Appendix A. Poultry Litter Subcommittee Report

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

Report of the Agricultural Modeling Subcommittee to the Poultry Litter Subcommittee and Agriculture Workgroup

March, 2015

Approved by the Agriculture Workgroup March, 2015

Approved by the Water Quality GIT April, 2015

Technical support provided by:

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Introduction

The Poultry Litter Subcommittee (PLS) summarized over a decade of litter sample data collected mainly from broilers and turkeys, with very small amounts of data from pullets and layers. In October, 2014, the Agriculture Workgroup asked the Agricultural Modeling Subcommittee (AMS) to review the PLS records (found in Appendix C) and report (found in Appendix A), and provide recommendations for incorporating the data into poultry nutrient production estimates for the Phase 6 Watershed Model. This report describes processes to estimate poultry litter production by year for each state and type of bird. Many of the recommendations in this report were originally suggested by the PLS. Some other recommendations are based on analysis of the submitted data and other data sources available.

Basic Recommendation

Where possible, the AMS recommends a simple approach to estimating poultry nutrient production. That approach combines bird population estimates with estimates of: 1) mass of litter or manure produced; 2) litter or manure dry solids content; 3) litter or manure nutrient concentrations; 4) recoverability of manure; and 5) nutrients in recoverable manure. The last two parameters account for any losses that are estimated to occur between excretion and application, and are only needed if estimating available nutrients from as-excreted manure. There is no need to include these recoverability factors if estimating available nutrients from litter because litter values are assumed to represent litter that is ready to be field applied after any losses occur. These parameters can be combined using the following basic equations:

Equation 1. Poultry Phosphorus Production Based on Litter (Used for Broilers)

Lbs of P/Year = (Lbs of Litter/Bird Produced) X (Lbs of Dry Matter/Lb of Litter) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Equation 2. Poultry Phosphorus Production Based on As-Excreted Manure (Used for Pullets)

Lbs of Recoverable P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Lbs of Recoverable P/Lb of P) X (Birds Produced/Year)

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Note that the same equations can be used to estimate nitrogen production.

Nutrient Concentration Data Availability

The AMS finds that enough quality data was reported by DE, MD, VA and WV for broilers to calculate each of the parameters in the litter equation. Additionally, VA and WV provided multiple years of concentration data for turkeys and layers. Where data is sufficient to establish state-wide concentrations, the AMS recommends the state-specific values be used. For states and animal types with no data, or limited data, the AMS recommends Bay-wide values be used. Finally, no data was collected for pullets, so the AMS recommends the use of manure nutrient concentration values reported by the American Society of Agricultural and Biological Engineers (ASABE). ASABE last released updated manure production, moisture and nutrient concentration values in a 2005 report (ASABE, 2005). These values represent as-excreted manure rather than litter. Detailed descriptions of how nutrient concentration data is combined with other parameters in the equations for each state and bird type are included in the following sections.

Note about Significant Digits: Values throughout the report will be listed using six significant digits. While the originally collected data was not reported to this level of specificity, the use of equations to estimate changes in the small values, such as nutrient concentrations, requires six significant digits. Any fewer would result in inaccurate assessments of trends in these small values.

Recoverability of As-Excreted Manure

Equations 2 and 3 require the use of "recoverability factors." Recoverability can be interpreted as the amount of as-excreted manure or nutrients left in litter to be made available to crops after all storage and handling losses and volatilization has occurred. As-excreted manure values cannot be compared to litter values without first applying estimates of recoverability. USDA provided the AMS a list of recoverability estimates based upon survey data from poultry operations (Gollehon, 2014). USDA estimates that recoverability has improved over time due to better manure management through comprehensive nutrient management planning efforts and implementation of better storage systems. The AMS recommends using USDA's 1985 estimates for manure recoverability as those estimates very closely represent operations with zero or limited implementation of best manure management practices. The AMS acknowledges that BMPs may be recommended by the Partnership that improve the recoverability factors over time, which will ultimately change the estimates for pounds of nutrients available to crops. However, the objective of this report is to represent an estimate of nutrients available to crops without taking BMP implementation into account.

Broilers

The PLS summarized over 9,800 laboratory records describing moisture and nutrient content of poultry litter from DE, MD, VA and WV. These states provided both ranges and mean values for moisture content and nutrient concentration by a given sample type (in-house, uncovered stack, covered stack, roofed storage or other) for each year. These yearly mean values were then combined across sample types to create a single, weighted mean value by state by year.

MD and VA also provided yearly mean values for litter production. It is not known how many samples were taken from manure haulers, planners and farmers, but the PLS recommended using these values to estimate the average litter production per bird in any given year.

The combination of these data allows for the use of Equation 1. This means that collected litter values can be directly estimated and no as-excreted values or recoverability factors from other literature sources are needed to estimate broiler nutrient production.

Equation 1. Poultry Phosphorus Production Based on Litter (Used for Broilers)

Lbs of P/Year = (Lbs of Litter/Bird Produced) X (Lbs of Dry Matter/Lb of Litter) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of Litter Produced

The litter mass production data provided by the PLS indicates a strong relationship between litter production and average bird market weight (also occasionally reported as slaughter weight or produced weight) as shown in Figure 1. It should be pointed out that some of the values reported in Figure 1 were interpolated by states between two years with collected manure hauler information, and some VA data was based upon book values when other information was not available for a year. These sources combined represent the best estimates of manure generation data available in VA and DE. The AMS notes that the relationship between these values and average bird market weight is very similar to a relationship described by the University of Delaware Extension in a 2007 broiler litter estimation tool (Malone, 2007). Due to the similarities, and without additional data, the AMS recommends using the relationship found in the PLS data, and described in Equation 4 to estimate broiler litter production per bird.

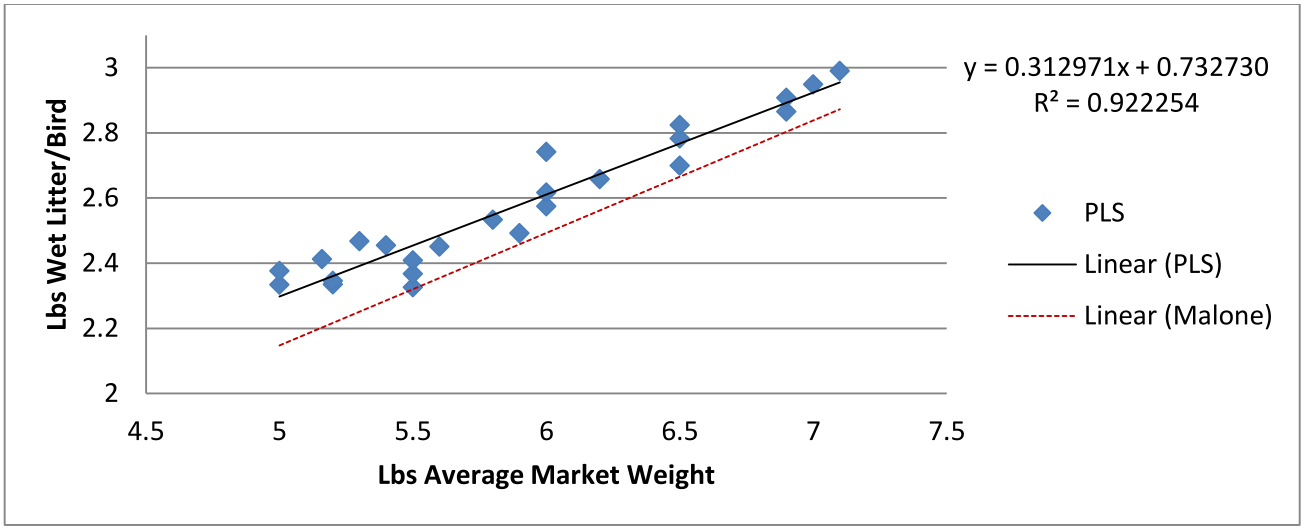
Equation 4. Broiler Litter Production

Lbs of Litter/Bird Produced = 0.312971 X (Average Bird Market Weight) + 0.732730

Source: Average Bird Market Weight can be calculated as Total Pounds Produced from Census of Agriculture/Total Birds Produced from Census of Agriculture

The AMS recommends using this equation to estimate broiler litter production each year from 1985 through the present. For all future years in which slaughter weights are not yet available, the AMS recommends keeping the value constant. For example, if the 2014 estimate is 3 lbs of litter per broiler, then the 2015 estimate should also be 3 lbs of litter per broiler until such time as 2015 values become available.

Figure 1. Broiler Litter Production and Average Market Weight



Moisture Content

The nutrient concentrations submitted are assumed to represent “as-is” litter. This means that moisture content can vary across samples. This variability requires nutrient concentrations be standardized based upon moisture content before they can be compared across sample years. While litter moisture content may vary across houses and across years, the standard deviation of the annual average moisture content across more than 9,800 broiler sample was relatively small (less than 5%). For this reason the AMS elected to use the average moisture content of all the annual average values. This value was 0.286500. The inverse of moisture content is solids content, or for our purposes, Lbs of Dry Matter/Lb of Litter. The inverse of the average moisture content was 0.713500. This value should be used for each year from 1985 through the present (and all future years). This value could be updated by new moisture content data collected in subsequent years.

Nutrient Concentrations

All nutrient concentrations were converted from “as-is” litter nutrient concentrations to dry weight nutrient concentrations. Again, the nutrient concentration values provided by the PLS represent average, annual concentrations. The PLS records indicate a downward trend in phosphorus concentrations from the mid- 1990s through the present. This seems to confirm that changes in feed formulas, genetics and the phytase amendment to feed contributed to reductions in phosphorus concentrations in litter. In fact, the overall decrease in phosphorus concentration across the watershed is estimated to be 16.5% from 1995 through 2013. This is very close to the 16% decrease in phosphorus concentrations credited in the current Phase 5.3.2 Watershed Model to mimic the changes in feed formulas, genetics and the phytase amendment.

However, the majority of these decreases appear to have occurred in the early 2000s, and there is a general increase of P concentrations across the watershed since 2005. Additionally, average market weights and PLS estimates of litter production indicate that producers are growing larger birds in some areas of the watershed, and with them, creating larger quantities of poultry litter. The AMS also acknowledges that changes in nutrient concentrations could be related to changes in management techniques within houses, including decreasing clean-out frequencies and changes to in-house composting techniques (among other contributing factors). Because of these dynamic changes in litter nutrient concentrations, the AMS recommends estimating each year’s nutrient concentration value (N or P) by calculating a three-year moving average based upon previous years’ data. The moving average results by state and across the watershed are provided in the figures below. The AMS recommends the following rules for applying these three-year moving averages in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values accordingly if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 2: Bay-Wide Lbs P/Lb Dry Litter for Broilers (to be used by NY, PA)

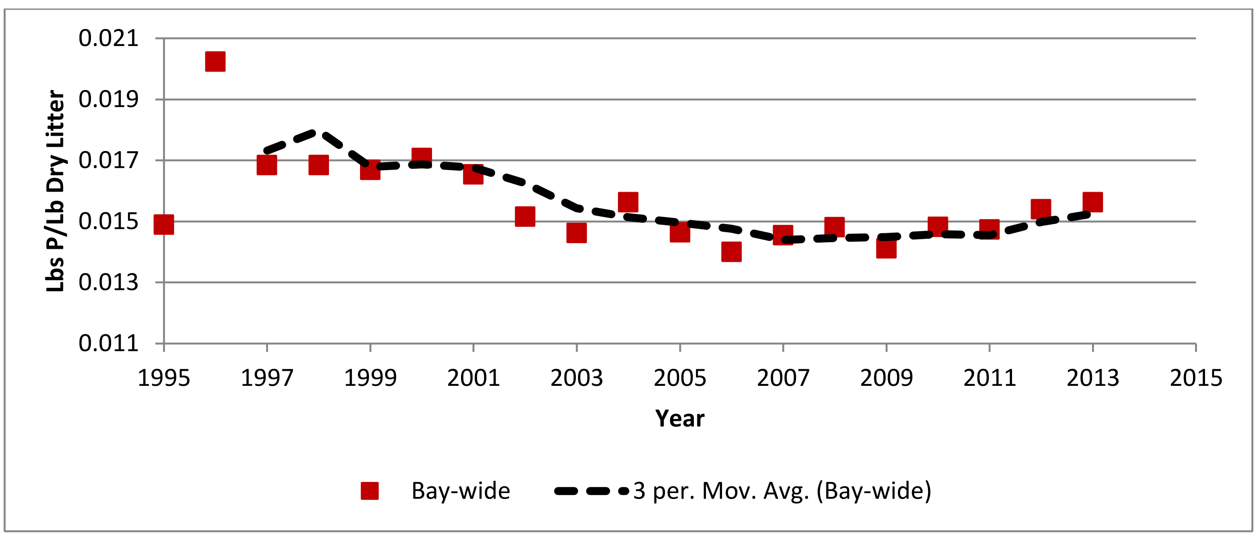


Figure 3: VA Lbs P/Lb Dry Litter for Broilers

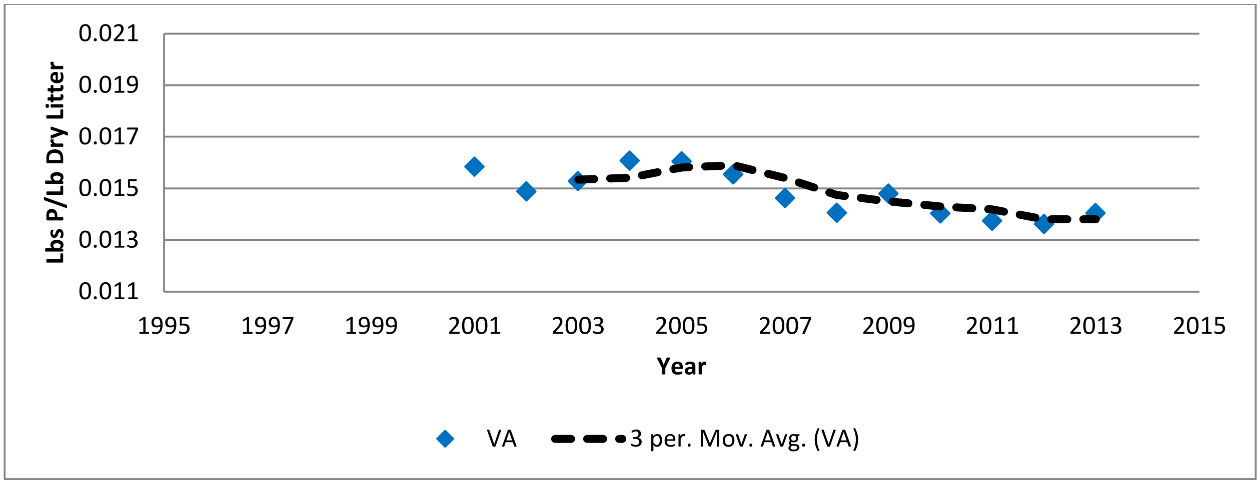


Figure 4: DE/MD Lbs P/Lb Dry Litter for Broilers

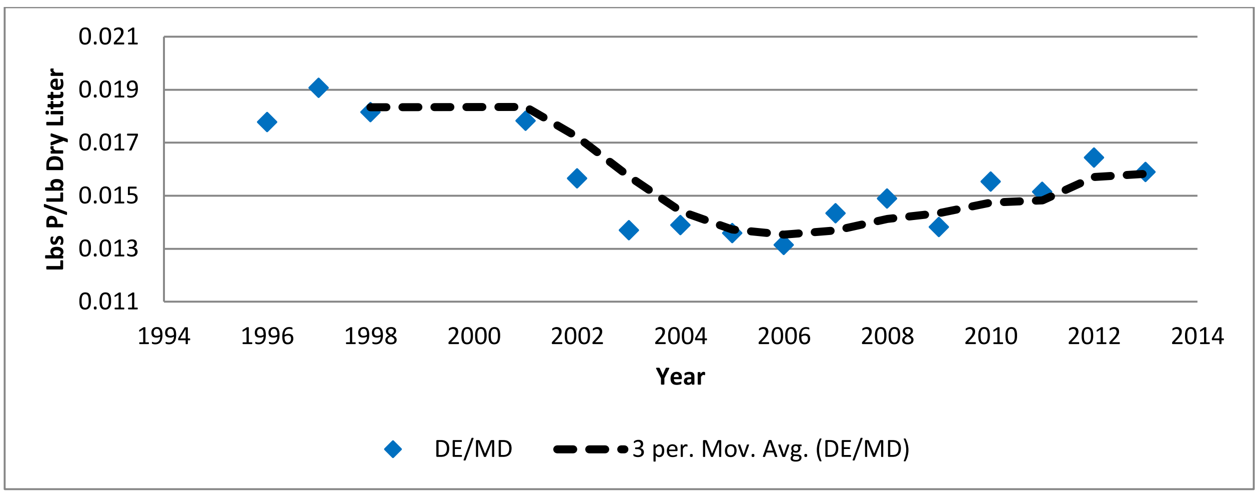


Figure 5: WV Lbs P/Lb Dry Litter for Broilers

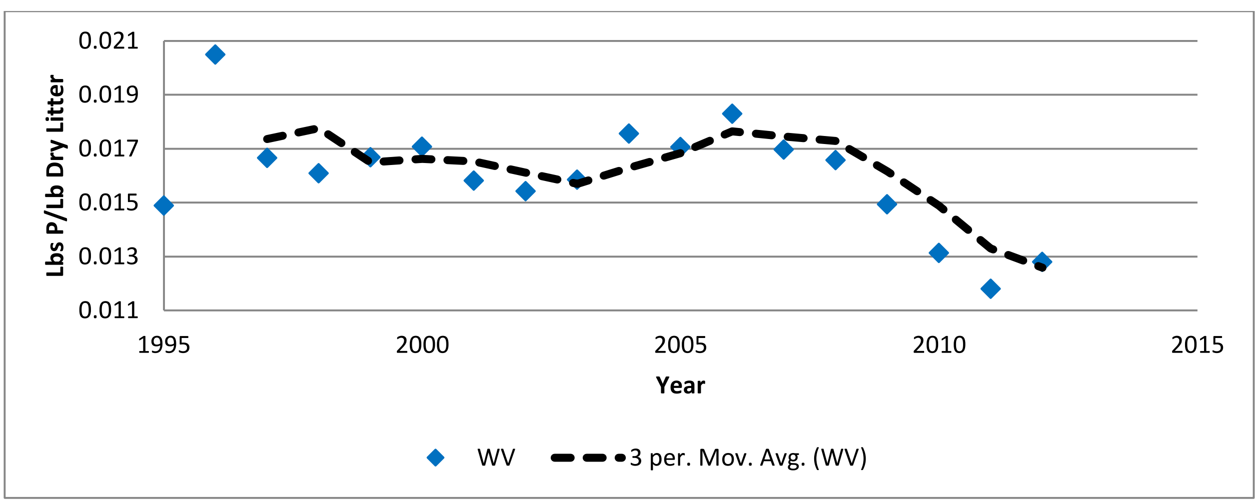


Figure 6: Bay-Wide Lbs N/Lb Dry Litter for Broilers (to be used by NY, PA)

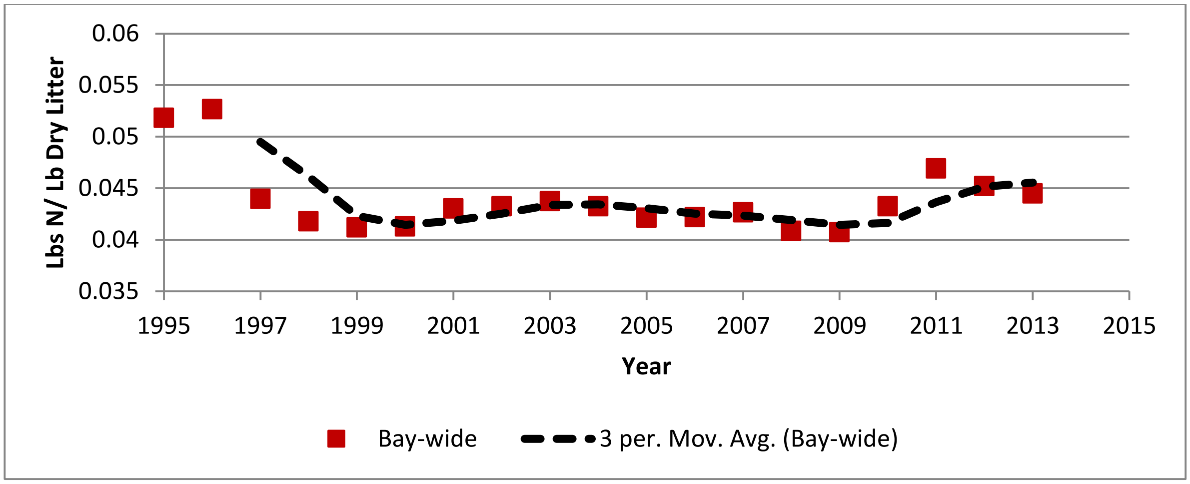


Figure 7: VA Lbs N/Lb Dry Litter for Broilers

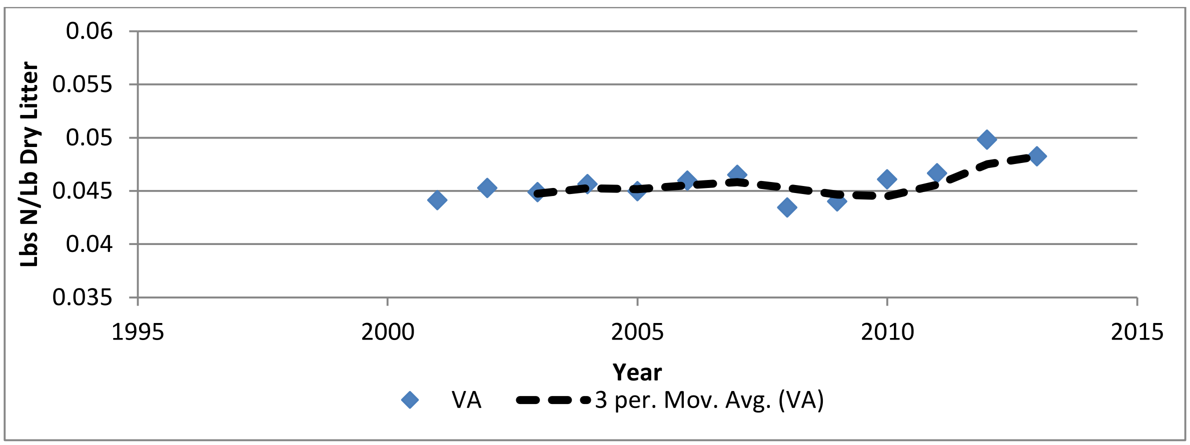


Figure 8: DE/MD Lbs N/Lb Dry Litter for Broilers

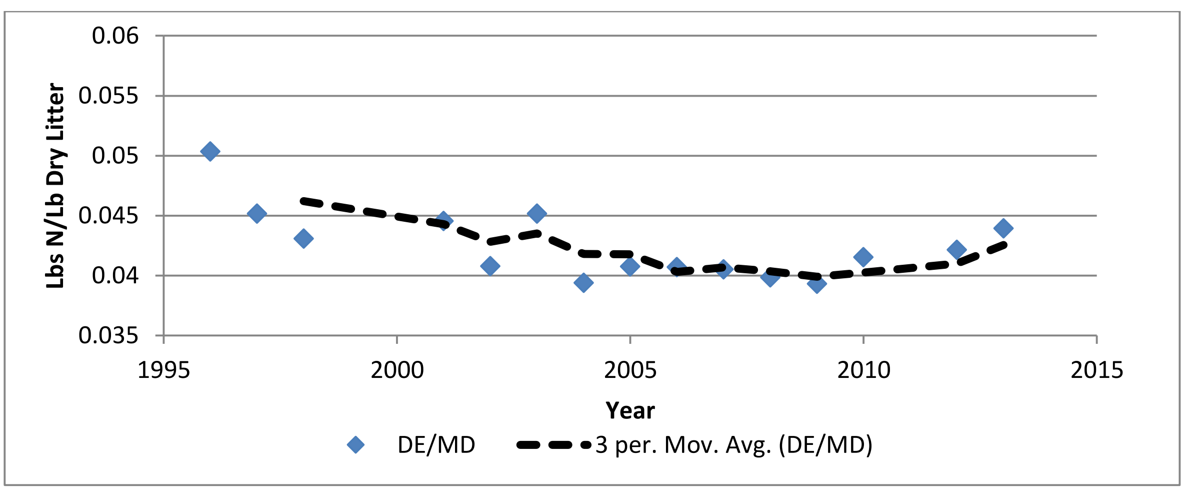
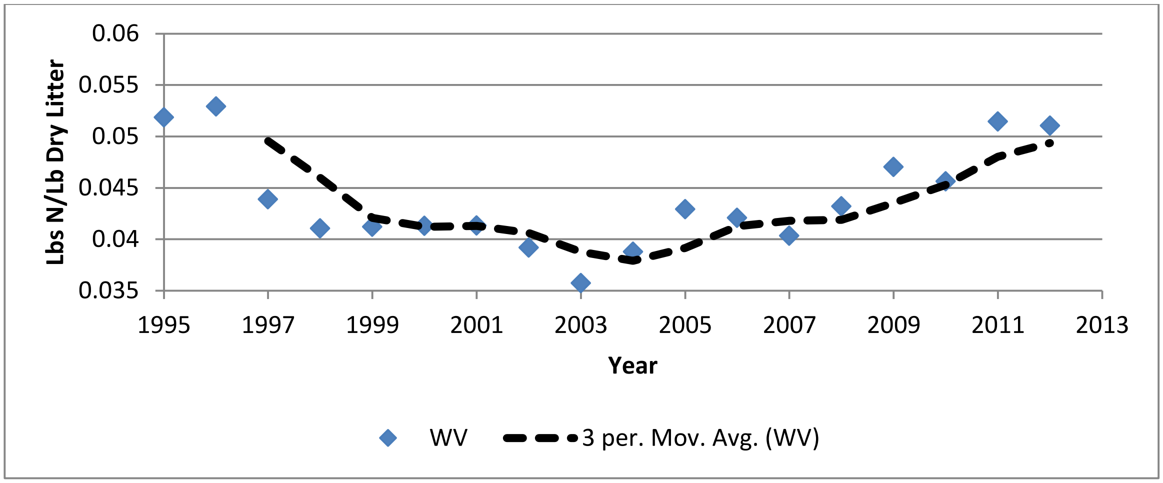


Figure 9: WV Lbs N/Lb Dry Litter for Broilers



Populations

The National Agricultural Statistics Service (NASS) provides statewide annual broiler production numbers at the following website: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1130. The AMS agrees with the PLS recommendation of using these annual production numbers and the annual inventory numbers provided in the Census of Agriculture to estimate countywide broiler production from 1985 through the present. Census of Agriculture inventory numbers are needed to determine the fraction of birds produced in each county because annual production numbers are only released at the statewide level. The two values can be combined using Equation 5 below, and an example of this calculation for DE is provided in Table 1.

Equation 5. Estimating Countywide Populations

Countywide Birds Produced/Year = Statewide Birds Produced/Year X (Countywide Ag Census Inventoried Birds/Ag Census Statewide Birds Produced)

Table 1. Broiler Population Estimates for DE

County	2012 Ag Census Inventory	2012 Ag Census Fraction	2013 NASS Production	Final 2013 Production Estimate
Kent	7,708,825	0.178418	-	37,824,641
New Castle	-	-	-	-
Sussex	35,497,689	0.821582	-	174,175,359
Statewide	43,206,514	-	212,000,000.00	212,000,000

This method should be used for all years for which there are NASS annual bird production data. Production numbers for any future years should be estimated according to the agricultural projection methods approved by the Partnership. These methods estimate future animal populations based upon trends in historic populations.

The resulting pounds of nutrients produced per broiler per year and per state can be found in Appendix C.

Turkeys

Together, VA and WV collected and summarized almost 2,000 samples of turkey litter with nutrient concentrations and moisture content. The concentrations again represented the annual mean concentration of all samples collected within a single year. The AMS recommends using this data to estimate nutrient concentrations in turkey litter across the watershed using the same method described in the broiler section. However, VA acknowledged a lack of confidence in litter mass production data collected from planners, farmers, and manure haulers, and WV did not collect litter mass production data. For this reason, the AMS recommends using ASABE values to estimate the mass of as-excreted manure produced by turkeys. This as-excreted number can then be multiplied by a recoverability factor to account for loss of manure between excretion and hauling to a field, and combined with nutrient concentration information collected by the PLS using Equation 3.

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of As-Excreted Manure

ASABE, 2005 reports that 78 lbs of as-excreted manure are produced per finished turkey tom, while 38 lbs of as-excreted manure are produced per finished turkey hen. Both of these values are reported on a wet basis with 74% moisture content. NASS only reports the number of turkeys sold, but reports no breakdown between turkey toms and turkey hens. For this reason, the AMS recommends averaging these two manure numbers together to represent the average manure production from a turkey until more detailed data on the breakdown between turkey toms and hens becomes available. The average of these two values is 58 lbs of As-Excreted Manure/Turkey Produced. Based upon the reported moisture content, we can assume that there is 0.26 Lbs of Dry Matter/Lb of Manure.

USDA estimates that approximately 72% of manure excreted on turkey operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 72% of as-excreted turkey manure is available for application. This results in approximately 41.76 lbs of Recoverable Manure/Turkey Produced. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 10.8576 lbs of Dry Recoverable Manure/Turkey Produced.

Because the PLS provided dry weight concentrations for turkey litter which are meant to represent concentrations in the litter after any manure has been lost in the production area, there is no need to apply any further loss factors to the turkey manure. We can assume that each remaining pound of manure has a nutrient concentration similar to that of the turkey litter sampled by the PLS.

Nutrient Concentrations

All nutrient concentrations were converted from “as-is” litter nutrient concentrations to dry weight nutrient concentrations. Again, the nutrient concentration values provided by the PLS represent average, annual concentrations. As shown in the figures below, while P has fluctuated over time within turkey litter sampled by VA and WV, the same decrease in P seen in broilers is not shown in the turkey data. However, there appears to be a decrease in P values in both states in recent years. Concentrations of N in turkey litter from both states appear to be steadily increasing through the sample period.

The AMS again recommends the following rules for applying these three-year moving averages of nutrient concentrations in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values according if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 10: Bay-wide P/Lb Dry Litter for Turkeys (to be used by NY, PA, MD, DE)

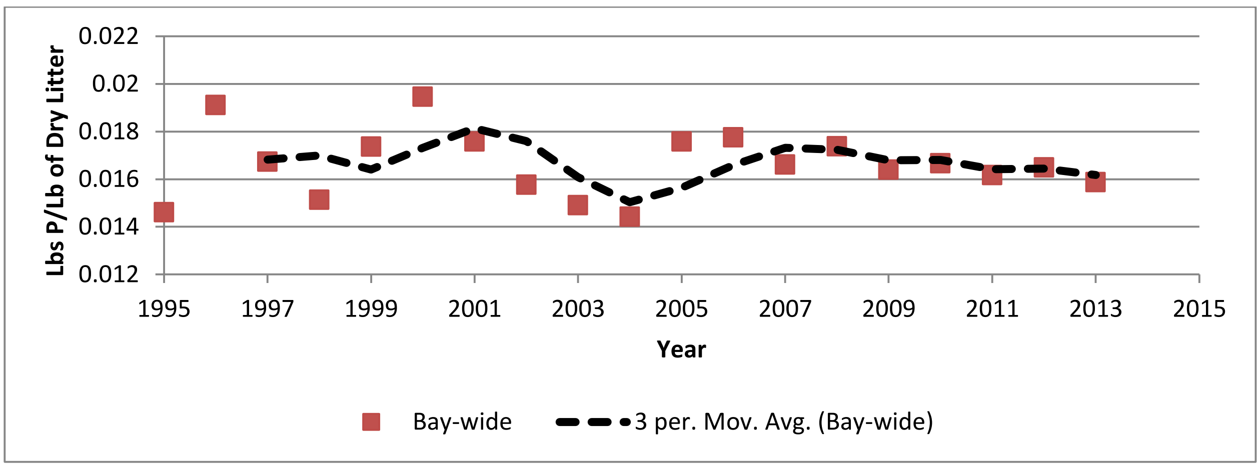


Figure 11: VA P/Lb Dry Litter for Turkeys

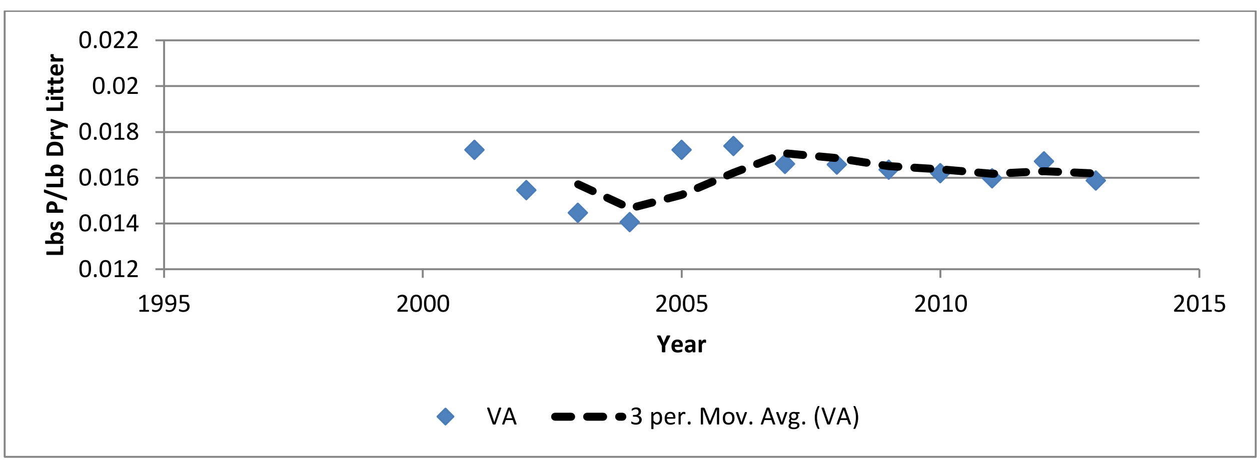


Figure 12: WV P/Lb Dry Litter for Turkeys

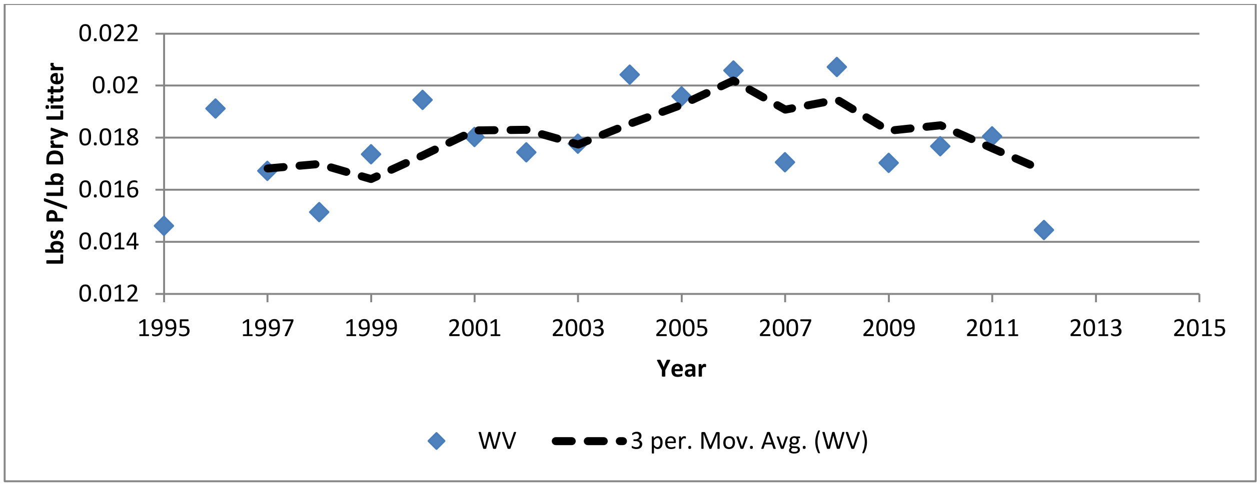


Figure 13: Bay-wide N/Lb Dry Litter for Turkeys (to be used by NY, PA, MD, DE)

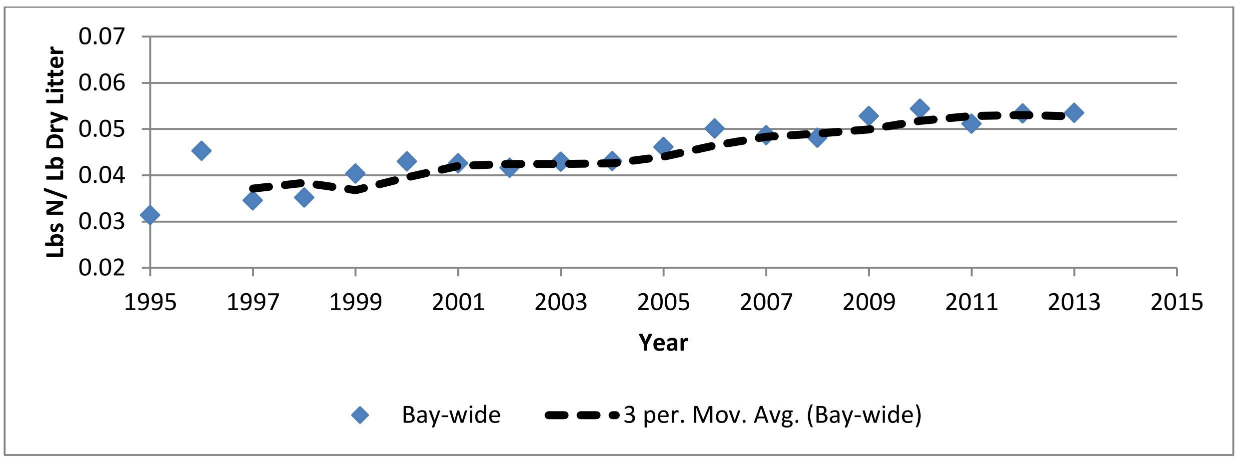


Figure 14: VA N/Lb Dry Litter for Turkeys

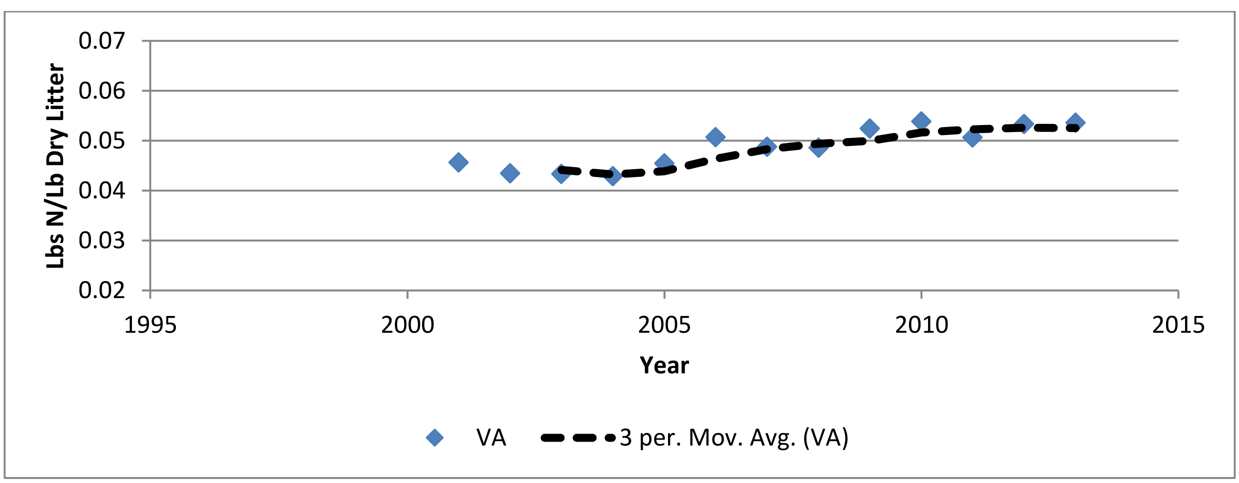
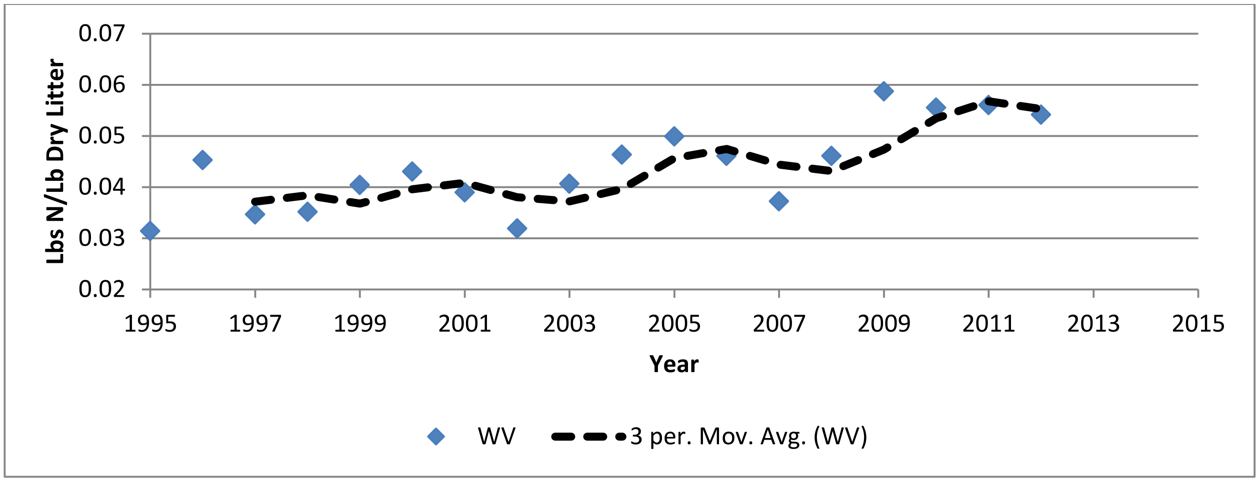


Figure 15: WV N/Lb Dry Litter for Turkeys



Populations

The National Agricultural Statistics Service (NASS) provides annual turkey production numbers by state at the following website: http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1130. The AMS agrees with the PLS recommendation of using these annual production numbers and the annual inventory numbers provided in the Census of Agriculture to estimate countywide turkey production from 1985 through the present. This can be done by calculating the fraction of inventoried turkeys within each county as reported by the Census of Agriculture, and multiplying the county fraction by the total statewide NASS production value. An example of this method is shown in Table 1.

The resulting pounds of nutrients produced per turkey per year and per state can be found in Appendix C.

Layers

The Ag Census defines layers as "table-egg type layers, hatching layers for meat-types, hatching layers for table egg types, and reported bantams." With this definition in mind, VA and WV summarized over 1,100 nutrient concentration records for "layer/breeders" with no breakdown between the two bird types. The majority of egg laying hens in the watershed are raised in PA. However, PA provided only a very small number of data points for the most recent years. Given the availability of data, the AMS recommends using the litter concentration data provided by VA and WV until more samples are collected and reported by PA and other states. No states collected data to accurately estimate mass of litter produced. For this reason, the AMS again recommends using ASABE values to estimate the mass of as-excreted manure produced by layers. This as-excreted number can then be multiplied by a recoverability factor to account for loss of manure between excretion and hauling to a field, and combined with nutrient concentration information collected by the PLS using Equation 3.

Equation 3. Poultry Phosphorus Production Based on As-Excreted Manure with Litter Concentrations (Used for Turkeys and Layers)

Lbs of P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Birds Produced/Year)

Mass of As-Excreted Manure

ASABE, 2005 estimates each layer excretes 69.35 lbs of manure. This manure is assumed to have a 74.21% moisture content, or 0.2579 lbs of dry matter/lb wet manure.

USDA estimates that approximately 82% of manure excreted on layer operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 82% of as-excreted turkey manure is available for application. This results in approximately 56.8670 lbs of Wet Recoverable Manure/Layer. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 14.6667 lbs of Dry Recoverable Manure/Layer Produced.

Because the PLS provided dry weight concentrations for layer litter which are meant to represent concentrations in the litter after any manure has been lost in the production area, there is no need to apply any further loss factors to the turkey manure. We can assume that each remaining pound of manure has a nutrient concentration similar to that of the layer litter sampled by the PLS.

Nutrient Concentrations

The figures below show the concentrations collected by VA and WV, and combined across both states for a Bay-wide average. Concentrations of P within layer litter in these two states appear to be decreasing over the long-term, but increasing slightly in the short-term, particularly in WV. However, WV's P concentration data varies significantly from year-to-year. Concentrations of N appear to remain fairly constant throughout the time period of collection.

The AMS again recommends the following rules for applying these three-year moving averages of nutrient concentrations in the Phase 6 modeling tools:

Apply a three-year moving average to state-specific nutrient concentrations. If state has submitted no data, then apply Bay-wide three-year moving average.

In past years where a moving average is not available, assume the concentration is equal to the first available moving average value.

Ex: Data collection begins in 2003. First three-year moving average value is available in 2005. Assume the 2005 value remained constant from 1985 through 2005.

In future years where data is not available, assume the concentration is equal to the last available moving average value.

Ex: Data collection ends in 2012. Last three-year moving average value is available in 2012. Assume the 2012 value remains constant from 2012 into all future years.

In future years where data is available, re-calculate three-year moving average, and update concentration values according if approved by Partnership.

Ex: Additional data is reported for 2013, 2014 and 2015 that was not previously reported. Last three-year moving average value is available in 2012. Assign new three-year moving average values to 2013, 2014 and 2015 and update values in the Phase 6 Model if approved by Partnership.

Figure 16: Bay-wide P/Lb Dry Litter for Layers (to be used for NY, PA, MD, DE)

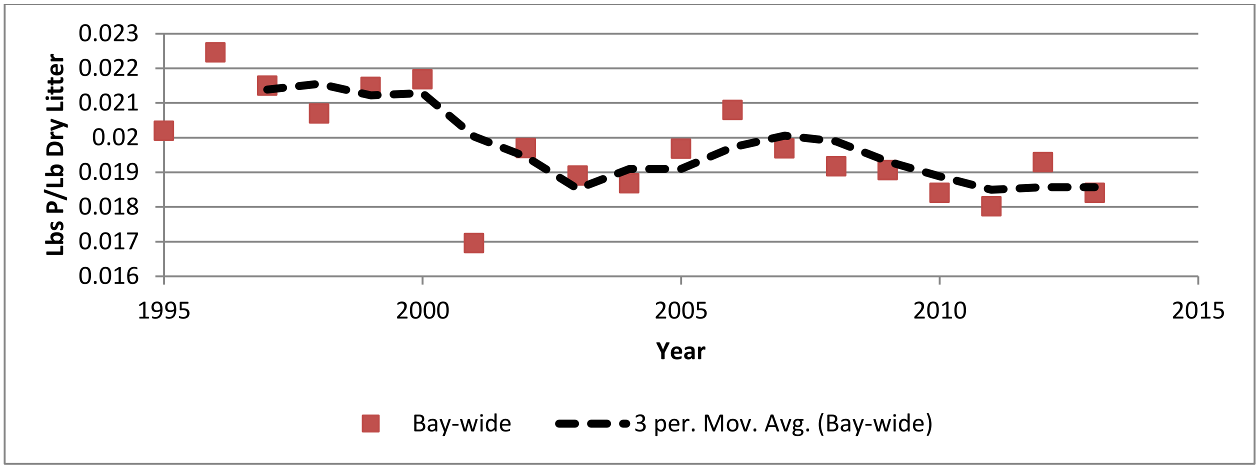


Figure 17: VA P/Lb Dry Litter for Layers

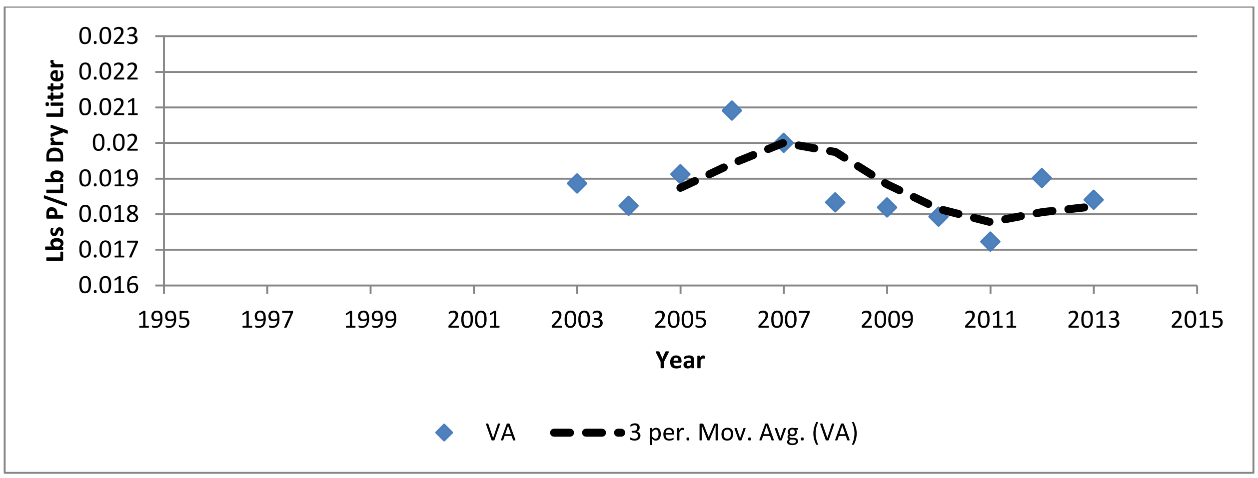


Figure 18: WV P/Lb Dry Litter for Layers

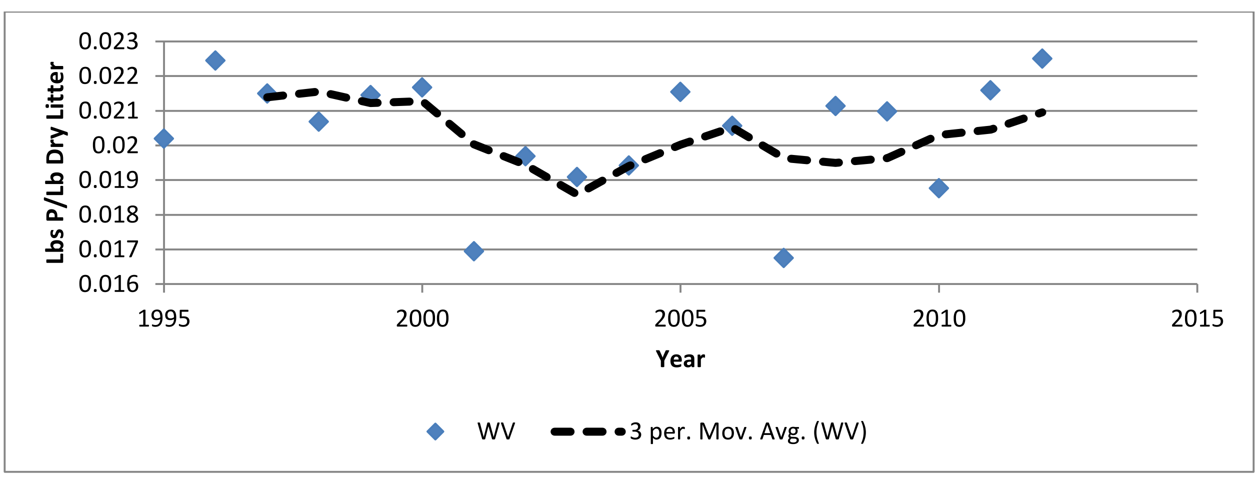


Figure 19: Bay-wide N/Lb Dry Litter for Layers (NY, PA, MD, DE)

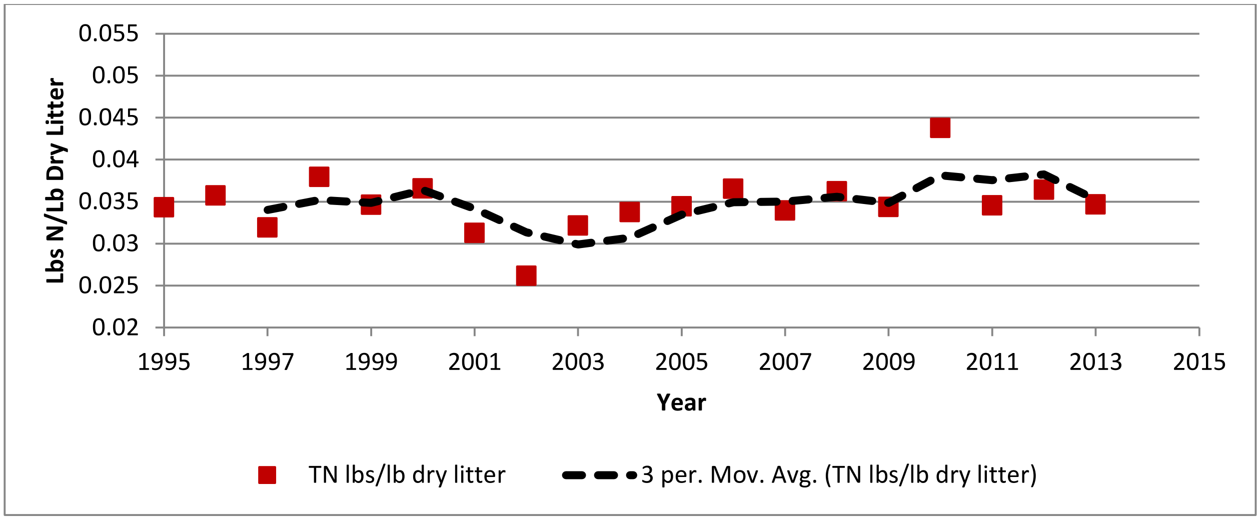


Figure 20: VA N/Lb Dry Litter for Layers

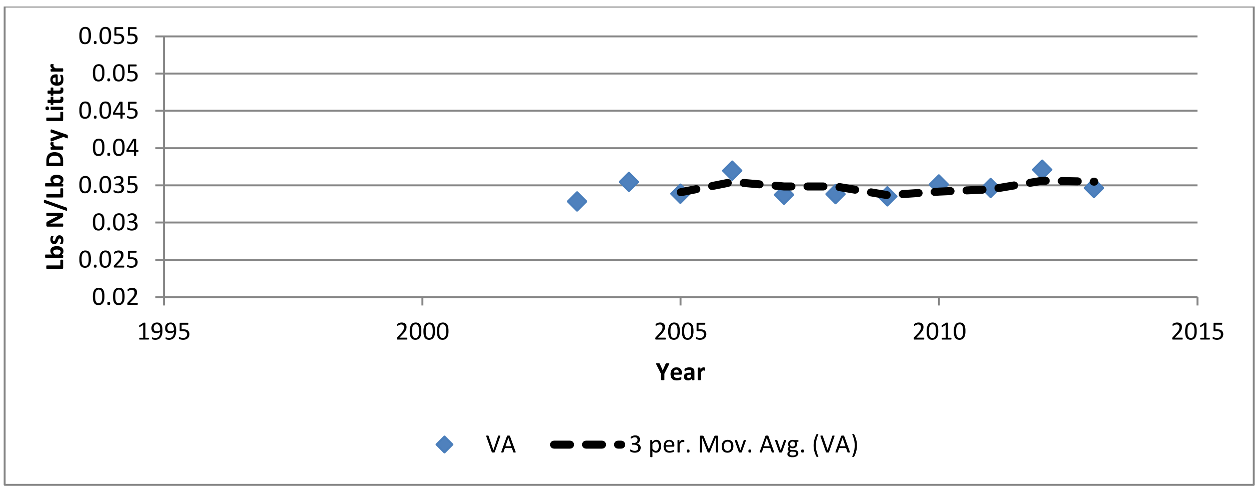
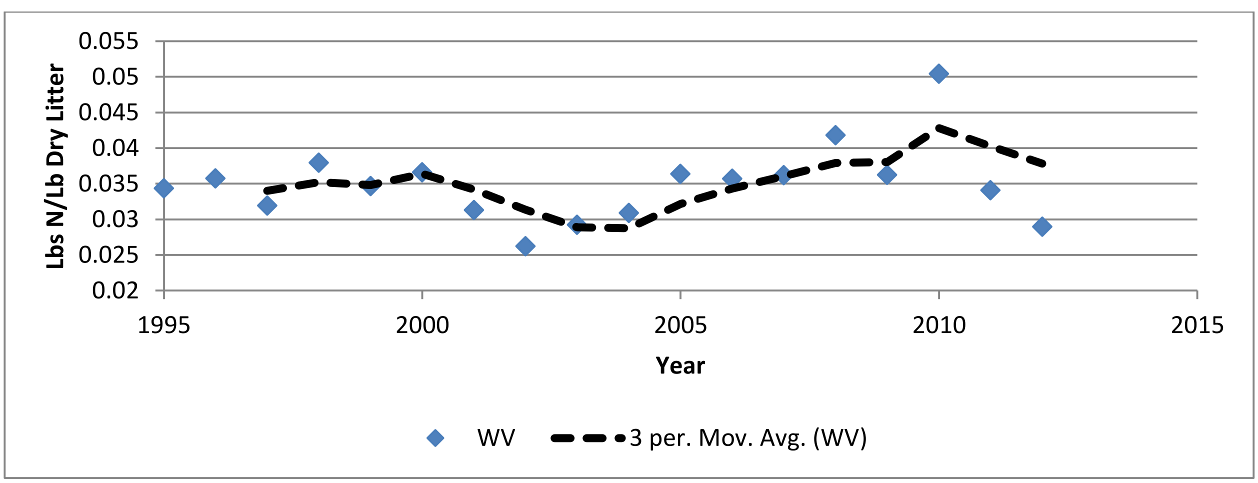


Figure 21: WV N/Lb Dry Litter for Layers



Populations

USDA estimates poultry (and other livestock) populations by combining both year-end inventory[1] and sales data reported in the Census of Agriculture. This is done by deflating both values by the number of typical cycles (flocks) for a bird type in a year. Equation 5 below shows how inventories, sales and cycles are combined to estimate an overall population in the absence of annual production statistics reported for broilers and turkeys.

Equation 5. USDA Bird Production Estimates

Birds Produced/Year = (Year-End Inventoried Birds X 1/Cycles of Birds per Year) + [(Annual Birds Sold/Cycles of Birds per Year) X ((Cycles of Birds per Year-1)/Cycles of Birds per Year)]

The USDA estimates that, on average, layer operations only have one cycle (flock) per year. Because of this, the resulting production estimate from Equation 5 is equivalent to the number of inventoried birds. Inventoried birds should be used to estimate layer production until annual production data is made available.

The resulting pounds of nutrients produced per layer per year and per state can be found in Appendix C.

[1] Census of Agriculture reports a year-end inventory value which represents the number of animals on the operation on December 31, 2012.

Pullets

Unfortunately, very little pullet litter nutrient data is available. Additionally, ASABE has not historically estimated pullet litter nutrients. However, USDA does estimate pullet nutrient production based upon as-excreted manure. The AMS recommends using these estimates in the absence of other data until better data on pullet litter production can be collected. Calculating recoverability of as-excreted nutrients for pullet requires a unique equation because the PLS collected no litter nutrient concentrations as it did for the other bird types. Because it is not known how much N and P that is excreted is lost between excretion and application, we must use a set of recoverability factors to estimate available nutrients for application. These recoverability factors provided by USDA are described in greater detail below.

Equation 2. Poultry Phosphorus Production Based on As-Excreted Manure (Used for Pullets)

Lbs of Recoverable P/Year = (Lbs of As-Excreted Manure/Bird Produced) X (Lbs of Manure Recovered/Lbs of As-Excreted Manure) X (Lbs of Dry Matter/Lb of Manure Recovered) X (Lbs of P/Lb of Dry Matter) X (Lbs of Recoverable P/Lb of P) X (Birds Produced/Year)

Mass of As-Excreted Manure

USDA estimates each pullet excretes 49.91 lbs of manure. This manure is assumed to have a 74.06% moisture content, or 0.2594 lbs of dry matter/lb wet manure.

USDA estimates that approximately 82% of manure excreted on pullet operations in 1985 were recovered and made available to crops (Gollehon, 2014). They also estimate that the recoverability of manure has increased through time due to better manure management through various best management practices. The AMS recommends assuming that with no animal waste management system BMP in place, only 82% of as-excreted turkey manure is available for application. This results in approximately 40.9262 lbs of Wet Recoverable Manure/Pullet. After accounting for the fraction of dry matter in the recoverable manure, this value drops to 10.6163 lbs of Dry Recoverable Manure/Pullet Produced.

Nutrient Concentrations

USDA estimates that each pound of recoverable, dry pullet manure has 0.0203 lbs P and 0.0524 lbs N. However, only 95 percent of that P is considered recoverable and only 50 percent of that N is considered recoverable due to volatilization losses and other pathways. After applying these recoverability factors, we find that each pound of recoverable, dry pullet manure has 0.019285 lbs of recoverable P and .026200 lbs of recoverable N.

The AMS recommends that these two nutrient values represent typical operations in the year 2002 (USDA estimates these represent typical pullets from 2002 through 2007). After contacting a regional feed manufacturer, the AMS feels that layer and pullet feed are related to such an extent that it would be appropriate to apply the trends in P concentrations seen in layer feed to the pullet data as well. The percent change in P concentrations shown in the Bay-wide layer data from 2002 through 2013 will be applied to estimate trends in pullet P concentrations in all states over this time period. Table 2 below shows this change.

Table 2. Pullet P Concentrations in Recoverable Manure

Year	Original Pullet P Concentration	Percent Change in Bay-wide Layer P	Final Pullet P Concentration
2002	0.019285	NA	0.019285
2003	0.019285	-4.76287%	0.018366
2004	0.019285	3.11706%	0.018939
2005	0.019285	-0.02386%	0.018934

2006	0.019285	3.31276%	0.019562
2007	0.019285	1.69592%	0.019893
2008	0.019285	-0.84711%	0.019725
2009	0.019285	-2.90331%	0.019152
2010	0.019285	-2.22071%	0.018727
2011	0.019285	-2.04213%	0.018345
2012	0.019285	0.41046%	0.018420
2013	0.019285	0.00124%	0.018420

Populations

USDA estimates poultry (and other livestock) populations by combining both year-end inventories[2] and sales data reported in the Census of Agriculture. This is done by deflating both values by the number of typical cycles (flocks) for a bird type in a year. USDA estimates producers grow approximately 2.25 cycles of pullets per year. Equation 5 shows how Census of Agriculture numbers are combined with cycles to produce a yearly production estimate.

Equation 5. USDA Bird Production Estimates

Birds Produced/Year = (Year-End Inventoried Birds X 1/Cycles of Birds per Year) + [(Annual Birds Sold/Cycles of Birds per Year) X ((Cycles of Birds per Year-1)/Cycles of Birds per Year)]

With no other pullet population data available, the AMS recommends using this method to estimate yearly production for each county during years in which the Census of Agriculture was released. Production values for all other years (including future years) should be estimated using the agricultural projection methods already approved by the Partnership.

The resulting pounds of nutrients produced per pullet per year and per state can be found in Appendix C.

[2] Census of Agriculture reports a year-end inventory value which represents the number of animals on the operation on December 31, 2012.

Future Data Collection and Submissions

The PLS established a clear process for collecting and summarizing laboratory analyses of poultry litter and litter production data. This process provided enough information to improve estimates of broiler, turkey and layer nutrient information. However, data gaps still exist, particularly for pullets and layers, and for turkey litter production estimates. The AMS recommends that all states begin regularly reporting laboratory analyses of poultry litter and litter production data on a yearly basis to the Chesapeake Bay Program. On a semi-regular basis (perhaps at the beginning of each Milestone period - 2 years - or more or less frequently), the estimates for poultry litter nutrient production should be updated in the Watershed Model to represent how values have changed since the calibration of the new model. These reported values should be used to update the key parameters in the basic equation: 1) mass of litter produced; 2) litter dry solids content; and 3) litter nutrient concentrations. Absent these values, the Partnership must rely on other widely published values such as those reported in the ASABE, 2005 report. Where possible, future data collection efforts should also focus on the correlation of these key parameters at the farm level, to quantify the effects and extent of various litter management scenarios. A dataset for broilers, for example, might include for each record the volume of litter removed (including total cleanout and removal of crust between flocks) in a cleanout period, the number of flocks and number of birds produced during that cleanout period and their finish weight, and a manure analyses showing the N, P and moisture content of that litter. This would allow the states to determine the amount of N and P produced per bird on a farm level, which can then be aggregated into an average.

The AMS recommends that raw sample data for each parameter be submitted to the Bay Program using standardized templates. This would allow the Partnership to conduct more thorough statistical analyses of the data which in turn would result in better litter estimates for the modeling tools. Ultimately, the Partnership will need to determine both the method and frequency of collecting and updating these values.

Additionally, there is still an opportunity for the Partnership to collect historical data on all bird types prior to final calibration of the Phase 6 Watershed Model. Calibration will occur in October, 2015, so states wishing to provide historic litter production and/or nutrient concentration data should submit the data to the Chesapeake Bay Program by September, 2015. The data can then be analyzed and potentially approved by the Partnership for use in the Phase 6 Watershed Model.

To address the further need for poultry production data, representatives of the commercial poultry industries and land grant universities in the region are currently working cooperatively with the Chesapeake Bay Program partnership to develop and implement a process whereby a more accurate understanding of the annual generation of nutrients by regional commercial poultry production can be realized. USDA National Agricultural Statistics Service (NASS) is recognized by the project partners as the primary source of validated agricultural production data in the region, and representing the optimal path forward to forming the critical data exchange linkage between the regional integrators and the CBP partnership. The PLS has identified the critical data gaps as well as the existing potential options to resolve them. In response to the finding of the PLS, the project partners have identified the implementation of an annual NASS integrator survey as the potential solution to address several existing data limitations. Expectations are for the new NASS survey to be implemented in late 2015, and the resulting data to be made publically available in 2016 for use in the final version of the partnership's Phase 6.0 modeling tools.

Comparing Methods

All nutrient balance analyses require assumptions about nutrient concentrations and manure or litter production. The AMS chose to compare the assumptions described in this document (using Delaware broilers as an example) to assumptions in the current Phase 5.3.2 Watershed Model and assumptions in ASABE's 2005 report. Table 3 shows how differences in population, litter/manure production and nutrient concentrations across these three methods impact final nutrient production estimates. As mentioned previously, both Phase 5.3.2 and ASABE, 2005 estimate as-excreted manure, while the Phase 6 method estimates litter directly. This means that estimates of storage and handling loss and volatilization must be applied to any as-excreted values in both the Phase 5.3.2 and ASABE, 2005 methods. No such estimates are needed in the Phase 6 method because litter values collected by the states are assumed to inherently reflect the losses which occurred after excretion.

This comparison shows that the Phase 5.3.2 method estimates more nutrients available to crops after losses than the other two methods. One main reason for this difference is the assumption that the Census of Agriculture's bird inventory number represents the average population of birds in county on any given day during the year. That assumption does not take into account the number of flocks or cycles of birds grown at a typical house within the county. If for example, the number of days of manure production were reduced from 365 to 300 to account for flock turnover and house cleanout throughout the year, then the Phase 5.3.2 method's estimates of nutrients would be in line with the other two methods. For this reason, the AMS strongly recommends deflating inventory numbers for layers and pullets using the USDA population method described earlier in the report.

The comparison also illustrates that estimates from the ASABE, 2005 method and the Phase 6 method are very similar once estimates of storage and handling loss and volatilization are applied to the ASABE as-excreted values. This comparison provides evidence that the ASABE, 2005 values match closely with estimates collected by the PLS, strengthening the confidence in the use of ASABE, 2005 values for pullets, layers and turkeys. While the AMS does recommend using ASABE, 2005 to estimate nutrient production for pullets and layers (and to a lesser extent for turkeys), the group strongly encourages states to collect sufficient litter data that will allow for direct estimates of litter rather than as-excreted manure for these bird types in the future.

Table 3. Estimates of Nutrients Produced by DE Broilers in 2012

Parameter	Phase 5.3.2 Method	ASABE 2005 Method	Phase 6 Method
Produced Birds	NA	212,000,000	212,000,000
Inventoried Birds	43,206,514	-	-
Days of Manure Production	365	-	-
Lbs of Manure Excreted/Bird/Day (Wet Basis)	0.186813	-	-
Lbs of Manure Excreted/Finished Bird (Wet Basis)	-	11	-
Lbs of Litter/Finished Bird (Wet Basis)	-	-	2.955
Lbs of Dry Matter/Lb of Manure Excreted	0.26	0.26	-
Lbs of Dry Matter/Lbs of Litter	-	-	0.7135
Lbs P/Lb of Manure Excreted (Dry Basis)	*0.011400	0.012500	-
Lbs P/Lb of Litter (Dry Basis)	-	-	0.014397

Lbs N/Lb of Manure Excreted (Dry Basis)	0.049800	0.042857	-
Lbs N/Lb of Litter (Dry Basis)	-	-	0.043065
Total Lbs of Manure Excreted (Wet Basis)	2,946,111,552	2,332,000,000	-
Total Lbs of Litter (Wet Basis)	-	-	626,460,000
Total Lbs of Manure Excreted (Dry Basis)	765,989,004	606,320,000	-
Total Lbs of Litter (Dry Basis)	-	-	446,979,210
Total Tons of Manure Excreted (Wet Basis)	1,473,056	1,166,000	-
Total Tons of Litter (Wet Basis)	-	-	313,230
Total Tons of Manure Excreted (Dry Basis)	382,995	303,160	-
Total Tons of Litter (Dry Basis)	-	-	223,490
Total Lbs of P Excreted	8,732,275	7,579,000	-
Total Lbs of N Excreted	38,146,252	25,985,056	-
Total Lbs of P After Storage and Handling Loss	**7,422,433	**6,442,150	**6,435,160
Total Lbs of N After Storage and Handling Loss and Volatilization	**27,083,839	**18,449,390	**19,249,160

*The Phase 5.3.2 Watershed Model assumes that phytase amendments to feed combined with changes to broiler diets and genetics results in the production of 16% less phosphorus. No such assumption was made for the ASABE 2005 or Phase 6 methods.

**The Phase 5.3.2 Watershed Model assumes that 15% of excreted manure is lost to the nearby environment prior to application on crops. It also estimates that approximately 15% of TN is lost due to volatilization between excretion and application. These same assumptions were applied to the ASABE 2005 Method. However, the Phase 6 Method estimates litter directly, and thus inherently includes any loss of nutrients that may have occurred through storage and handling or volatilization of nitrogen. There has been concern over the Phase 5.3.2 Model's use of this 15% loss factor. This loss only occurs on operations with no animal waste storage BMPs. This loss factor decreases when animal waste storage systems are applied.

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Appendix B. Pasture Subgroup Recommendations for Direct Deposition in Riparian Pasture Access Area

Agricultural Modeling Subcommittee – Pasture Subgroup

Recommendations on Riparian Pasture and Exclusion Fencing for CBP Phase 6 Watershed Model

Background

Simulation of pastures and livestock loadings and the Best Management Practices (BMPs) used to mitigate these loadings have varied over time by the Chesapeake Bay Program (CBP). Going back to the Tributary Strategies of 2005 and the phase 4.3 watershed model (WSM) simulated livestock exclusion BMP as a percent efficiency reduction applied to 51 upland pasture acres per linear mile of exclusion fencing implemented. The basis for the percent reduction and the extent of pasture impacted were poorly documented and not consistent with current understanding. With the advent of the phase 5.x WSM a land use for the area adjacent to streams with livestock access was developed to represent a degraded riparian pasture situation. Application of exclusion fencing in the phase 5 WSM would result in a land use change from the degraded condition to an unfertilized grass (hay without nutrients) or grassed riparian buffer situation or if trees were planted as forest or a forested riparian buffer. The actual extent of the degraded riparian pasture land use was not discernible via remote sensing of the imagery or other data sets used for land use determinations in phase 5.x. Each partner jurisdiction in consultation with CBP modeling staff analysis of projected Tributary Strategies exclusion made their best estimate of the extent of this degraded riparian pasture land use as a percentage of the total pasture. The relative loadings benefits of exclusion fencing from the phase 4.3 WSM were used to back calculate the estimated unit area loading from the degraded riparian pasture land use. This calculation produced on average across the entire watershed a 9 times (9X) the pasture unit area loading for nutrients and sediment delivered to the edge of stream. Since this was based on the phase 4.3 estimated exclusion benefit there is little documented scientific basis for this loading or benefit of exclusion fencing as simulated in the phase 5 WSM. And since the extent was based on educated guesses some jurisdictions either estimated too little or too much of this land use. Too little degraded riparian pasture land use area resulted in BMP cut-off in subsequent annual progress run scenarios and too much area estimated resulted in loadings that are not real or misattributed in the model calibration and could never be treated by real world implementation of exclusion fencing. These issues related to the extent, justification, and impact on loadings of the degraded riparian pasture land use have resulted in the Agricultural Modeling Subcommittee (AMS) to propose the elimination of this land use for the phase 6 WSM.

Because of this proposed change in land uses between phase 5 and phase 6 WSM the AMS established a Pasture Subgroup (PSG) to propose a solution to estimate loadings from livestock to the simulated streams and crediting exclusion fencing in phase 6 WSM. The membership of the PSG consisted of William Keeling VADEQ (PSG lead), Curtis Dell USDA ARS (AMS Chair), Les Vough UMD retired, Jim Cropper Northeast Pasture Consortium, Gary Shenk EPA, Matt Johnston UMD-CBP, Chris Brosch VT/VADCR, Dave Montali WVDEP, Mark Dubin Coordinator AGWG, Emma Giese CRC.

Evaluation of Simulation Options

The PSG had its initial meeting on September 4, 2014. At this meeting the potential options for simulating loadings from livestock access to streams and how exclusion BMP could be simulated were explored. The three options were: reverting to a pasture efficiency as in phase 4.3, keeping a land use change as in phase 5, or simulating direct deposition. The first option considered was reverting back to the phase 4.3 WSM methods of a percent reduction efficiency applied to the pasture Unit Annual Loading (UAL) per some extent of exclusion fencing implemented. As stated above the documentation in the scientific literature to justify this method of simulation is lacking and to establish a scientifically defensible efficiency for phase 6 WSM exclusion fencing would require a BMP panel to be established. With the extent of pasture in the watershed, numerous assumptions needed, and the limited time available for model development the PSG's consensus opinion was to explore other options for phase 6. Another option was to retain the land use change benefit to exclusion fencing as is currently done in the phase 5 WSM. This option also requires assumptions to be made primarily regarding the extent of the acreage of the degraded riparian pasture land use as well as UAL for this land use. Neither method actually represents one of the main impacts livestock with unrestricted access to streams have that being direct fecal depositions. Without a definitive way to estimate the degraded riparian pasture land use extent, justification for the current UAL, or a mechanistic way of simulating all aspects of livestock loadings a third option was put forward.

The third option is to simulate the direct deposition of fecal matter by livestock to the streams similarly to how point sources are simulated in CBP WSM. This option requires an estimate of the time spent in the riparian area of pastures by animal type and how much of the daily fecal matter is deposited directly into or adjacent to the stream as well as how many of each animal type are excluded per unit of exclusion fencing applied.

Virginia has developed hundreds of bacteria TMDLs for local scale watershed throughout the Commonwealth as well as studies in the Upper Susquehanna detailing livestock access to streams in that portion of the Bay Watershed. It was proposed to evaluate primarily rural TMDLs developed in Virginia and the Susquehanna to see if the needed factors for direct deposition loadings and fencing could be estimated. Additionally the PSG consulted key individuals from the Virginia Tech Department of Biological Engineering due to their extensive experience developing local scale TMDLs for fecal bacteria and their extensive knowledge of watershed modeling and the available literature. This consultation was to seek potential additional methods of simulation and any insights to the 3 options the PSG discussed. Dr. Brian Benham, Dr. Gene Yagow, and Erin Ling were contacted to discuss the various options for simulating livestock loadings and BMPs. They agreed that the three options discussed by the PSG were ways to simulate loadings and BMP benefits in a watershed model and did they not offer any additional potential methodology. Each option has plusses and minuses and that there was no single correct way. Each option requires assumptions to be made and documented. The percent reduction efficiency would be the simplest method of simulation but as detailed above would require extensive evaluation of the available literature and likely to include considerable best professional judgment of any panel of assembled experts. This method also does not represent the actual loading and remediation pathways of to real world situations. The land use change option requires an accurate determination of the extent of the land use and UAL and also does not simulate the actual loading processes. These modeling experts were not sure that the available literature would produce exactly what is needed for either option though there is literature on the benefits of riparian buffers. They did offer suggestions on possible data sets to use such as NHD-Plus, NLCD land use data sets, and NASS Crop Data Layer as possible data sets to be evaluated using GIS for the land use change option if that is the PSG's ultimate preferred recommended method. Though there is data in Virginia and parts of the Upper Susquehanna on potential direct fecal deposition loadings it likely does not exist across the entire Bay Watershed and would require assumptions being made for those areas based on the data available in the portions of the watershed that data does exist. That being said the third option represents the actual loading mechanism of direct fecal deposition and, in conjunction with riparian buffer simulation, could be a mechanistic way to represent the actual loading pathways and BMP applications over the efficiency or land use change options.

Analyses Conducted by PSG

In an effort to see if GIS analysis could provide better estimates of the extent of riparian pasture an analysis was conducted using the NHD-Plus stream network data layer and the 2011 NLCD to estimate the potential extent of pasture and stream intersections across the watershed. Table 1 illustrates the results of that analysis and comparison to existing phase 5 WSM acreage of pasture and degraded riparian pasture land uses. Based on this analysis the overall acreage determined is similar to that currently used in the phase 5 WSM. It is therefore likely that choosing option 2, simulation as a land use change, would retain the characteristics of the phase 5 model.

Table 1 Pasture, Degraded Riparian Pasture, and GIS Statistics

2010 No-Action	Phase 5 Pasture	Phase 5 Pasture	Degraded Riparian Pasture (DRP)	DRP	DRP	GIS
Jurisdiction	Acres	Percent in CB watershed	Acres	Percent in CB watershed	Percent of Pasture	Acres
DC	0	0.00%	0	0.00%	0.00%	NA
DE	5,837	0.25%	0	0.00%	0.00%	NA
MD	202,375	8.74%	806	0.70%	0.40%	NA
NY	180,302	7.78%	12,624	10.95%	7.00%	NA
PA	517,173	22.33%	16,617	14.41%	3.21%	NA
VA	1,162,126	50.17%	61,165	53.03%	5.26%	NA
WV	248,504	10.73%	24,124	20.92%	9.71%	NA
All	2,316,317	100.00%	115,336	100.00%	4.98%	122,743

An evaluation of several dozen local scale bacteria TMDLs from Virginia resulted in the selection of 7 TMDL areas where direct deposition from both beef and dairy cattle was characterized. The key factors common between these TMDL studies necessary for the PSG's effort are time spent by animal type in the stream access area, pasture, and confinement or loafing areas. The stream access area was uniformly considered to be pasture acreage adjacent to the stream. These times varied by month with less time spent in the access area during winter months and more during summer months. Dairy cattle were estimated to be primarily in confinement (loafing, feeding, milking areas) with relatively minor time spent in the access areas or pastures as compared to beef cattle. There were differences between TMDL developers on the percentage of fecal deposits directly deposited to the stream per time spent in the access area. For example some assumed that for the time spent in the access area that 100 percent of that fraction of the daily fecal production was directly deposited in the stream. For example if a beef cow spent 1 hour per day in the access area it was assumed that $1/24^{th}$ of the daily fecal production was deposited in that zone. Other developers assumed a smaller percentage. The basis for this particular assumption was not documented in the TMDL reports and may have been used as a calibration parameter by the modelers.

Based on the Virginia TMDL analysis a spreadsheet was developed using the Virginia specific factors for time in the access area, pasture or confinement, and percentage of daily production directly deposited to the streams (90%) by animal type and each county across the Bay watershed. The 2012 NASS Census of Agriculture was used to derive the county specific animal numbers. This analysis was conducted to gauge the relative loadings differences the proposed direct deposition method would produce as compared to the phase 5 WSM modeled degraded riparian pasture loadings. From the 2012 Census data beef, horses, sheep and lambs, other cattle, and angora goats had the Virginia factors for beef cattle applied with dairy cattle and milk goats getting the Virginia dairy factors applied. These factors by animal type were applied to every county across all states in the watershed. For this comparison the 2010 no-action loadings scenario was used so that the impact of other BMPs would be eliminated. This analysis was presented to the PSG for comment in late January 2015. Comments from the PSG membership on this analysis resulted in modifications to eliminate direct deposited loadings from sheep and lambs, angora goats, and milk goats and recommended these animal types load only to pasture acres and not directly to streams. The experts on the PSG knowledgeable on livestock behavior by animal type made this recommendation since these animals rarely spend time in the stream and spend the vast preponderance of time pastured. It was also determined to collect Pennsylvania and New York (if available) specific factors since grass species and management of livestock including confinement schedules for the northern portion of the watershed are significantly different than in Virginia. Since it was thought the key factors needed for this effort were not available from the remaining Bay jurisdictions it was decided that the Virginia factors would be applied to the Coastal Plain of Maryland and to Delaware. And the Pennsylvania specific factors would be applied to the remaining hydrogeomorphic regions of Maryland, and all of West Virginia’s Bay draining areas and if New York data could not be found to New York as well. Table 2 provides the Virginia and Pennsylvania specific factors used for the estimate on magnitude of loadings. Note that for the 2010 no-action scenario phase 5.3.2 Virginia and Pennsylvania constitute approximately 73% of all pasture acres in the modeling domain.

Insert Table 2 here:

Table 3 illustrates the results of this analysis as compared to the phase 5 WSM 2010 no-action scenario. This analysis indicates the same order of magnitude of loadings for TN and TP by simulating direct deposition verses the degraded riparian pasture loadings.

Table 3: VA Factors only revise with PA

Direct Deposition			2010 No-Action DRP		
TN	TP	TSED	TN	TP	TSED

Jurisdiction	lbs/year	lbs/year	tons/year	lbs/year	lbs/year	tons/year
DC	0	0	0	0	0	0
DE	204,997	48,722	0	0	0	0
MD	1,391,376	330,375	0	103,581	10,360	1,825
NY	3,107,746	702,585	0	843,536	123,981	16,755
PA	7,286,163	1,672,429	0	3,102,909	250,898	32,988
VA	4,733,619	1,211,210	0	6,028,494	869,766	374,307
WV	681,188	178,077	0	2,764,962	315,512	113,581
All	17,405,090	4,143,398	0	12,843,482	1,570,517	539,456

Pasture Subgroup Recommendations

It is the opinion of the Pasture Subgroup that **the preferred method to simulate livestock loadings and the benefit of exclusion fencing is to simulate the direct deposition of fecal matter and associated nutrients to the stream network in the phase 6 WSM**. This eliminates the need to estimate an extent of degraded riparian pasture or to estimate the loadings from that land use neither of which can be readily determined or justified. This should eliminate or significantly reduce the currently experienced cut-off of progress implementation reported since exclusion fencing would be applied against the available pasture acres and animals in the segment exclusion fencing implementation is reported. It provides a more realistic simulation of the actual loadings mechanisms that exist from pasture and livestock with unrestricted access to streams. The loadings and benefits of exclusion are tied directly to the numbers and types of animals excluded including reductions associated with buffer establishment. It can be readily implemented in the phase 6 WSM with all needed assumptions clearly documented. It will result in a different attribution of loadings in the phase 6 WSM as compared to the phase 5 WSM. However, it is the Pasture Subgroups opinion that this is an improvement in the simulation because the animal numbers by county are considered more reliable than estimates of a land use that cannot be derived via remote sensing efforts or land use loadings that cannot be justified by the available literature.

NEIEN Reporting using Direct Livestock Loadings

To report and receive credit in the phase 6 WSM for livestock exclusion fencing states will have two options: direct reporting of excluded livestock or reporting of fenced length combined with a default livestock per unit of fencing. Currently both Pennsylvania and Virginia collect the numbers and animals types excluded for each installation of exclusion fencing. Since 2010 Virginia has collected the length of streambank protected, average buffer width, primary, secondary, and tertiary animal type, animal numbers, and animal units excluded. The NEIEN schema would need to be modified to allow reporting of the selected data elements. If a jurisdiction does not collect this specific type of information it is proposed that an average animal unit of livestock excluded per unit of fencing or streambank protected be derived from the Pennsylvania and Virginia data and applied to the reported linear feet of exclusion fencing reported. This method would also be applied to the historic data used for calibration since the pertinent data was not collected throughout the calibration period for phase 6 WSM.

Crediting Exclusion Fencing in Phase 6

If the reporting jurisdiction provides the animal type and numbers excluded along with the length of streambank protected or fencing installed. The corresponding loadings as calculated per animal would be eliminated from being directly input to the simulated stream network and those loadings would be applied as input to the upland pasture acres left after accounting for any buffer created by the exclusion fencing. This loading to pasture would be subject to reduction through watershed processes in accordance with the phase 6 simulation methods. The benefits of buffers are documented in the Agricultural Buffer Expert Panel report recently approved by the WQGIT. Consistent with that report, areported buffer width of 35 feet or greater would generate a land use change converting the impacted pasture acres to unfertilized grass or a riparian grass or herbaceous buffer. A riparian forested buffer established via the planting of trees between the fence and stream would receive the benefit of the riparian forested buffer BMP. If a partner jurisdiction were not able to document a minimum of 35 setback it would be credited assuming a 10 foot setback and the impacted acreage would only get the land use change of pasture to unfertilized grass for that area (10' times length of streambank protected). The upland benefit applied to buffers would not be eligible in this particular situation. As stated above the number and type of livestock excluded would be reported or approximated and the direct loadings reductions would be identical to installations of exclusion fencing that do create a riparian buffer.

Appendix C. Establishing Yield Goals for Major Crops

Establishing Yield Goals by Crop, County and Year

Raw Datasets:

1) "Yearly NASS" yields for major crops
2) "Ag Census" yields
3) Scenario Builder "Max Yields"

Rule 1: Remove Outliers

1) Calculate Watershed-wide MEDIAN for crop for year for "Yearly NASS" data.
2) Calculate ABSOLUTE DEVIATION FROM MEDIAN as: Yearly County Crop Yield – Watershed-wide MEDIAN.
3) Calculate MEDIAN OF ABSOLUTE DEVIATIONS as: median of results from step 2.
4) Multiply result of step 3 by "4" to determine the MEDIAN OF ABSOLUTE DEVIATION OUTLIER CONSTANT
5) Add result of step 4 to result of step 1 to establish UPPER LIMIT.
6) Subtract result of step 4 from result of step 1 to establish LOWER LIMIT.
7) Remove all yields that do not fall within the range of UPPER LIMIT and LOWER LIMIT, making them NULL. Result becomes "Yearly NASS Revised."
8) Repeat process for "Ag Census" data. Result becomes "Ag Census Revised."

Rule 2: Populate with Yearly NASS yields

1) For each county, crop and year, calculate the average of the highest 3 out of the previous 5 values from "Yearly NASS Revised."
2) If NULL, make equal to most recent non-null value. For example, 1985 is NULL because there are not 3 previous values. Make 1985 equal 1988 where a non-NULL value exists.
3) If NULL, make equal to the average yearly yield across Scenario Builder Growth Region. For example, 1990 is NULL for Somerset County, MD. Make 1990 equal average 1990 yield for Scenario Builder Growth Region MD_2.
4) If NULL, make equal to the average yield over all records for all years for the Scenario Builder Growth Region. For example, 1990 is NULL for ALL counties in Scenario Builder Growth Region MD_2, and no other data exists for Somerset County, so steps 1, 2 and 3 will not provide results. However, data exists for other counties within the Growth Region for other years. Make 1990 for Somerset County equal the average yield for all counties in the Growth Region over all years.
5) Result of above steps becomes "Yearly NASS Final."

Rule 3: Populate with Ag Census Yields

1) Repeat steps from Rule 2 above for “Ag Census Revised.”
2) If NULL, make equal to the average of all available yields from “Ag Census Revised.”
3) Result of steps becomes “Ag Census Final.”

Rule 4: Combine Yearly NASS Final with Ag Census Final

1) If value exists in “Yearly NASS Final,” use value.
2) If NULL, use existing values from “Ag Census Final.”
3) Result of above steps becomes “USDA Combined Yields.”

Rule 5: Calculate Ratio of USDA Combined Yields to Max Yields

1) For each county, crop and year, calculate the MAX YIELD RATIO from “USDA Combined Yields” to the value from “Max Yield.”
2) Calculate a single COUNTY AVERAGE MAX YIELD RATIO over all crops for a single county from the results of step 1.
3) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to most recent non-null value.
4) If NULL, make COUNTY AVERAGE MAX YIELD RATIO equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for that year.
5) If NULL, make equal to the average of all COUNTY AVERAGE MAX YIELD RATIOS within Scenario Builder Growth Region for all years.
6) If NULL, make equal to 1.
7) Result of steps becomes MAX YIELD RATIO.

Rule 6: Calculate Revised Max Yields

1) Multiply Max Yield values by MAX YIELD RATIO for each county, crop and year.
2) Result of steps becomes “Revised Max Yields.

Rule 7: Combine Revised Max Yields with USDA Combined Yields

1) If value exists in “USDA Combined Yields,” use value.
2) If NULL, use values from “Revised Max Yields.”
3) Result becomes “Combined Yields.”

Rule 8: Remove and Replace Outliers

1) Repeat steps from Rule 1 using “Combined Yields.”
2) If NULL, make equal to non-null value from “Combined Yields.”
3) If NULL, make equal to the average of yields for all counties within Scenario Builder Growth Region for that year.
4) If NULL, make equal to average of yields across all counties within Scenario Builder Growth Region for all years.
5) Result becomes “Final Yield Goals.”

1984 a = 1985

Appendix D. Crop Cover and Detached Soil Detailed Methods

Documentation of Scenario Builder Crop Cover and Detached Sediment Storage

10/12/2015

This documentation describes the data and calculation process used to generate the crop cover and detached sediment storage (DETS) files generated by Scenario Builder.

Development of Cover and DETS files

Scenario Builder outputs include crop cover and detached sediment storage (DETS). Crop cover is the area of land available to be eroded. This area is the fraction of residue or canopy cover, whichever is greatest. DETS is the difference in sediment eroded due to plowing. The difference in tons of sediment eroded with and without plowing was determined by subtracting the difference between RUSLE2 scenarios that included plowing and those that did not include any plowing other than plowing associated with planting. DETS is calculated for row crops, not pasture or hay.

Where there were missing data for a particular crop in a particular growing region, values from the nearest growing region or most similar crop were used. The fruit and vegetable cover data was generalized among similar plants according to viney or bushy plant character. Turf grass (urban lawns) did not have a cover value generated from RUSLE2 and 0.95 was used for the entire year. For cultivated summer fallow cropland and idle cropland, a consistent value of 0.05 was used. Failed crops were assigned a consistent value of 0.2. The crop cover data are bound by zero and 95%.

The residue and canopy cover fractions were generated using USDA's Revised Universal Soil Loss Equation, Version 2 (RUSLE2, Renard 1997). RUSLE2 and Scenario Builder are not linked. Rather the RUSLE2 data are in look up tables and Scenario Builder uses these data to create crop cover and DETS based on the acres of each crop. The crop cover and DETS files are generated with values for a monthly time scale, county geographic scale, and by crops. The data are generalized to land use prior to input to the Watershed Model.

Plant/harvest dates and other farming decisions such as double cropping, rotations or continuous planting, as well as representative field conditions such as erodibility, climate regime, and field slopes and lengths were all incorporated. These parameters were determined through existing data from Scenario Builder and discussions with the NRCS conservation staff in each state. The NRCS Chesapeake Bay Coordinator, Timothy Garcia, facilitated contacts with each state to answer questions on typical farming practices that were used as inputs to RUSLE2. The RUSLE2 data were generated with no BMPs, since BMPs are represented separately in Scenario Builder. Tetra Tech performed nearly 250 scenarios in the RUSLE2 program to support this effort. These RUSLE2 inputs are discussed in the following sections.

Development of RUSLE2 Input Selections

RUSLE2 scenarios were developed for ten different "Crop Types" (including pasture/grazing land uses) within each of the 7 Crop Management Zones (CMZ) of the CBWS (Figure 1). To ensure that major crop types were represented, the acres of crop types most prevalent in the CBWS were evaluated. Nine of the top 27 crop types (ranked by % of all agriculture in CBWS) were selected for subsequent RUSLE2 scenarios:

Pasture / Range (15.3% of agriculture in CBWS)

"Corn for Grain Harvested Area" (10.2%)

“Other managed hay Harvested Area” (9.4%)

“Soybeans for beans Harvested Area” (8.1%)

“Corn for silage or greenchop Harvested Area” (3.7%)

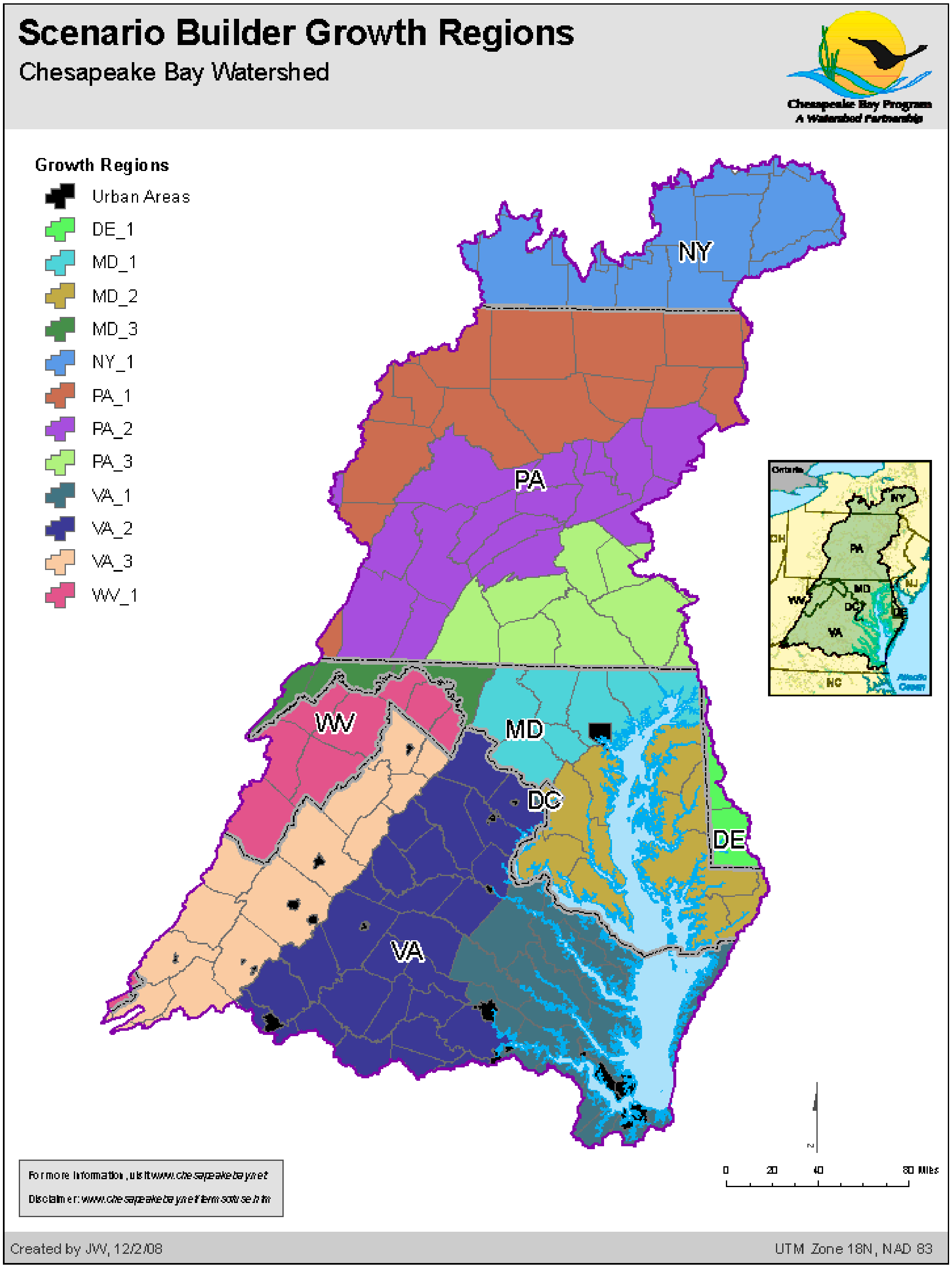
“Alfalfa Hay Harvested Area” (3.1%)

Wheat for Grain Harvested Area” (2.2%)

“Cotton/Potato Harvested Area” (0.2/0.1%, respectively

“Snap Beans Harvested Area” (0.1%)

These crops were modeled for a representative county in each CMZ. The CMZ was mapped to the counties in the Chesapeake Bay Watershed. Groups of counties are classified by growth regions. Scenario Builder Growth Region MD 2 was divided into two areas—one east of the Bay and one west of the Bay. Kent and Queen Anne’s County in Maryland use the same data as MD 1. CMZ 4.1 was used to generate the data for NY 1 and PA 1; CMZ 65.0 for Pa 2 and MD 3; CMZ 66.0 for MD 2 West and VA 2; CMZ 65.0 for MD 1 and PA 3; CMZ 62.0 for WV 1; CMZ 59.0 for MD 2 east and DE 1; CMZ 67.0 for VA 1; and CMZ 64.0 for VA 3.


Scenario Builder Growth Regions
Chesapeake Bay Watershed
Chesapeake Bay Program
A Watershed Partnership
Growth Regions
Urban Areas
DE_1
MD_1
MD_2
MD_3
NY_1
PA_1
PA_2
PA_3
VA_1
VA_2
VA_3
WV_1
NY
PA
WV
MD
DC
DE
VA
Ontario
OH
NJ
NC
0
20
40
80 Miles
For more information, visit www.chesapeakebay.net
Disclaimer: www.chesapeakebay.net/termsofuse.htm
Created by JW, 12/2/08
UTM Zone 18N, NAD 83

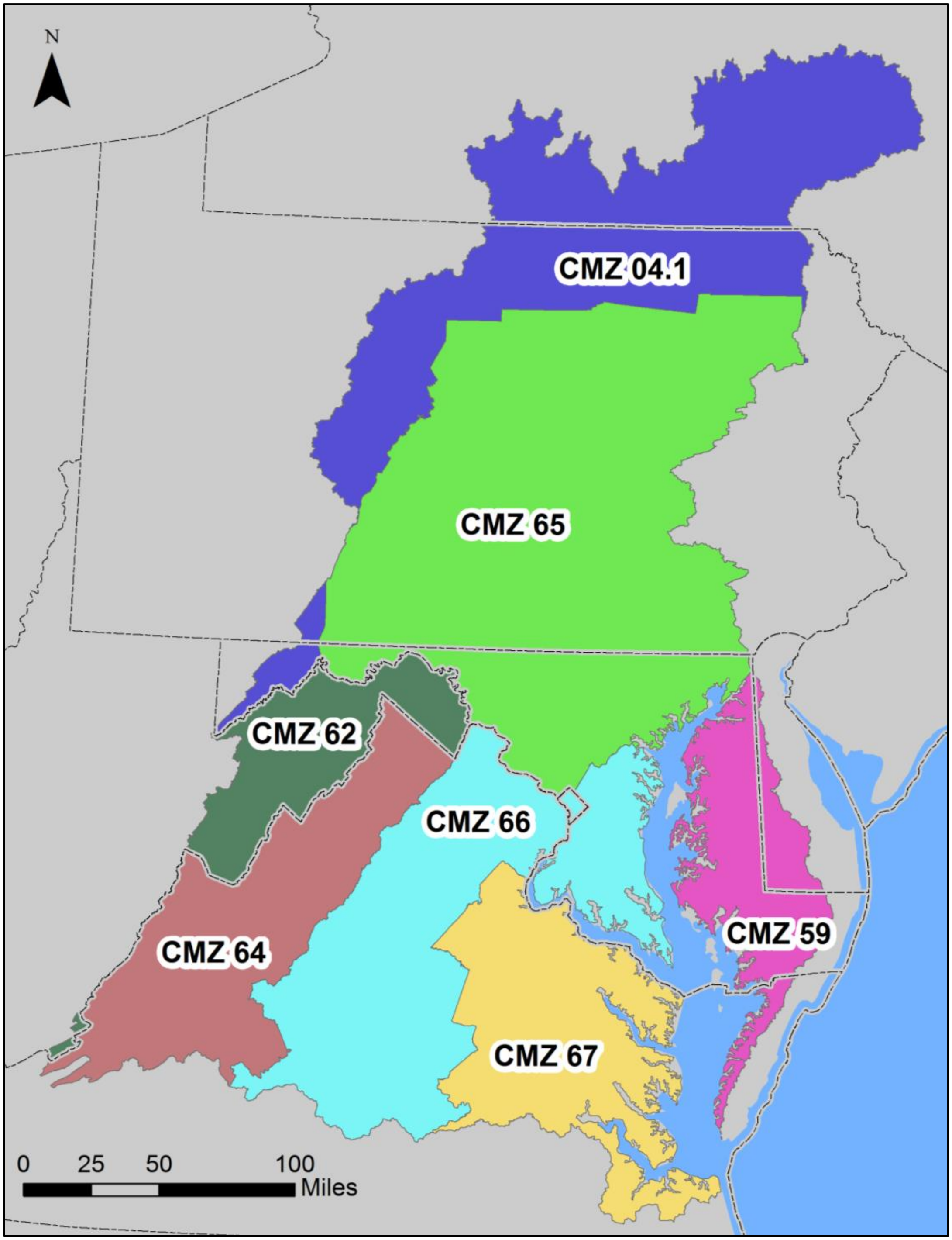


Figure 1. Scenario Builder Growth Regions (first map) Crop Management Zones in CBWS (second map)

All nine selected major crop types listed above were used to develop RUSLE2 scenarios as continuous, "non-double cropped" systems. Because some of these crop types (Corn, Soybean, Wheat) are often under double-cropping systems (DC) a tenth RUSLE2 scenario type was run in select CMZs and states. A comprehensive list of every crop type modeled with RUSLE2 can be found in Table 1.

The following sections discuss the different inputs required for successful RUSLE2 modeling scenarios as well as the specific input values selected through consultation with the Chesapeake Bay Program (CBP) and state NRCS conservation staff. The NRCS staff consulted included:

Chesapeake Bay Timothy Garcia, Chesapeake Bay Watershd Coordinator

Delaware Jayme Arthurs and Phillip King

Maryland Christy Brown

West Virginia Isaac Wolford

Pennsylvania Mark Goodson and Joe Kraft

New York Dale Gates

Virginia Chris Lawrence

Table 1. List of All Crop Cover Types by State/CMZ Combinations Modeled in RUSLE2

	State/CMZ Combination											
	4.1			59		62	64	65		66		67
Crop Cover Type	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	x	x	x	x	x	x	x	x	x	x	x	x
Broccoli, spring						x						
Cabbage		x										
Corn & Wheat			x		x		x	x	x	x	x	x
Corn for Grain	x	x	x	x	x	x	x	x	x	x	x	x
Corn for Silage	x	x	x	x	x	x	x	x	x	x	x	x
Cucumber	x		x	x	x			x	x	x		
Other managed hay Harvested Area	x	x	x	x	x	x	x	x	x	x	x	x
Pasture / Range	x	x	x	x	x	x	x	x	x	x	x	x
Potato	x	x		x	x	x	x	x		x	x	x
Snap Beans				x								
Soybean		x	x	x	x	x	x	x	x	x	x	x
Soybean & Wheat				x	x	x	x	x	x	x	x	x
Tomato							x				x	x
Watermelon	x		x		x			x	x	x		
Wheat for Grain		x	x	x	x	x	x	x	x	x	x	x
Soybean Wheat - Relay			x									

RUSLE2 Factor Selection

There are 6 major factors used in RUSLE2 (R, K, L, S, C, and P). RUSLE2 also has many subfactors under some of these major factors (e.g., C factor is composed of PLU, CC, SC, SR, and SM subfactors). Many of these subfactors are predetermined at daily time steps when selecting RUSLE2 inputs. For example, by selecting a particular county and state, an R factor is calculated on a daily time step for that specific location in the CBWS. The remainder of this section explains the RUSLE2 factors and how certain parameters were selected.

R Factor

The rainfall and runoff factor (R) is based on the erosivity of local rainfall. Erosivity is estimated from the multiplication of two factors for each time step: 1) expected total storm energy (E), and 2) the maximum 30-minute intensity (I_{30}). RUSLE2 has numerous databases from which it accesses this information for each county selected by the user. One representative county for each crop type, for each CMZ was modeled. The counties selected based on communication with state NRCS personnel is shown in Figure 2.

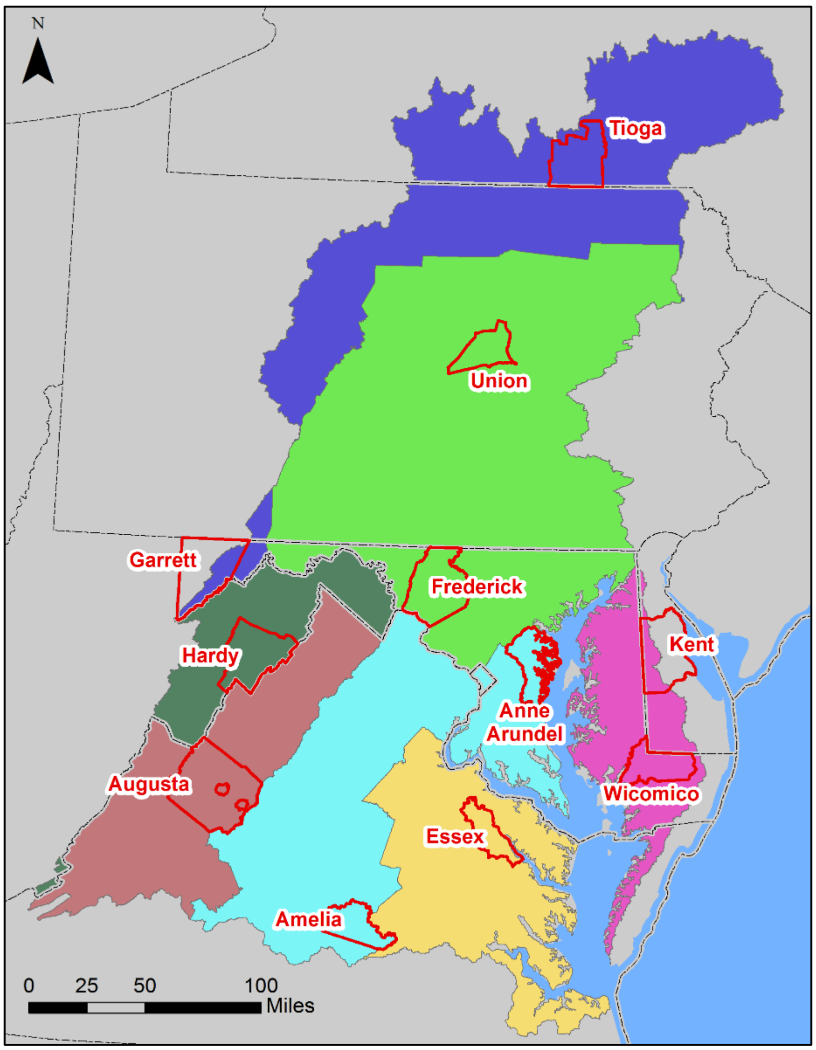


Figure 2. Counties in CBWS Selected for RUSLE2 R-factor Parameter Inputs

C Factor

As previously mentioned, the C (cover) factor is composed of several subfactors. For the purposes of this task the following information was solicited from state NRCS personnel for each of the selected crop types for each CMZ:

Specific Crop Type

Start Date of Planting/Grazing

Planting Technique (when applicable)

Start Date of Harvesting (or, End Date of Grazing)

Harvesting/Grazing Technique

Information for Items 1, 2 and 3 from above can be found in Table 2, where in most cases the day is the 1st of the month. For those Start and End (i.e., Planting and Grazing/Harvesting) dates that did not fall on the first of the month the closest "first of the month" was selected for simpler display purposes in Table 2. For multi-year scenarios (e.g., Alfalfa Hay) that have varying harvest dates the median harvest month is provided in Table 2. Finally, the start date of a winter cover of wheat (e.g., Corn & Wheat) is the essentially the same day of the summer cover crop harvest, and the winter cover's end date is the start date of the summer cover crop's date range.

Table 2. Start and End (Plant and Harvest/Graze) Dates - All Modeled Crop Cover Types

Crop Cover Type	State/CMZ combination											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Apr - Oct	Oct - Aug	Apr - Oct	Apr - Sep	Apr - Oct	Oct - Aug	Oct - Aug
Broccoli, Spring[3]						Apr - Jul						
Cabbage1		May - Nov										
Corn & Wheat1			May - Oct		May - Oct		May - Oct	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct
Corn for Grain1	May - Oct	May - Oct	May - Oct	May - Oct	Apr - Oct	Apr - Oct	May - Oct	Apr - Oct	May - Oct	Apr - Oct	May - Oct	May - Oct
Corn for Silage1	May - Oct	May - Sep	May - Sep	May - Sep	Apr - Sep	Apr - Aug	May - Sep	Apr - Sep	May - Sep	Apr - Sep	May - Sep	May - Sep
Cucumber1	May - Nov		May - Nov	Apr - Aug	Apr - Aug			Apr - Aug	May - Nov	Apr - Aug		

[3] RUSLE2 model scenarios represent the same crop types(s) and practice(s) year after year.

Crop Cover Type	State/CMZ combination											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Other Managed Hay Harvested Area	May - Sep	May - Oct	May - Oct	Apr - Oct	Apr - Oct	Apr - Aug	May - Sep**	Apr - Oct	Apr - Oct	Apr - Oct	May - Sep**	May - Sep**
Pasture / Range	May - Sep	May - Oct	May - Oct	Apr - Oct	Apr - Oct	Apr - Aug	Mar - Nov**	Apr - Oct	Apr - Oct	Apr - Oct	Mar - Nov**	Mar - Nov**
Potato1	Apr - Sep	Apr - Sep		Mar - Jun	Mar - Jun	May - Sep	Mar - Jul	Mar - Jun		Mar - Jun	Mar - Jul	Mar - Jul
Snap Beans1				Apr - Aug								
Soybean1		Jun - Oct	Jun - Oct	May - Oct	May - Oct	Jul - Oct	Jun - Nov	May - Oct	May - Oct	May - Oct	Jun – Nov	Jun - Nov
Soybean & Wheat1				May - Oct	May - Oct	May - Sep	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct	May - Oct
Tomato1							May - Aug				May - Aug	May - Aug
Watermelon1	May - Aug		May - Aug		Apr - Nov			Apr - Nov	May - Aug	Apr - Nov		
Wheat for Grain1		Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jun	Oct - Jul	Oct - Jul	Oct - Jul	Oct - Jun	Oct - Jun
Soybean Wheat - Relay1			Jun - Oct									

** no direct seeding/planting occurs; start date is for grazing initiation.

K Factor

The K factor indexes soil erodibility. State NRCS personnel were asked to provide a soil series that would best represent the soil types on which agricultural and pastoral land uses are found within in each CMZ and state combination. RUSLE2 allows the user to select the soil series from publicly-available state level databases. These databases were obtained and accessed during RUSLE2 scenario development and employed along with the information found in Table 3.

Table 3. Soil Series Recommended by State NRCS Personnel

CMZ	State	Representative Soil Series/Type
4.1	MD	Calvin-Gilpin-Ungers channery loams, 10 to 20 percent slopes, moderately eroded\Gilpin Channery loam 30%
	NY	Mardin channery silt loam, 9 to 15 percent slopes, moderately deep\Mardin Channery silt loam moderately deep 75%
	PA	Alvira silt loam, 8 to 15 percent slopes\Alvira Silt loam 80%
59	DE	Mullica mucky sandy loam, 0 to 2 percent slopes\Mullica Mucky sandy loam drained 50%
	MD	Hambrook sandy loam, 0 to 2 percent slopes\Hambrook Sandy loam 80%
62	WV	Monongahela Silt Loam, 3 to 8 percent slopes\Monongahela silt loam 100%
64	VA	Craigsville cobbly sandy loam\Craigsville Cobbly sandy loam 85%
65	MD	Hagerstown loam, 3 to 8 percent slopes\Hagerstown Loam 85%
	PA	Alvira silt loam, 8 to 15 percent slopes\Alvira Silt loam 80%
66	MD	Collington-Wist complex, 0 to 2 percent slopes\Collington Fine sandy loam 60%
	VA	Appling fine sandy loam, 2 to 7 percent slopes\Appling Fine sandy loam 90%
67	VA	Emporia sandy loam, 2 to 6 percent slopes\Emporia Sandy loam 90%

P Factor

The P (practice) factor is used to account for potential management actions that can be taken to reduce or minimize soil erosion from wind and rain-induced detachment. It is often associated with different types and levels of tillage; however, there are many other actions that can be taken.

Start Date of High Till action, where multiple dates were provided for double-cropping scenarios

Type of High Till management action

These data were taken from the plant and harvest date used in Scenario Builder except in Virginia and West Virginia where state NRCS personnel provided RUSLE2 databases. The number of unique dates and times of the different tillage practices involved with the various RUSLE2 scenarios is not reproduced here but is accessible via a RUSLE2 database provided along with the final RUSLE2 outputs.

P Factor – “No Plow” Scenario for developing DETS

A second round of RUSLE2 scenarios was modeled for all those crop scenarios that had plowing, disking, or harrowing as a separate management event from the planting/seeding management event. The majority of modeled cover crops were run under this “no plow” scenario where all separate management practices involving plowing, disking, or harrowing were removed from the management file. The differences between this “no plow” scenario and the High Till scenario for each crop is used to estimate ‘detached sediment storage’ on the landscape under different management scenarios. This was done for all crop types except for the following (as there was no separate management practice of such types):

“Other Managed Hay Harvested Area” in DE-CMZ59 and VA – all CMZs (64, 66, and 67)

“Soybean & Wheat” in DE-CMZ59 and MD-CMZ66

“Alfalfa Hay Harvested Area” in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

"Alfalfa Hay Harvested Area" in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

"Pasture / Range" in MD-CMZ66 and VA – all CMZs (64, 66, and 67)

L and S Factors

The field slope length (L factor, expressed as meters) and field slope (S factor, expressed as a percent) are used to represent landscape characteristics. One value for each of these two factors is required for each crop type within each CMZ/State combination for RUSLE2 model execution (Table 4). Values were provided by all states with the exception of Pennsylvania (PA). For PA, percent slope numbers in neighboring states and CMZ's, and a relationship between percent slope and slope length provided by PA NRCS (see Appendix A) were used as a proxy for Crop Cover types within PA (

Table 5).

Table 4. Recommended Slope Length (L factor) and Slope (S factor) Inputs to RUSLE2

CMZ	State	Representative Slope Length (L factor, meters)	Representative Slope (S factor, percent)
4.1	MD	150	3
	NY	100 (Alfalfa, Hay, Pasture); 150 (Cabbage, Potato); 200 (Corn, Soybeans, Wheat)	10 (Alfalfa, Hay, Pasture); 5.5 (Cabbage, Potato, Corn, Soybeans, Wheat)
	PA[4]	120 (Alfalfa, Hay, Pasture); 160 (Corn, Soybeans, Wheat); 190 (Cucumber, Watermelon)	10 (Alfalfa, Hay, Pasture); 5.5 (Corn, Soybeans, Wheat); 3.5 (Cucumber, Watermelon)
59	DE	150	1
	MD	150	2.5
62	WV	150	6
64	VA	130	8
65	MD	150	4
	PA2	140 (Alfalfa, Hay, Pasture); 160 (Corn, Soybeans, Wheat); 190 (Cucumber, Watermelon)	7 (Alfalfa, Hay, Pasture); 5.5 (Corn, Soybeans, Wheat); 3.5 (Cucumber, Watermelon)
66	MD	150	1
	VA	160	4
67	VA	200	2

Table 5. Values Recommended by Tetra Tech for L and S Factor Inputs to RUSLE2 for PA

Cover Crop Type	CMZ 4.1			CMZ 65	
	MD	NY	PA (recommended)	MD	PA (recommended)
Alfalfa Hay Harvested Area	3	10	10	4	7
Corn & Wheat	-	-	5.5	4	5.5
Corn for Grain	3	5.5	5.5	4	5.5

[44] See next table for how L and S factor inputs were determined for PA.

Corn for Silage	3	5.5	5.5	4	5.5
Cucumber	3	-	3.5	4	3.5
Other managed hay Harvested Area	3	10	10	4	7
Pasture / Range	3	10	10	4	7
Soybean	-	5.5	5.5	4	5.5
Soybean & Wheat	-	-	-	4	5.5
Watermelon	3	-	3.5	4	3.5
Wheat for Grain	-	5.5	5.5	4	5.5

RUSLE2 Outputs

Outputs from each RUSLE2 scenario were extracted into Microsoft Excel for post-processing. Daily outputs were summarized (averaged) to monthly-scale outputs for subsequent work in Scenario Builder. The following parameters were extracted and summarized:

From RUSLE2's "Erosion by day" tab, "Slope daily erosion values" table:

detach t/ac/yr

slope sed del rate t/ac/yr

slope soil loss rate t/ac/yr

slope soil loss for cons plan t/ac/yr

From RUSLE2's "C subfactor by day" tab and table:

PLU, fraction

Res. surf. cover, fraction

Live surf. cover, %

Rock cover, %

Net surf. cover, fraction

SC, fraction

SC top, fraction

SC bottom, fraction

CC, fraction

Roughness, mm

SR, fraction

SM, fraction

C factor, fraction

C factor top, fraction

C factor bottom, fraction

EI, %

(SEG_SIM_DAY_SURF_COVER_EFF_BOTTOM) slope soil loss for cons plan t/ac/yr

From RUSLE2’s "Extra C, L, crit. Length values" tab and table:

Net Canopy cover %

Tables 6 through14 provide annual summary statistics of the “No Plow” scenario monthly outputs provided for the subsequent work. The full data set of all RUSLE2 monthly outputs post-processed in Excel was used to develop the crop cover and DETS data used by Scenario Builder.

Table 6. Annual Average Erosion Rate (lbs/ac/year) – State/CMZ Combinations

	State											
	4.1			59		62	64	65		66		67
Crop Cover Type	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	536	612	2,156	282	3,636	1,931	168	2,528	4,868	78	255	214
Broccoli, spring						2,491						
Cabbage		3,330										
Corn & Wheat			2,313		1,323		5,400	3,078	2,320	275	1,343	955
Corn for Grain	457	352	1,006	1,638	4,970	707	508	748	1,031	223	687	637
Corn for Silage	3,541	4,570	11,103	844	11,397	7,562	6,467	5,275	10,496	1,063	6,574	4,499
Cucumber	8,745		6,777	2,676	17,975			18,595	7,538	459		
Other managed hay Harvested Area	10	1,595	397	367	3,101	1,931	45	162	363	613	49	47
Pasture / Range	158	333	939	551	16	1,204	104	8	76	3	125	104
Potato	20,337	16,222		3,085	20,603	24,111	15,161	41,907		6,743	15,097	18,392
Snap Beans				3,127								

Crop Cover Type	State											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Soybean		5,339	9,168	638	3,696	6,096	1,533	2,219	3,394	532	1,763	1,474
Soybean & Wheat				206	2,513	1,951	1,230	2,085	3,452	1,051	1,732	1,312
Tomato							11,942				11,238	13,755
Watermelon	1,614		9,797		7,181			6,425	9,797	1,214		
Wheat for Grain		7,064	13,064	301	2,423	2,103	153	2,186	3,615	483	235	223
Soybean Wheat - Relay			2,061									

Table 7. Annual Average Erosion Rate (lbs/ac/year) – State Scale

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	282	1,694	612	3,512	212	1,931
Broccoli, spring						2,491
Cabbage			3,330			
Corn & Wheat		1,559		2,316	2,566	
Corn for Grain	1,638	1,600	352	1,019	611	707
Corn for Silage	844	5,319	4,570	10,800	5,847	7,562
Cucumber	2,676	11,444		7,158		
Other managed hay Harvested Area	367	972	1,595	380	47	1,931
Pasture / Range	551	46	333	507	111	1,204

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Potato	3,085	22,397	16,222		16,217	24,111
Snap Beans	3,127					
Soybean	638	2,149	5,339	6,281	1,590	6,096
Soybean & Wheat	206	1,883		3,452	1,424	1,951
Tomato					12,312	
Watermelon		4,109		9,797		
Wheat for Grain	301	1,697	7,064	8,340	204	2,103
Soybean Wheat - Relay				2,061		

Table 8. Annual Average Erosion Rate (lbs/ac/year) – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	1,101	1,959	1,931	168	3,698	166	214
Broccoli, spring			2,491				
Cabbage	3,330						
Corn & Wheat	2,313	1,323		5,400	2,699	809	955
Corn for Grain	605	3,304	707	508	890	455	637
Corn for Silage	6,405	6,120	7,562	6,467	7,886	3,818	4,499
Cucumber	7,761	10,325			13,067	459	
Other managed hay Harvested Area	899	1,734	1,931	45	262	331	47

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Pasture / Range	477	284	1,204	104	42	64	104
Potato	18,280	11,844	24,111	15,161	41,907	10,920	18,392
Snap Beans		3,127					
Soybean	7,254	2,167	6,096	1,533	2,806	1,147	1,474
Soybean & Wheat		1,359	1,951	1,230	2,768	1,391	1,312
Tomato				11,942		11,238	13,755
Watermelon	5,706	7,181			8,111	1,214	
Wheat for Grain	10,064	1,362	2,103	153	2,901	359	223
Soybean Wheat - Relay	2,061						

Table 9. Annual Average Canopy Cover Percentages – State/CMZ Combinations

Crop Cover Type	State											
	4.1			59		62	64	65		66		67
	MD	**NY**	**PA**	**DE**	**MD**	**WV**	**VA**	**MD**	**PA**	**MD**	**VA**	**VA**
Alfalfa Hay Harvested Area	55.9	56.5	56.6	53.7	38.7	41.4	40.8	35.8	36.4	38.1	38.2	38.7
Broccoli, spring						7.68						
Cabbage		35.1										
Corn & Wheat			48.6		48.9		12	21.5	48.9	48.1	48.2	48.1
Corn for Grain	28.3	28.3	28.1	28.9	34.7	32.2	25.6	34.1	28.1	34.1	30.2	29.3
Corn for Silage	27.2	19.8	19.6	44.1	27.3	22.8	14.4	27.3	19.8	27.3	16.2	15.3
Cucumber	30		62.8	19.4	19.4			19.4	32	63.3		
Other managed hay Harvested Area	81.1	51.8	87.3	37.4	38.1	41.4	80	87.1	87.2	38.2	79	79.5
Pasture / Range	69.4	60.9	90.8	38.2	79	42.2	81.2	74.6	83.8	74.3	81.2	81.2
Potato	20.7	20.7		9.9	9.47	15	12.9	7.67		8.06	12.9	12.9

Crop Cover Type	State											
	4.1			59		62	64	65		66		67
	MD	**NY**	**PA**	**DE**	**MD**	**WV**	**VA**	**MD**	**PA**	**MD**	**VA**	**VA**
Snap Beans				12.3								
Soybean		39.7	37	38.6	38.1	41.1	34.3	38.5	39.7	37.6	35	33.5
Soybean & Wheat				47.2	51.6	51.2	44	52.2	52.8	48.6	44	44.1
Tomato							8.42				8.54	8.42
Watermelon	85.2		49.1		49.3			49.3	49.1	49.3		
Wheat for Grain		36.2	36.2	39	38.4	35.2	44.1	36.2	39	39	38.6	33.9
Soybean Wheat - Relay			58.9									

Table 10. Annual Average Canopy Cover Percentages – State Scale

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	53.7	42.1	56.5	46.5	39.3	41.4
Broccoli, spring						7.68
Cabbage			35.1			
Corn & Wheat		39.5		48.7	36.1	
Corn for Grain	28.9	32.8	28.3	28.1	28.4	32.2
Corn for Silage	44.1	27.3	19.8	19.7	15.3	22.8
Cucumber	19.4	33		47.4		
Other managed hay Harvested Area	37.4	61.2	51.8	87.2	79.5	41.4
Pasture / Range	38.2	74.3	60.9	87.3	81.2	42.2
Potato	9.9	11.5	20.7		12.9	15
Snap Beans	12.3					
Soybean	38.6	38.1	39.7	38.4	34.3	41.1
Soybean & Wheat	47.2	50.8		52.8	44	51.2
Tomato					8.46	
Watermelon		58.3		49.1		
Wheat for Grain	39	37.9	36.2	37.6	38.8	35.2
Soybean Wheat - Relay				58.9		

Table 11. Annual Average Canopy Cover Percentages – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	56.3	46.2	41.4	40.8	36.1	38.1	38.7
Broccoli, spring			7.68				
Cabbage	35.1						
Corn & Wheat	48.6	48.9		12	35.2	48.2	48.1
Corn for Grain	28.2	31.8	32.2	25.6	31.1	32.1	29.3
Corn for Silage	22.2	35.7	22.8	14.4	23.6	21.8	15.3
Cucumber	46.4	19.4			25.7	63.3	
Other managed hay Harvested Area	68	37.8	41.4	80	87.2	58.6	79.5
Pasture / Range	73.7	58.6	42.2	81.2	79.2	77.7	81.2
Potato	20.7	9.69	15	12.9	7.67	10.5	12.9
Snap Beans		12.3					
Soybean	38.4	38.4	41.1	34.3	39.1	36.3	33.5
Soybean & Wheat		49.4	51.2	44	52.5	46.3	44.1
Tomato				8.42		8.54	8.42
Watermelon	67.1	49.3			49.2	49.3	
Wheat for Grain	36.2	38.7	35.2	44.1	37.6	38.8	33.9
Soybean Wheat - Relay	58.9						

Table 12. Annual Average Crop Residue Percentages – State/CMZ Combinations

Crop Cover Type	State/CMZ combination											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Alfalfa Hay Harvested Area	57.3	47.4	53.8	43.8	25.8	47.2	46.3	37.5	40.9	48.4	44.7	43.5
Broccoli, spring						36.3						
Cabbage		14.7										
Corn & Wheat			81.2		87.7		50	59.3	81.2	87.9	83.3	84.3
Corn for Grain	75.8	78.6	71.6	54.1	50.9	69.2	67.6	67.8	71.2	64	61.2	59.7

Crop Cover Type	State/CMZ combination											
	4.1			59		62	64	65		66		67
	MD	NY	PA	DE	MD	WV	VA	MD	PA	MD	VA	VA
Corn for Silage	28.4	30	26	32.8	19.6	25.5	22.7	24.4	25.8	23	19.6	17.8
Cucumber	13.2		43.6	14.4	13.6			4.39	21.4	41.3		
Other managed hay Harvested Area	77.8	57.5	45.5	30.1	26.1	47.2	59.8	45.9	46.8	27.5	59.6	56.8
Pasture / Range	47.4	49.6	8.33	26.9	46.9	72.3	29.9	56.7	38.1	54.7	27.5	26.8
Potato	5.83	6.15		14.6	14.5	7.17	15.6	1.35		1.4	13.7	13.1
Snap Beans				14.4								
Soybean		59.9	53	34	33.3	35.4	59.1	45.8	49.4	42.2	53.4	50
Soybean & Wheat				80.8	76.3	65.1	72.3	81	82.8	30.5	64.3	63
Tomato							25.4				24.1	21.5
Watermelon	28.1		33.7		27.6			30.6	33.7	28.7		
Wheat for Grain		28.3	28.7	80.3	52.4	79.8	89	53.9	55.3	53.1	84.5	82.7
Soybean Wheat - Relay			89.8									

Table 13. Annual Average Crop Residue Percentages – State Scale

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Alfalfa Hay Harvested Area	43.8	42.2	47.4	47.4	44.9	47.2
Broccoli, spring						36.3
Cabbage			14.7			
Corn & Wheat		78.3		81.2	72.5	
Corn for Grain	54.1	64.7	78.6	71.4	62.8	69.2
Corn for Silage	32.8	23.9	30	25.9	20	25.5

Crop Cover Type	State					
	DE	MD	NY	PA	VA	WV
Cucumber	14.4	18.1		32.5		
Other managed hay Harvested Area	30.1	44.3	57.5	46.2	58.8	47.2
Pasture / Range	26.9	51.4	49.6	23.2	28.1	72.3
Potato	14.6	5.76	6.15		14.1	7.17
Snap Beans	14.4					
Soybean	34	40.4	59.9	51.2	54.2	35.4
Soybean & Wheat	80.8	62.6		82.8	66.5	65.1
Tomato					23.7	
Watermelon		28.7		33.7		
Wheat for Grain	80.3	53.1	28.3	42	85.4	79.8
Soybean Wheat - Relay				89.8		

Table 14. Annual Average Crop Residue Percentages – CMZ Scale

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Alfalfa Hay Harvested Area	52.8	34.8	47.2	46.3	39.2	46.5	43.5
Broccoli, spring			36.3				
Cabbage	14.7						
Corn & Wheat	81.2	87.7		50	70.3	85.6	84.3
Corn for Grain	75.3	52.5	69.2	67.6	69.5	62.6	59.7
Corn for Silage	28.1	26.2	25.5	22.7	25.1	21.3	17.8
Cucumber	28.4	14			12.9	41.3	
Other managed hay Harvested Area	59.6	28.1	47.2	59.8	46.4	43.6	56.8
Pasture / Range	35.1	36.9	72.3	29.9	47.4	41.1	26.8
Potato	5.99	14.5	7.17	15.6	1.35	7.57	13.1
Snap Beans		14.4					
Soybean	56.5	33.6	35.4	59.1	47.6	47.8	50
Soybean & Wheat		78.5	65.1	72.3	81.9	47.4	63
Tomato				25.4		24.1	21.5
Watermelon	30.9	27.6			32.1	28.7	
Wheat for Grain	28.5	66.4	79.8	89	54.6	68.8	82.7

Crop Cover Type	CMZ						
	4.1	59	62	64	65	66	67
Soybean Wheat - Relay	89.8						

Pennsylvania (PA) Slope and Length Relationship Guidance

The following information was provided by Pennsylvania NRCS personnel to assist with determination of the L and S factor inputs for RUSLE2. It was provided exactly as follows in a Microsoft Word document.

Default Slope Length for each Increment of Slope Steepness

For use in all areas of the US except the "Palouse"

Slope	Length
0.5	100
	200
	300
	200
	180
	160
	150
	140
	130
	125
	120
	110
	100
	90
	80
	70
	60
	60
	50
	50
	50
	50

50

50

50

Slope steepness is the average of the map unit slope range

By Lightle and Weesies 10/1/96

The following slope lengths for the "Palouse" (MLRA B 9) area were determined by Tom Gohlke in consultation with Don McCool, ARS and Harry Riehle. Tom says, "Keep in mind that many real LS's in the field are complex slopes and consist of combinations of these slopes. For instance, it is common to find an "L" beginning on a 2%-5% slope and extending onto and ending on a 21%-25% slope. The total "L" may be less than the sum of the values for these two segments as shown in the following table."

Default Slope ranges for Use in the "Palouse"

slope range	length
2-5%	350 ft.
6-10%	275 ft.
11-15%	225 ft.
16-20%	175 ft
21-25%	150 ft
26-35%	125 ft
36 45%	100 ft