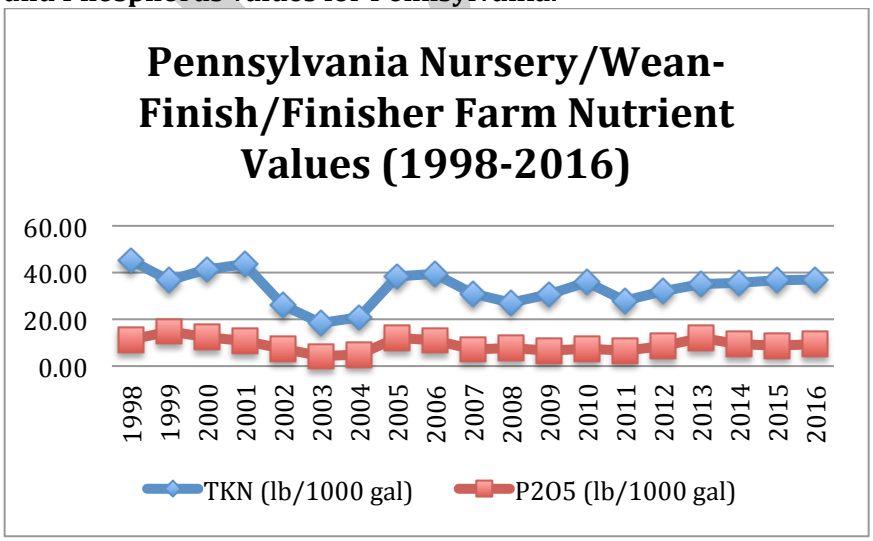


Table 13. Historic nursery/grow-finish/finisher farm nutrient values from Pennsylvania.

Historic Nursery/Grow-Finish/Finisher Farm Data (Penn State AASL)						
	Number of Samples in the Year	TKN (lb/1000 gal)	NH4 (lb/1000 gal)	P2O5 (lb/1000 gal)	K2O (lb/1000 gal)	% solids
1998	2	45.21	30.97	11.37	15.09	4.05
1999	79	36.80	24.48	14.88	15.66	4.39
2000	24	41.25	21.07	12.32	14.74	4.26
2001	26	43.57	26.84	10.65	18.80	4.41
2002	25	26.11	20.54	7.50	14.25	2.89
2003	71	18.46	15.93	4.22	11.81	1.87
2004	60	20.94	17.24	5.04	11.44	2.21
2005	42	38.33	29.53	12.11	19.09	4.97
2006	52	39.50	28.89	11.08	22.96	4.63
2007	12	30.97	23.01	7.24	19.82	2.69
2008	71	27.26	19.16	7.61	14.49	2.85
2009	21	30.70	20.50	6.62	17.89	2.99
2010	13	36.03	19.82	7.53	21.78	3.57
2011	40	28.08	18.05	6.62	12.73	3.17
2012	37	32.06	22.76	8.56	16.50	3.37
2013	26	34.98	19.98	12.16	18.46	3.97
2014	31	35.73	21.40	9.48	21.34	3.31
2015	16	36.64	22.78	8.90	24.13	3.81
2016	21	36.98	24.58	9.24	23.38	4.09

Figure 4. Plot of nursery/grow-finish/finisher farm manure analysis Total Nitrogen and Phosphorus values for Pennsylvania.



APPENDICES

Appendix 1: Swine Biosecurity Guidelines (Tim Sexton)

The following protocol was followed during data collection.

- Respect all entrance prohibitions on swine farms and /or barns
- Only enter a swine house if absolutely necessary. **NO Entrance on Infected Barn Under Any Conditions**
- Upon arrival at any swine farm, report to the farm manager or responsible party
- Wash hands immediately upon arrival before putting on disposable gloves, and again before leaving farm.
- Leave vehicles outside of service areas. Walk!
- Avoid visiting two swine farms within 48 hours if possible absolutely no visitation of swine farms from two separate sow units within 48 hours
- Wear Boots that can be disinfected, disposable gloves
- Put all manure samples into sealed bottles, spray outside of bottle and then put sample into sealable plastic bag.
- All materials used on the site must be disinfected before and after use
- Boots should be dipped at the entrance and exit of every farm with Clorox solution or Vircon solution
- Spray all equipment with a mix of 8 oz. of Clorox/gallon or 10% Vircon solution of water until wet. Leave on for 30 seconds. Dry off with disposable paper towels. Put gloves and paper towels in plastic bag and keep tightly sealed.
- Keep cleaned materials away from contaminated materials.
- Remove all dry litter, manure, mud, straw etc. from vehicle, especially wheels and wheel wells
- Spray wheels, tires and wheel wells with disinfection solution. Let drain and dry before moving. If dusty or wet, spray underside of vehicle. Alternative: park vehicle outside farm entrance and WALK!

Appendix 2: Swine Manure Sampling Protocol and Methodology (Tim Sexton)

For the Swine characterization study in Pennsylvania, manure samples are taken from under floor deep pit storage of each barn located on the farm visited. The samples from each barn are mixed together unless the grower indicated that the manure from each barn is treated differently on separate fields. The samples are mixed in a plastic bucket and transferred to 500 ml bottles, labeled, refrigerated until prepared for shipping to Clemson and PSU laboratories.

Samples are taken using a Teflon Liquid Point Cup Sampler with lid, controlled in the handle so that samples taken from the under house storage can be taken at varying depths, as mixing of the storage is not feasible. The sampler is inserted into the manure inverted until the desired depth is reached in the pit. It is then turned over and the lever in the handle is pushed so that manure can be gathered. Since the

pits are six feet deep samples are taken at 1.5 ft., 3.0 ft. and 4.5 ft. The samples are poured into a bucket mixed and then the composite sample is delivered into 500 ml labeled bottles, refrigerated until shipping. This procedure is consistent with PSU's Agronomy Fact Sheet #69 "Manure Sampling for Nutrient Management Planning".

All Equipment is then washed, and sprayed down with a 10% solution of Vircon dried and placed separately from any sampling material as spelled out in the Bio-Security Protocol.

Appendix 3: Penn State Fact Sheet #69, Manure Sampling for Nutrient Management Planning

(to be inserted or attached)

Appendix 4: Quality Control Protocol for Swine Characterization Study (Tim Sexton)

As a Co-principal investigator of the Swine Characterization Study, it is the responsibility of Tim Sexton to make sure that the IRB standards are met and followed, that the farmer interview procedures are maintained, the sampling procedures outlined are followed, and the bio-security procedures are strictly adhered to.

At the beginning of the project, I met with the intern, Jordan Kristoff and explained the protocols and the security issues both with personal data that would be collected, the routines that would be expected, the strict bio-security procedures that would be required on all farm visits, and the IRB process that would also be required.

The intern was awarded a VT computer so that no information collected would be stored on any DCR or government related server, or computer or storage device. All hand written data sheets and notes are kept in a secure location, with access only to the intern and the Co-PI.

The Co-PI checked the data base that was created on a weekly basis for journal entry errors, and entries that appeared to be outside the norm, and requested that the interns follow back up with those farmers to see if they could determine why the information gathered might be outside the norm. The data collected from Smithfield Hog Production Division is maintained on one data sheet, and the Country View Family Farms data base is maintained on another to insure that there is no cross contamination of data collected.

The intern is quizzed on a regular basis to make sure that she is continuing to follow the questioning process for all farmers, that the sampling procedures are the same, and that the bio-security procedures are being adhered to.
Information forwarded to the VT and/or PSU PI is also copied to this PI so that if a question arises, this PI has the ability to answer if possible.