ESTIMATES OF COUNTY-LEVEL NITROGEN AND PHOSPHORUS DATA FOR USE IN MODELING POLLUTANT REDUCTION

By:

Olivia Harcourt Devereux

Documentation submitted to the University of Maryland and the Chesapeake Bay Program

June 2009

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

FIGURES

TABLES

SECTION 1. OVERVIEW OF THE NUTRIENT AND SEDIMENT SCENARIO BUILDER

Purpose of the Scenario Builder

The Chesapeake Bay Program is facilitating increased nutrient and sediment control strategies by creating a framework and toolkit for adaptive management. The Chesapeake Bay Program recognizes that integrating regional water quality needs into local land use decisions is key to restoring the Bay. The Chesapeake Bay Program has worked for 25 years to track progress toward abating nitrogen, phosphorus, and sediment pollution in the Bay. With the onset of a basin-wide TMDL and amidst criticism of overestimating progress in achieving decreased nutrient and sediment loads, the Chesapeake Bay Program, through a grant to the University of Maryland, is developing a free and on-line decision-support tool known as the Nutrient and Sediment Scenario Builder. This tool is designed to assist planners in meeting cap-loads associated with the TMDL. Since the Bay Program staff will also use this tool, the methods used for tracking progress will become more transparent.

The tool is designed for rapid scenario development so users may understand the impacts of management practices and land use change, as well as develop more effective nitrogen and phosphorus management strategies. In essence, Scenario Builder allows local governments and watershed organizations to translate land use decisions such as zoning, permit approvals and BMP implementation into changes in pounds of nitrogen, phosphorus and sediment originating from a particular county or watershed. The underlying model to the Nutrient and Sediment Scenario Builder is process-based. The sources of nutrients include farm animals, chemical fertilizer, sewage sludge, septic and sewer systems. Users can estimate the impact of land use changes on nutrient and sediment loads by comparing scenarios. The implication of where and which best management practices are applied may also be determined. This information can help users target limited resources to the locations where they will have the most impact. Exploring these scenarios, coupled with monitoring and explanatory information, provides a powerful adaptive management tool to decrease nutrient and sediment loads to the Chesapeake Bay.

The Scenario Builder is also used to provide the inputs to the Chesapeake Bay Program's Watershed Model – HSPF, which is newly updated to Phase 5.2. In order to take advantage of the improvements in the Phase 5 Watershed Model, the intent is to have the inputs fully developed in Scenario Builder. The data used to calculate the inputs to the Watershed Model – HSPF Phase 5 are finer scale and takes additional factors into consideration, such as mineralization from organic fertilizer, crop types, and double-cropping.

User-Controlled Variables

The tool is designed so that users will have the ability to control many of the parameters. While the user interface is not yet complete (as of July 2009), it will be designed so that users may select an area of one or more counties, the livestock types and the number of animals, along with a land use using the Watershed Model-HSPF categories. Next, users may alter the crop mix that is nested in each of the agricultural land uses. Best management practices (BMPs) may then be applied at the county scale. Users may select the approved Chesapeake Bay Program BMPs and efficiencies, or enter additional BMPs and/or their own effectiveness values.

The output gives the loading of nutrients to the land and the area of soil available to be eroded. To get actual loads as delivered to the Chesapeake Bay, users must submit the data they generated in Scenario Builder to the Bay Program to run through the Watershed Model – HSPF.
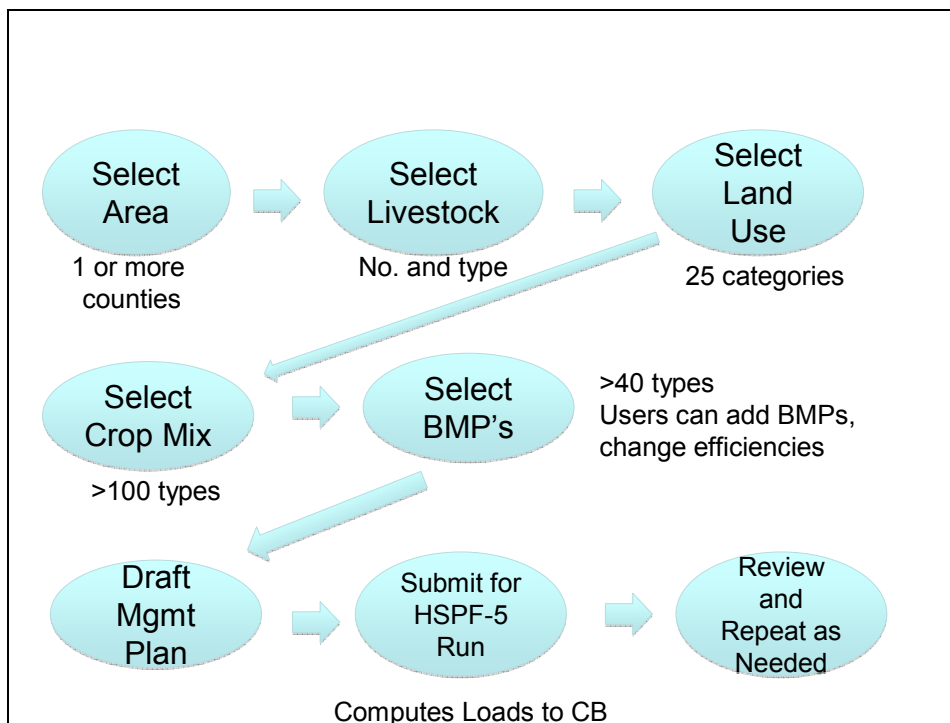
Figure 1-1: User-controlled model parameters

Process-Based Model

Scenario Builder was designed to follow the nutrient generation process from the animal through storage and application. Loss of nitrogen and phosphorus to groundwater is not considered in Scenario Builder.

 While the calculations are performed at the county scale, the processes follow what happens at a farm scale. For example, manure from various animal types is kept separate throughout the production, volatilization, storage, and application to crops' sequence. This was deliberate and allows for considerations about changes in animal types, along with the particular animal's manure that is applied to crops. We could ask what would

happen if we only applied poultry litter to corn, how much extra poultry litter would there be if holding poultry population the same. Alternatively, if we put all beef in an area that previously had dairy cattle, what would the change in nutrient applications be if we altered the crops to match the nutritional needs of the animals? Multiple other questions may be asked that would arise on a farm scale.

Even though the model is at a county scale or greater, these more specific questions may be asked if we assume a county as a single farm. This is not an optimal solution to the lack of a farm scale model, but it does provide an interim tool until such a model is available. More importantly, the consideration of farm-scale decisions in the design allows for a true process based model.

Crop growth parameters are also considered in nutrient applications. We calculate nitrogen fixation by legumes, amount of bare soil based on residue and leaf cover, and nutrient uptake by plants. Scenario Builder is designed to be a full crop growth model, but rather estimates these parameters independent of each other. The types of data and parameters used in this process-based model are listed in Figure 1-2.

INPUTS	PARAMETERS (Changeable by User)	OUTPUTS
• BMP type and location (NEIEN-state supplied) • Land acres • Remote sensing, NASS Cropland Data Layer • Crop acres • Yield • Animal numbers (Ag Census or state supplied) • Biosolids • Septic system nos.	• BMP types and efficiencies • Land use change (BMPs, other) • RUSLE2 data: % Leaf area and residue cover • Plant and harvest dates • Best potential yield • Animal factors (weight, phytase feed factor, manure amount and concentration) • Crop application rates and timing • Plant nutrient uptake • Time in pasture • Storage loss • Volatilization • Animals' manure to crops • N Fixation • Septic delivery factors	• BMPs, no. and location • Land use • % bare soil, available to erode • Nutrient uptake • Manure and chemical fertilizer (lb/segment) • N fixation ((lb/segment) • Septic loads

Figure 1-2: Model data relationships

Scenario Builder Output

Scenario Builder produces graphed and tabular reports of loading to land by land use and segment for the following data. Interim data products may also be made available.

- Manure and Chemical Fertilizer (lbs/acre)
- Land Use
- BMP reduction
- Plant Uptake
- N Fixation

- Bare soil % (erodible portion)
- Septic N delivery
- Scenario parameters specified by user

The manure and chemical fertilizer are two separate files of the applications by each nutrient type. The manure file includes sewage sludge as well. The land use is simply the acres in each land use. An interim data product could provide acres in each crop type. The BMP reduction file is the area of land that is affected by each BMP. Plant uptake gives the amount of total nitrogen and total phosphorus taken into the entire plant (roots, and all above-ground parts) each month. The nitrogen fixation is the amount of N fixed by leguminous plants each month. The bare soil fraction is the area of soil that is not covered by residue or leaves and is available to be eroded. The amount of nitrogen from septic system drainage fields is calculated and reported as well.

The last output is the parameters. The scenario parameters specified by the user is the documentation of each scenario parameters. This documentation ensures fair comparison among various scenarios.

SECTION 2. AVAILABLE DATA SOURCES FOR AGRICULTURAL NONPOINT SOURCE LOADING TO THE LAND

The nutrients sources are from animal manure and fertilizer. Atmospheric deposition and point sources are applied to the land outside of the Nutrient and Sediment Scenario Builder. Loss of nitrogen and phosphorus to groundwater is not accounted for in Scenario Builder.

No model is useful unless it uses reliable and credible data. Table 2-1 lists the sources of data used to estimate nutrients applied to crops, crop area, and land area. Each is discussed in the following sections.

Table 2-1: Data sources used

Source	Data	Time Period	Scale
USDA National Agricultural Statistics Service—Census of Agriculture	Animal population, Land Area, Crop Area, Yield	1982, 1987, 1992, 1997, 2002	State and county
State reported (2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State, 2002 Maryland Equine Census - Maryland Agricultural Statistics Service, 2000 New York Equine Survey - New York Agricultural Statistics Service, 2001 Virginia Equine Report - Virginia Agricultural Statistics Service, 2004 Tennessee Department of Agriculture - NASS - Equine Survey, and 2004 Delaware State Equine Survey)	Horse population	2002, 2000, 2001, 2004	County
State reported	Sewage Sludge	2008	County, for Virginia only
Association of American Plant Food Control	Fertilizer sales	Annually from 1982 to 2002	State and county

USDA National Agricultural Statistics Service

Introduction

Major sources of non-point source nutrients are farm animals. To model nutrient concentrations in the Chesapeake Bay Watershed Model, the Chesapeake Bay Program (CBP) must know the population and location of animals. The United States Department of Agriculture National Agricultural Statistics Service (NASS) produces a census in years ending with a two or seven. The Census is conducted on a county scale and includes data on animal populations, farms, and agricultural land areas, and crop yields.

The Census' land area, crop area, crop yields, and animal population inventory data are used. The NASS data are available for the period covered in the Watershed Model, which is 1982 to present with projections into the future. Years in between the Censuses are interpolated. Years beyond the Censuses are projected. Processing is required for all years retroactively with each new Census to align the Census categories with CBP model categories and to make data among the Censuses comparable in spite of Census changes to sampling methodology or categorization. Land use is processed from a variety of different sources, of which the Census' land area is only one. Land use is processed as part of the Chesapeake Bay Land Change Model and separate documentation is available (P. Claggett, 2009).

Sampling Methodology Change

With each subsequent Census, the prior census data with revisions are reported. Data are obtained from the latest Census that reports any year's data. Where a category was not reported in revised data, the data from the original publication of that year's Census was obtained. There were major revisions in 2002 and only a portion of 1997 data was revised. The unrevised categories were culled from the original publication of the 1997 Census.

NASS first employed a sampling methodology in the 1982 Agricultural Census. Previously, the Agricultural Census was compiled from direct enumeration. In 2002, NASS changed its sampling methodology for the Agricultural Census. The changes were made to address under reporting. NASS used statistical methods to determine where under reporting was likely, and targeted efforts to improve the response rate in those areas. NASS revised the 1997 Census using statistical methods to make the 1997 data comparable to that collected in 2002. The categories in the revised 1997 census that were not adjusted and annotated as NA were those that were new categories in 2002. In these cases, the original 1997 data were used. Adjustments for the 1982, 1987, and 1992 Censuses are unavailable. NASS recommended against making adjustments for those years (Barbara Rater, MD NASS, personal communication, 4/14/2008 and Jim Burt, NASS National Office).

Data Reported as "D"

NASS withholds data that could identify any particular farm operation. Withheld data are reported as "D". When withholding one county's data could identify a farm in a neighboring county, then the neighboring county is reported as "D" also. This situation is

likely to occur where there is a single large farm operation of a specific type in one county and zero farm operations of that type in the neighboring county. The NASS Census reports data on a county scale and as a state total. Data for omitted counties are combined in the Census and presented as "all other counties". Counties may report a "D" in one year, yet report in other years. Procedures for estimating a "D" value are listed.

1. Make a linear interpolation for the non-reported value between prior and subsequent Census years for which values were reported. This interpolation is for county and state scale. If this interpolation causes the sum of counties to be greater than the reported state values for that item in that year, then proceed to method two. If 30% or more of all counties in a state can not be done with this method, then proceed to method two.

2. Where there is no reported value for prior and subsequent years, then the difference between the state total and the sum of the counties is parsed between all the counties that were listed as "D". The data listed for *All Other Counties* represent the sum of the data for all counties in which data were omitted (denoted by an *N* in the electronic version of the census). Parsing of the omitted data is done in proportion to the average of the item in that county to the state total for each year where there are reported data. This average is calculated as the ratio of the average of the item in that county for any reported years to the state total for that same year.

3. Where there is no reported state value for any Census year, and the state value is listed as "D", perform a linear regression over all Census years.

4. Where there is no reported value for any Census year, then the difference between the state total and the sum of the counties is parsed in proportion to agricultural land area in the county to the state for the year in question. Agricultural land areas are from the Census table Farms, Land in Farms, Value of Land and Buildings, and Land Use. Items from this table include: "Total Cropland", "Pastureland and Rangeland other than cropland and woodland pastured". (When converted to Chesapeake Bay Program land uses these include pasture, degraded riparian pasture, hay with nutrients, hay without nutrients, high till without manure, high till with manure, low till with manure, nutrient management pasture, nutrient management hay, nutrient management alfalfa, nutrient management high till without manure, nutrient management high till with manure, nutrient management low till, and animal feeding operations). This is to be done for each year. The total of all of the counties, reported and estimated, should be no greater than the state total for the given year. If the total of all the counties is greater than the state total, and there is a county that reported zero agricultural land uses, then set that county animal population to zero. For land or crop areas, reduce the counties proportionally.

Crop area and crop yield are related data and cannot be estimated independently. Where *yield is reported and acres are withheld* for a crop in a county, then the acres are estimated from the yield. NASS reports yields as total yield, and not yield/acre so it is possible to estimate these acres directly from the yield. The procedures below address situations where the yields are reported and acres are withheld.

Where *both acres and yields are withheld*, then estimate acres first using the census classification for withheld data and proceed the same as with the scenario of acres reported and yield withheld.

Where *acres are reported but yields are withheld*, and then use the average yield/acre for the state from the same year. If the average yield can not be calculated due to less than 2 values reported, then use the state value. If the state value is withheld, then use the theoretical maximum yield as defined in SECTION 5 below ACCOUNTING FOR SPATIAL AND TEMPORAL VARIATION IN AGRICULTURAL PRACTICES, page 5-50.

1. Determine the average yield/acre for the state from reported data for that year where pairs (acres, yield) are available. Where there are less than three values and an average may not be determined, use the average from that state among any years.
2. For areas without reported pairs, use the theoretical maximum yield for the average yield/acre.
3. Calculate state totals where not reported
4. For all pairs where acres were not reported, divide the reported yield for that county and crop type by the average yield of that crop type.
5. Check that the sum of these calculated acres equals the total reported for the acres of that crop type in the state. In each of the cases below, follow the same procedure to adjust the yields to match the state yield value.
   a. If the sum of the calculated county acres are 10% > state total and the state acre was reported, not calculated, then decrease the yield so that the calculated acres have the average yield. (Note: this assumes that the yield was incorrectly reported.) Where the state acres are exceeded, set the remaining yields and acres pairs to zero where neither acres nor yields were reported.
   b. If the calculated county acres are 10% < or > the state total and the state acre was calculated, then adjust the calculated state acres total to accommodate the calculated county acres. (Note: this assumes that the state acres were incorrectly calculated.)
   c. If the calculated county acres are 10% < state total and the state acre was reported, not calculated, then increase the county acres proportional to that area. (Note: this will result in lower than average yields.)
   d. If the acres are within 10% of the state total, then adjust the county acres to match the state acres proportional to the calculated county area.
6. For all pairs where yield were not reported, multiply the acres by the average yield to get yield
7. Should there be a yield adjustment like the acres adjustment where the calculated yields would be reduced to match the state reported yield where all counties in state have either reported yields or yields calculated in the method in step 6 immediately above, calculate the yield by multiplying the calculated acres by the

average yield for all pairs missing yield. Note that this step, if necessary, would have to be done prior to acres having the withheld data estimated.

Interpolation

Annual data between the Agricultural Censuses is produced by interpolation using the following methodology:

> *Where:*
> Interpolated year = 1993
> Agricultural Census year=1992 and 1997
>
> 1993population = 1992 population + 1 * (1997 population – 1992population) / 5

Interpolations are calculated at the county level by each item type.

Projection

To project data beyond the most recent Agricultural Census year, a linear regression is performed. This is done at the county level by each animal type. Use at least three Census reported values where available. If less than three values are available, then use calculated data points.

y=α + βx
Calculate β first.
N=number of observations

$$\beta = \frac{N\sum xy - \sum x\sum y}{N(\sum x^2) - (\sum x)^2}$$

$$\alpha = \frac{\sum y - \beta\sum x}{N}$$

Animal Data

Two types of animal-related information were obtained from the Agricultural Census— the number of animals and the number of farms for each county and year.

Animal numbers

The Agricultural Census animal inventory data is used in lieu of animal sales data. The inventory information from the Agricultural Census is the number of animals on the farm at the end of the year. Using the animal inventory data assumes no seasonal fluctuations in herd size and continuous replacement. This steady state assumption tends to underestimate animal numbers.

The alternative to using animal inventory values is to use animal sales data, which overcomes the error inherent in assuming steady state. The sales data are more complete because some farms only report sales data. If animal sales data are used, then the

calculation requires the number of sales per cycle. These data would be converted to an annual average animal number and used the same way inventory data are used. The inventory may be used as follows:

AU= (inventory of pullets * 1/2.25)/666 + (pullet sales/2.25 * (1.25./2.25)) / 666

This assumes there are 2.25 cycles per year for pullets and the au conversion is 666 for pullets. For pullet sales, the animals are assumed to be 17 weeks old with an animal unit conversion of 666, but this would need to be adapted to reflect that all animals are heavier at time of sale. The 1.25 is the number of cycles minus 1, since that first cycle is accounted for in the first term.

A comparison of pullets in PA for 2002 using both inventory and sales follows:

Using inventory, there are 5,334,483 pullets simply based on inventory. This gives us au=8010.

Using sales, there are 14,387,070 sold, which gives us au=8894.

Sales data deliver a greater number of pullets in PA in 2002 than inventory. To be conservative, the Chesapeake Bay Program is using the inventory data.

Categorization Changes among Censuses

Data types reported by the Agricultural Census have changed from one Census year to the next. Specific changes are described by specie.

Bovine Category Changes

Agricultural Census categories of "beef cattle" and "cows and heifers that have calved" directly relate to Chesapeake Bay Program (CBP) categories of beef and heifers. The 2002 Census category of other cattle encompasses what were two separate categories in previous years—"heifers and heifer calves" and "steers, steer calves, bulls, and bull calves". Years prior to 2002 add those categories together to make them comparable to the 2002 Census and CBP category of other cattle.

Poultry Category Changes

The classification of poultry changed significantly with the 2002 Census. The "pullet chicks < 13 weeks" and "pullets 13 – 20 weeks" categories were eliminated and replaced by "pullets for laying flock replacement". The "pullet 13 – 20 weeks" category had been a subcategory of layers, so this clearly conveys to the new pullet for laying replacement category. The pullet chicks < 13 weeks could have been comprised of either future layers or broilers. The CBP has assumed that all of the birds in this category grow up to be layers. NASS confirmed that this is a valid assumption (Barbara Rater, MD NASS, personal communication on 4/14/2008).

The "layers 20+ weeks" category was a subcategory prior to the revised 1997 and subsequent years. This equated directly to the new categorization. Broilers and turkeys are not split out by age group, so equate directly as well.

Swine Category Changes

The Agricultural Census categories of "Hogs and pigs for breeding" and "Other hogs and pigs" relate directly to the CBP category of "Sows" and "Hogs", respectively.

Table 2-2: Agricultural Census animal categorization changes

Species	Watershed model phase 5 animal categories	Agricultural Census – County Inventory Categories
Bovine	Beef	Beef cows – 1982, 1987, 1992, 1997, and 2002.
Bovine	Dairy	Milk cows – 1982, 1987, 1992, 1997, and 2002.
Bovine	Other cattle	Heifers and heifer calves + steers, steer calves, bulls, and bull calves – 1982, 1987, 1992, and 1997. 'Other cattle' including steers, steer calves, bulls, and bull calves category + heifers and heifer calves - 2002.
Horses	Horses	Handled separately through state supplied equine census data. 2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State Results of the 2002 Maryland Equine Census - Maryland Agricultural Statistics Service 2000 New York Equine Survey - New York Agricultural Statistics Service - Covers 1988 and 2000 data 2001 Virginia Equine Report - Virginia Agricultural Statistics Service 2004 Tennessee Department of Agriculture - NASS - Equine Survey 2004 Delaware State Equine Survey
Poultry	Layers	Hens and pullets of laying age – 1982, 1987, and 1992. Layers > 20 weeks – 1997 and 2002.
Poultry	Pullets	Pullet chicks and pullets < 13 weeks old + Pullets 13+ weeks, not laying – 1982, 1987, and 1992. Pullet chicks and pullets < 13 weeks old + Pullets between 13 and 20 weeks – 1997. Pullets for laying flock replacement – 2002.

Poultry	Broilers	Broilers – 1982, 1987, 1992, 1997, and 2002.
Poultry	Turkeys	Turkeys – 1982, 1987, 1992, 1997, and 2002.
Swine	Sows	Hogs and pigs for breeding – 1982, 1987, 1992, 1997, and 2002.
Swine	Hogs	Other hogs and pigs – 1982, 1987, 1992, 1997, and 2002.
Ovine	Sheep and Lambs--Inventory, Wool Production, and Number Sold	Sheep and Lambs—Inventory – 1982, 1987, 1992, 1997, and 2002.
Caprine	Milk Goats	Milk goats inventory – 1982, 1987, 1992, 1997, and 2002.
Caprine	Angora Goats	Angora goats inventory – 1982, 1987, 1992, 1997, and 2002.

Agricultural Census categories that are not included in the CBP Watershed model are shown in Table 2-3.

Table 2-3: Agricultural Census categories not included in the Watershed Model

Species	*Reason for not including*	*Agricultural Census – County Inventory Categories*
Poultry	Data pulled from a more specific Agricultural Census subcategory	Chickens 13+ weeks – 1982, 1987, and 1992.
Poultry	Data pulled from a more specific Agricultural Census subcategory	Layers and pullets 13+ weeks – 1997.
Swine	No immature swine categories are included. Specific animal numbers not listed, just number of litters.	Pig litters farrowed – 1982, 1987, 1992, and 1997.

Horses

Horses are not directly pulled from the Agricultural Census. The horse information is culled from state-supplied data including: 2002 Pennsylvania Equine Survey - Department of Dairy and Animal Science - Penn State, Results of the 2002 Maryland Equine Census - Maryland Agricultural Statistics Service, 2000 New York Equine Survey - New York Agricultural Statistics Service - Covers 1988 and 2000 data, 2001 Virginia Equine Report - Virginia Agricultural Statistics Service, 2004 Tennessee Department of Agriculture - NASS - Equine Survey, and the 2004 Delaware State Equine Survey. These data are used for every year.

Number of Farms

The number of farms for each animal type is also selected from the Censuses (Table 2-4). The number of farms informs the acres assigned for the *Animal Feeding Operation* land use category. As with the other data from the Agricultural Census, these data are selected for each county, state, and year.

Table 2-4: Agricultural Census Number of Farms

Table Name	Item Name	Unit
Cattle and calves – Inventory and Sales	Cattle and calves	no. of farms
Hogs and Pigs – Inventory and Sales	Total hogs and Pigs	no. of farms
Poultry--Inventory and Sales	Any Poultry	no. of farms
Sheep and Lambs--Inventory, Wool Production, and Number Sold	Sheep and Lambs--Inventory	no. of farms
Milk Goats	Milk goats inventory	no. of farms
Angora Goats	Angora goats inventory	no. of farms

Crop Data

To model nutrient applications in the Chesapeake Bay Watershed Model, the Chesapeake Bay Program must know the land area in agriculture and the types and acreage of crops. The Census' data on crop types, harvested acres and yields, farms, and agricultural land uses are obtained from the Censuses between 1982 and 2002 for the crops listed in Table 2-5. Some of the items listed are referred to as "protected area". This denotes crops grown under glass or other protection, such as in a greenhouse. Otherwise, the crop types are grown in the open.

Table 2-5: Crops modeled in Scenario Builder

Crop name
Wheat for Grain Harvested Area
Winter wheat for grain Harvested Area
Triticale Harvested Area
Sorghum for Grain Harvested Area
Sorghum for silage or greenchop Area
Soybeans for beans Harvested Area
Sunflower seed, non-oil varieties Harvested Area
Sunflower seed, oil varieties Harvested Area
Rye for grain Harvested Area
Peanuts for nuts Harvested Area
Popcorn Harvested Area
Oats for grain Harvested Area
Mushrooms Area
Mushrooms Protected Area
Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area
Barley for grain Harvested Area
Canola Harvested Area
Corn for Grain Harvested Area
Corn for silage or greenchop Harvested Area
Buckwheat Harvested Area
Dry edible beans, excluding limas Harvested Area

Emmer and spelt Harvested Area
Escarole and Endive Harvested Area
Dry Onions Harvested Area
Eggplant Harvested Area
Cucumbers and Pickles Harvested Area
Cut Christmas Trees Production Area
Cut flowers and cut florist greens Area
Bulbs, corms, rhizomes, and tubers – dry Harvested Area
Cotton Harvested Area
Cantaloupe Harvested Area
Carrots Harvested Area
Cauliflower Harvested Area
Celery Harvested Area
Chinese Cabbage Harvested Area
Collards Harvested Area
Beets Harvested Area
Berries- all Harvested Area
Broccoli Harvested Area
Bedding/garden plants Area
Asparagus Harvested Area
Aquatic plants Area
Other nursery and greenhouse crops Area
Brussels Sprouts Harvested Area
Parsley Harvested Area
Mustard Greens Harvested Area
Nursery stock Area
Okra Area
Land in Orchards Area
Lettuce, All Harvested Area
Head Cabbage Harvested Area
Herbs, Fresh Cut Harvested Area
Honeydew Melons Harvested Area
Kale Harvested Area
Foliage plants Area
Garlic Harvested Area
Green Lima Beans Harvested Area
Green Onions Harvested Area
Potatoes Harvested Area
Potted flowering plants Area
Peas, Chinese (sugar and Snow) Harvested Area
Peas, Green (excluding southern) Harvested Area
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area
Peppers, Bell Harvested Area
Peppers, Chile (all peppers – excluding bell) Harvested Area
short-rotation woody crops Harvest Area

short-rotation woody crops Production Area
Pumpkins Harvested Area
Radishes Harvested Area
Sweet Corn Harvested Area
Sweet potatoes Harvested Area
Spinach Harvested Area
Squash Harvested Area
Turnip Greens Harvested Area
Turnips Harvested Area
Vegetable & flower seeds Area
Snap Beans Harvested Area
Sod harvested Area
tobacco Harvested Area
Tomatoes Harvested Area
Vegetables, Mixed Area
Vegetables, Other Harvested Area
Rhubarb Harvested Area
Watermelons Harvested Area
Vetch seed Harvested Area
Timothy seed Harvested Area
Red clover seed Harvested Area
Small grain hay Harvested Area
Ryegrass seed Harvested Area
Orchardgrass seed Harvested Area
Other field and grass seed crops Harvested Area
Other haylage, grass silage, and greenchop Harvested Area
Other managed hay Harvested Area
Bromegrass seed Harvested Area
Birdsfoot trefoil seed Harvested Area
Cropland on which all crops failed or were abandoned Area
Fescue Seed Harvested Area
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area
Cropland in cultivated summer fallow Area
Wild hay Harvested Area
Pastureland and rangeland other than cropland and woodland pastured Area
Cropland used only for pasture or grazing Area
Bulbs, corms, rhizomes, and tubers – dry Protected Area
Cut flowers and cut florist greens Protected Area
Aquatic plants Protected Area
Bedding/garden plants Protected Area
Other nursery and greenhouse crops Protected Area
Nursery stock Protected Area
Greenhouse vegetables Area
Greenhouse vegetables Protected Area

Foliage plants Protected Area	
Potted flowering plants Protected Area	
Sod harvested Protected Area	
Vegetable & flower seeds Protected Area	
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	
Alfalfa Hay Harvested Area	
Alfalfa seed Harvested Area	
Turf grass	

Obtaining Data from the Agricultural Census

Land area data are obtained to give the total area classified as agricultural. Crop data are obtained to determine crop yields and crop areas. There may be more crop acres than land acres because each acre of land may have more than one crop planted and harvested during a year; this is termed double cropping. Chapter 1 of the Agricultural Census is state-scale data and Chapter 2 is county-scale data. The states that are modeled include: New York, Pennsylvania, Delaware, Maryland, District of Columbia, West Virginia, Tennessee, and North Carolina. Tennessee, and North Carolina are included even they don't drain to the Bay because the Bay Program models the southern rivers of Virginia.

Categorization changes over time

Item names change among census years. Specific actions to address these changes are described in Table 2-6. Some data items selected from different tables are identical. Selecting both items allows for validation. In other cases, state aggregated data are selected as well as county level data. This is to inform the calculation of withheld data values. Some crops are listed in one state's census but not in another because certain crops are not present in all states.

Table 2-6: Agricultural Census crop categorization changes

Agricultural Census Item Name	Chesapeake Bay Program item name	Categorization Action
Cropland idle, cover crops or soil improvement but not harvested and not pastured or grazed	Cropland idle, cover crops or soil improvement but not harvested and not pastured or grazed	Combined the two categories from the Census of "cropland idle" with "cover crops or soil improvement but not harvested and not pastured or grazed"
Cut Christmas Trees	Cut Christmas Trees	Data only available from 2002
Flower seeds, vegetable seeds	Flower and vegetable seeds	Combined with vegetable seeds in 1997 and 1992 and 1987 and 1982 for some states. Summed 2002 flower and vegetable seed categories
Other crops	Sorghum hogged or grazed,	This was a new category in

	sorghum for syrup, and corn cut for dry fodder, hogged, or grazed	2002. Summed sorghum hogged and grazed + Corn cut for dry fodder, hogged, or grazed + Sorghum for syrup in all prior years
Sunflower seed-oil, sunflower seed-non-oil	Sunflower seed (all)	In years where there was no oil vs. non-oil varieties <u>all</u> was used as <u>non-oil</u>
Wild hay	Managed hay	Renamed

Turf grass

The crop type "Turf grass" is the only portion of urban land that has nutrients applied directly. Other nutrients on urban lands come from point sources and atmospheric deposition. Turf grass is comprised of those areas that include lawns for private homes and businesses. Sod farms are not considered part of this category. On average, turf grass equals 79% of the urban area in each county and 93% of what we call either high or low intensity pervious urban. Cappiella and Brown (2001) measured the percentage of open space on residential lots to range from 68% to 90%. Robbins et al., (2003) calculated the maximum potential lawn area in 205 residential census tracts in Ohio as averaging 82%. These estimates are liberal in that they do not subtract non-lawn areas (forests, flower beds, etc.) from their open space percentages. However, the numbers do lend some support to the calculated county average of 79% (44% min and 97% max).

Turf grass acreage was determined on a county scale as follows:
Total acres of pervious urban land - acres of forested urban land

Many older subdivisions appear forested from a land cover perspective. The land cover used for the Watershed Model-HSPF Phase 5.2 uses housing unit and residential road density to identify such areas. To differentiate urban forests from lawns under canopy, the larger interior forest patches were classified as urban forests while the edge and speckled forest areas were identified as lawns under canopy (P. Claggett, 2009).

SECTION 3. CALCULATION OF AVAILABLE NITROGEN AND PHOSPHORUS FOR APPLICATION TO THE LAND

The nutrient sources that are considered in the Scenario Builder include animals, inorganic fertilizer, septic systems and land-applied sewage sludge. Each is discussed in the following sections. Other contributions of nutrients modeled in the Chesapeake Bay Program's Watershed Model-HSPF include atmospheric deposition and point sources. These data are produced by data analysis systems separate from the Scenario Builder.

Animals

The animals whose manure is considered as nutrient sources are those listed along with the amount of manure per animal unit in Table 3-1. We assume the market weight of animals has not varied over the modeling period and does not vary throughout the Chesapeake Bay region.

The amount of manure is the as-excreted value, so is the wet weight and includes urine. The manure produced and live animal weights were drawn from literature in late 1980s and early 1990s, which is the midpoint of the period for which these data are used in the Scenario Builder.

The animal units are determined by the number of animals it takes to comprise 1,000 lbs. To calculate this, the average live weight of each animal type is required. The methodology for determining the live animal weight uses the amount of manure produced, and then back calculates to the average live animal weight (Kellogg 2000; Agricultural Waste Management Field Handbook, Moffitt and Lander 1997, Moffitt and Alt 1998). The average live weight is the average of the animals at any age in that category. For example, pullets are defined by NASS as < 20 weeks, so the live animal weight is the average of a pullets' weight during those 20 weeks. Animal units are calculated for each animal type as:

> No. of animals / animal unit

Turkey weights are the average weight at slaughter split equally among hens and toms rather than the average over the growing period (Kellogg, 2000). Source information on horse weights and manure are from the USDA-NRCS National Engineering Handbook Part 651, Agricultural Waste Management Field Handbook. Animal weights were set for sheep and lambs as 100 lb, angora goats (including kids, but assuming not as many as milk goats) as 65 lbs, and milk goats including kids as 65 lbs (S. Schoenian, Sheep 201, Sheep & Goat Specialist, Maryland Cooperative Extension). The Agricultural Census does not categorize meat goats, which are prominent in the Mid-Atlantic region (S. Schoenian, personal communication, 2008). Thus, the primary goat type is not considered by the NASS data, which may lead to an underrepresentation of this animal type.

The 2002 Census defines "other cattle" as: heifers, steers, bulls 500 lbs+, and all calves less than 500 lbs. Using Kellogg, 2000, the average weight for other cattle is 2.08

animals/animal unit. This weight and the amount of manure produced were derived by averaging the following:

- beef calves from calving to about 500 lbs, 4 animals/au
- beef heifers for replacement herds, 1.14 animals/au
- beef breeding herds (cows and bulls), 1 animal/au
- beef stockers and grass fed beef, 1.73 animals/au
- dairy calves from calving to about 500 lbs, 4 animals/au
- dairy heifers for replacement herds, 0.94 animals/au
- dairy stockers and grass fed animals marketed as beef, 1.73 animals/au

This average was used because each state has a different mix of the animals that are in the "other" category. Weighting toward any one type creates an unfair bias toward a particular state or region. Weighting also creates a static variable eliminating the possibility of fluctuation over time.

The pullets' category includes those < 13 weeks and also those between 13 and 20 weeks. These categories were separated in censuses prior to 2002. Average animals per animal unit for these categories are 250 pullets for those between 13 and 20 weeks and 455 pullets for those < 13 weeks. The average of these two is 352.5 and is used for the combined pullets' category.

These data were found to be comparable with the Virginia Nutrient Management Standards and Criteria, Revised October 2005, Virginia Department of Conservation and Recreation.

Table 3-1: Animal types, animal units, and pounds of manure/day/animal unit

Animal type	Live animal weight (lbs)	No. of animals per animal unit (animal unit=1000 lbs)	Manure (lbs) per day per animal unit	Animal weight and manure (lbs) data source
beef	877.19	1.14	57.96	Kellogg et. al. (2000)
dairy	1351.35	0.74	83.41	Kellogg et. al. (2000)
other cattle	480.77	2.08	64.38	Kellogg et. al. (2000)
broilers	2.20	455	81.94	Kellogg et. al. (2000)
layers	4.00	250	62.67	Kellogg et. al. (2000)
pullets	2.84	352.5	45.54	Kellogg et. al. (2000)
turkeys	14.93	67	44.78	Kellogg et. al. (2000)
hogs and pigs for breeding	374.53	2.67	33.44	Kellogg et. al. (2000)
hogs for slaughter	110.01	9.09	80.41	Kellogg et. al. (2000)
horses	1000.00	1	50	USDA-NRCS National Engineering Handbook Part 651, Agricultural Waste Management Field

				Handbook
angora goats	65.02	15.38	40	Schoenian (2008)
milk goats	65.02	15.38	40	Schoenian (2008)
sheep and lambs	100.00	10	40	Schoenian (2008)

The number of animals in each category except horses comes directly from the 5-year NASS Agricultural Censuses. The horse data came from state-sponsored censuses ranging from 2000-2004. The NASS Agricultural Census data does collect data on horses and ponies, but this information is typically completed only by farmers who use horses and ponies as work animals. This leaves out all pleasure horse farms and racehorse training and breeding operations. It is the pleasure horses and racehorses that comprise the majority of horses in many parts of the watershed.

Inorganic Fertilizer

In the Scenario Builder, fertilizer sales data were used only to inform annual variation in application rates. The inter-annual variation is due to management practice changes and genetic modification of crops. A factor was developed using analysis of the fertilizer sales data and is in Table 3-2 (R. Burgholzer, former data analyst at the Chesapeake Bay Program). The factor is multiplied by the application rate for each year and crop type and growth region. For years with missing fertilizer data, the factor is interpolated. The value is normalized to the last year in which data are available and is carried forward into future years.

The fertilizer sales data are prepared by the Association of American Plant Food Control Officials based on fertilizer consumption information submitted by state fertilizer control offices. The consumption data include total fertilizer sales or shipments for farm and non-farm use. Liming materials, peat, potting soils, soil amendments, soil additives, and soil conditioners are excluded. Materials used for the manufacture or blending of reported fertilizer grades or for use in other fertilizers are excluded to avoid duplicate reporting.

The fertilizer sales data were not used directly due to complications with consistency of reported data throughout the modeled time period and region. In addition, there are several major ports in the Chesapeake Bay Watershed. Fertilizer may be sold at the port and transferred to another region for resale, which could result in double counting these sales.

Table 3-2: Annual fertilizer application adjustment factor

Sample Year	Nitrogen Multiplier	Phosphorus Multiplier
1980	1.01	1.25
1982	1.1	1.37
1983	1.092	1.358
1984	1.084	1.346
1985	1.076	1.334
1986	1.068	1.322
1987	1.06	1.31
1988	1.05	1.298

1989	1.04	1.286
1990	1.03	1.274
1991	1.02	1.262
1992	1.01	1.25
1993	1.005	1.26
1994	1	1.27
1995	1	1.24
1996	1	1.21
1997	1	1.18
1998	1	1.14
1999	1	1.1
2000	1	1.07
2001	1	1.03
2002 +	1	1

Septic Systems

Septic systems are commonly designed so that the waste goes into a tank, where solids sink to the bottom, and liquids flow through to a septic field. While some phosphorus can become soluble, in this model, we assume that only nitrogen is distributed to the septic field.

To calculate the amount of nitrogen generated from septic systems, we used the number of people on septic systems in the Chesapeake Bay Watershed. This question was asked on the 1990 U.S. Census, but was removed in subsequent censuses. To estimate this number, we calculate the ratio of the number of people in a county on septic to the total number of people in the county from 1990. That ratio is multiplied by the total population in the county, from the U.S. Census.

The calculation is on a county scale for each year where:

(No. of people on septic in 1990 / no. of people in 1990) * total population of year being calculated

Sewage Sludge

Land-applied sewage sludge can be a significant source of nutrients on farm land. The Chesapeake Bay Program requested that each state submit data on the use of sewage sludge used as a fertilizer. Virginia submitted such data for the modeled period of 1982-2005. These data were in units of dry tons/year. The data were further broken out so that each month received an equal amount, but the distribution was to the most likely land use type between hay/pasture and crops. This likelihood was informed by a regulatory change influencing management practices in 1997 (K. Berger and W. Keeling, personal communication, 2008). Between 1982 and 1996, there are more months with cropland applications. Crops receive 80% of monthly production hay and pasture receives the other 20% during certain months. The remaining monthly production numbers are 100% applied to hay and pasture. After 1996, there are more months where sewage sludge only goes on hay and pasture.

Some data were received from Maryland, but these data were in wet tons. Maryland was unable to provide information on how to convert from wet to dry tons for each sewage sludge provider. A general assumption of moisture content was unacceptable to Maryland.

SECTION 4. ACCOUNTING FOR NITROGEN AND PHOSPHORUS LOSSES AND TRANSFORMATIONS

Methods for calculating the nutrient speciation, volatilization, and storage and handling loss for organic and inorganic fertilizer, and manure directly excreted onto pasture are discussed in the following sections.

Nutrient Speciation

The forms of nitrogen and phosphorus that are modeled in the Scenario Builder were established to mirror those in the Chesapeake Bay Program's Watershed Model-HSPF with the addition of mineralized forms of nitrogen and phosphorus. Since the amount of manure applied to crops is generally calculated by farmers to include only the plant-available portion, we included the mineralized forms. These mineralized forms are the conversion of organic N to NH_4. The mineralization process liberates plant-available N. While the nutrient NH_3 is written and referred to as such, it is generally used to represent both NH_3 and NH_4 in the Scenario Builder and Watershed Model-HSPF lexicon. Nutrients modeled in the Scenario Builder include:

1. NH_3
2. Organic N
3. Mineralized N
4. NO_3
5. PO_4
6. Organic P
7. Mineralized P

Inorganic Fertilizer

The amount of nitrogen and phosphorus are independent of each other for inorganic fertilizer. The speciation was set at the most commonly perceived mixture since fertilizer sales data were unable to be analyzed for this purpose (Chesapeake Bay Program, Agricultural Nutrient and Sediment Workgroup, 2008). The nitrogen component of inorganic fertilizer is comprised of NH_3 and NO_3. NH_3 is 0.75% of total N, with the other 25% is NO_3. All of the phosphorus is found in the form of PO_4.

Organic Fertilizer

Organic fertilizer sources include animal manure and sewage sludge. In organic fertilizer, N and P are linked, since a farmer does not chemically separate the various forms. The total mass of manure per day per animal unit is split into total N and total P for each animal species (Table 4-1). The category of other cattle is an average of the animal types used in determining the average live animal weights and are listed separately in that section.

Table 4-1: Nutrient content of animal manure and biosolids (ASAE, 1998) Goat waste is assumed to have the same proportion of nutrients as sheep waste.)

Source types	Nutrient	lb-Nutrient/lb manure
angora goats	TN	0.01125
beef	TN	0.00587
biosolids	TN	0.03900
broilers	TN	0.01342
dairy	TN	0.00540
hogs and pigs for breeding	TN	0.01555
hogs for slaughter	TN	0.00647
horses	TN	0.00600
layers	TN	0.01340
milk goats	TN	0.01125
other cattle	TN	0.00528
pullets	TN	0.01845
sheep and lambs	TN	0.01050
turkeys	TN	0.01385
angora goats	TP	0.00275
beef	TP	0.00159
biosolids	TP	0.02500
broilers	TP	0.00366
dairy	TP	0.00113
hogs and pigs for breeding	TP	0.00538
hogs for slaughter	TP	0.00224
horses	TP	0.00142
layers	TP	0.00479
milk goats	TP	0.00275
other cattle	TP	0.00143
pullets	TP	0.00659
sheep and lambs	TP	0.00218
turkeys	TP	0.00514

Total N is further broken into NH3, organic N, and mineralized N. NO_3 is not present in animal wastes in measurable amounts (USDA-NRCS, 1998). TN, NH_3, TP, and PO_4 values were taken from ASAE standards, 1998. Organic N and P are determined as:

$TN-NH_3=ORG\ N$
$TP-PO_4=ORG\ P$

Where values are not specified, then data from the most similar animal species are used (Table 4-2).

Table 4-2: Animal type used for specific nutrients if specified animal type data unavailable

Animal type missing nutrient fraction	Animal type used	Nutrient type(s)
goats	beef	Org N

other cattle	beef	Org N
sheep	beef	Org N
broilers	layers	NH_3
pullets	layers	NH_3
turkeys	layers	NH_3
goats	sheep	Org P and PO_4
Horses	swine	Org N

The calculation of mineralized N uses the values for spring or early fall manure applied; less winter top-dress (Table 4-3). Temperature, water content, drainage features, and organic carbon all have an impact on mineralization; these factors are not considered in this estimation. Mineralized N is calculated as:

Mineralization factor * Organic N

Organic N is then adjusted as:
    Original Organic N – Mineralized N

Plant available phosphorus behaves conservatively in the soil so all organic P is assumed to be biologically available.

Table 4-3: Nutrient mineralization factors (N mineralization factors for bovine, swine and poultry were taken from the Mid-Atlantic Nutrient Management Handbook, February 2006, originally cited from VaDCR, 2005).

Animal type	Phosphorus Mineralization factor	Nitrogen Mineralization factor
bovine	1	0.35
swine	1	0.50
poultry	1	0.60
horses	1	0.50
sheep, lambs, and goats	1	0.35

The species of each nutrient are then used as:

Mass of waste / animal unit / unit of time * concentration fraction for each N and P form (forms of N and P (lbs) / animal type manure (lb))

Phytase Feed Additive

Phytase is an enzyme added to poultry-feed that helps poultry absorb phosphorus. The addition of phytase to poultry feed allows more efficient nutrient uptake by poultry, which in turn allows decreased phosphorus levels in feed and less overall phosphorus in poultry waste. The use of phytase is a best management practice (BMP). In Scenario Builder, no poultry have the phytase feed additive prior to 2002, 50% are classified as phytase for 2002, and 100% for 2003 and later. Phosphate nutrient forms are 80% of the

non-phytase animals' values for the forms of phosphorus (Agricultural Nutrient and Sediment Reduction Workgroup).

Volatilization

Volatilization rates are calculated as the amount of NH_3 that moves into the atmosphere from stored manure. Ammonia volatilization is highly variable and literature suggests values that range from 0 to 40%. Numerous factors affect the volatilization rate including temperature, moisture, pH, etc...

In Scenario Builder, volatilization is not calculated for directly excreted manure or for manure once it is applied to the land. Volatilization for direct excretion and land-applied manure is handled by the Watershed Model, which uses rates based on temperature and hydrology.

Ammonia volatilization in inorganic fertilizer varies by factors other than just the type or composition of inorganic fertilizer. Therefore, there is also no volatilization for inorganic fertilizer in Scenario Builder.

In addition, volatilization data are not reconciled with the atmospheric deposition model.

The rates have been used in the previous versions of the Watershed Model-HSPF and were not changed when incorporated into the Scenario Builder (Table 4-4). Sheep, lambs and goats are new animal types; they are given the same volatilization rates as cattle since all of those animal species are ruminants (S. Schoenian, personal communication 2008).

Table 4-4: Volatilization rates of ammonia from nutrient sources

Source name	Fraction not volatilized
pullets	0.43
turkeys	0.43
hogs and pigs for breeding	0.19
beef	0.35
broilers	0.43
Heifers (cows and heifers that have calved)	0.35
hogs for slaughter	0.5
horses	0.68
layers	0.43
other cattle	0.35
sheep and lambs	0.35
angora goats	0.35
milk goats	0.35
biosolids	0.4875

Animal confinement (% time in pasture)

The amount of time an animal is in pasture determines the amount of manure directly excreted on pasture. In the Scenario Builder model, animals are always in one of two locations while alive, in a pasture or an animal production area. Chesapeake Bay Program Watershed Model-HSPF pasture land uses include: pasture, nutrient management pasture, or trampled riparian buffer. The animal production area land use is named 'animal feeding operation'.

The amount of time animals are in pasture varies by the animal type and the region of the watershed. Table 4-5 lists the fraction of time each animal is in pasture based on the region of the watershed (SECTION 5: Growing Regions, page 5-29).

While animals may be turned out to fields to forage after a crop is harvested, the length of time is typically only a few days (Doug Goodlander, PA DOE, personal communication, 2008). While the animal is foraging, they may excrete manure. This excreted manure is not captured in this model. In Virginia, this practice occurred primarily in the Shenandoah Valley (specifically in Augusta and Rockingham Counties). According to staff in the valley, that practice is fading out and need not be addressed (William Keeling, VA DCR, personal communication, 2008).

Should there be no pasture land in a county, then Table 4-5 is not relevant; rather the Scenario Builder classifies the animals as 100% confined and all manure is considered stored and available for distribution to row crops.

The amount of nutrients applied directly to pasture for each animal type by county is calculated as:
> Number of animals * fraction of time in pasture
> Convert to animal unit (process previously described)
> Determine mass of manure in terms of N and P forms (process previously described)

The land use of trampled riparian pasture receives nine times whatever the other two pasture components receive in a county.

Table 4-5: Fraction of time animals are confined by animal type and region. (Region descriptions are in SECTION 5: Growing Regions).

Animal type	Fraction of time confined (month - fraction)	Region
Angora goats, Milk goats, Sheep and lambs	Dec., Feb. – 0.5 Jan. – 0.0 All other months – 1.0	DE_1
Angora goats, Milk goats, Sheep and lambs	Dec., Jan., Feb – 0.0 Nov., Mar. – 0.5 All other months – 1.0	MD_1, MD_2, MD_3
Angora goats, Milk goats, Sheep and lambs	Nov. through Apr. – 0.0 All other months – 1.0	NY_1, PA_1, PA_2, PA_3

Angora goats, Milk goats, Sheep and lambs	Dec. through Feb. – 0.0 All other months – 1.0	VA_1 VA_2 VA_3
Angora goats, Milk goats, Sheep and lambs	Mar. – 0.5 Nov. through Feb. – 0.0 All other months – 1.0	WV_1
Beef	All months – 1.0	DE_1, VA_1, VA_2, PA_3 MD_1, MD_2
Beef	Jan., Feb. – 0.0 Dec. – 0.4 All other months – 1.0	MD_3, NY_1, PA_1, PA_2, WV_1
Beef	Jan., Feb. – 0.2 All other months – 1.0	VA_3
Poultry, hogs, sows	All months – 1.0	All regions
Dairy	All months – 0.75	All regions
Horses	All months – 0.4	All regions
Other cattle	All months – 0.25	All regions

Manure Storage and Handling Residual

Loss of manure and other nutrient sources occurs during storage from physical processes. The physical loss occurs when some manure falls out of the bucket of a front-end loader, leaks out of a spreader in unintended locations, or inadvertently slips off a concrete pad where it is stored. However, storage loss is most common when manure is absorbed or incorporated into the soil in animal concentration areas (Doug Goodlander, PA DEP, personal communication, 2008).

Storage loss will vary by animal type, since management practices associated with animal concentration areas and storage facilities vary by animal type. Storage loss does not account for the type of storage system used on any particular farm or the angle of repose for dry heaps of manure. Rather, storage loss applies the average loss across the dominant storage systems in use.

For all poultry and swine, 15% of manure is lost during storage. For beef, dairy, sheep and lambs, goats, and horses, 20% is lost (Appendix H, Watershed Model-HSPF Phase 4.3 documentation, CBP Watershed Technical Workgroup and CBP Agricultural and Nutrient Sediment Reduction Workgroup approval, 2008)).

The mass of nutrients lost during storage and handling is applied to the land use that includes the animal production area (animal feeding operation, or AFO).

SECTION 5. ACCOUNTING FOR SPATIAL AND TEMPORAL VARIATION IN AGRICULTURAL PRACTICES

Nutrient application amount and timing is governed by the following principles:
- Temperature zone variations
- State nutrient management and land grant university cooperative extension recommendations
- Regional management practices
- Actual yield history, from the NASS Agricultural Census

To introduce spatial variability, the construct of growing regions was created. Each state is established as its own region to accommodate variations in state-recommended nutrient application rates and timing. The three largest states—Virginia, Maryland, and Pennsylvania—are each classified further into three smaller regions. This further classification into growing regions allows for variation among planting and harvest dates based on typical last frost and first killing frost.

Modeled agricultural variables include plant and harvest dates, nitrogen fixation, bare soil cover, plant nutrient uptake, nutrient application rate, and nutrient application timing. These agricultural practices are modeled where each year is independent of the previous or subsequent year. While this seems counter-intuitive based on how a farmer operates, it holds true to the scale of the source data and avoids making assumptions which would only introduce error.

The classifications of the growing regions, temporal scale, and agricultural practice data are discussed separately in the following sections.

Growing Regions

There are twelve growth regions in the Chesapeake Bay Watershed. Each state is necessarily its own region, since there are separate crop management and nutrient guidelines for each state. Where the agronomy guide from each state divided the state into different growing regions, then those regions were used. Where the guides did not make a distinction, the 1990 USDA Hardiness Zone delineations were used see if the state should be divided. The more recent 2003 hardiness zones were not used since it is considered unlikely that farmers changed planting dates and 1990 is closer to the mid-point of the modeled period (1982 – 2005). The USDA Hardiness Zone boundaries are set where there is a 10° Fahrenheit difference in the average annual temperature. The lines were established by comparing multiple maps and determined which counties fell into which regions. Boundary lines were shifted to match county lines. Specifically:

- In New York, the portion of the state that lies in the watershed is primarily the central part, which the Cornell Ag Guide considers one region.
- In Pennsylvania, the Agronomy Guide divides the state into separate growing regions for each crop; however, the lines of the regions are very similar to each other and to

the lines of USDA Hardiness Zones. Therefore, it was determined that Pennsylvania would be divided into three regions that follow the boundaries given in the Agronomy Guide: Zone 1, Zone 2 and Zone 3.

- In West Virginia, the portion of the state that lies in the watershed was in a single USDA Zone, so WV has one region.
- Maryland's Nutrient Management Manual does not divide the state; however, there are two USDA Zones. Therefore, MD was divided into USDA Zone 6 and USDA Zone 7. Concern arose that this left a nearly eastern shore county in the same zone as a Western Maryland county and were thus subject to the same conditions. To address this concern, a third zone, "Western MD" was added that includes Garrett, Allegheny and Washington counties.
- Delaware also falls into one USDA Zone, and was therefore left undivided.
- Virginia's Ag Guide divides the state into three sections that roughly follow geologic provinces: Eastern, Piedmont and West of Blue Ridge.
- North Carolina and Tennessee counties follow physiographic provinces.
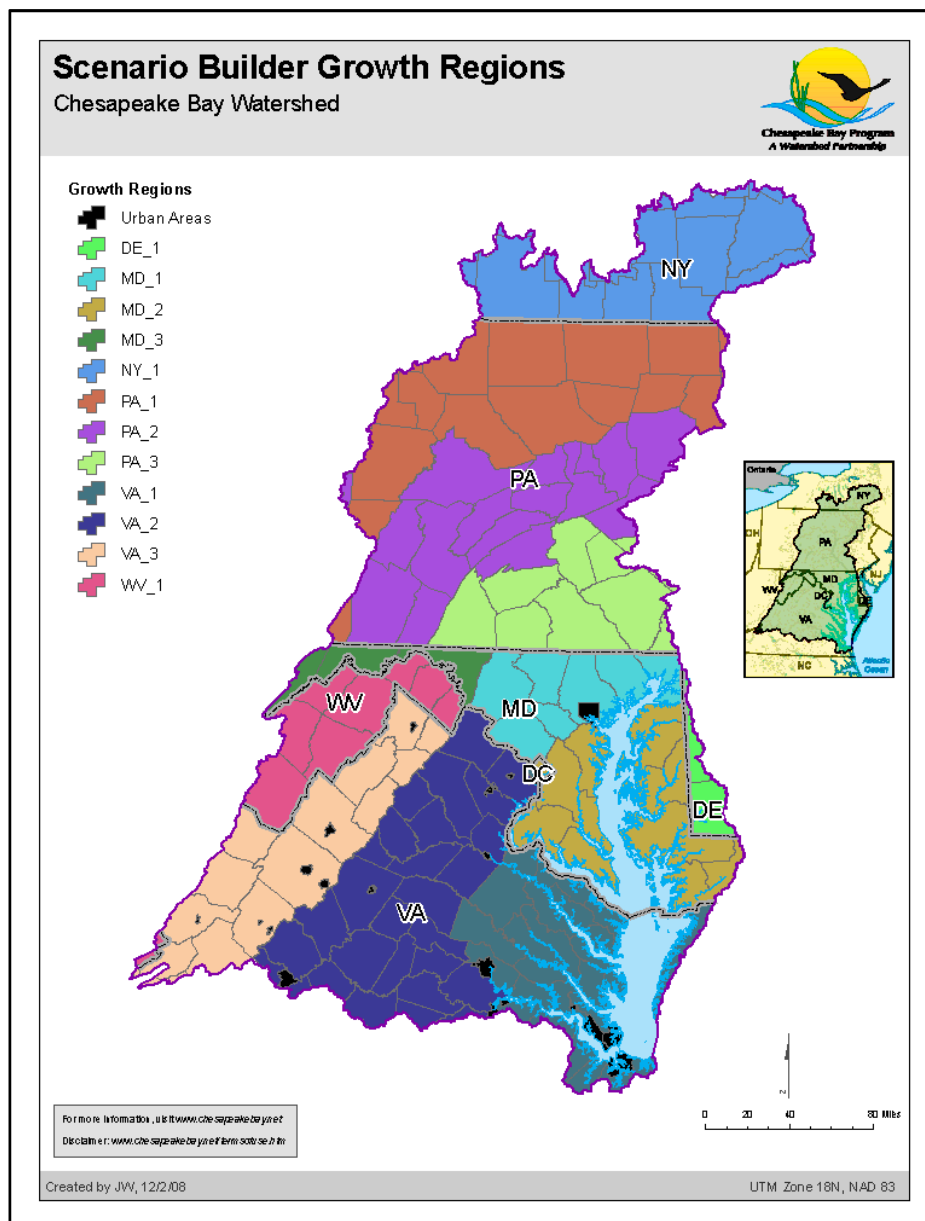
Figure 5-1: Growing Regions

USDA Hardiness Zones were incorporated into the identification of the regions to make it possible to relate data on planting and harvesting dates in one state to another state. The guides in Maryland, Delaware and West Virginia only report recommended nutrient application rates, not dates. If a region in one of these states corresponds to a region in another state that lies in the same USDA Hardiness Zone, it was assumed that the planting and harvesting dates would be similar for both of those regions. For example, the dates for Eastern VA were also used for MD Zone 2 and Delaware because all three lie in USDA Zone 7.

While source data was initially prepared using growing regions, it is stored at the county scale. This has allowed more precision as source data is fine-tuned to the county level.

Temporal Scale

Data is calculated on a monthly time scale. Much of the source data is taken from the National Agricultural Statistics Service's (NASS) Agricultural Census and is from the years 1982, 1987, 1992, 1997, and 2002. Years between Agricultural Census years and those in the future are interpolated or projected using a linear regression. Each year is calculated separately with no interaction between the years. The 2007 Census is not prepared or included as of June 2009.

Agricultural Practices

Scenario Builder uses agricultural practice information only to determine the timing of nutrient application and the amount of nutrients required. Scenario Builder does not have temperature or rainfall data and is not designed to be a full crop growth model. For this reason, few of the crop parameters are linked. (For example, uptake and nutrient application are calculated independently.)

Crop-related data include plant and harvest dates, nitrogen fixation, bare soil cover, crop yields, plant uptake, nutrient application rates, and nutrient application timing. Each of these parameters is discussed separately in the sections below.

Plant and harvest dates

Plant and harvest dates are used to inform the timing of plant uptake, nitrogen fixation, and nutrient application. Uptake and nitrogen fixation can only occur when the plant is growing. The days between the plant and harvest date define this growing time. The nutrient application has a fraction applied in relationship to plant date. For example, split application to corn could have 50% applied 20 days prior to planting and 50% applied 60 days after planting. Thus, the correct application timing is keyed to the time of planting.

A single plant and harvest date is used for each crop or plant type in each growth region. Crops that are considered for double-cropping are assigned different dates when they are double cropped.

Having only a single date for planting and harvesting is problematic for crops such as vegetables, which are planted and harvested multiple times in a single season, or hay and alfalfa, which are harvested multiple times in a single season. The need to incorporate multiple plant and harvest dates is a known issue and will be incorporated in a future phase of the model development. Currently, the last harvest date is used for hay and alfalfa and the last plant and harvest dates are used for vegetables.

Scenario Builder's calculations are performed on a county scale and use the most typical plant and harvest dates at that scale. While it is commonly understood that there is variation among plant and harvest dates among farmers, the spatial scale of this model is at the county and can not accommodate farm-scale variation.

First and last frost dates were used as a guiding parameter for the plant and harvest dates. Agronomy guides for each state frequently base planting and harvesting dates on the last frost in the spring and the first frost in the fall. In order to determine those dates for each

growing region, the "Freeze/Frost Data" from the National Climatic Data Center (CLIM20) was used. This publication lists the frost dates for numerous sites within each state in the United States at various probability levels.

Using five monitoring sites within the watershed in each of the 12 growing regions, the 50% probability level was used. Then the midpoint of the range among the five sites in each growing region was used (Table 5-1).

Table 5-1: First and last frost dates for each growing region

Growing Region	Last Frost	First Killing Frost
DE 1	April	October
MD 1	April	October
MD 2	April	October
MD 3	April	October
NY 1	May	October
PA 1	May	October
PA 2	May	September
PA 3	April	October
VA 3	May	October
VA 2	April	October
VA 1	April	November
WV 1	May	October

Most planting and harvest dates are given as a range for each crop in each state's agronomy guide. Sometimes a season alone was given as a planting or harvest range. Sometimes harvest dates were not given at all. Rules that applied where the planting and harvest dates are not expressly stated in the agronomy guide are as follows:

- Spring and fall dates were assumed the true range of spring and fall. If a guide referred to early spring, the range of dates for the first half of spring was used in lieu of the midpoint. Likewise, late spring referred to the second half of spring. Early fall referred to the first half of fall and late fall referred to the second half of fall. Since Scenario Builder is at a monthly scale, these typically fell in the same month as the midpoint.
- Where the guides gave a choice of plant dates, the first was used.
- If the crop or plant type is a perennial, the plant date corresponds to emergence and the harvest date corresponds to the killing frost.
- If the guide did not provide planting and harvest dates at all, then the dates are used for an adjacent region. For example, Maryland's eastern shore (MD 2) could be used for Delaware (DE 1).
- Frequently harvest times were specified in terms of stages of maturity. In those cases, a variety of sources was consulted to estimate the time taken to reach the indicated maturity stage. Sources include Cooperative Extension factsheets, and variety trials. Zadok's growth stages were used where possible.
- Where data was unavailable from state agronomy or nutrient management guides, then the crop cover canopy estimates generated from RUSLE 2 were consulted.

- For green lima beans in Delaware, the plant and harvest dates were taken from the RUSLE 2 data for snap beans
- Vegetable planting dates were taken from http//www.hgic.umd.edu/_media/documents/hg16_000.pdf.

Nutrient application timing and fraction

Each state issues recommendations for nutrient application rates and timing. These recommendations were used for the fraction of nutrients applied on each crop at a particular time. For example, split application to corn may be 50% of the total nutrients applied 20 days prior to planting and 50% applied 60 days after planting. This section discusses how the data are used and the data generalizations.

The state recommendations for application timing were used for all crops; including those under a nutrient management plan as well as those without a plan (Penn State Agronomy Guide 2009-2010, University of Delaware Soil Testing Program Nutrient Guidelines, consulted on-line 2008-2009, Virginia Cooperative Extension Agronomy Guide 2000, Maryland Cooperative Extension Soil Fertility Management-1 2002, Nitrogen Guidelines for Field Crops in New York 2003). Nutrient application timing (as well as rates, form, and methods) may vary between farmers using a nutrient management plan as opposed to those farmers without a plan. However, specific dates can only be defined if there is a consistent behavior among a specific set of farmers. That is, if farmers not under a nutrient management plan always applied nutrients all at once, or always at inopportune times, such as in the winter when crops may not be actively growing, then those dates could be specified for crops not under nutrient management. We were unable to define a consistent behavior among farmers without a nutrient management plan. Thus, the nutrient application timing does not vary according to nutrient management planning. In contrast, the nutrient application rate does vary between nutrient management and non-nutrient management.

A number of strategies were necessarily employed to convert the recommendations to normalized data (Table 5-2). The recommendations for the fraction of nutrients applied at each time were originally in multiple formats. A list of the strategies to normalize the various recommendations in which the formats were made follows:

- Commonly, nutrient application timing is dictated by the growth stage of the plant. Zadok's growth stage scale was used to inform the number of days after planting that a particular stage would be reached.

- Whenever the guides recommend nutrients applied as pre-plant, 20 days prior to the plant date was used.

- When no timing information was offered at all, it was assumed the recommended nutrients were applied at planting.

- Where not other specified for small grains, hay and pasture, all nutrients were applied 60 days after planting

- For all crops where the nutrient application timing was "when vines start to run", it was assumed to be 60 days after planting.

- If the application method was "Banded with planter" then the application timing was set to apply with planting.

- If the application method was broadcast and disk in, then the application timing was set as pre-plant (20 days prior to planting).

Table 5-2: Generalization of fraction applied and application timing

Growing Region	Crop	Generalization, source of data
All	Dry edible beans	Used the same recommendations as for peas, black eyed
All	garlic	Used the same recommendations as for dry onions
All	Peanuts and popcorn	Used the same recommendations from Virginia throughout the watershed
All	rhubarb	Used the same plant dates and nutrient recommendations as buckwheat since rhubarb is in the buckwheat family
All	Turf grass	Nutrient application timing information was taken from the Maryland Home and Garden Information Center (http//www.hgic.umd.edu/_media/documents/hg103_002.pdf)
All regions	Aquatic plants	Assumed to be planted bimonthly with split application
DC	All crops	Used the same recommendations as Maryland for all crops in the District
DE	Alfalfa Hay Harvested Area	Used the same recommendations as "alfalfa," which did not specify "hay"
DE	Asparagus Harvested Area	Used the recommendation for "Cutting Beds"
DE	Broccoli	Four P-Index values for soil are given; used the 26-50 which was consistent with the optimum value of 30 that was used in PA
DE	Chinese cabbage	Used the same recommendations as for "cabbage", did not specify Chinese
DE	Cut Christmas Trees Production Area	Used the recommendation for "field-grown Christmas trees"
DE	Eggplant Harvested Area	Used the recommendation for "traditional culture"
DE	orchard grass seed	Used the same recommendation as Maryland
DE	Potatoes Harvested Area	Used the recommendation for "russet potatoes". Second application of TN specified for second cultivation of crop and assumed to be five months after planting.
DE	Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area	Used the recommendation for Sorghum for silage
DE	Squash Harvested Area	Used the recommendation for "summer squash"
DE	Sunflower seed, oil varieties and	Used the recommendation for "sunflowers", did not specify oil or non-oil

	non-oil varieties Harvested Area	
DE	Sweet Corn Harvested Area	Used the recommendation for "fresh market" corn
DE	Tobacco	Used the same recommendation for as for Maryland
DE	Tomatoes Harvested Area	Used the recommendation for "traditional production" under "loams and silt loams"
DE	Turf grass	Used the recommendation for "turf- athletic fields and industrial lawns- blue grass-fescue mixes, maintenance"
DE, MD	Dry Onions Harvested Area	Used the recommendation for Bulb Onions
DE, MD	Head Cabbage Harvested Area	Used the recommendation for "cabbage"- did not specify "head cabbage"
DE, MD	Oats for grain Harvested Area – not double-cropped	Used the recommendation for spring oats
DE, MD	Oats for grain Harvested Area – double-cropped	Used the recommendation for winter oats
DE, MD, VA, NY	Peppers, Bell Harvested Area ; Peppers, Chile all peppers – excluding bell Harvested Area;	Used the recommendation for "peppers", did not specify type
DE, VA	Fescue	Used the same recommendation for as for Maryland
MD	Alfalfa Hay Harvested Area and Alfalfa Seed Harvested Area	Used the recommendation for "Alfalfa & Alfalfa-Grass Mix"
MD	Asparagus Harvested Area	Used the recommendation for "cutting beds".
MD	Berries- all Harvested Area	Used the recommendation for strawberries- matted row older plantings
MD	Corn for Grain Harvested Area	Used the recommendation for full season corn
MD	Cut Christmas Trees Production Area	Averaged all varieties for the second year of growth
MD	Green Lima Beans Harvested Area	Used the recommendation for a single crop, not after peas
MD	Potatoes Harvested Area	Used the recommendation for "White Potatoes", did not specify type
MD	Red clover seed Harvested Area	Used the recommendation for "clover and clover-grass mix", didn't specify red clover
MD	Ryegrass seed Harvested Area	Used the recommendation for perennial ryegrass, not annual ryegrass

MD	Snap Beans Harvested Area	Used the recommendation for Snap Beans single crop, not after peas
MD	Soybeans for beans Harvested Area – double cropped	Used the recommendation for small grain double cropped with soybean
MD	Soybeans for beans Harvested Area – not double-cropped	Used the recommendation for Soybean-full season, NOT forage-type soybeans (http//www.hgic.umd.edu/_media/documents/hg16_000.pdf)
MD	Spinach Harvested Area	Used the recommendation for Spring/Fall, NOT Overwinter
MD	Squash Harvested Area	Used the recommendation for Summer Squash, not Pumpkins/Winter Squash
MD	Timothy seed	Used the recommendation for hay
MD	Turf grass	Used the recommendation for warm season grasses, like tall fescue
MD	Watermelons Harvested Area	Used the recommendation for non-irrigated
MD	Wheat for Grain Harvested Area – double-cropped	Used the recommendation for small grain double cropped with soybeans
MD, PA	Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area	Used the recommendation for forage sorghum
MD, VA, NY	Peas, Chinese sugar and Snow Harvested Area; Peas, Green excluding southern Harvested Area; Peas, Green Southern cowpeas – Black-eyed, Crowder, etc. Harvested Area	Used the recommendation for "Peas"- did not specify which variety
NY	All crops, except for barley, soybeans, and winter wheat	Used the same recommendations as PA_1
NY	Barley for grain Harvested Area	Used the recommendation for spring barley (http://ipmguidelines.org/FieldCrops/content/CH05/CH05-5.asp)
PA	Alfalfa	Used the recommendation for early spring alfalfa.
PA	Barley for grain Harvested Area – double-cropped	Used the recommendation for spring barley
PA	Barley for grain Harvested Area – not double-cropped	Used the recommendation for winter barley

PA	Buckwheat	Used RUSLE2 plant and harvest dates.
PA	canola	uses MD nut application timing recommendations
PA	Corn grain and silage or greenchop	Apply when plant is 10-20 inches tall was interpreted as 45 days after planting.
PA	Hay or silage	Used the recommendations from RUSLE 2 cover data, which were specific to growing regions.
PA	Oats for grain Harvested Area	Used recommendations for spring oats
PA	Red clover seed	Used recommendations for spring red clover
PA	Rye for grain Harvested Area	Used recommendations for winter rye
PA	Soybeans for beans Harvested Area – double-cropped	Used soybeans double cropped with barley. The planting date for non-double cropped soybeans was selected. The harvest date was the planting month for winter barley, since in this situation the soybeans were being double cropped with barley.
PA	spring wheat	No varieties recommended-Maryland recommendation for nutrient application timing was used.
PA	Tobacco and sunflowers	Used the recommendation for Maryland nutrient application timing
PA	Triticale Harvested Area	Used winter triticale for forage- winter or spring. Triticale for grain was not recommended so no information was available.
PA , DE	cotton	Used the recommendations for Maryland
VA	canola	Used the recommendations for Delaware
VA	Lettuce	Used the recommendation for "leaf"
VA	sod and turf	Used the recommendation for Maryland
VA, DE	Timothy seed	Used the recommendation for Maryland
VA, NY	Cabbage, Chinese and head	Used the recommendation from RUSLE 2 cover data
WV	All crops	Used the same recommendations as Pennsylvania growing region 1
WV, NY, PA, VA	Hay crops	Application timing was changed to match alfalfa which had a split application, per G. Shenk. This accommodates a spikiness exhibited by the loading data.

Nitrogen fixation

The Scenario Builder calculates the amount of nitrogen that is fixed by the plant on a monthly time-scale. Nitrogen fixation includes the portion fixed in the roots and taken up into the plant.

Legumes are a class of plants that generally grow pods. Legumes develop nodules on the roots that are an infection from bacteria. These bacteria transform N_2 to NH_3, a process called nitrogen fixation. Thus, N is added to the plant-soil system from the air. The Scenario Builder reports the pounds/acre of ammonia (NH_3) that is fixed by crop, county, month, and year.

Leguminous plant types that we model are listed in Table 5-3. The Agricultural Census categories that include legumes but are not exclusively legumes are not considered for legume fixation. We do not calculate N fixation from these broader categories because the fraction of legumes is not known and can significantly vary at a plot scale (Table 5-4).

Each year is considered independent of any other year. Therefore, nutrients can not accumulate in the soil in data produced by the Scenario Builder. It follows that N in the soil after one year may repress N fixation. This situation is not considered in the calculation of these data.

No N is fixed in the month of planting. We assume that the nodules take 2-4 weeks to establish. For subsequent months of growth, the total amount of NH_3 is parsed evenly. That means that the same amount of N is fixed in the second month of growing as in the final month before the plant senesces. A perennial, like alfalfa, will fix the same amount every month between emergence (plant date for annuals) and first hard frost (harvest date for annuals).

We assume that fixation occurs on all leguminous plants. This assumes that legumes are inoculated or sufficient rhizobia are present. It also assumes that carbon is at optimum levels for fixation to occur.

Nitrogen fixation amounts are not adjusted for temperature or rainfall in Scenario Builder or in the Chesapeake Bay Program's Watershed Model. The exception is alfalfa. The Watershed Model users can choose whether to calculate alfalfa fixation or use the alfalfa fixation provided from Scenario Builder. As of October 14, 2008, nitrogen fixation for alfalfa will likely be calculated by the Watershed Model so that rainfall and temperature data can parameterize fixation amounts.

The Chesapeake Bay Program's Watershed Model accounts for processes that occur after N fixation, such as where crops are killed and left on the soil or incorporated into the soil, thereby returning N to the soil. These data are not included in Scenario Builder.

Many researchers have indicated that fertilizer applications in the form of NO_3 do not decrease N fixation by legumes (Johnson et al., 1975; Blumenthal et al., 1996). These data refute the dogma that NO_3 substitutes for fixed N where NO_3 is increased. Literature searches did not produce data that quantifies the reciprocally of the NO_3 sorption and N_2 fixation. Without identifying values of N fixation and the interaction with NO_3 for each leguminous plant, we are unable to consider these data in the Scenario Builder model. Therefore, Scenario Builder calculates N fixation so that if there is adequate N available to the plant from nutrient applications, then N fixation is suppressed. The implication is that if a farmer applies fertilizer to legumes, then N is not fixed.

Additionally, this parameter is based on the assumption that 50% of what is fixed is taken up into the plant. The remaining 50% is returned to the soil in crop residue or is in the roots and is released into the soil over the coming seasons. This does not mean it is available; it may become immobilized in the organic fraction. The portion returned at senescence is the nitrogen credit considered in nutrient management plans (PA Agronomy Guide 2007-2008, Table 1.2-7 and the Mid-Atlantic NM Handbook, 2006 Table 4.4. The data in the Mid-Atlantic Nutrient Management Handbook summarized the 2005 PA Agronomy Guide, 2005 Maryland Nutrient Management Manual, Sims and Gartley 1996, and VaDCR 2005). The calculation for adjusting nitrogen fixation downward when nitrogen is applied in the form of manure or fertilizer is:

2 * Nitrogen Credit + (ideal application rate – actual application rate) = amount of
N fixation as NH_3 (Lb/A)

The ideal minus the actual is only considered when the amount < 0.
Where the amount fixed is < 0, the lower bound is set to zero. It is not possible for a plant
to "unfix" nitrogen.

In New York, alfalfa is not persistent in years subsequent to planting. Within one to two
years after planting, an alfalfa field typically only has 50% alfalfa. Yet, it is reported by
the farmer to the Agricultural Census as an alfalfa crop. For this reason, New York alfalfa
was reduced by 50%.

The source of data for the soybean N fixation was based on a yield. For soybeans in
Delaware, a yield of 30 lbs/acre was used. This was based on the average yield from
Agricultural Census years between 1992 and 2002. For those states where fixation values
were not reported for a crop, data was used from the nearest state that did report a value.

Table 5-3: Legumes for which N fixation is calculated.

NASS Crop Type	CBP Land use	CBP Land use abbreviation
Alfalfa hay	alfalfa	Alf
Alfalfa seed	alfalfa	Alf
Birdsfoot trefoil seed	hay-fertilized	HYW
Dry edible beans, excluding limas	Conventional or Conservation Tillage with Manure	HWM or LWM
Green Lima Beans	Conventional Tillage without Manure	HOM
Peanuts for nuts	Conventional or Conservation Tillage with Manure	HWM or LWM
Peas, Chinese (sugar and Snow)	Conventional Tillage without Manure	HOM
Peas, Green (excluding southern)	Conventional Tillage without Manure	HOM
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc.	Conventional Tillage without Manure	HOM
Red clover seed	hay-fertilized	HYW
Snap Beans	Conventional Tillage without Manure	HOM

Soybeans for beans	Conventional or Conservation Tillage with Manure	HWM or LWM
Vetch seed	hay-fertilized	HYW

Table 5-4: NASS categories that include legumes, but are not exclusively legumes

NASS Crop Type	CBP Land use	CBP Land use abbreviation
Other tame hay	hay-fertilized	HYW
Pastureland and rangeland other than cropland and woodland pastured	pasture	PAS
Wild hay	hay-unfertilized	HYO

Table 5-5: Annual nitrogen fixation values for each crop and growth region

Growth Region	Watershed Model Land Use	Crop	N Fixed (lbs/acre)
DE_1	alfalfa	Alfalfa Hay Harvested Area	180
MD_1	alfalfa	Alfalfa Hay Harvested Area	300
MD_2	alfalfa	Alfalfa Hay Harvested Area	300
MD_3	alfalfa	Alfalfa Hay Harvested Area	300
NY_1	alfalfa	Alfalfa Hay Harvested Area	120
PA_1	alfalfa	Alfalfa Hay Harvested Area	240
PA_2	alfalfa	Alfalfa Hay Harvested Area	240
PA_3	alfalfa	Alfalfa Hay Harvested Area	240
VA_1	alfalfa	Alfalfa Hay Harvested Area	180
VA_2	alfalfa	Alfalfa Hay Harvested Area	180
VA_3	alfalfa	Alfalfa Hay Harvested Area	180
WV_1	alfalfa	Alfalfa Hay Harvested Area	180
DE_1	alfalfa	Alfalfa seed Harvested Area	180
MD_1	alfalfa	Alfalfa seed Harvested Area	300
MD_2	alfalfa	Alfalfa seed Harvested Area	300
MD_3	alfalfa	Alfalfa seed Harvested Area	300
NY_1	alfalfa	Alfalfa seed Harvested Area	120
PA_1	alfalfa	Alfalfa seed Harvested Area	240
PA_2	alfalfa	Alfalfa seed Harvested Area	240
PA_3	alfalfa	Alfalfa seed Harvested Area	240
VA_1	alfalfa	Alfalfa seed Harvested Area	180
VA_2	alfalfa	Alfalfa seed Harvested Area	180

Growth Region	Watershed Model Land Use	Crop	N Fixed (lbs/acre)
VA_3	alfalfa	Alfalfa seed Harvested Area	180
WV_1	alfalfa	Alfalfa seed Harvested Area	180
DE_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	120
MD_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	80
MD_2	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	80
MD_3	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	80
NY_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	180
PA_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	180
PA_2	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	180
PA_3	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	180
VA_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	160
VA_2	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	160
VA_3	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	160
WV_1	hay w/nutrients	Birdsfoot trefoil seed Harvested Area	160
DE_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
MD_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
MD_2	row w/manure	Dry edible beans, excluding limas Harvested Area	300
MD_3	row w/manure	Dry edible beans, excluding limas Harvested Area	300
NY_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
PA_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
PA_2	row w/manure	Dry edible beans, excluding limas Harvested Area	300
PA_3	row w/manure	Dry edible beans, excluding limas Harvested Area	300
VA_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
VA_2	row w/manure	Dry edible beans, excluding limas Harvested Area	300
VA_3	row w/manure	Dry edible beans, excluding limas Harvested Area	300
WV_1	row w/manure	Dry edible beans, excluding limas Harvested Area	300
DE_1	row w/manure	Peanuts for nuts Harvested Area	90
MD_1	row w/manure	Peanuts for nuts Harvested Area	90
MD_2	row w/manure	Peanuts for nuts Harvested Area	90
MD_3	row w/manure	Peanuts for nuts Harvested Area	90
NY_1	row w/manure	Peanuts for nuts Harvested Area	90
PA_1	row w/manure	Peanuts for nuts Harvested Area	90
PA_2	row w/manure	Peanuts for nuts Harvested Area	90
PA_3	row w/manure	Peanuts for nuts Harvested Area	90
VA_1	row w/manure	Peanuts for nuts Harvested Area	90
VA_2	row w/manure	Peanuts for nuts Harvested Area	90

Growth Region	Watershed Model Land Use	Crop	N Fixed (lbs/acre)
VA_3	row w/manure	Peanuts for nuts Harvested Area	90
WV_1	row w/manure	Peanuts for nuts Harvested Area	90
DE_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
MD_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
MD_2	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
MD_3	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
NY_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
PA_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
PA_2	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
PA_3	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
VA_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
VA_2	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
VA_3	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
WV_1	row w/o manure	Peas, Chinese (sugar and Snow) Harvested Area	300
DE_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
MD_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
MD_2	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
MD_3	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
NY_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
PA_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
PA_2	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
PA_3	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
VA_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
VA_2	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
VA_3	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
WV_1	row w/o manure	Peas, Green (excluding southern) Harvested Area	300
DE_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
MD_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
MD_2	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
MD_3	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
NY_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
PA_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300

Growth Region	Watershed Model Land Use	Crop	N Fixed (lbs/acre)
PA_2	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
PA_3	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
VA_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
VA_2	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
VA_3	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
WV_1	row w/o manure	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	300
DE_1	hay w/nutrients	Red clover seed Harvested Area	120
MD_1	hay w/nutrients	Red clover seed Harvested Area	80
MD_2	hay w/nutrients	Red clover seed Harvested Area	80
MD_3	hay w/nutrients	Red clover seed Harvested Area	80
NY_1	hay w/nutrients	Red clover seed Harvested Area	180
PA_1	hay w/nutrients	Red clover seed Harvested Area	360
PA_2	hay w/nutrients	Red clover seed Harvested Area	360
PA_3	hay w/nutrients	Red clover seed Harvested Area	360
VA_1	hay w/nutrients	Red clover seed Harvested Area	160
VA_2	hay w/nutrients	Red clover seed Harvested Area	160
VA_3	hay w/nutrients	Red clover seed Harvested Area	160
WV_1	hay w/nutrients	Red clover seed Harvested Area	160
DE_1	row w/o manure	Snap Beans Harvested Area	300
MD_1	row w/o manure	Snap Beans Harvested Area	300
MD_2	row w/o manure	Snap Beans Harvested Area	300
MD_3	row w/o manure	Snap Beans Harvested Area	300
NY_1	row w/o manure	Snap Beans Harvested Area	300
PA_1	row w/o manure	Snap Beans Harvested Area	300
PA_2	row w/o manure	Snap Beans Harvested Area	300
PA_3	row w/o manure	Snap Beans Harvested Area	300
VA_1	row w/o manure	Snap Beans Harvested Area	300
VA_2	row w/o manure	Snap Beans Harvested Area	300
VA_3	row w/o manure	Snap Beans Harvested Area	300
WV_1	row w/o manure	Snap Beans Harvested Area	300
DE_1	row w/manure	Soybeans for beans Harvested Area	30
MD_1	row w/manure	Soybeans for beans Harvested Area	40

Growth Region	Watershed Model Land Use	Crop	N Fixed (lbs/acre)
MD_2	row w/manure	Soybeans for beans Harvested Area	40
MD_3	row w/manure	Soybeans for beans Harvested Area	40
NY_1	row w/manure	Soybeans for beans Harvested Area	130
PA_1	row w/manure	Soybeans for beans Harvested Area	130
PA_2	row w/manure	Soybeans for beans Harvested Area	130
PA_3	row w/manure	Soybeans for beans Harvested Area	130
VA_1	row w/manure	Soybeans for beans Harvested Area	40
VA_2	row w/manure	Soybeans for beans Harvested Area	40
VA_3	row w/manure	Soybeans for beans Harvested Area	40
WV_1	row w/manure	Soybeans for beans Harvested Area	40
DE_1	hay w/nutrients	Vetch seed Harvested Area	300
MD_1	hay w/nutrients	Vetch seed Harvested Area	300
MD_2	hay w/nutrients	Vetch seed Harvested Area	300
MD_3	hay w/nutrients	Vetch seed Harvested Area	300
NY_1	hay w/nutrients	Vetch seed Harvested Area	300
PA_1	hay w/nutrients	Vetch seed Harvested Area	300
PA_2	hay w/nutrients	Vetch seed Harvested Area	300
PA_3	hay w/nutrients	Vetch seed Harvested Area	300
VA_1	hay w/nutrients	Vetch seed Harvested Area	200
VA_2	hay w/nutrients	Vetch seed Harvested Area	200
VA_3	hay w/nutrients	Vetch seed Harvested Area	200
WV_1	hay w/nutrients	Vetch seed Harvested Area	200

Erodible Area

Scenario Builder calculates the area of land available to be eroded. The area of bare soil is considered the amount available to be eroded. Therefore, we estimate the fraction of residue cover and canopy cover and assume the remainder is available for erosion. Residue and canopy cover are calculated using the Revised Universal Soil Loss Equation modeling tool (RUSLE 2 Version 1.26.6.4, Nov. 13, 2006). It should be noted that residue and canopy cover do not directly correlate to the percentage of bare ground and that neither of these values used alone or the values used in combination are the same as the percentage of the ground covered. However, we were able to achieve realistic results in a consistent manner across the entire Chesapeake Bay Watershed.

The greater of the two variables, residue cover and canopy cover, were used on a monthly time scale. An underestimation may result in early plant growth period for low till crops because residue may still be on the ground and leaf cover may not overlap. This is not an

issue for high till crops where most of the residue is plowed under at planting. This calculation is bound where the monthly value is greater than zero and less than 0.95. An alternative method of summing the residue and canopy cover was tested. This method provided less accurate results because canopy shades residue.

In general, the data are not representative of any individual site or situation. In addition, the data are not reflective of typical crop rotations used in the watershed. RUSLE 2 values should not be averaged. The planting dates used influence when the canopy cover numbers change. RUSLE 2 can show growth at any time of year, even if a crop will not grow at that time of year or in a given area. All data was generated without applying any other conservation practices or methods.

Variations in residue and canopy cover exist due to climatic variation, yields, tillage, and double cropping. How each of these variables was handled will be discussed in the following sections.

Spatial differentiation

The NRCS Crop Management Zones (CMZs) were used for generating the data (Figure 5-2). The data in the CMZs are representative of typical planting dates and yields that are possible for a crop in the area. If more than one yield was available for a crop, a moderate yield was used. The information included in the CMZs is periodically updated and may vary from the information used in a different version. The templates used were those available in RUSLE 2 as of January 2009.

More than one Scenario Builder Growth Region may be represented by the same data set. Scenario Builder Growth Region MD 2 was divided into two areas—one east of the Bay and one west of the Bay. In the initial preparation of the dataset, the MD 2 East values were used for the entire MD 2 growing region. Quality control and assurance are being performed in summer 2009 as the data are more carefully being prepared for use. These generalizations will be removed as part of that process. 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.
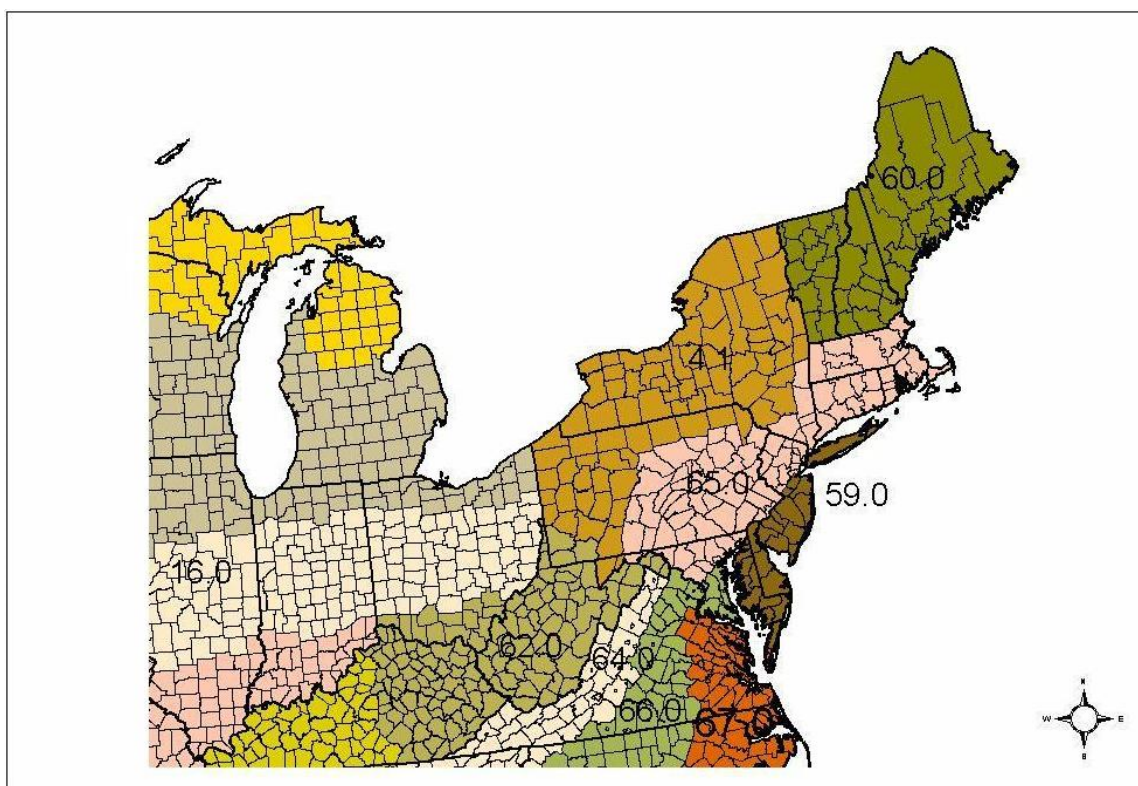
Figure 5-2: RUSLE 2 Crop Management Zones

Tillage

One of the most important variations in erodible land data is in the tillage practice. The Chesapeake Bay Program currently recognizes two different tillage practices: low till and high till. Low till is generally equated as conservation till and high till is generally equated with conventional till. NRCS Practice Standard 345 for Residue Management Mulch Till states, "The annual Soil Tillage Intensity Rating (STIR) value for all soil-disturbing activities shall be no more than 70 for high residue crops (e.g., grain corn) and no more than 10 for low residue crops (e.g., grain, soybeans). These STIR values will result in approximately 30% or more surface residue for the entire crop rotation." By using the RUSLE 2 tillage management practices, the data necessarily meets the conservation tillage STIR values. Conventional establishment was usually represented by moldboard plowing and conservation tillage was usually represented by no-till planting methods as appropriate to the crop. The tillage method has minimal impact on the crop canopy but a major impact on the residue.

Continuous monoculture

The RUSLE 2 single year crop templates were used for annual crops and a non-establishment year was used for perennial crops. When using continuous monoculture, RUSLE 2 assumes a one-year rotation, where the same crop is grown with the same method year after year. This will potentially underestimate residue for fragile residue crops and overestimate residue for coarse residue crops. This is especially true in low till systems. In most places in the Chesapeake Bay Watershed, crops are not typically grown in a continuous fashion. Usually crops are grown as part of a rotation. This process of

single crops is particularly limited for fruit and vegetables, which may have several crops in the same year. There are also differences in the timing and staggering of planting of fruit and vegetable production for direct sale versus processing purposes.

Data generalizations among crops

Where there were missing data for a particular crop in a particular growing region, values from the nearest growing region 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 value generated from RUSLE 2 and 0.95 was used for the entire year (per G. Shenk, personal communication). 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. Many nursery crops that are grown out in the open used a consistent value of 0.5.

Pasture

Pasture cover data should be regarded with special care and considered as general guidance. Pastures vary greatly in management and grazing frequency and this variability is much greater than the management options in agronomic fields. The grazing variability particularly impacts canopy cover. Because of this management and impact variability, there are many limitations to using pasture cover values from RUSLE 2. RUSLE 2 is scheduled to be updated in late 2009 to better represent pastures. Other options for addressing pasture cover may involve summing the residue and canopy cover rather than selecting the greater of the two for any given date. This option may be explored for a later release of Scenario Builder.

Double cropping

Double cropping cover is addressed by classifying a double-cropped crop as its own crop type with different plant and harvest dates than the same crop that is not double-cropped. Since the first crop planted is not considered as the double-crop, then those dates are not shortened to reflect what may be an earlier harvest. Therefore, there may be some overestimate of cover from leaf area coverage and an underestimate of residue cover during the harvest time of the first crop and the planting time of the double crop. Cover values for double cropping are the same as single crops. Variation is addressed by differences in plant and harvest dates.

Crop harvest yield-informed parameters

Crop harvest yield data are used indirectly to inform nutrient application rates and uptake. Crop harvest yield data are not a direct output of Scenario Builder. Yield data are selected from the NASS Agricultural Census for each crop modeled in Scenario Builder and the years 1982, 1987, 1992, 1997, 2002. Yield data are used to introduce variability due to geographical yield differences, such as those from soils.

A ratio is calculated for the difference between an average of actual yields and the typical yield over the period 1982-2002. This ratio is then used to adjust the uptake and application rates. The ratio is calculated for each county over the years on record where:

Average actual yield / typical yield

The typical yield data is drawn from each state's nutrient management manuals and agronomy manuals for optimal soil conditions. This typical yield reflects the regional management and climatic variations. These yields are generally maximum possible given best soil and best weather conditions.

Plant uptake

Uptake is the amount of N and P taken from the soil into the plant. It includes the amount that would be removed with a harvest as well as the amount in the roots and shoots, which is in contrast with many other models that only examine crop removal. Scenario Builder calculates three sets of data for uptake:

1. Total uptake / county / year / crop or plant type

2. Fraction taken up each month / county / year / crop or plant type

3. Watershed Model – HSPF calibration input file: Average nutrient uptake over entire modeling period on average crop and land areas

Total plant uptake

Total plant uptake is calculated in terms of percent by month for each crop type. There are no differences in uptake for nutrient management or tillage practices. The Scenario Builder introduces variability due to geographical yield differences such as those from soil. Actual uptake is not used as an input to the Watershed Model. Rather, the maximum potential uptake is reported. Therefore, any variation in uptake from Scenario Builder is the result of variation in crops planted and average regional variations, not annual growth conditions. The average actual yield, which is used in the ratio described above, is calculated as a *maximum potential yield* (Shapiro et al., 2003):

> Highest yield from any year + 0.05

Averaging yield in this way gives the maximum potential yield, from which maximum potential uptake is calculated. It was designed thus so that the Watershed Model could decrease the uptake using temperature, rainfall, and other parameters. *Maximum potential uptake* is calculated where:

> (Maximum potential yield / typical yield) * Theoretical maximum uptake

Should there be missing data such that the theoretical maximum yield is null, then the yield ratio is set to one. If the theoretical maximum yield is zero, then the yield ratio is set to zero. The maximum uptake is calculated as total nitrogen or total phosphorus in units of uptake/month/yield unit.

The theoretical maximum uptake is taken from crop removal data and doubled to represent the whole plant, unless other data indicated differently (as with corn at 2/3 in removal). Uptake values for crops grown for silage are used directly without doubling since most of the plant is harvested.

The data are produced on a monthly basis. Uptake only occurs in months where the plants are growing. Uptake only occurs between the plant and harvest dates. For those crops that over winter, the data are reflected in the appropriate month of the same year. This is

because there is no interaction among years and each year stands on its own in Scenario Builder.

An improved method of preparing these data is underway. Additional data on uptake were identified (Meisinger and Randall, 1991). These data are being prepared for incorporation in the database as of June 2009.

Fraction of uptake per month

The fraction of the annual uptake mass is calculated on a monthly basis for each of the 12 growing regions using the recommended plant date. This does not account for the range of varieties used throughout the watershed. The curve information was informed by normalizing empirical data from peer-reviewed research to a fraction of the total uptake / month. For each crop type where measurements were available, the normalized data were averaged. Uptake fraction per month was generalized to all the crop types modeled in Scenario Builder from the peer-reviewed research data on corn, soybeans, and winter wheat.

Improved methodology is being used for informing the curves. The timing of uptake should be based on the average temperature. Thus, heat units and the number of growing degree days establish plant growth stages. The growing degree days are calculated as:

(Temperature Minimum + Temperature Maximum) / 2 – crop basal unit

The basal unit for corn is generally accepted as 50 degrees F. There are established basal units for most crops that are modeled in Scenario Builder. Since development is faster when temperatures are warmer, and slower when temperatures are cooler, then the use of growing degree days more closely informs the timing of nutrient uptake. Moreover, maturity dates for crops change by variety. In the Scenario Builder, we do not have various varieties of crops. The heat units serve to approximate the uptake for crops even without varietal differences being specified. Data using these methods is being prepared as of June 2009.

Calibration input data

Average data are produced for calibrating the Watershed Model. This set of data averages the actual yields for each crop over the entire period on record. Since this set of data must be applied to a land and crop area, the average area of each crop over the same period of record is also calculated. Thus, the data is produced as uptake (lbs) / acre.

Nutrient Application Rate

The application rate sets the amount of nutrients to be applied. This rate does not inform the source of those nutrients. Thus, nutrients may be sewage sludge, manure, or inorganic fertilizer. Note that if there is manure in excess of the application rate, the manure will be disposed of on some plant or crop type in the Scenario Builder model. So, the nutrient application rate is idealized and is not based on the actual amount of nutrients available.

Each year is modeled independently. This means that Scenario Builder does not model situations where a farmer put less nutrients on a crop because the previous season's crop failed. In addition, Scenario Builder does not account for the likelihood that higher value

crops may receive more nutrients than lower value crops, regardless of nutrient management.

The nutrient application rate varies depending on whether the crop is under a nutrient management plan or not. Those areas that are not under a nutrient management plan do not have the adjustment for yield goal history. Thus, the areas not under nutrient management generally have a higher application rate. These nutrient application rates are taken from each states agronomy guide or nutrient management recommendations for optimum soil conditions. These state recommendations include an estimate of nitrogen from atmospheric nitrogen deposition.

The nutrient application rate calculation for nutrient management is informed by the same yield ratio concept as was used in the plant uptake calculation. However, the average actual yield, which was generally discussed in the introduction to this section and is used in the yield ratio, is calculated as a *maximum potential yield* and is different than the calculation of this variable for uptake. This *maximum potential yield* is calculated according to the nutrient management recommendations for each state where available. Nutrient management planners typically use soil test data for determining application rates. However, soil test data is not available on a county scale throughout the watershed. Where soil test data are not available to nutrient management planners, on-farm yield records are used. Should an on-farm yield record be unavailable, then regional databases or the Agricultural Census is used. In Scenario Builder only the Agricultural Census is used, because it is the only available data currently. Each state is calculated differently.

> *Delaware*: average of the highest four of seven yields from the agricultural census. If less than seven agricultural censuses are available, use as manure are available as long as there are greater than four.

> *Maryland*: average the highest 60% of the available agricultural censuses.

> *New York, Pennsylvania, District of Columbia, West Virginia, Tennessee, and North Carolina*: average the highest three of five yields from the agricultural censuses.

Nutrient management application rate is calculated where:

(Maximum potential yield / typical yield) * Non-nutrient management application rate

Methods of application are not modeled differently. Methods of application include side-dress, pelletized, coated or other slow-release fertilizers, injected, or disked-in. Equipment availability, custom, and emerging technology all introduce a degree of variability that is difficult to generalize to the county scale.

The recommendations from each state's agronomy guide or nutrient management handbook were not complete for all of the crops modeled in Scenario Builder. Some generalizations were made among crops and geographic regions (Table 5-6).

Table 5-6: Nutrient application rate data generalizations

Growing Region	Crop	Generalization, source of data
DC 1	All crops	uses same values as MD

WV 1	All crops	uses same values as PA
NY 1	all hay with nutrients	Chenango County was used for calculations for nitrogen in grasses. Average yield was 75 T/A.
All regions	All seed crops	Used the theoretical maximum yield calculated from the census-reported yields and acres. For the years with missing data, used the average of the years with data. Delaware was missing all years so used MD data.
All regions	Aquatic plants	Used Maryland's published data
All regions	Bedding/garden plants	Used Maryland's published data
All regions	Bulbs, corms, rhizomes, and tubers,	Used Maryland's published data
All regions except DE	Canola	Used MD published information which correlated to http://www.ag.ndsu.edu/pubs/plantsci/crops/a1280.pdf
All regions	Cropland on which all crops failed or were abandoned	Set application rate to 50 lbs of N and P
All regions	Cut flowers and cut florist greens	Used Maryland's published data
DE	fescue, orchard grass, and other field and forage	Used millet-sudangrass.
All regions	Foliage plants	Used Maryland's published data
All regions	Greenhouse vegetables	Used Maryland's published data
All regions	mushrooms	Spent mushroom substrate nutrient content from Penn state: http://spentmushroomsubstrate.turfgrass.psu.edu/links.cfm. Amount/acre assumes maximum amount is 10,000 lbs of spent mushroom substrate per acre, 2% N and 1% P per lb. Peter Shenderschoot, Penn State, personal communication, 1/9/2009
All regions	Nursery stock	Used Maryland's published data
All regions	Other nursery and greenhouse crops	Used Maryland's published data
All regions	Peanuts	Used Virginia's recommendations

All regions	Potted flowering plants	Used Maryland's published data
All regions	sod	Used Maryland's published data
NY 1, PA 1, PA 2, PA 3	Sunflower seed	used MD yields and NY app rates
MD 1, MD 2, MD 3, DC, NY, PA 1, PA 2, PA 3, WV	Tobacco	Advised by Dave Conrad, MD Tobacco Extension Specialist. Use Type 32, light air cured. Verified application rate in extension publications.
VA 1, DE	Tobacco	Used burley tobacco recommendations from Virginia
All regions but VA 1, VA 2, VA 3	Turf grass (urban lawns)	100 lbs N/A, 50 lbs P/A based on ratio of difference from HGIC Master Gardeners and the Phase 4.3 rate for N. (For Virginia, used actual recommendation.)
All regions	Vegetable and flower seeds	Used Maryland's published data
All regions	vegetables	MD vegetable values used where not available for other states.

There are several special cases for application rates. Pasture land uses used by the Watershed Model-HSPF include the following classifications: Nutrient Management Pasture, Pasture, and Trampled Riparian Pasture. Trampled Riparian Pasture has an application rate set as:

9 * pasture land use rate

The purpose of this is to reflect the proclivity of cattle to spend more time in riparian areas. The implication is that more manure is directly deposited in these areas.

SECTION 6. BEST NUTRIENT MASS LOADING WITH TEMPORAL AND SPATIAL CHARACTER

Nitrogen and phosphorus are applied to crops, pasture, and turf in urban areas according to plant growth requirements. The plant growth requirements were established as application rates, discussed in SECTION 5: 0 above.

Nutrient loading would equal nutrient application were the Chesapeake Bay Watershed in perfect balance between plant growth need and available nitrogen and phosphorus. However, in some areas there is more manure produced than is needed by the crops even under optimal growing conditions. In these cases, manure may be moved to a neighboring county or over-applied simply as a way to dispose of the excess manure.

Scenario Builder applies nutrients in a sequence, intended to mirror the applications in order of unavoidable, highest priority, and then least damaging from an economic point of view. The unavoidable is the amount of manure that goes on pasture that is directly excreted from the animals. The highest priority applications are those that are high-value crops and would be a priority for a farmer. Lastly, manure may be applied simply as a way to dispose of excess. We assume that a farmer will do this application in such a way as to avoid harming crops. Nutrient over application could cause lodging in grains or other harmful effects on plants. This is least likely to occur on hay and pasture crops so application greater than plant need may occur where excess manure is produced.

The sequence of nutrient application is described in order in the following sections.

Manure Applied to Animal Production Areas

The sum of the manure that was removed due to storage loss is applied to land in the Watershed Model-HSPF land use classification as Animal Feeding Operation (AFO). These areas are considered the animal production areas. The manure is applied evenly across months and the data on the amount of manure from each animal type is kept distinct. Manure is applied to AFO in the county in which it was produced. There is no transport of manure calculated from storage loss.

Manure Applied through Direct Excretion

Manure is applied to pasture according to the amount of animals in a county and the amount of time that animal type spends in the pasture. These data are calculated on a monthly time scale for each county, keeping animal type distinct.

Even where there are animals in a county that typically would be pastured, if there are no pasture acres in that county, then there is no manure applied as direct excretion. Therefore, all of that animal type's manure will be stored and applied to cropland.

Manure applied via direct excretion is not considered as a component meeting the application rate. For example, if the application rate for a pasture were 25 lbs-N/A and there were a herd of beef cattle pastured all the time on that land, then the amount of direct excretion on that land would not contribute toward meeting that 25 lb-N/A rate. If the herd is large enough and in the pasture a lot of the time, then a lot of manure would be directly excreted. On top of the direct excretion, the 25 lb-N/A would also be applied.

Stored manure may augment the manure directly excreted on pasture, but direct excretion can only be applied to pasture and not other land uses. Livestock are sometimes foraged on harvested crop land. In Scenario Builder, we do not account for direct excretion of livestock on harvested crop land. The amount of time livestock are on this land is insignificant (Doug Goodlander, Pennsylvania, personal communication, 2008). Moreover, NASS data does not track this item and no source of data on the number of livestock or days livestock spend on these lands was available.

Starter Fertilizer Application

Starter is specified by crop type, county, and timing. Applications applied at the same time as planting generally were assumed to be starter. Since it is unlikely that manure is applied at the same time that seeds are planted, starter is always classified as inorganic fertilizer. Many crop types have split applications and other applications may be manure. Starter fertilizer is considered a portion of the total amount applied toward meeting the application rate.

Sewage Sludge Application

Sewage sludge, or biosolids, is applied next in the sequence of nutrient applications. Note that the source of sewage sludge data is from each state in the watershed. As of September 2008, the only state that had provided biosolid data was Virginia.

Sewage sludge data is provided with the amount in an annual total. This annual amount is proportioned across the months based on the unmet amount in the application rate. A crop is eligible to receive sewage sludge if it is on a land use that is eligible to receive manure.

The crop type, nutrient type, and month are all kept distinct throughout this calculation. If there is remaining sewage sludge remaining after the application rate is met, then an error is logged with the amount of sewage sludge that could not be applied and reported to the user.

A modification to apportion the sewage sludge to various crops with a preference toward certain months that changes prior to 1997 was not implemented as of June 2009.

Manure Application

Manure follows next in the sequence of application. A crop may receive manure if it is a crop specified as a type that is eligible to have a manure application. Fruits and vegetables are among those that are not eligible to receive manure, for example. A crop is

also eligible to receive manure if the application rate was not already met by direct excretion, starter, or sewage sludge. The amount of manure available to be applied is:

Manure produced – volatilization – storage loss – direct excretion = available manure

This manure is assumed to have been stored. Data are unavailable on the type and capacity of manure storage facilities throughout the Chesapeake Bay Watershed. Therefore, manure is available by an annual total. We assume that manure is applied only when the crop could utilize the nutrients. It follows that manure storage is available to handle the volume produced until applied. Manure is applied based on nutrient application rates and optimal crop use based on regional planting dates.

The annual amount of stored manure is proportioned across the months based on the unmet application rate amount. Manure is a limited nutrient, so it is applied in a priority order. The priority order is determined by crop sets. That is, crops are grouped into sets, and all crops in the first set receive manure nutrients prior to the subsequent set of crops. Where there is not enough manure to meet the application rate in any one set, then the manure is proportioned evenly among the crops in that crop set. This is calculated such that if crop A and crop B comprise crop set 1, and there is not enough manure to meet the full application rate of crops A and B, then whatever proportion of available manure is set to meet the same fraction of the application rate for crops A and B even though those application rates may differ.

Likewise, manure is proportioned over months where there is inadequate amount to meet the full application rate.

Crop, animal type, nutrient, and month are all kept distinct when tracking this data.

Transport of Manure in Excess of Application Rate

Manure is more likely to be applied in the county in which it was produced. Should excess manure be available after all application rates are met, then manure is eligible for transport. This transport function is not the same, and is in addition to any manure transport reported by the Chesapeake Bay Program's regional partners as a best management practice.

Manure is transported only to another county if it shares a county border and is in the home state. Manure may not be transported across state lines in this function. Only counties that have excess manure after meeting the application rate are eligible for transport. The order in which counties transport within a state is based on the greatest amount of excess manure. Manure is transported to all adjacent counties proportionally based on adjacent counties remaining application mass need. That is, if an adjacent county does not have enough manure to meet its application rates, then manure will be transported to it. Transported manure is spread the same way stored manure is spread. If a county cannot transport all of its excess manure to adjacent counties, the remainder goes to disposal load in the home county.

Disposal of Manure beyond Meeting Crop Application Rate

Manure that exceeded the application rate in the county in which it was produced as well as any adjoining county is classified as disposal load. Disposal load manure is applied to crops at ten times the application rate in a series based on the Watershed Model-HSPF land uses. The series is:

1. Non nutrient management pasture (PAS)
2. trampled riparian pasture (TRP)
3. hay with nutrients (HYW)
4. non nutrient management row w/manure (HWM, LWM)

If there is still excess after applying to all of these crops on these land uses, then an error is logged with the amount of disposal load that could not be applied.

The amount applied is proportioned across the months equally. The monthly allocation for each crop in the land use(s) is applied based on the proportion of acres in the crop to the total acres of the crops in the land use(s).

Inorganic Fertilizer Application

Inorganic fertilizer is applied last in the sequence of nutrient application. Where the application rate has not already been met, then inorganic fertilizer is applied to meet the application rate. It is not a limited nutrient and is never under or over-applied.

Chemical fertilizer is assumed to be mixed to specification. If N was met through manure, then chemical fertilizer containing only P may be applied. This is a more precise use of chemical fertilizers than may be typical in the Chesapeake Bay Watershed.

For urban lawns, or turf grass, the nutrients are only applied to the urban lawn areas that are in low intensity pervious urban and high intensity pervious urban land uses. However, the turf grass area was calculated using GIS methods that included the construction land use.

Nitrogen or Phosphorus-Based Nutrient Plan

Manure nutrients may be applied on either an N or P-based nutrient management plan. Depending on whether an N or P-based plan is selected, then the opposite nutrient (P for an N-based plan) may be over or under applied depending on manure content of an animal type and crop application rate requirements.

Manure and biosolids are applied on an N-based plan for calibration of the Watershed Model-HSPF. The nitrogen application mass is compared to the plant available nitrogen applied. Phosphorus can be over or under applied. Remaining phosphorus need is only considered when applying fertilizer.

Comparison of Manure and Inorganic Fertilizer Application Amounts

Mineralization

A portion of manure N and P is mineralized. The portion of organic N and organic P mineralized during the first year is included in the calculation of plant available nutrients. The other portion of the manure, which includes organic N that is not mineralized, is applied to the land as well.

This means that an acre of corn with an application rate of 100 lb-N/A will receive different masses of N depending on the nutrient source. If there are no animals in that county, then the corn acre will receive 100 lb of TN in the form of inorganic fertilizer. If there are all broilers in that county, then the corn acre will receive 148 lb of TN. The inorganic fertilizer composition is 75 lb NH_3 and 25 lb NO_3. The broiler manure is 0.26 lb NH_3/lb manure, 0.43 lb organic N/lb manure, 0.65 lb mineralized N/lb manure, and 0.0 lb NO_3/lb manure (Table 6-1). The nitrogen application rate is met through the nutrient forms of NH_3, mineralized N, and NO_3. The organic N is also applied, but not counted toward the application rate.

Table 6-1: Nutrient comparison of fertilizer and broiler manure

Nutrient	Fertilizer	Broiler manure (lb-nutrient/lb-manure)
NH_3	0.75	0.0026
Organic N	0	0.0043
Mineralized N	0	0.0065
NO_3	0.25	0

Crop Sets

The nutrients are applied to crops, which may be configured in sets; each set may have a member of one crop, or may be grouped so that many crops comprise one set. Sets can be configured so they are comparable to Watershed Model-HSPF land uses. Application of the nutrients within each nutrient type category (starter, biosolids, manure, and/or fertilizer) is proportional among the crops in each set where the nutrient is limited. Limited nutrients are biosolids and manure.

The crops are grouped so that each crop within a set receives nutrients as a group rather than sequentially within each set. The implication is that if there is only enough manure, for example, to meet the 20% of the nutrient application rate, then the other 80% will be met by fertilizer. Since this is done as sets, then each crop within the set each receives 20% of its nutrient application rate as manure and 80% as fertilizer rather than one set receiving primarily manure and the others receiving primarily fertilizer. The next set in the sequence would not have any manure available. The percent application is the same for crops within a set as well as for the months within that year.

Inflation of Nutrient Management Land Applications under Certain Circumstances

The Watershed Model-HSPF Phase 5.2 was calibrated with crops grouped into sets that matched the Watershed Model-HSPF land uses. Since land uses are distinguished by nutrient management, and the crop sets were grouped so that nutrient management land uses were first in the sequence, then the nutrient management land was more likely to have manure applied than inorganic fertilizer. This, combined with the mineralization factor, means that the total nutrients applied on nutrient management land appear higher than those on non-nutrient management land even though the application rate is higher for non-nutrient management land.

Septic load

Septic systems are commonly designed so that the waste goes into a tank, where solids sink to the bottom, and liquids flow through to a septic field (that greener area in a septic homeowner's lawn). While some P can become soluble, we assume that only N is distributed to the septic field.

Using the average household size and the number of septic systems on a land-river segmentation scale, we apply a value of 8.92 lbs-N / person / year and assume a 60% attenuation rate. This is calculated as no. of people * 8.92 lbs-N / person * 0.40.

The number of septic systems and average household size originally came from the 1990 Census (people census, not animal census). The number of septic systems question was not asked in subsequent censuses. Therefore, we use the ratio of the number of people in a county on septic to the total number of people in the county from 1990 and apply that ratio to later years' population data. The number of people in a county on septic is determined from the average of the household size.

SECTION 7. APPORTIONING DATA TO THE WATERSHED MODEL - HSPF SEGMENTATION AND LAND USE CLASSIFICATIONS

The Scenario Builder model performs calculations at a county scale. Output may also be delivered at the Watershed Model-HSPF scale (Figure 7-1). Data is narrowed to the Watershed Model-HSPF scale using an area weighted average. Methods for creating the land use data and apportioning it to the Watershed Model-HSPF scale are described in detail in the following sections.

Figure 7-1: Scale of Watershed Model-HSPF Phase 5 Output. Each segment has up to 25 land uses.

Using Land Cover Data to Create the Land Use Data

Land cover data are integrated and used to inform the area in each land use for each of the Watershed Model-HSPF's segments. These calculations are performed in the Chesapeake Bay Land Change Model (CBLCM) developed by P. Claggett, 2008. The CBLCM forecasts the proportional future growth in urban land and resulting proportional loss of forests and agricultural for each Watershed Model segment. These segments are named land river segments, or lrsegs.

For each Watershed Model segment, the proportional increase in total urban area is distributed proportionally to the five urban land uses reported for the base year of the forecast. For example, a forecasted growth of 100 urban acres from 2002 to 2010 in LRseg *x* should be distributed to the five urban land use classes in LRseg *x* reported in the 2002 land use dataset used as part of the Phase 5.2 calibration. The resulting increase in total urban area is then subtracted from the total of all forest land uses (e.g., forests + harvested forests) and from the total of all agricultural land uses reported in the 2002 land use dataset for LRseg *x*.

All of the proportions of urban, forest, and agricultural land uses relative to the total urban, total forest, and total agricultural land uses are kept constant through time. However, an iterative mass balance routine must be implemented to maintain total land acres in each LRseg while preventing any one land use (e.g., hay with manure) from falling into negative acres. Negative land use acres must be redistributed to other related land uses. For example, if "hay with manure" is forecasted to fall below zero acres in year 2010 then "hay with manure" must be set to zero and the deficit acres subtracted proportionally from all remaining agricultural land uses. This correction must be run iteratively until all land uses contain zero or more acres. Note that Animal Feeding Operations, Extractive, Nursery, and Open Water were kept constant throughout the forecast period.

Determining the Agricultural Land Use Area

The agricultural land use area is taken directly from the National Agricultural Statistics Service's Agricultural Census. The data in Chapter 1 of these Censuses informs the area of agricultural land. The CBLCM informs urban area, and projects land use area into the future, but the Agricultural Census data on agricultural area is not altered for historical years in the CBLCM.

Assembling Land Use Data from Multiple Data Sets

Agricultural land use area is set from the Agricultural Censuses. The total segment area and water areas are never changed. Other land use areas may be changed to accommodate the segment area, agricultural areas, and water areas. This is done in a recursive procedure in a set order. Forest is found by subtraction from all other calculated areas.

Determining Crop Areas on Each Land Use

The Watershed Model-HSPF, Phase 5.2 uses 25 land use categories. Of these, 11 are aggregated crop types, three are pasture, and one is animal feeding operation (AFO). AFO and one of the pasture types (TRP) are created by subtracting a set percentage from pasture as reported by the agricultural census.

All calculations in the Scenario Builder are at the crop level. The Scenario Builder may accommodate infinite crop types. For the Watershed Model-HSPF Phase 5.2 calibration, most of the crops reported in the NASS Agricultural Census are used (exceptions include ginseng and dried herbs).

For data reported to the Watershed Model - HSPF, the crops are summed into Watershed Model land uses. The matrix of which crops fall into Watershed Model land categories is in Table 7-1. The Watershed Model land uses have nutrient management and conservation vs. conventional tillage analogues for most of the land categories in the matrix. The nutrient management and tillage analogues only affect how many acres are in each land use, not which crop is in each land use and are not reported separately in Table 7-1: Crops and the land use to which they are applied. The land uses that have nutrient management analogues include: alfalfa, row with manure, row without manure, hay with nutrients, and pasture. The land uses that have low-till (conservation) tillage analogues include: row with manure and nutrient management row with manure.

Table 7-1: Crops and the land use to which they are applied

Crop id	Crop name	Major land use name
178	Wheat for Grain Harvested Area	Row with manure
182	Winter wheat for grain Harvested Area	Row with manure
166	Triticale Harvested Area	Row with manure
141	Sorghum for Grain Harvested Area	Row with manure
143	Sorghum for silage or greenchop Area	Row with manure
145	Soybeans for beans Harvested Area	Row with manure
153	Sunflower seed, non-oil varieties Harvested Area	Row with manure
155	Sunflower seed, oil varieties Harvested Area	Row with manure
130	Rye for grain Harvested Area	Row with manure
112	Peanuts for nuts Harvested Area	Row with manure
119	Popcorn Harvested Area	Row with manure
94	Oats for grain Harvested Area	Row with manure
87	Mushrooms Area	Row with manure
88	Mushrooms Protected Area	Row with manure
99	Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area	Row with manure
10	Barley for grain Harvested Area	Row with manure
27	Canola Harvested Area	Row with manure
35	Corn for Grain Harvested Area	Row with manure
37	Corn for silage or greenchop Harvested Area	Row with manure
23	Buckwheat Harvested Area	Row with manure
50	Dry edible beans, excluding	Row with

	limas Harvested Area	manure
54	Emmer and spelt Harvested Area	Row with manure
56	Escarole and Endive Harvested Area	Row without manure
52	Dry Onions Harvested Area	Row without manure
53	Eggplant Harvested Area	Row without manure
46	Cucumbers and Pickles Harvested Area	Row without manure
47	Cut Christmas Trees Production Area	Row without manure
48	Cut flowers and cut florist greens Area	Row without manure
25	Bulbs, corms, rhizomes, and tubers – dry Harvested Area	Row without manure
39	Cotton Harvested Area	Row without manure
29	Cantaloupe Harvested Area	Row without manure
30	Carrots Harvested Area	Row without manure
31	Cauliflower Harvested Area	Row without manure
32	Celery Harvested Area	Row without manure
33	Chinese Cabbage Harvested Area	Row without manure
34	Collards Harvested Area	Row without manure
14	Beets Harvested Area	Row without manure
15	Berries- all Harvested Area	Row without manure
19	Broccoli Harvested Area	Row without manure
12	Bedding/garden plants Area	Row without manure
9	Asparagus Harvested Area	Row without manure
7	Aquatic plants Area	Row without manure
107	Other nursery and greenhouse crops Area	Row without manure
22	Brussels Sprouts Harvested	Row without

	Area	manure
109	Parsley Harvested Area	Row without manure
89	Mustard Greens Harvested Area	Row without manure
90	Nursery stock Area	Row without manure
96	Okra Area	Row without manure
84	Land in Orchards Area	Row without manure
86	Lettuce, All Harvested Area	Row without manure
78	Head Cabbage Harvested Area	Row without manure
79	Herbs, Fresh Cut Harvested Area	Row without manure
80	Honeydew Melons Harvested Area	Row without manure
81	Kale Harvested Area	Row without manure
64	Foliage plants Area	Row without manure
68	Garlic Harvested Area	Row without manure
69	Green Lima Beans Harvested Area	Row without manure
70	Green Onions Harvested Area	Row without manure
121	Potatoes Harvested Area	Row without manure
123	Potted flowering plants Area	Row without manure
114	Peas, Chinese (sugar and Snow) Harvested Area	Row without manure
115	Peas, Green (excluding southern) Harvested Area	Row without manure
116	Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area	Row without manure
117	Peppers, Bell Harvested Area	Row without manure
118	Peppers, Chile (all peppers – excluding bell) Harvested Area	Row without manure
134	short-rotation woody crops	Row without

	Harvest Area	manure
135	short-rotation woody crops Production Area	Row without manure
125	Pumpkins Harvested Area	Row without manure
126	Radishes Harvested Area	Row without manure
157	Sweet Corn Harvested Area	Row without manure
158	Sweet potatoes Harvested Area	Row without manure
147	Spinach Harvested Area	Row without manure
148	Squash Harvested Area	Row without manure
168	Turnip Greens Harvested Area	Row without manure
169	Turnips Harvested Area	Row without manure
170	Vegetable & flower seeds Area	Row without manure
138	Snap Beans Harvested Area	Row without manure
139	Sod harvested Area	Row without manure
162	tobacco Harvested Area	Row without manure
164	Tomatoes Harvested Area	Row without manure
173	Vegetables, Mixed Area	Row without manure
174	Vegetables, Other Harvested Area	Row without manure
129	Rhubarb Harvested Area	Row without manure
177	Watermelons Harvested Area	Row without manure
175	Vetch seed Harvested Area	Hay with nutrients
160	Timothy seed Harvested Area	Hay with nutrients
127	Red clover seed Harvested Area	Hay with nutrients
136	Small grain hay Harvested Area	Hay with nutrients
132	Ryegrass seed Harvested Area	Hay with

		nutrients
97	Orchardgrass seed Harvested Area	Hay with nutrients
101	Other field and grass seed crops Harvested Area	Hay with nutrients
103	Other haylage, grass silage, and greenchop Harvested Area	Hay with nutrients
105	Other managed hay Harvested Area	Hay with nutrients
20	Bromegrass seed Harvested Area	Hay with nutrients
17	Birdsfoot trefoil seed Harvested Area	Hay with nutrients
44	Cropland on which all crops failed or were abandoned Area	Hay with nutrients
58	Fescue Seed Harvested Area	Hay with nutrients
41	Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed Area	Hay without nutrients
42	Cropland in cultivated summer fallow Area	Hay without nutrients
180	Wild hay Harvested Area	Hay without nutrients
111	Pastureland and rangeland other than cropland and woodland pastured Area	Pasture
45	Cropland used only for pasture or grazing Area	Pasture
26	Bulbs, corms, rhizomes, and tubers – dry Protected Area	Nursery
49	Cut flowers and cut florist greens Protected Area	Nursery
8	Aquatic plants Protected Area	Nursery
13	Bedding/garden plants Protected Area	Nursery
108	Other nursery and greenhouse crops Protected Area	Nursery
91	Nursery stock Protected Area	Nursery
71	Greenhouse vegetables Area	Nursery
72	Greenhouse vegetables Protected Area	Nursery
65	Foliage plants Protected Area	Nursery
124	Potted flowering plants	Nursery

	Protected Area	
140	Sod harvested Protected Area	Nursery
171	Vegetable & flower seeds Protected Area	Nursery
76	Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area	Alfalfa
1	Alfalfa Hay Harvested Area	Alfalfa
3	Alfalfa seed Harvested Area	Alfalfa
0	Turf grass	Urban

Some over-arching guidelines governed the calculations. Where inconsistencies or error introduced in the estimation of withheld ("D") data led to inconsistencies between crop areas and land areas, then the land areas were adjusted to be commiserate with the crop areas.

Maryland currently has a commodity cover crop program that allows a partial payment for crops planted but not harvested when no nutrients are applied in the fall. If the farmer applies spring nutrients and harvests the crop for sale, then there is a smaller subsidy payment (R. Wieland, personal communication, 2008). This may provide some overlap in NASS data for small grains and cover crops reported as a best management practice.

Vegetables that are grown in plasticulture are not treated differently in this model. Plasticulture–managed vegetables are grown so that approximately one third of a field is covered (Ed Joiner, Nutrient Management Planner, VA, personal communication 2008). This increases infiltration since the irrigation system is under the plastic and decreases erosion. It also decreases volatilization. If plasticulture is about 7,000 acres in Virginia, and there are 195,000 acres in high-till row crop without manure (HOM), then these acres comprise 3.6% of the total and the plastic-covered portion of the field is 1.1% of that land use. Therefore, this is assumed to be insignificant portion for the outcome of loads.

Sunflower can be for seed oil or for wildlife. Where sunflower is grown for wildlife stands then it is not double cropped but left fallow other times of the year. NASS reports sunflowers in two categories: Sunflower seed, non-oil varieties and Sunflower seed, oil varieties. Only sunflower seed, oil variety is available to be double cropped. Years prior to 2002 do not have sunflower seed split into the two categories, so double cropping is not calculated for sunflowers prior to the categorization split. Rather, sunflower-all are categorized as sunflower non-oil varieties for the years prior to 2002.

Barley can be grown for grain or silage, yet the agricultural census does not differentiate. Barley for silage is lumped into the category haylage, grass silage, or greenchop whereas corn and sorghum silage or greenchop are distinct. Where grown for silage it is harvested 1.5 months earlier and is double-cropped with either sorghum or corn. This is common in the dairy industry (Bobby Long, Nutrient Management Planner, VA, personal communication 2008). Since the source data do not allow barley for silage as a distinct category, barley effectively will only be double cropped as a grain with sorghum.

While potatoes grown in the southern portion of the Chesapeake Bay Watershed are harvested early enough that they may be double cropped with beans and wheat, they are not included as a crop that may be double cropped with anything other than vegetables (Ed Joiner, Nutrient Management Planner, VA, personal communication 2008). Vegetables are double cropped. This is to be handled by a not-yet-implemented feature to Scenario Builder for multiple plant and harvest dates within each crop type or the land use.

Determining when two crops are planted on the same acre in the same 12-month period

When a farmer plants a summer crop followed by a winter crop, then two different crops may exist on the same acre of land. This situation is termed double-cropping. Double cropping is accounted for in Scenario Builder by determining the amount of land available to be double-cropped and subtracting the actual cropped areas of crop types that are eligible to be double-cropped. This requires identifying pairs of crop types that are typically cropped one after the other.

The actual procedure is below.

1. Area of crop land that is available to be double-cropped Subtract the following categories from the Item - Harvested croplands that is found in the Agricultural Census Table - Farms, Land in Farms, Value of Land and Buildings, and Land Use. Note that the item Harvested croplands is a land category so is not listed in the crop list above.

    a. Hay that was cut (found in table Field Seeds, Grass Seeds, Hay, Forage, and Silage under item Hay – all hay including alfalfa, other tame, small grain and wild). This item is the sum of the crops:
        1. Alfalfa hay

        2. Small grain hay

        3. Other managed hay

        4. Wild hay

    b. Total Woodland. This is not a crop type, but does encompass the correct area for this calculation.
    c. Land in orchards,
    d. Christmas trees, data only available for 2002 forward.
    e. Land in Nursery, Greenhouse, Floriculture, Mushrooms, Sod, and Vegetable Seeds Grown for Sale under the item Floriculture crops – bedding/garden plants, cut flowers and cut florist greens, foliage plants, and potted flowering plants, total for both the Square feet under glass or other protection and acres in the open. Note this is not a crop type, but a land area.

f. If a negative value results, then set the land use to equal the crop area. The negative values for land area are likely due to scenarios with internal logic flaws or from error associated with estimating withheld ("D") data from the NASS Agricultural Census.

2. Sum the <u>double cropped eligible crop types</u> from the agricultural census. Double cropped eligible crop types include:

> Barley for grain
> Corn for Grain Harvested
> Corn for silage or greenchop
> Emmer and spelt
> Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder
>   Harvested Area
> Popcorn
> Rye for grain
> Sorghum for Grain
> Sorghum for silage or greenchop
> Soybeans for beans
> Sunflower seed, oil varieties
> Triticale
> Wheat for Grain
> Winter wheat for grain

3. Double-cropped crop type area - Area of cropland available to be double-cropped. (Subtract the area in item #1 from the area in item #2.) This yields the acres double cropped by crop type which are in the Watershed Model-HSPF land use categories of conventional or conservation tillage with manure.

    a. Where crops minus land (#2 - #1) yields a positive number, then this is the area double cropped.

    b. Where the result is ≤ 0, then decrease the land area to match the crops. In this case, no land is double cropped.

4. Apportion the acres that are double cropped proportional to the amount of total land each comprises among:

    a. Corn for grain

    b. Corn for silage or greenchop

    c. Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area

    d. Popcorn

    e. Sorghum for grain

    f. Sorghum for silage or greenchop

g. sunflower seed-oil varieties

For example, if corn is 50%, sunflower seed-oil is 2%, and sorghum is 48% of land acreage as reported in the agricultural census, then the number of acres double-cropped will be covered by 50% corn, 2% sunflower seed-oil, and 48% sorghum.

h. Where the acres of double cropped crops in the group calculated in step #4 is less than the difference between the crop and land areas from step #3, use the acreage calculated in step#4 for double-cropping. Increase the land area from step #1 by the difference between the double cropped crops and the double-croppable land acres.

5. The crops paired with the corn varieties, sunflower seed-oil, and sorghum varieties are soybeans, barley, and total winter grains.

a. Total winter grains are the sum of the following items: rye, triticale, emmer spelt, barley, and wheat (both types). The percent of total winter grains of each component is maintained. Total winter grains is by definition 100%, which may be composed of, for example, rye 30%, triticale 25%, barley 20%, wheat-both types 20%, and emmer spelt 5%.

6. For the total winter grains group and soybeans, each crop is paired proportionally with corn varieties, sunflower seed-oil, and sorghum varieties. The pairing is split so that the total proportion of corn varieties, sunflower seed-oil, and sorghum varieties is maintained. For example, if corn is 50%, sunflower seed is 2%, and sorghum is 48% (from step #4 above), then apply 50% of total winter grains group or soybeans to corn, 2% to sunflower seed, and 48% of soybeans or the total winter grains group to sorghum.

a. Within the total winter grains group applied to corn varieties, sunflower seed, or sorghum varieties, use the specific crop type percentages calculated in step #5 above. This gives the grain group proportioned as a second step to determining the corn varieties, sunflower, and sorghum varieties amount double cropped.

These acres will be stored by the county and year marked as double-cropped crop. It is a separate category of crop type because it has its own plant and harvest dates as well as fertilizer application amount and time.

7. Acres of the soybeans, total winter grains group, or barley that exceed the corn varieties, sunflower oil-seed, or sorghum variety acres available for double-cropping remain as a single crop.

At this point, we have the acres of crops on model land uses including double cropped acres. Note that all failed cropland is included in the Watershed Model land use hay-fertilized. The agricultural census does not report which crops failed. Therefore, whatever failed is not double-cropped. In addition, corn and sorghum are equally likely to be double cropped in this model. Note that oats are not considered as a crop type eligible for double-cropping.

An additional step that is not implement in the Phase 1 of Scenario Builder development is to verify that the timing of plant and harvest dates by growth region do not result in two crops growing at the same time. That is, if corn is planted in April and harvested in August, then soybeans can not be planted in July. In this case, apply the double cropping to a different available crop (among corn, sorghum, and sunflowers) where there is no overlap of crop plant and harvest time periods. This step was not implemented as of June 30, 2009.

Determining urban lawn areas

Determine the area of the crop type "turf grass" by multiplying the fraction of urban lawn by each of the urban categories: low intensity pervious urban, high intensity pervious urban, and construction for each county and year. The fraction of urban lawn was determined by subtracting the acres of forested urban land from the total acres of pervious urban land within each county. The remaining pervious urban land is assumed to be turf grass. Many older subdivisions appear forested from a land cover perspective. The Watershed Model-HSPF Phase 5.2 land cover, however, uses housing unit and residential road density to identify such areas. To differentiate urban forests from lawns under canopy, the larger interior forest patches were used - eliminating edge and speckled forest areas. The GIS methods were as follows:

1) Create an urban mask using the Phase 5.2 land cover dataset
2) Within the urban mask, separate and group all forests and wetlands
3) Map interior forests by shrinking the forest/wetland extent around the edges by 1 cell (98.4 ft.).
4) Eliminate all patches of interior forest less than one-acre.
5) Expand remaining interior forest patches back to their original extent.
6) Summarize the acres of interior urban forest for each county.
7) Summarize the total urban extent (land cover, not land use).
8) Using a 2001 P5.2 land use file (corresponding to the date of the imagery), estimate the total urban and pervious urban land use acres by county. Pervious urban acres include "construction".
9) Calculate a land cover to land use adjustment factor based on the ratio of total urban land cover to total urban land use per county.
10) Multiply the adjustment factor by the total acres of interior urban forest per county and subtract that from the total pervious urban land use acres to derive acres of turf grass.

On average, turf grass equals 79% of the urban area in each county and 93% of what we call either high or low intensity pervious urban. Cappiella and Brown (2001) measured the percentage of open space on residential lots to range from 68% to 90%. Robbins et al., (2003) calculated the maximum potential lawn area in 205 residential census tracts in Ohio as averaging 82%. These estimates are liberal in that they do not subtract non-lawn areas (forests, flower beds, etc.) from their open space percentages. However, the numbers due lend some support to our county average of 79% (44% min and 97% max) (P. Claggett, personal communication, 2009).

The nutrients are only applied to the urban lawn areas that are in low intensity pervious urban and high intensity pervious urban land uses, although the turf grass area available was calculated using construction.

Deriving the Area for Agricultural Production

Animal production areas are generally those areas located around barns and where manure storage is most likely to occur. The Chesapeake Bay Program names these areas "Animal Feeding Operations" (AFOs). These areas are where manure lost during storage and handling loss is applied. AFO land areas are added to existing agricultural land use areas using the following criteria.

1. For each county and year, multiply the number of farms by animal type times the value Table 7-2.

2. AFO acres are added to the agricultural acres.

3. AFOs are broken down into land segments, and later into land-river segments, using an area weighted average based on the amount of agriculture in the county. Multiply the acres of AFOs in the county by the agricultural acres in each land-river segment divided by the total agricultural acres in the county. Agricultural acres are defined as those in the land uses:
   - animal feeding operations
   - alfalfa
   - row without manure
   - row with manure
   - hay without nutrients
   - hay with nutrients
   - pasture
   - degraded riparian pasture
   - nursery

Table 7-2: Animal Feeding Operation Acres/Farm by Animal Type (Data source, Jeff Sweeney, 2009)

Item Name	Acreage/farm
Cattle and calves	0.5
Total hogs and Pigs	0.2
Any Poultry	0.25
Sheep and Lambs--Inventory	0.1
Milk goats inventory	0.05
angora goats inventory	0.05

The Agricultural Census only lists farms by animal type, yet many farms have more than one animal type. Certain acreages are designated for each farm with an animal type; therefore areas that are shared by more than one species of animal are overestimated.

The land area of the farm is not related to the AFO size, but rather the size of an animal type and the number of animals.

On AFO land, we are not capturing the following animal types: Other poultry (such as ducks, geese, emus, ostriches and squab) or misc. livestock and animal specialties (such as bison, llamas, and rabbits). We assume that there are few farms with significant enough acreage specializing in solely these animals, so that land area is captured under other animal types.

Disaggregating Data from County to Watershed Model-HSPF Segments

County data is parsed to the Watershed Model-HSPF land-river segments by computing the ratio of agricultural acres in the land-river segment to the amount of agricultural acres in the county and multiplying that ratio by the crop are in the county. Checks are put in place to make sure the sum of land area in the land-river segments that make up a county match the total for the county. The same procedure is used for animal numbers.

SECTION 8. REVIEWS

Internal and external review

The objective in conducting reviews was to: 1) mirror in Scenario Builder the actual practices used by the agricultural community, and 2) correctly reflect the urban loadings. An extensive team of people both internal and external to the Chesapeake Bay Program were consulted throughout the development process. Working through a team brought diverse perspectives and made Scenario Builder more accurately reflect on-the-ground practices.

Internal reviews were conducted with he Chesapeake Bay Program modeling and nutrient staff (Jing Wu, Gary Shenk, Lewis Linker, Jeffrey Sweeney, and Mark Dubin), and the software development team leader (Jessica Rigelman). Each set of requirements were presented, discussed, and edited as recommended.

External guidance was provided primarily by:
1. Karl Berger-MWCOG
2. William Keeling-VA-DCR
3. Larry Fender-VA-DCR
4. Kenn Pattison-PA-DEP
5. Norm Goulet-Northern Virginia Regional Commission
6. David Kindig-VA-DCR
7. William Angstadt-MD and VA Fertilizer Sales Consultant
8. Bobby Long-VA-DCR Nutrient Management Planner
9. Edward Joyner-VA-DCR-Nutrient Management Planner
10. Robert Shoemaker-VA-DCR Nutrient Managed Planner
11. Doug Goodlander-PA State Conservation Commission
12. Don Fiesta-PA-DEP
13. Bill Rohr-Delaware Department of Agriculture

A series of conference calls were conducted from August through October, 2009. Each call addressed a different set of calculation procedures. In addition, Patricia Steinhilber-Program Coordinator, Agricultural Nutrient Management Program of the University of Maryland and David Hansen-University of Delaware Extension Program Leader for Agriculture and Natural Resources, were consulted throughout.

A joint meeting of the Agricultural and Nutrient and Sediment Reduction Workgroup and the Watershed Technical Workgroup was held 12/11/2008. Minutes from this meeting may be found on the Chesapeake Bay Program's website (http://www.chesapeakebay.net/committee_agworkgroup_meetings.aspx?menuitem=167 33). The primary purpose was to approve source data and also review all the calculation processes for determining uptake and application rates. The group provided valuable input on volatilization changes to beef and hogs where beef TN would be 42.5% and hogs and pigs for breeding and growing TN would be 30%. However, since volatilization occurs after the nutrients are split into the various species of N and P, then these values

were unable to be incorporated. Members of these workgroups also advised on the amount of time horses and heifers spend in pasture. As a result, changes were made to these variables. In addition, the workgroup members identified a more comprehensive source of data for animal manure speciation (ASAE 1998). The workgroup members were in consensus that the ratio of NH_3 to NO_3 for inorganic fertilizer was incorrect, but no method was agreed upon for how to make a more representative split.

Validation

There were no set quality assurance procedures and no predetermined acceptable level of variability among the data. Data were compared to those that were produced from the Watershed Model Phase 4.3. However, no acceptable level of variability was determined in advance. There was no set procedure for evaluating the Scenario Builder data.

Test cases were developed and conducted parallel to the actual Watershed Model-HSPF calibration. The data from the Agricultural Census was spot checked by John Clune of USGS. His analysis was presented at the aforementioned joint workgroup meeting on 12/11/2009.

Further quality control and quality assurance procedures could not be implemented due to deadlines that were set for this project completion.

SECTION 9. APPENDICES

Requirements

Manure and Fertilizer Application Process (J. Rigelman 01/30/09

1. Calculate Best Potential and Max Application Mass and Rate
   a. The best potential and max should be the total mass needed by the crop inclusive of starter mass
   b. This is calculated for crops on land uses keeping double cropped crops separate by major nutrient by month

2. Calculate Starter Application Mass and Rate
   a. This is calculated for crop on land uses keeping double cropped crops separate by nutrient by month
   b. Starter is calculated from best potential application mass, not max.
   c. There is no starter max.

3. Calculate Direct Deposit Manure
   a. This is calculated on a monthly basis and nutrients and sources are kept separate

4. Calculate Manure and Biosolid Storage Loss
   a. This is calculated on a monthly basis and sources and nutrients are kept separate

5. Calculate Stored Manure and Biosolids

      a. This is calculated on an annual basis and sources and nutrients are kept separate

6. Apply Starter
      a. Apply fertilizer equal to the N and P starter mass.
      b. Take amount applied and subtract from best potential and max application masses.
      c. Take amount applied and add to applied source total.

7. Apply Storage Loss Manure to AFO
      a. Take all manure lost in storage and put on AFO land use.
      b. Keep months, animals, nutrients separate.
      c. AFO has no crops. Therefore, AFO has no N and P application mass.

8. Apply Direct Deposit Manure
      a. This manure is applied to pasture land uses – PAS, NPA, TRP
      b. TRP has an acres effective area of 9* the actual acres.
      c. This data is available monthly and will need to be applied monthly and animals and nutrients are should be kept separate
      d. DO NOT take the mass of the plant available N and plant available P pooped in pasture and subtract from best potential and max application mass. Take the total mass of N and total mass of P pooped in pasture and add to applied source total.
      e. If more nutrients pooped in pasture than is needed by the crops, apply it all anyway, since direct deposit is not applied against the application rate.
9. Apply Biosolids
      a. Biosolids are available by yearly total.
      b. Whether a crop is eligible to receive biosolids is determined by
            i. If the crop is on a land use that can receive manure
            ii. If the crop-land use can receive biosolids.
            iii. If the crop-land use has a remaining best potential or max application mass
      c. The annual amount of biosolids should be proportioned across the months based on remaining best potential and max application mass for crop-land use combinations that are eligible to receive biosolids.
      d. Once the biosolids are proportioned monthly, the monthly allocation is applied in crop set order.
      e. If the amount of biosolids available is between best potential and max then best potential must be met for all crops in all months before proportioning out the remainder to the remaining max application mass.
      f. Take the mass of the plant available N and plant available P in biosolids that were applied and subtract from best potential and max application mass. Take the total mass of N and total mass of P in biosolids that were applied and add to applied source total.
      g. Crop, land use, source, nutrient, month should all be kept separate.
      h. If there are biosolids remaining after meeting max, an error is logged with the amount of biosolids that could not be applied.

10. Apply Stored Manure
      a. Stored manure is available by yearly total.
      b. Whether a crop is eligible to receive manure is determined by
            i. If the crop is on a land use that can receive manure
            ii. If the crop-land use has a remaining best potential or max application mass
            iii. It is assumed that if a crop is on a land use that can receive manure that it can receive all animal sources of manure.

c. The annual amount of stored manure should be proportioned across the months based on remaining best potential and max application mass for crop-land use combinations that are eligible to receive manure.
d. Once the stored manure is proportioned monthly, the monthly allocation is applied in crop set order.
e. If the amount of manure available is between best potential and max then best potential must be met for all crops in all months before proportioning out the remainder to the remaining max application mass.
f. If there is manure remaining after spreading the max for all crop-land use combinations, the remainder is eligible for transport.
g. Take the mass of the plant available N and plant available P in manure that was applied and subtract from best potential and max application mass. Take the total mass of N and total mass of P in manure that was applied and add to applied source total.
h. Crop, land use, source, nutrient, month should all be kept separate.

11. Manure Transport
    a. Manure can only be transported to another county if it shares a border.
    b. Manure transport cannot cross state lines.
    c. Only counties that have excess manure after meeting max application mass for all crop-land use combinations that can receive manure are eligible for transport.
    d. The order in which counties transport within a state is based on the greatest amount of excess manure.
    e. Manure is transported to adjacent counties proportionally based on the remaining best potential application mass. If an adjacent county does not have enough manure to meet best potential than you will transport to it.
    f. Manure is transported to all adjacent counties proportionally based on adjacent counties remaining application mass.
    g. Never transport manure to an adjacent county to meet a crops max application mass.
    h. Transported manure is spread the same way stored manure is spread.
    i. If a county cannot transport all of its excess manure to adjacent counties, the remainder goes to disposal load.

12. Disposal Load
    a. Apply disposal load manure to crops on the land use non nutrient management pasture (PAS) first.
    b. Apply disposal load manure to crops on the land use trampled riparian pasture (TRP) second if not eliminated on PAS.
    c. Apply disposal load manure to crops on the land use hay with nutrients (HYW) third if not eliminated on TRP.
    d. Apply disposal load manure to crops on the land use non nutrient management row w/manure (HWM, LWM) forth if not eliminated on HYW.
    e. If there is still excess after applying to HWM and LWM crops, an error is logged with the amount of disposal load that could not be applied.
    f. Sum max application mass for all crops on the land use(s) you are applying to annually.
    g. Multiply the annual sum for all crop times 10 to get the annual disposal load application mass for all crop on the land use(s).
    h. Proportion the annual mass across the months equally. 1/12 for each month.
    i. Apply the monthly allocation the crops in the land use(s) proportionally based on the proportion of acres in the crop to the total acres of the crops in the land use(s).
    j. If you have more manure than disposal load need in that land use(s) move to next land use(s)

k. Take the total mass of N and total mass of P in the disposal manure that was applied and add to applied source total. There is no reason to subtract from application mass.

13. Apply Fertilizer
   a. Apply fertilizer to crops to meet remaining N and P best potential application mass
   b. Do not apply fertilizer to meet max
   c. Do not apply fertilizer to crops that do not take fertilizer as a source.
   d. Some crops only take fertilizer as a source and do not take biosolids or manure.
   e. Fertilizer is mixed to the exact remaining N and P application mass. If there is no remaining N application mass after manure spreading but P application mass remains then the fertilizer applied would only contain P.

Assumptions:
We are applying manure and biosolids on an N based plan. For these 2 application types we are comparing N application mass to plant available N applied. P can be over or under applied. We only look at possible remaining P need when applying fertilizer.

Manure and Fertilizer Input File (O. Devereux, 1/10/09)

Format

The input files to the Watershed Model are to match the sample below. All landsegs, land uses, and constituents are represented. NULL values are to be reported in the Watershed Model input files as "-9". Do not code any NULL values as anything for any other output. Values of zero will be assumed to equal zero. Data is reported to two decimal places with a unique column for each month.

A separate table is constructed for nutrient types manure, which includes biosolids, and fertilizer. Each year is a separate table. Table name is to include: whether it is manure or fertilizer, year, and version. Data that needs to be associated with the table are the parameters used to create the data. This includes whether an N or P-based plan was in effect, year, nutrient type, units (lbs/acre), date created, and user.

Sample input table

lseg	lu	constituent	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
A10001	alf	nh3n	0	0	0	0	0	0	0	0	0	0	0	0
A10001	alf	no3n	0	0	0	0	0	0	0	0	0	0	0	0
A10001	alf	po4p	0	18.85	18.85	0	0	0	0	0	0	0	0	0
A10003	alf	nh3n	0	0	0	0	0	0	0	0	0	0	0	0
A10003	alf	no3n	0	0	0	0	0	0	0	0	0	0	0	0
A10003	alf	po4p	0	21.42	21.42	0	0	0	0	0	0	0	0	0

Procedure for grouping all nutrient application by land use and rescaling data from county to land segment
   1. Sum the lbs of manure and biosolids by each form of n and p, county, month, year, and land use.

2. Add Mineralized N to Organic N and Mineralized P to Organic P. Do not report Mineralized portions since they are now in the organic portions.
3. Insert storage loss manure on AFO land use. (The Nutrient Application Procedures calculated the mass of nutrients applied to all land uses for which nutrients are eligible to be applied except for animal feeding operation (AFO). AFO receives manure from storage loss.)
4. Sum the lbs of fertilizer by each form of n and p, county, month, year, and land use.
5. For both the manure+biosolids mass (steps 1 and 2) and the fertilizer mass (step 3) lbs, multiply by the landseg acres divided by the area of all the landsegs in that county for each month and year. An example for a single month of a year, given 300 lbs in land use hwm in county 10001, where that county has 50 acres in segment A10001 and 75 in segment B10001, then 300 lbs * 50/125 acres = 120 lbs in land segment A10001. This yields the lbs/landseg.
6. For chemical fertilizer, 0.75 of TN is NH_3 and 0.25 of TN is NO_3. These percentages should remain flexible to the user. In addition, the ability to classify these percentages by county should remain a possibility as the user-interface interface and accompanying flexibility is introduced.

lbs	lu	County
300	hwm	10001

lu	lseg	acres
hwm	a10001	50
hwm	b10001	75
300 lbs * 50/125 acres = 120 lbs		
300 lbs * 75/125 acres = 180 lbs		

7. To report the lbs/acre in each landseg, divide by the number of acres in that landseg. Following the example above, landseg A10001 with land use hwm would have 2.40 lbs/acre. There are simpler ways to calculate the number. As long as the results are the same, the simplest method will suffice. However, interim data products for the broader range of users and data products for quality assurance may require calculating this differently.

Data checks
1. Land uses that receive no nutrients are: bar, ext, for, hvf, hyo, imh, and iml. Check that these land uses have zero nutrients applied.
2. No manure is applied to nursery (urs), high till without manure (hom), nutrient management high till without manure (nhi), or pervious urban (puh and pul). Check the manure input file to ensure that these land uses have zero manure and biosolids applied.
3. Check that the correct number of landsegs is in each nutrient file (236 at last check).

4. Manual checks by the user should include:
   a. No applications outside of crop plant to harvest months.
   b. The rate by aggregated categories of land uses is reasonable given knowledge of crops, application rates, and like knowledge.
   c. Total rate by crop is reasonable given knowledge of crop nutrient application rates.

To afford the capacity to rapidly perform the data checks that require agronomy and related discipline knowledge, data needs to be summarized by crops and also by land uses.

Summarize land use categories for an N or P rate (lb/acre) and annual application rate for each crop

Produce a table with the columns: crop, land use, land use category, lbs/acre, nutrient type (manure, biosolids, and fertilizer), nutrient form (total nitrogen or total phosphorus), months, and year. The spatial scale is land segment. Thus, there is not a separate column for each month, but rather one column with data ranging from 1 to 12. Similar land uses are grouped together. While it would be most helpful to have flexibility in grouping land use categories, we can define a priori the categories as:

Nutrient management row: nhi, nho, nlo
Row: lwm, hwm, hom
Alfalfa: nal, alf
Pasture: npa, pas, trp
Urban: puh, pul
Hay: hyw, nhy
Nursery: urs
Animal feeding operation: AFO

1. Convert N and P from lbs/acre to total mass by multiplying the segment by the number of acres for each land use.
2. Sum the acres for the land use types that support the desired type, e.g.: agriculture row crop, all agriculture, agriculture hay and forage, or etc. on the desired segment scale (e.g.: county, lrseg, etc.).
3. Sum the N and P mass by the same categorization of land uses in #2.
4. Convert N and P to lbs/acre for the new aggregated land use by multiplying the total mass by the acres in the aggregated land use categories.

Summarize animal types and other nutrient sources for mass of nutrients contributed to each crop or land use

Produce a table with the columns: crop, land use, lbs, nutrient form (total nitrogen or total phosphorus), animal type, animal unit, and year. The spatial scale is land segment. Thus, we can assess which species and other nutrient sources contribute what amount of manure to which crop or land use.

Manure Mineralization (O. Devereux, 1/10/2009)

Calculate amount of manure mineralized

Uses mineralization factor and amount of organic N and P by county, year and animal type.

1. Calculate the amount of organic N available in first year as Organic N * Mineralization factor. The mineralization factor is in a look up table.
2. Subtract the amount of mineralized N in first year from step 1 from organic N. This gives the mineralized N fraction.
3. Perform the same process for phosphorus. Since no phosphorus is immobilized, all organic P becomes mineralized P.

animal type	Phosphorus Mineralization factor	Nitrogen Mineralization factor
bovine	1	0.35
swine	1	0.5
poultry	1	0.6

Assumptions:
Mineralization factors taken from Mid-Atlantic Nutrient Management Handbook, 2002.

Mineralization factor: used values for spring or early fall applied, less winter topdress. Mineralization originally from VaDCR, 2005.

While temperature, water content, drainage features, and organic C all have an impact on mineralization, these factors are not considered in this Bay-wide estimation.

Plant Available Phosphorus behaves conservatively in the soil and not considered in model.

Septic Loads (J. Sweeney, 12/09/2008)

Following is a sequenced listing of parameters and functions used to calculate septic input decks for the Phase 5 Watershed Model. The calculations occur for each land-river segment (CATCODE2FIPSAB) in the domain.

Base data tables and an example of all calculations can be found in the Excel workbook "Septic_BaseTables-Calculations" under S:\VortexDevelopment\Requirements. The base data tables are identified as "PopSeptic (lrseg)" and "AHHS (county)". Worksheet "scenario_BMPs" is an example a scenario's BMPs for the septic work-up. Worksheet "septic_calculations" are the step-by-step calculations. Worksheet "septic_input-deck" is an example Watershed Model input deck for septic.

PopSepticyr (Pre-SC) – the number of septic systems, pre-septic connections for the relevant year of the scenario is taken from the base table "PopSeptic (lrseg)" and the respective column

- For example, column "PopSeptic00" is the population on septic for the year 2000
- The number of septic systems is the systems prior to changes due to "septic connections" practice
- If a land-river segment is not identified on the table "PopSeptic (lrseg)", the default for *PopSepticyr (Pre-SC)* = 0
- Years not specifically identified in the base data table "PopSeptic (lrseg) can be populated through interpolation between known years.

AHHSyr – average household size by county for the relevant year of the scenario is also taken from the base data table "AHHS (county)" and the respective column

- For example, column "AHHS2000" is the average household size for the year 2000
- The average household size for a county, by FIPS designation, is applied to the respective FIPS for the land-river segment
- If a county (FIPS) is not identified on the table "AHHS (county)", the default for *AHHSyr* = 0
- Years not specifically identified in the base data table "AHHS (county)" can be populated through interpolation between known years.

Systems (Pre-SC) – pre-septic connection systems for the scenario year

- Divide *PopSepticyr* by *AHHSyr*
- If *AHHSyr* = 0, then the number of pre-septic connection systems = 0

Septic Connections (SC)

- The number of septic connections is a BMP that varies by scenario, read from the BMP table "scenario_BMPs"
- The number of septic connections is summed by county in the BMP table and redistributed to land-river segments according to relative number of *Systems (Pre-SC)*
- If there is division by 0, the default *Septic Connections (SC)* = 0
- The number of *Septic Connections (SC)* cannot exceed the number of *Systems (Pre-SC)*

Systems (Post-SC) – post-septic connection systems for the scenario year:

- Subtract *Septic Connections (SC)* from *Systems (Pre-SC)*

PopSepticyr (Post-SC)

- Subtract (*AHHSyr* * *SC*) from *PopSeptic10 (Pre-SC)*

Load w/o SD-SP – TN (total nitrogen) load without septic denitrification and septic pumping in units of lbs. TN/year

- *PopSepticyr (Post-SC) * Lbs/Person-Year (edge of septic field) * Pass-through Factor* where

- *Lbs/Person-Year (edge of septic field)* = 8.91586080319759
- *Pass-through Factor* = 0.4

Septic Denitrification systems (SD)
- The number of septic denitrification systems is a BMP that varies by scenario, read from the BMP table "scenario_BMPs"
- The number of denitrifying systems is summed by county in the BMP table and redistributed to land-river segments according to relative number of *Systems (Post-SC)*
- If there is division by 0, the default *Septic Denitrification systems (SD)* = 0
- The number of *Septic Denitrification systems (SD)* cannot exceed the number of *Systems (Post-SC)*

Septic Pumping systems (SP)
- The number of septic pumping systems is a BMP that varies by scenario, read from the BMP table "scenario_BMPs"
- The number of pumped systems is summed by county in the BMP table and redistributed to land-river segments according to relative number of *Systems (Post-SC)*
- If there is division by 0, the default *Septic Pumping systems (SP)* = 0
- The number of *Septic Pumping systems (SP)* cannot exceed the number of *Systems (Post-SC)*

SD Reduction – the load reduction due to septic denitrification
- *SD Reduction = SD (systems)* divided by *Systems (Post-SC)* * 0.5
- Where *SD (systems)* is the number of septic systems with denitrification is a BMP that varies by scenario, read from the BMP table by land-river segment
- 0.5 is the TN reduction efficiency associated with the practice
- If *Systems (Post-SC)* = 0, then *SD Reduction* = 0

SP Reduction – the load reduction due to septic pumping
- *SP Reduction = SP (systems)* divided by *Systems (Post-SC)* * 0.05
- Where *SP (systems)* is the number of septic systems with pumping as maintenance is a BMP that varies by scenario, read from the BMP table by land-river segment
- 0.05 is the TN reduction efficiency associated with the practice
- If *Systems (Post-SC)* = 0, then *SD Reduction* = 0

BMP Reduction – the combined reduction of septic denitrification and septic pumping
- Add *SD Reduction* and *SP Reduction*

BMP Pass-through
- 1 minus *BMP Reduction*

Load (lbs TN/year) – annual TN load after all BMPs are applied in units of lbs. TN/year
- *Load w/o SD-SP * BMP Pass-through*

Load (lbs TN/day) – annual TN load after all BMPs are applied in units of lbs. TN/day

- *Load (lbs TN/year)* divided by 365.25
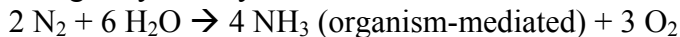- *Load (lbs TN/day)* is the input deck for the Phase 5 Watershed Model with the example as follows:

landseg	riverseg	thisyear	constit	septicload
A10001	DE0_3380_0000	2010	totn	46.20288874
A10001	DE0_3410_0000	2010	totn	96.66787702
A10001	DE0_3790_0000	2010	totn	119.7432514
A10001	DE0_3791_0001	2010	totn	72.11308665
A10001	DE0_3840_0000	2010	totn	24.82286021
A10001	DE0_4140_0000	2010	totn	189.4786688
A10001	DE0_4141_0001	2010	totn	19.3595919

Nitrogen Fixation by Legumes (O. Devereux, 1/27/2009)

Legumes are a class of plants that generally grow pods. Legumes develop nodules on the roots that are an infection from bacteria. These bacteria transform N_2 to NH_3, a process called nitrogen fixation. The Scenario Builder reports the pounds/acre of ammonia (NH_3) that is fixed by crop, county, month, and year. These data may also be reported as Watershed Model land uses and land segments.
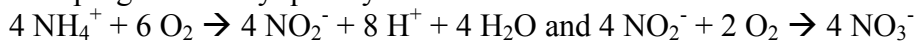
Nitrogen fixation

When in an aerobic system, not a wetland, then N fixation occurs. For a refresher, the nitrogen cycle may be summarized as:

$2 N_2 + 6 H_2O \rightarrow 4 NH_3$ (organism-mediated) $+ 3 O_2$

When the organism dies, then

$4 NH_3 + 4 H_2O \rightarrow 4 NH_4^+ + 4 OH^-$

This progresses very quickly to

$4 NH_4^+ + 6 O_2 \rightarrow 4 NO_2^- + 8 H^+ + 4 H_2O$ and $4 NO_2^- + 2 O_2 \rightarrow 4 NO_3^-$

Plant roots take up the NO_2^- and NO_3^- and convert to an amino acid.

Thus, N is added to the plant-soil system from the air. Leguminous plant types that we model are listed in Table 1. There are also broader categories in the NASS Agricultural Census that include legumes, but are not predominantly legumes. We do not calculate N fixation from these broader categories because the amount of legumes is not known (Table 2).

If there is adequate N available in the soil, then N fixation is suppressed. The implication is that if a farmer applies fertilizer to legumes, then N is not fixed.

Procedure

1. For legume crops on a county and annual scale, subtract the actual amount of N applied from the application rate for N (best potential rate). The actual amount of N applied and the application rate were calculated as part of the nutrient application procedures. Legume crops are listed in Table 1.

a. If the result is ≥ 0, then record the full amount of N fixed from the look up table with the name of the crop, growth region, and amount in lbs/acre fixed.

b. If the result is < 0, then the amount of N fixed is zero or a partial amount from the look up table with the name of the crop, growth region, and amount in lbs/acre fixed.

  i. In this case, add the difference between the application rate and actual amount of N applied (from step #1) to the amount of N fixed from the look up table.

  ii. Where the amount fixed is equal to the difference between the application rate and the actual amount applied, then the amount fixed will be zero.

  iii. Where the amount fixed is less than the difference between the application rate and the actual amount applied, then the amount fixed will be less than zero. When this situation occurs, set the lower bound to zero. It is not possible for a plant to "unfix" nitrogen.

  iv. Where the amount fixed is greater than the difference between the application rate and the actual amount applied, then the amount fixed will be a portion of the amount fixed.

    1. For example: if the amount of N fixed is 200 lbs-N/acre and N applied is 150 lbs-N/acre and the N application rate is 10 lbs-N/acre, then the result of step #1 is -140. Add -140 and 200 to get 60 lbs-N/acre.

2. Take the calculated lbs-N/acre that is fixed and multiply by the number of acres of that crop in the county. This yields the mass of N that is fixed by crop and year.

3. Distribute this mass of N fixed over the months that the plant is growing.

a. N is fixed in the month after planting until harvest (For perennials, planting date corresponds to emergence and harvest date corresponds to hard frost. This is set in the source data table).

b. Distribute the mass of N fixed evenly over these months by dividing the total N fixed in a year by the number of months the plant is growing minus the month of planting.

4. Convert N fixation monthly mass to land use. Sum the crops' monthly values that correspond to the same land use for each land use. Use the crops to land use table.

5. Convert to lbs-NH_3/acre by dividing by the number of acres in that land use.

6. Check to make sure that fixation < uptake. If fixation is ≥ uptake, then report an error.

Table 1: Legumes for which N fixation is calculated.

NASS Crop Type	CBP Land use	CBP Land use abbreviation
Alfalfa hay	alfalfa	Alf
Alfalfa seed	alfalfa	Alf
Birdsfoot trefoil seed	hay-fertilized	HYW
Dry edible beans, excluding limas	Conventional or Conservation Tillage with Manure	HWM or LWM
Green Lima Beans	Conventional Tillage without Manure	HOM
Peanuts for nuts	Conventional or Conservation Tillage with Manure	HWM or LWM
Peas, Chinese (sugar and Snow)	Conventional Tillage without Manure	HOM
Peas, Green (excluding southern)	Conventional Tillage without Manure	HOM
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc.	Conventional Tillage without Manure	HOM
Red clover seed	hay-fertilized	HYW
Snap Beans	Conventional Tillage without Manure	HOM
Soybeans for beans	Conventional or Conservation Tillage with Manure	HWM or LWM
Vetch seed	hay-fertilized	HYW

Table 2: NASS categories that include legumes, but are not exclusively legumes.

NASS Crop Type	CBP Land use	CBP Land use abbreviation
Other tame hay	hay-fertilized	HYW
Pastureland and rangeland other than cropland and woodland pastured	pasture	PAS
Wild hay	hay-unfertilized	HYO

Assumptions

The Agricultural Census categories that include legumes but are not exclusively legumes are not considered for legume fixation. We assume the area comprising legumes is insignificant.

Each year is considered independent of any other year. Therefore, nutrients can not "build up" in the soil in data produced by the Scenario Builder. It follows that N in the soil after one year may repress N fixation. This situation is not considered in the calculation of these data.

No N is fixed in the month of planting. We assume that the nodules take 2-4 weeks to establish. For subsequent months of growth, the total amount of NH_3 is parsed evenly. That means that the same amount of N is fixed in month 2 as in the final month before the plant is killed or dies. A perennial, like alfalfa, will fix the same amount every month between emergence (plant date for annuals) and first hard frost (harvest date for perennials).

We assume that fixation occurs on all leguminous plants. This assumes that legumes are inoculated or sufficient rhizobia are present. It also assumes that carbon is at optimum levels.

Nitrogen fixation amounts are not adjusted for temperature or rainfall in the Chesapeake Bay Program's Watershed Model. The exception is alfalfa. As of October 14, 2008, nitrogen fixation for alfalfa will likely be calculated by the Watershed Model so that rainfall and temperature data can parameterize fixation amounts.

The Chesapeake Bay Program's Watershed Model accounts for processes that occur after N fixation, such as where crops are killed and left on the soil or incorporated into the soil, thereby returning N to the soil.

Many researchers have indicated that fertilizer application in the form of NO_3 does not decrease N fixation by legumes (Johnson et al., 1975; Blumenthal et al., 1996). These data refute the dogma that NO_3 substitutes for fixed N where NO_3 is increased. Literature searches did not produce data that quantifies the reciprocally of the NO_3 sorption and N2 fixation. Without identifying values of N fixation and the interaction with NO_3 for each leguminous plant, we are unable to consider these data in our model.

References

Bourion, 2007; Brady and Weil, 2002; Xu-Ri and Prentice, 2008; Johnson et al., 1975; Blumenthal et.al., 1996.

Land Use (O. Devereux, P. Claggett, J. Sweeney, G. Shenk, 1/27/2009)
Note on precision:
Land use acreage is an intermediate calculation between source data sets and loads, rather than a reported value, so values should not be rounded. On the output step, there should be at least 7 significant digits as the values are read in as single precision FORTRAN variables

Note on Time Scale:
Each run of the scenario builder land use calculation creates a data set that represents a single point in time or a year if the outputs are monthly. The direct inputs to the scenario builder land use calculation are files that represent a single set of assumptions. These files are

1. urban (5 uses), extractive, water, total acres by LRseg
2. crop types and animals by county from the Ag census
3. BMPs by LRseg

These files are identified by a scenario identifier that may or may not pertain to any given year. The calibration is a particular set of cases of the scenario builder land use generator where the inputs and outputs represent each year from 1982-2005.

Spatial reference:

"County" means County or independent city, referenced by the 5-digit FIPS code

"Lseg" = Land segment, which are divisions of counties. Referenced by the 5-digit FIPS code, with a preceding "A", "B", or "C"

"Rseg" = River segment or watershed, independent of county or lseg, referenced by a 13-character name, with the form XYn_1234_5678 where:

X = major basin
Y = minor basin
n = logarithmic reference to stream size
1234 = unique numerical ID, semi-randomly assigned
5678 = downstream ID. The unique ID of the downstream segment
Rsegs can be referenced by their full 13-character name or just their unique ID

LRseg = spatial intersection of the Lsegs and Rsegs. Referenced by the concatenation of thier names

Apply crops to land use: calculated on a county scale by year.

Use source data table: Ag Census crop type, county, year, and associated CBP land use

The land uses that have nutrient management analogues include: alfalfa, row with manure, row without manure, hay with nutrients, and pasture. The land uses that have low-till (conservation) tillage analogues include: row with manure and nutrient management row with manure.

1. Sum acres of crop type for the types of crops that relate to a CBP land use type, using the table of agricultural census crops. (Crop type area comes from a table derived from the agricultural census. There can be one land use with many crops but a crop can not be put on more than one land use, except where a portion is grown in a protected area or out in the open.)

This gives acres of crop where the total acres match the Watershed Model land use acres for each year and county.

Crops modeled include the following, which comes from the agricultural census. Where there are duplicates, it is because a portion of the crop area falls into two separate land uses, depending on whether it is grown in the open or in protected areas.

Alfalfa Hay Harvested Area
Alfalfa seed Harvested Area
Aquatic plants Area
Aquatic plants Protected Area
Asparagus Harvested Area
Barley for grain Harvested Area
Bedding/garden plants Area
Bedding/garden plants Protected Area
Beets Harvested Area
Berries- all Harvested Area
Birdsfoot trefoil seed Harvested Area
Broccoli Harvested Area
Bromegrass seed Harvested Area
Brussels Sprouts Harvested Area
Buckwheat Harvested Area

Bulbs, corms, rhizomes, and tubers – dry Harvested Area
Bulbs, corms, rhizomes, and tubers – dry Protected Area
Canola Harvested Area
Cantaloupe Harvested Area
Carrots Harvested Area
Cauliflower Harvested Area
Celery Harvested Area
Chinese Cabbage Harvested Area
Collards Harvested Area
Corn for Grain Harvested Area
Corn for silage or greenchop Harvested Area
Cotton Harvested Area
Cropland idle or used for cover crops or soil improvement but not harvested and not pastured or grazed
Area
Cropland in cultivated summer fallow Area
Cropland on which all crops failed or were abandoned Area
Cropland used only for pasture or grazing Area
Cucumbers and Pickles Harvested Area
Cut Christmas Trees Production Area
Cut flowers and cut florist greens Area
Cut flowers and cut florist greens Protected Area
Dry edible beans, excluding limas Harvested Area
Dry Onions Harvested Area
Eggplant Harvested Area
Emmer and spelt Harvested Area
Escarole and Endive Harvested Area
Fescue Seed Harvested Area
Foliage plants Area
Foliage plants Protected Area
Garlic Harvested Area
Green Lima Beans Harvested Area
Green Onions Harvested Area
Greenhouse vegetables Area
Greenhouse vegetables Protected Area
Haylage or greenchop from alfalfa or alfalfa mixtures Harvested Area
Head Cabbage Harvested Area
Herbs, Fresh Cut Harvested Area
Honeydew Melons Harvested Area
Kale Harvested Area
Land in Orchards Area
Lettuce, All Harvested Area
Mushrooms Area
Mushrooms Protected Area
Mustard Greens Harvested Area
Nursery stock Area
Nursery stock Protected Area
Oats for grain Harvested Area
Okra Area
Orchardgrass seed Harvested Area
Other field and grass seed crops Harvested Area
Other haylage, grass silage, and greenchop Harvested Area
Other managed hay Harvested Area
Other nursery and greenhouse crops Area
Other nursery and greenhouse crops Protected Area
Parsley Harvested Area
Pastureland and rangeland other than cropland and woodland pastured Area

Peanuts for nuts Harvested Area
Peas, Chinese (sugar and Snow) Harvested Area
Peas, Green (excluding southern) Harvested Area
Peas, Green Southern (cowpeas) – Black-eyed, Crowder, etc. Harvested Area
Peppers, Bell Harvested Area
Peppers, Chile (all peppers – excluding bell) Harvested Area
Popcorn Harvested Area
Potatoes Harvested Area
Potted flowering plants Area
Potted flowering plants Protected Area
Pumpkins Harvested Area
Radishes Harvested Area
Red clover seed Harvested Area
Rhubarb Harvested Area
Rye for grain Harvested Area
Ryegrass seed Harvested Area
short-rotation woody crops Harvest Area
short-rotation woody crops Production Area
Small grain hay Harvested Area
Snap Beans Harvested Area
Sod harvested Area
Sod harvested Protected Area
Sorghum for Grain Harvested Area
Sorghum for silage or greenchop Area
Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area
Soybeans for beans Harvested Area
Spinach Harvested Area
Squash Harvested Area
Sunflower seed, non-oil varieties Harvested Area
Sunflower seed, oil varieties Harvested Area
Sweet Corn Harvested Area
Sweet potatoes Harvested Area
Timothy seed Harvested Area
tobacco Harvested Area
Tomatoes Harvested Area
Triticale Harvested Area
Turfgrass
Turnip Greens Harvested Area
Turnips Harvested Area
Vegetable & flower seeds Area
Vegetable & flower seeds Protected Area
Vegetables, Mixed Area
Vegetables, Other Harvested Area
Vetch seed Harvested Area
Watermelons Harvested Area
Wheat for Grain Harvested Area
Wild hay Harvested Area
Winter wheat for grain Harvested Area

Double cropping: calculated on a county scale by year.

8. Subtract the following categories from the Item - Harvested croplands that is found in the Agricultural Census Table - *Farms, Land in Farms, Value of Land and Buildings, and Land Use*. Note that the item Harvested croplands is a land category so is not listed in the crop list above.

a. Hay that was cut (found in table Field Seeds, Grass Seeds, Hay, Forage, and Silage under item Hay – all hay including alfalfa, other tame, small grain and wild). This item is the sum of the crops:

    1. Alfalfa hay

    2. Small grain hay

    3. Other managed hay

    4. Wild hay

b. Land used to grow short-rotation woody crops. This is not a crop type, but does encompass the correct area for this calculation.
c. land in orchards,
d. Christmas trees, data only available for 2002 forward.
e. Land in Nursery, Greenhouse, Floriculture, Mushrooms, Sod, and Vegetable Seeds Grown for Sale under the item Floriculture crops – bedding/garden plants, cut flowers and cut florist greens, foliage plants, and potted flowering plants, total for both the Square feet under glass or other protection and acres in the open. Note this is not a crop type, but a land area.

f. If a negative value results, then set the land use to equal the crop area. The negative values for land area are likely due to scenarios with internal logic flaws or from error associated with estimating withheld ("D") data from the NASS Agricultural Census.

9. Sum the double cropped eligible crop types from the agricultural census or user-input crops and acres data. Double cropped eligible crop types include:

Barley for grain
Corn for Grain Harvested
Corn for silage or greenchop
Emmer and spelt
Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area
Popcorn
Rye for grain
Sorghum for Grain
Sorghum for silage or greenchop
Soybeans for beans
Sunflower seed, oil varieties
Triticale
Wheat for Grain
Winter wheat for grain

Subtract the area in item #1 from the area in item #2. This yields the acres double cropped by crop type which are in the CBP land use categories of conventional or conservation tillage with manure.

a. Where crops minus land (#2 - #1) yields a positive number, then this is the area double cropped.

b. Where the subtraction is ≤ 0, then decrease the land area to match the crops. In this case, no land is double cropped.

10. Apportion the acres that are double cropped proportional to the amount of total land each comprises among:

a. Corn for grain

b. Corn for silage or greenchop

c. Sorghum Hogged or Grazed, Sorghum for Syrup, Corn for dry fodder Harvested Area

d. Popcorn

e. Sorghum for grain

f. Sorghum for silage or greenchop

g. sunflower seed-oil varieties

For example, if corn is 50%, sunflower seed-oil is 2%, and sorghum is 48% of land acreage as reported in the agricultural census, then the number of acres double-cropped will be covered by 50% corn, 2% sunflower seed-oil, and 48% sorghum.

h. Where the acres of double cropped crops in the group calculated in step #4 is less than the difference between the crop and land areas from step #3, use the acreage calculated in step#4 for doublecropping. Increase the land area from step #1 by the difference between the double cropped crops and the doublecroppable land acres.

11. The crops paired with the corn varieties, sunflower seed-oil, and sorghum varieties are soybeans, barley, and total winter grains.

   a. Total winter grains are the sum of the following items: rye, triticale, emmer spelt, barley, and wheat (both types). The percent of total winter grains of each component is maintained. Total winter grains is by definition 100%, which may be composed of, for example, rye 30%, triticale 25%, barley 20%, wheat-both types 20%, and emmer spelt 5%.

12. For the total winter grains group and soybeans, each crop is paired proportionally with corn varieties, sunflower seed-oil, and sorghum varieties. The pairing is split so that the total proportion of corn varieties, sunflower seed-oil, and sorghum varieties is maintained. For example, if corn is 50%, sunflower seed is 2%, and sorghum is 48% (from step #4 above), then apply 50% of total winter grains group or soybeans to corn, 2% to sunflower seed, and 48% of soybeans or the total winter grains group to sorghum.

   a. Within the total winter grains group applied to corn varieties, sunflower seed, or sorghum varieties, use the specific crop type percentages calculated in step #5 above. This gives the grain group proportioned as a second step to determining the corn varieties, sunflower, and sorghum varieties amount double cropped.

These acres will be stored by the county and year marked as double-cropped crop. It is a separate category of crop type because it has its own plant and harvest dates as well as fertilizer application amount and time.

13. Acres of the soybeans, total winter grains group, or barley that exceed the corn varieties, sunflower oil-seed, or sorghum variety acres available for double-cropping remain as a single crop.

14. Verify that the timing of plant and harvest dates by growth region do not result in two crops growing at the same time. That is, if corn is planted in April and harvested in August, then soybeans can not be planted in July. In this case, apply the double cropping to a different available crop (among corn, sorghum, and sunflowers) where there is no overlap of crop plant and harvest time periods. *NOTE: THIS REQUIREMENT WAS NOT IMPLEMENTED.*

At this point, we have the acres of crops on model land uses including double cropped acres.

Turf grass

Determine the crop type turf grass area by multiplying the fraction of urban lawn by each of the urban categories: barren-construction, low intensity pervious urban, and high intensity pervious urban for each county and year.

Assumptions for crops to land uses and double cropping

Where inconsistencies or error introduced in the estimation of withheld ("D") data led to inconsistencies between crop areas and land areas, then the land areas were adjusted to be commiserate with the crop areas.

All failed cropland is included in the Watershed Model land use hay-fertilized. The agricultural census does not report which crops failed. Therefore, whatever failed is not double cropped.

Corn and sorghum are equally likely to be double cropped in this model.

Maryland currently has a commodity cover crop program that allows a partial payment for crops planted but not harvested when no nutrients are applied in the fall. If the farmer applies spring nutrients and harvests the crop for sale, then there is a smaller subsidy payment (R. Wieland, personal communication, 2008). This may provide some overlap in NASS data for small grains and cover crops reported as a best management practice

Vegetables that are grown in plasticulture are not treated differently in this model. Plasticulture–managed vegetables are grown so that approximately one third of a field is covered(Ed Joiner, Nutrient Management Planner, VA). This increases infiltration since the irrigation system is under the plastic and decreases erosion. It also decreases volatilization. If plasticulture is about 7,000 acres in Virginia, and there are 195,000 acres in high-till row crop without manure (HOM), then these acres comprise 3.6% of the total and the plastic-covered portion of the field is 1.1% of that land use. Therefore, this is assumed to be insignificant portion for the outcome of loads.

Sunflower can be for seed oil or for wildlife. Where sunflower is grown for wildlife stands then it is not double cropped but left fallow. NASS reports sunflowers in two categories: Sunflower seed, non-oil varieties and Sunflower seed, oil varieties. Only sunflower seed, oil variety is available to be double cropped. Years prior to 2002 do not have sunflower seed split into the two categories, so double cropping is not calculated for sunflowers prior to the categorization split. Rather, sunflower-all are categorized as sunflower non-oil varieties for the years prior to 2002.

Barley can be grown for grain or silage, yet the agricultural census does not differentiate. Barley for silage is lumped into the category haylage, grass silage, or greenchop whereas corn and sorghum silage or greenchop are distinct. Where grown for silage it is harvested 1.5 months earlier and is double-cropped with either sorghum or corn. This is common in the dairy industry (Bobby Long, Nutrient Management Planner, VA). Since the source data do not allow barley for silage as a distinct category, barley effectively will only be double cropped as a grain with sorghum.

While potatoes grown in the southern portion of the Chesapeake Bay Watershed are harvested early enough that they may be double cropped with beans and wheat, they are not included as a crop that may be double cropped with anything other than vegetables (Ed Joiner, Nutrient Management Planner, VA). Vegetables are double cropped. This is handled by multiple plant and harvest dates within each crop type or the land use.

Derived Agricultural Land Uses—Animal Feeding Operation

Animal Feeding Operations (AFO) are those areas where manure lost during storage and handling loss is applied. AFO land areas are added using the following criteria.

4. For each county and year, multiply the number of farms by animal type times the value in the look-up table. A sample look up table is below; it should be populated from the Agricultural Census.

5. AFO acres are added to the agricultural acres.

6. AFOs are broken down into land segments, and later into land-river segments, using an area weighted average based on the amount of agriculture in the county. Multiply the acres of AFOs in the county by the agricultural acres in each land-river segment divided by the total agricultural acres in the county. Agricultural acres are defined as those in the land uses:

    - animal feeding operations
    - alfalfa
    - row without manure
    - row with manure
    - hay without nutrients
    - hay with nutrients
    - pasture
    - degraded riparian pasture
    - nursery

Table CountySourceFarmAcres: Sample data

Agricultural Census Table Name	Item Name	No. of Farms	Acreage/farm	Year	County
Cattle and calves – Inventory and Sales	Cattle and calves		5		
Hogs and Pigs – Inventory and Sales	Total hogs and Pigs		2		
Poultry--Inventory and Sales	Any Poultry		2.5		
Sheep and Lambs-- Inventory, Wool Production, and Number Sold	Sheep and Lambs--Inventory		1		
Milk Goats	Milk goats inventory		0.5		
Angora Goats	angora goats inventory		0.5		

Where the area of BMPs reported by the states exceeds the land area in AFO, then the AFO land area is increased. Further specificity will be included in the BMP requirements.

Assumptions for derived land use: AFOs

The Agricultural Census only lists farms by animal type, yet many farms have more than one animal type. Certain acreages are designated for each farm with an animal type; therefore areas that are shared by more than one species of animal are overestimated.

The land area of the farm is not related to the AFO size, but rather the size of an animal type and the number of animals.

On AFO land, we are not capturing the following animal types: Other poultry (such as ducks, geese, emus, ostriches and squab) or Misc. livestock and animal specialties (such as bison, llamas, and rabbits). We assume that there are few farms with significant enough acreage specializing in solely these animals, so that land area is captured under other animal types.

The acreage/farm was 0.5 as specified by Robert W. Burgholzer. Jeff Sweeney indicated this was not enough area to apply the state-reported BMPs. Values were increased relative to animal size and typical operation management principles, and approved by CBP workgroups.

Integrating Ag Census with other data sources and scaling from County to Land-River Segmentation

Procedure 1: Creating "CBP Ag LU by LRseg"

INPUTS
1. P5lc
Tabular summary of raster land cover acres with unique classes for undefined agriculture (AG), cropland (CROP), and pasture/hay (PH) by Lrseg
    Note: this will be static for the calibration and most scenarios.

Nursery, row crops with and without manure are considered CROP. Hay with and without nutrients, alfalfa and pasture are considered PH.

2. Agricultural Land Uses by County
These data are in a source table derived from the Agricultural Census above. Where the steps below refer to a land use, perform the same procedure on all of the crops in that land use.

3. AG Land Cover Index = AG / (CROP + PH)

Distribute undefined agriculture land cover into cropland and pasturehay land cover classes at the LRseg scale.
1. For LRsegs with a non-zero Ag Land Cover Index that is also less than 1, inflate the PH and CROP acres by distributing the undefined agriculture (AG) class to PH and CROP based on the proportions of PH and CROP in each LRseg.
    1a. Create a multiplier = (PH + CROP +AG)/(PH + CROP)
     This must always be >= 1
    1b. Multiply PH and CROP by this multiplier

2. For LRsegs with no undefined agriculture (AG) and for LRsegs where the Ag Land Cover Index >=1 (e.g., the amount of undefined agriculture equals or exceeds the combined amount of PH and CROP), distribute the undefined agriculture (AG) class to LRsegs based on the proportions of pasturehay land use (CountyPastureHay) and cropland land use (CountyCropland) to total amount of agricultural land uses reported in the 2002 County Agricultural Census:
    2a. PH = PH + (AG * CountyPastureHay/TotalCountyAgriculture)
    2a. CROP = CROP + (AG * CountyCropland/TotalCountyAgriculture)

3. You now have PH and CROP acres for all LRsegs and zero 'AG' acres for all LRsegs, The acres do not add up to the ag census, however.
Distribute the ag land use classes based on the proportion of each ag land cover class within each LRseg
For all 'crop' classes:
  Acres of crop land uses = acres of CROP in lrseg / acres of CROP in county
 Do the same for PH

For a zero Ag Land Cover Index and crops available to go on that land, apply proportional to the lrseg acres / county acres.

AFOs are disaggregated to land river segments proportional to the area of all agricultural acres in each LRseg to the total agricultural acres in the county.

Procedure 2: Creating"CBP Land Use by LRseg"

INPUT
1. "CBP Ag LU by LRseg", from procedure 1
2. "CBP Urban LU by LRseg" – external table
3. Total Acres by LRseg – external table
4. water acres by LRseg – external table
5. extractive acres by LRseg – external table

The purpose of this procedure is to assemble the data set from different sources. Since these are based on different data sets, they do not add up to 100% of the area. Some guidelines have been developed in order of importance:
1. Total LRseg size and water must be preserved
2. Forest is found by subtraction

Procedure: follow for each Lrseg

Forest = total acres minus water, ext, urban, and ag.
If forest is non-negative STOP

Set AcresNeeded = -forest
Set forest to zero

Low intensity pervious urban = Low intensity pervious urban - AcresNeeded
If low intensity pervious urban is non-negative STOP

Set AcresNeeded = -(low Intensity pervious urban)
Set Low intensity pervious urban to zero

If ag > 0
    Set ag multiplier = 1 - (AcresNeeded)/(total ag)   (multiplier < 1)
    Multiply all ag categories by the ag multiplier
    If ag multiplier is positive STOP

    Set AcresNeeded = - (total ag)
    Set all ag to zero
End if ag > 0

If total urban > 0
    Set urban multiplier = 1 - (AcresNeeded) / (total urban)
    Multiply all urban categories by the urban multiplier
    If urban multiplier is positive STOP

    Set AcresNeeded = - (total urban)
    Set all urban to zero
End If total urban > 0

Set ext = LRseg total minus water
If ext positive STOP

Set ext = 0
Set water = LRseg total

End Procedure

Projecting Land Use

THIS IS NOT PART OF THE REQUIREMENTS FOR CALCULATING LAND USE
For the purposes of integration and consistency with the Phase 5.2 Watershed Model, the Chesapeake Bay Land Change Model (CBLCM) forecasts the proportional future growth in urban land and resulting proportional loss of forests and farmlands for each LRseg. .
1. For each LRSEG, the proportional increase in total urban area should be distributed proportionally to the five urban land uses reported for the base year of the forecast. For example, a forecasted growth of 100 urban acres from 2002 to 2010 in LRseg X should be distributed to the five urban land use classes in LRseg X reported in the 2002 land use dataset used as part of the Phase 5.2 calibration. The resulting increase in total urban area is then subtracted from the total of all forest land uses (e.g., forests + harvested forests) and from the total of all agricultural land uses reported in the 2002 land use dataset for LRseg X.

    a.   2. All of the proportions of urban, forest, and agricultural land uses relative to the total urban, total forest, and total agricultural land uses are kept constant through time. However, an iterative mass balance routine must be implemented to maintain total land acres in each LRseg while preventing any one land use (e.g., hay with manure) from falling into negative acres. Negative land use acres must be redistributed to other related land uses. For example, if "hay with manure" is forecasted to falls below zero acres in year 2010 then "hay with manure" must be set to zero and the deficit acres subtracted proportionally from all remaining agricultural land uses. This correction must be run iteratively until all land uses contain zero or more acres.

Manure Transformations (O. Devereux, 10/28/2008)

Calculate amount of manure available for direct excretion method on a county scale by year
Uses fraction of time in pasture by animal by month and growth region
Yields stored manure
Yields manure produced in pasture/month

Check to see if the county has pasture (pas, npa, trp) acres. If a county has no pasture acres, no manure is available for direct excretion. All manure will move into storage.

Take the lbs of nutrients that are produced by animals daily from "manure production" and aggregate to months.

Multiply sources by time in pasture to filter lbs of nutrients directly excreted in pasture.

Take lbs of nutrients excreted in pasture and disaggregate to pasture land use types (pas, npa, and trp). Trp gets 9 times the rate of pas and npa.

Crop Uptake (O. Devereux, 4/17/2009)

N and P Uptake Mass calculated at a land segment scale for all forms of N and P

Uptake is the amount of N and P taken from the soil into the plant. It includes the amount that would be removed with a harvest. It is calculated as a mass by month for each crop type. Maximum potential uptake is that which is calculated from a longer term average regional yield.

HARVEST YIELD	UPTAKE OR NUTRIENT USE	NUTRIENT APPLICATION RATE
Actual	Average of actual yields (calculated) #	Actual (unknown)
Best potential (two different calculation methods, one for uptake and another for nutrient application rates)	Maximum potential (calculated)$	Nutrient management (calculated)#$
Theoretical maximum ***	Theoretical maximum***	Theoretical maximum***#$

Notes:
\#   Watershed model calibration input file
\$ Watershed model scenario input file
***   Source data table. Table includes the N and P application rates and uptake mass by month in a look-up table.
    1.   Nutrient application rate is included for comprehensiveness, but not relative to uptake or land cover calculations.
    2.   The <u>theoretical maximum</u> is the yield, rate, or uptake from the maximum possible given best soil and best weather conditions.

Calculation of Best Potential Yield

<u>Best potential</u> for uptake is calculated as the best yield from any year plus 5%. Best potential for the nutrient application rate is described in detail in nutrient application requirements.

    Transform the NASS Ag Census yield data from bushels to bushels per acre. Use NASS data for each county, crop type, and year.

    1.   There should be no occurrences of yields without acres or acres without yields. The source data from the ag census has been cleaned up to remove these situations. Where a user imports their data and this error occurs, the user should be notified of the error.

    2.   Using the bushels per acre, determine which year had the highest yield. (TblCropHarvest)

    3.   Add 5% to the year with the highest yield, which gives the best potential yield for that crop type.

Calculation of Nutrient Uptake Mass
The look-up table data looks like:

CID	Crop	nutrient	max uptake/mo/yield unit	month after planting
0	Turf grass	N	0.0024061	1
0	Turf grass	N	0.0101054	2
0	Turf grass	N	0.0015124	4
0	Turf grass	N	0.0023526	5
0	Turf grass	N	0.0117629	6
0	Turf grass	N	0.0117629	7
0	Turf grass	N	0.0084021	8
0	Turf grass	P	0.0003711	1
0	Turf grass	P	0.0015585	2
0	Turf grass	P	0.0002333	4
0	Turf grass	P	0.0003628	5
0	Turf grass	P	0.0018142	6
0	Turf grass	P	0.0018142	7
0	Turf grass	P	0.0012958	8
1	Alfalfa Hay Harvested Area	N	3.0068182	1
1	Alfalfa Hay Harvested Area	N	12.628636	2
1	Alfalfa Hay Harvested Area	N	1.89	4
1	Alfalfa Hay Harvested Area	N	2.94	5
1	Alfalfa Hay Harvested Area	N	14.7	6
1	Alfalfa Hay Harvested Area	N	14.7	7
1	Alfalfa Hay Harvested Area	N	10.5	8

1. Determine plant date and harvest date for each crop and county. Using the month after planting, assign a month for the crop and county. (TblCropCounty)

   a. All other months will equal zero.

   b. Where a crop's harvest date is after January 1, and the plant date is prior to December 31, then the crop growth period will loop back to the beginning of that year. This means that where a winter wheat crop may have a plant date of October 1 and a harvest date of April 1, it will have growing dates of Jan, Feb, Mar, Apr, Oct, Nov, and December. This preserves the internal logic of each year being independent.

   c. If there is a month between plant and harvest dates that does not have a "month after planting" number assigned, the max uptake/mo/yield unit equals zero.

2. Calculate the best potential yield for *uptake* rather than the calculated best potential yield table for the *nutrient application rate*.

   a. Determine the **yield ratio** of the calculated best potential yield to the theoretical maximum yield for each year. (TblCropMaxYield)

   b. If theoretical maximum yield= null, then set yield ratio to 1

   c. If theoretical maximum yield=0, then set yield ratio to 0

3. Multiply this yield ratio for each county, crop type, month and nutrient by the theoretical maximum uptake in the source data table to get **best potential uptake**. The maximum uptake is by TN or TP in units of uptake/month/yield unit.

4. Convert units from uptake/month/yield unit as follows.

a. Multiply the maximum uptake adjusted for annual yield variation (best potential uptake from step 3) by the *actual annual yield* (for example (bushels).

b. Multiply the uptake/month by the acres for each crop type so the data is now in units of uptake/month.

5. Convert the uptake monthly mass to land use by summing the crops' monthly values that correspond to the same land use for each land use. Use the crops to land use table.

6. This gives a monthly mass by land use that may be summed across months for an annual mass.

Calibration nutrient uptake file—average over all years.

The one-time file for the Watershed Model calibration is calculated in a similar way. Since there is only a single file that is the average of the period, all related data used in the uptake calculation is averaged. This includes the yields, crop acres, and land acres. In addition, the source data file for yield is the actual harvest yield rather than the calculated best potential yield.

N and P Uptake Curve calculated at a county scale for all forms of N and P

Data used are N and P uptake percentages in a look-up table. The monthly curve number is the percent N or P applied per month. These percents are in a look-up table by crop type. Any variation is from crop variation or land use change from year to year.

1. To compute the curve by land use, use the monthly mass by land use (from #5 in crop uptake mass procedure) and sum these by land use for each month and for the annual sum.

2. Divide the monthly mass of N and P by the annual sum for each month. Report this fraction.

Assumptions:

The Watershed Model will calculate actual uptake based on temperature, rainfall, and other parameters not including yields. The Scenario Builder introduces variability due to geographical yield differences such as those from soil. Actual uptake is not calculated as part of the Watershed Model scenario inputs. Rather, best potential uptake is reported. Therefore, any variation in uptake is the result of variation in crops planted, not growth conditions.

There are no differences in uptake for nutrient management or tillage practices. Uptake is based on best potential yields calculated from actual yield data.

Maximum potential uptake is taken from crop removal data and doubled to represent the whole plant, unless other data indicated differently (as with corn at 2/3 in removal).

The crop uptake curve information is calculated for each of the 12 growth regions using the recommended plant date. This does not account for the variation in varieties used throughout the watershed. A better way and one that should be investigated in the future is using heat units to inform the curves.

The <u>theoretical maximum</u> is the yield, rate, or uptake from the maximum possible given best soil and best weather conditions. These data are from states' nutrient management handbooks and the state extension programs' agronomy recommendations.

Unexposed Soil Surface (O. Devereux, 4/17/2009)

Uses data:

> County
> Plant and harvest dates
> Tillage practice: low till or high till as associated with land use
> Soil surface cover by month
> Acres of crops
> Double cropped

1. Calculate crop residue cover

    a. For each crop and double cropped crop and tillage practice in each county, multiply the monthly soil surface cover fraction (given in a source data table) by the acres of cropland to get acres/month.

    b. Sum the crop residue cover by land use for each month to get land use acres/month.

2. Divide the monthly acres of unexposed soil surface cover from #1 by the total acres of land in that land use. This gives the percent cover by land use.

3. This calculation is bound where:

    a. monthly value is < 0.95

    b. monthly value is >zero

Assumptions
Double cropping cover is addressed by classifying a double-cropped crop as its own crop type with different plant and harvest dates than the same crop that is not double-cropped. Since the first crop planted is not considered as the double-crop, then those dates are not shortened to reflect what may be an earlier harvest. Therefore, there may be some overestimate of cover from leaf area coverage and an underestimate of residue cover during the harvest time of the first crop and the planting time of the double crop.

This process selects the residue cover or the canopy cover fraction, whichever is higher. An underestimation may result in early plant growth period for low till crops because residue may still be on the ground and leaf cover may not overlap. This is not an issue for high till crops where most of the residue is plowed under at planting.

NRCS Practice Standard 345 for Residue Management Mulch Till states, "The annual Soil Tillage Intensity Rating (STIR) value for all soil-disturbing activities shall be no more than 70 for high residue crops (e.g., grain corn) and no more than 10 for low residue crops (e.g., grain soybeans). These STIR values will result in approximately 30% or more surface residue for the entire crop rotation." By using the RUSLE2 tillage management practices, the data necessarily meets the conservation tillage STIR values.

Classifying Nutrient Applications in Terms of Land Use

Nutrients are eligible to be applied to land based on the land use in which they are classified. Table 9-1 indicates which broader categorization of agricultural land each land use falls into: row, hay, or pasture. These classifications are used to establish the eligibility of manure and/or fertilizer applications to crops within each of these land uses.

Table 9-1: Nutrient type classifications

Name	Short Name	Tillage	Row	Hay	Pasture	Nutrient Management	Manure	Fertilizer
animal feeding operations	afo	NA	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE
alfalfa	alf	NA	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
hightill without manure	hom	High	TRUE	FALSE	FALSE	FALSE	FALSE	TRUE
hightill with manure	hwm	High	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE
hay without nutrients	hyo	NA	FALSE	TRUE	FALSE	FALSE	FALSE	FALSE
hay with nutrients	hyw	NA	FALSE	TRUE	FALSE	FALSE	TRUE	TRUE
lowtill with manure	lwm	Low	TRUE	FALSE	FALSE	FALSE	TRUE	TRUE
nutrient management alfalfa	nal	NA	FALSE	TRUE	FALSE	TRUE	TRUE	TRUE
nutrient management hitil with manure	nhi	High	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
nutrient management hitil without manure	nho	High	TRUE	FALSE	FALSE	TRUE	FALSE	TRUE
nutrient management hay	nhy	NA	FALSE	TRUE	FALSE	TRUE	TRUE	TRUE
nutrient management lotil	nlo	Low	TRUE	FALSE	FALSE	TRUE	TRUE	TRUE
nutrient management pasture	npa	NA	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
pasture	pas	NA	FALSE	FALSE	TRUE	FALSE	TRUE	TRUE
degraded riparian pasture	trp	NA	FALSE	FALSE	TRUE	FALSE	TRUE	FALSE
nursery	urs	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
low intensity pervious urban	Pul	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE
high intensity pervious urban	Puh	NA	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE

SECTION 10.   REFERENCES

Koroncai, R. L. Linker, J. Sweeney, and R. Batiuk. 2003. Setting and allocating the Chesapeake Bay nutrient and sediment loads: the collaborative process, technical tools and innovative approaches. U.S. Environmental Protection Agency. Region III. Chesapeake Bay Program Office. EPA 903-R-03-007.

Potter, S.R., S. Andrews, J.D. Atwood, R.L. Kellogg, J. Lemunyon, L. Norfleet, and D. Oman. 2006. Model simulation of soil loss, nutrient loss, and change in soil organic carbon associated with crop production. U.S. Department of Agriculture. Natural Resources Conservation Service.

Duiker, S.W. Rudisill, A. (ed.) 2007. The Agronomy Guide 2007-2008. Penn State.

Palace, M.W., J.E. Hannawald, L.C. Linker, G.W. Shenk, J.M. Storrick, and M.L. Clipper. 1998. Chesapeake Bay watershed model application and calculations of nutrient and sediment loadings Appendix H. U.S. EPA for the Chesapeake Bay Program.

Schoenian, S. Sheep 201. Maryland Cooperative Extension. Accessed October, 2008 from http://www.sheep101.info/201/

Census of Agriculture. 1982, 1987, 1992, 1997, 2002. U.S. Department of Agriculture, Research, Education, and Economics, National Agricultural Statistics Service.

Fiesta, D., J. Griswold, B. Horsey, T. Juengst, R. Mader, R. Perkinson, and J. Sweeney. 2005. Agricultural Nutrient Reduction Workgroup: BMP Taskforce Conference Call. Chesapeake Bay Program.

Manure Production and Transformation

Burger, M. and Venterea, R. 2008. Nitrogen immobilization and mineralization kinetics of cattle, hog, and turkey manure applied to soil. Soil Science Society of America Journal 72(6): 1570-1579.

Carter, J.G. 2007. Updating the animal unit month. Western Watershed Project.

Evanylo, G.K. 1999. Agricultural land application of biosolids in Virginia: Managing biosolids for agricultural use. Crop and Soil Environmental Science 452-303.

Evanylo, G.K. 1999. Agricultural land application of biosolids in Virginia: Production and characteristics of biosolids. *Crop and Soil Environmental Science* 452-301.

Gartley, K., and J. Sims. 1994. Phosphorus soil testing: environmental uses and implications. Communications in Soil Science and Plant Analysis 25(9/10): 1565-1582.

Lander, C., D. Moffitt, and K. Alt. 1998. Nutrients available from livestock manure relative to crop growth requirements. Appendix II: Manure characteristics. U.S. Department of Agriculture. Natural Resources Conservation Service. Resource Assessment and Strategic Planning Working Paper 98-1.

Manure production and characteristics. 2003. American Society of Agricultural Engineers. ASAE D384.1.

Crops and Land Uses

Brann D., Abaye A. and P. Peterson. 2000. Agronomy Handbook Part I: Crop Descriptions. Virginia Cooperative Extension.

Brann, D.E., A.O. Abaye, and P.R. Peterson. 2000. Agronomy handbook. Part I – Crop descriptions. Brann, D.E., D.L. Holshouser, and G.L. Mullins (eds.). Virginia Cooperative Extension. 424-100.

Claggett, P. and Schueler, T. 2009. The grass crop of the Chesapeake Bay watershed. Environmental Management, in review.

Spence, G. 1988. Enterprise guide for Southern Maryland: grain sorghum production. Maryland Cooperative Extension. Fact Sheet 460.

Swecker, E.L. 1988. Straw production. Maryland Cooperative Extension. Fact Sheet 449.

Crop Growth

Holshouser, D.L. (ed.) 2001. Soybean production guide. Virginia Agricultural Experiment Station. Information Series 408.

Meek, B.D., D.L. Carter, D.T. Westermann, and R.E. Peckenpaugh. 1994. Root-zone mineral nitrogen changes as affected by crop sequence and tillage. *Soil Science Society of America Journal* **58**(5): 1464-1469.

Neitsch, S.L., J.G. Arnold, J.R. Kiniry, and J.R. Williams. 2005. Equations: optimal growth. In: soil and water assessment tool theoretical documentation. Version 2005. USDA Agricultural Research Service.

Crop Uptake

Bandel, V.A., B.R. James, J.J. Meisinger, and M.D. Woodward. 1991. Nitrogen recommendation for corn using the pre-sidedress nitrate-nitrogen soil test. University of Maryland Cooperative Extension: Fact Sheet 559.

Hanaway, J. J. 1962. Corn growth and composition in relation to soil fertility: II uptake of N, P, and K and their distribution in different plant parts during the growing season. *Agronomy Journal* **54**: 217–222.

Meier, K., and D. Nychka. 1993. Nonparametric estimation of rate equations for nutrient uptake. Journal of the American Statistical Association 88(422): 602-614.

Crop Cover

Foster, G.R., D.C. Yoder, G.A. Weesies, D.K. McCool, K.C. McGregor, R.L. Bingner. 2003. Draft user's guide: revised universal soil loss equation. Version 2. U.S. Department of Agriculture.

RUSLE2 Instructions and user guide. 2004. U.S. Department of Agriculture. Natural Resources Conservation Service.

Nitrogen Fixation

Blumenthal J., Russelle M. 1996. Subsoil nitrate uptake and symbiotic dinitrogen fixation by alfalfa. *Agronomy Journal* **88**: 909-915.

Bourion, V., G. Laguerre, G. Depret, A. Voisin, C. Salon and G. Duc. 2007. Genetic variability in nodulation and root growth affects nitrogen fixation and accumulation in pea. *Annals of Botany* **100**: 589-598. DOI: 10.1093/annbot/mcm147.

Durst, P. and S. Bosworth. 1986. Inoculation of forage and grain legumes. Penn State Cooperative Extension. Agronomy facts 11.

Johnson J., Welch L. and L. Kurtz. 1975. Environmental implications of N fixation by soybeans. *Journal of Environmental Quality* **4**(3): 303-306.

Loynachan T. Nitrogen fixation by forage legumes. Department of Agronomy. Iowa State University.

Lindemann, W.C. and C.R. Glover. 2003. Nitrogen fixation by legumes. New Mexico State University Cooperative Extension Service: A-129.

Xu-Ri, P.I. 2008. Terrestrial nitrogen cycle simulation with a dynamic global vegetation model. *Global Change Biology* **14**: 1745-1764. DOI: 10.1111/j.1365-2486.2008.01625.x.

Yield

Sammons, D.J., F.R. Mulford, J.G. Kantzes, P.R. Thomison, V.A. Bandel, G.P. Dively, A.P. Grybauskas, and R.L. Ritter. 1989. Managing wheat for maximum economic yield in Maryland. Maryland Cooperative Extension. Fact Sheet 446.

Nutrient Applications

Abaye A.O., T.J. Basden, D. Beegle, G.D. Binford, W.L. Daniels, S.W. Duiker, G.K. Evanylo, K.C. Haering, D.J. Hansen, G. Mullins, and R.W. Taylor. 2006. Mid-Atlantic Nutrient Management Handbook. Mid-Atlantic Regional Water Program.

Alley, M.M., P. Scharf, D.E. Brann, W.E. Baethgen, and S.J. Donohue. 1991. Efficient N fertilization of winter wheat: principles and recommendations. Virginia Cooperative Extension Service: 424-026.

Alley M.M., M.E. Martz, Jr., P.H. Davis, and J.L. Hammons. 1997. Nitrogen and Phosphorus fertilization of corn. Virginia Cooperative Extension. 424-027.

Black, C.A. 1993. Plant testing and fertilizer requirement. In: soil fertility evaluation and control. Chapter 3: Lewis Publishers.

Bouwman A., Boumans J. 2002. Estimation of global NH_3 volatilization loss from synthetic fertilizers and animal manure applied to arable lands and grasslands. *Global Biogeochemical Cycles* **16**(2): 8.1-8.11. DOI: 10.1029/2000GB001389.

Coale, F.J. 2002. Soil fertility management: agronomic crop nutrient recommendations based on soil tests and yield goals. Maryland Cooperative Extension. SFM-1.

Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1993. Soil fertility and fertilizers. 5th ed. Collier Macmillan Publishers.

Hearing, K.C. and G.K. Evanylo (eds.). 2006. The mid-Atlantic nutrient management handbook. Mid-Atlantic Regional Water Program. MAWP 06-02.

Johnston, A.E. 2005. Phosphorus nutrition of arable crops. In: Sims, J.T. and Sharpley, A.N. (eds.) *Phosphorus: Agriculture and the Environment*. Agronomy Monograph No. 22, ASA-CSSA-SSSA, 567-604.

N. Vaio, M.L. Cabrera, D.E. Kissel, J.A. Rema, J.F. Newsome and V.H. Calvert, II. 2008. Ammonia volatilization from urea-based fertilizers applied to tall fescue pastures in Georgia, USA. *Soil Science Society of America Journal* **72**(6): 1665-1671.

Olson, R.A. and L.T. Kurtz. 1982. Crop nitrogen requirements, utilization, and fertilization. In: F.J. Stevenson (ed.) *Nitrogen in Agricultural Soils*. Agronomy Monograph No. 22, ASA-CSSA-SSSA, 567-604.

Plant nutrient recommendations based on soil tests for turf maintenance. 1999. Maryland Nutrient Management Manual. COMAR 15.20.06.04. I-E1-1 - I-E1-9.

Sims, J.T. and K.L. Gartley. 1996. Nutrient management handbook for Delaware. University of Delaware Cooperative Extension. Cooperative Bulletin 59.

Sommer S., Schjoerring J. and O. Denmead. 2004. Ammonia emission from mineral fertilizers and fertilizer crops. *Advances in Agronomy* **82**: 557-622.

Van Es, H.M., B.D. Kay, J.M. Sogbedji, J.J. Melkonian, R.S. Dharmakeerthi, H. Dadfer, and I.Y.S. Tan. 2006. Nitrogen management under maize in humid regions: the case for the dynamic approach. Cornell University. University of Guelph.

Manure and fertilizer

Edmonds, L., N. Gollehon, R.L. Kellogg, B. Kintzer, L. Knight, C. Lander, J. Lemunyon, D.C. Moffitt, and J. Schaefer. 2003. Costs associated with development and implementation of comprehensive nutrient management plans. Part I – Nutrient management, land treatment, manure and wastewater handling and storage, and recordkeeping. U.S. Department of Agriculture. Natural Resources Conservation Service.

Kellogg, R.L., C.H. Lander, D.C. Moffitt, N. Gollehon. 2000. Manure nutrients relative to the capacity of cropland and pastureland to assimilate nutrients: spatial and temporal trends for the United States. U.S. Department of Agriculture. Natural Resources Conservation Service. NPS00-0579.

Lander, C. H., D. Moffitt, K.F. Alt. 1998. Nutrients available from livestock manure relative to crop growth requirements. Resource assessment and strategic planning working paper: 98-1. U.S. Department of Agriculture, Natural Resources Conservation Service.

Moffitt, D., and C. Lander. 1997. Using manure characteristics to determine land-based utilization. USDA-Natural Resources Conservation Service. ASAE 97-2039.

Sommers, L. 1977. Chemical composition of sewage sludges and analysis of their potential use as fertilizers. J. Environ. Qual. 6:225-239.

U.S. Department of Agriculture. Natural Resources Conservation Service. Agricultural Waste Management Field Handbook. National Engineering Handbook Part 651.

Virginia Department of Conservation and Recreation. 2005. Virginia Nutrient Management Standards and Criteria

Virginia. 1997. http://www.ext.vt.edu/pubs/compost/452-303/452-303.pdf. Statutory Authority: § 32.1-164.5 of the Code of Virginia.