Detailed Responses from the Chesapeake Bay Program Partnership to STAC's Recommendations/Comments re: Nutrient Input Estimation for the Chesapeake Bay Watershed Model

Note: Draft document provided to the Agricultural Modeling Subcommittee (AMS) and Agricultural Workgroup for review and approval. Contents may change prior to submission to Water Quality GIT.

11/15/2016

Introduction: The numbered recommendations and comments listed below can be found on pages 2 through 7 of STAC's Review of Nutrient Input Estimates for the Chesapeake Bay Watershed Model. Detailed responses from the AMS are set off from the numbered questions with bullet points.

1. We recommend that a comparative analysis of nutritive content at different stages of decomposition and application be performed across animal types to evaluate volatilization in the storage process and under typical best management practices.
    - The final documentation will contain detailed figures, with hypothetical nutritive content values, describing the transformation of manure within the barnyard, pasture and field. This will include a description of the volatilization process, and best management practices which can impact volatilization and other transformations.
2. The current "Scenario Builder" approach assumes zero nitrate nitrogen is available in animal manure. We recommend that this assumption be reviewed. Chastain et al. (2001) found that "the amount of nitrate-N can be significant in poultry litter that has gone through several 'heats' in a stacking shed. Manure stored in stacking sheds should be tested for nitrate-N in addition to ammonium-N and organic-N." Nitrogen can transform speciation quickly, and while ammonium may be the most common form of inorganic N in manure, it can be oxidized rapidly to nitrate.
    - Many of the values used in the Phase 6 Model are derived from laboratory analyses of manure and litter data. These labs often do not report a value for nitrate-N as it is assumed to be negligible and only measured on request The Partnership will consider including a value for nitrate-N when it is reported by laboratories across the region in the future.
3. Mineralization of organic nutrients in manure transforms previously unavailable nutrients into forms that can be used for plant uptake. We recommend that the contribution of manure N mineralization from previous years' applications be credited to the system and the current year crop N demand consequently reduced.
    - The Phase 6 Model does assume multiple years of manure mineralization beginning in the 1990s and continuing until this day. It is not considered in the 1980s because the Partnership felt that nutrient management plans likely were not considering multiple years of mineralization during that time. The mineralized manure is assumed to be made available to the crop in the year of growth, decreasing the need for additional nutrients from other sources. The exact mineralization rates by year and animal type will be included in the final documentation.

4. Information for separating manure into areas of deposition is provided by jurisdictions. We recommend that a review of inputs be conducted to ensure relative consistency among the states, and that any difference in values among states be explained and documented.
    - While the initial information used to separate manure into areas was not thoroughly reviewed, the Partnership has since gathered representatives from state agricultural agencies around the watershed to conduct such a review. This effort resulted in much more consistent information across the states that will be provided in the final documentation.
5. Direct deposition of manure on pasture is currently assumed to not meet any portion of the nutrient needs of pasture. While this may have made some sense historically prior to the widespread use of nutrient management, this assumption is now suspect. We recommend that some fraction of the direct deposition be counted towards meeting the "crop needs" of the pasture, perhaps evaluated from recent credits given to this source in nutrient management plans based on P. In this regard, and although the associated documentation was not provided as part of this review, we have observed from results of the alternative Beta3A scenario that many counties already have amounts of direct deposition on pasture in excess of their "crop needs," without any applications from any other source.
    - "Crop need" as referenced in this recommendation is best characterized in the Phase 6 Model as the pounds of nutrients per acre or yield unit that a crop should receive above and beyond any direct deposition. For example, the Maryland Department of Agriculture's Annual Implementation Reports indicate that producers apply an average of 15 pounds of nitrogen per acre of pasture in addition to direct deposition. This value accounts for many pastures receiving nothing in addition to direct deposition while other pastures receive well over 15 pounds of additional nitrogen. The Partnership elected to use this value as the "crop need" for pasture, understanding that direct deposition would occur regardless of the additional applications because this would be approximate the total applications to pasture beyond direct deposition.
    - The Partnership also feels that much of the direct deposition on pasture would not be available for plant uptake if this calculation was needed for the model because direct deposition of manure and urine on continuously grazed pastures often results in very low per acre N availability values – resulting in N deficient situations for large areas of the pasture.
6. We recommend that efforts to continually refine the values of manure nutrients in storage be encouraged in order to improve national excreted N and P values.
    - Agreed. The Partnership is currently collecting manure and nutrient concentration data from swine producers and litter and nutrient concentration data from poultry producers to better characterize the quantity of manure nutrients from these animal industries. The Partnership would also welcome efforts from the cattle and dairy industry to collect similar information in the future.

7. Since storage and handling losses are some of the most well-documented and understood losses, we recommend calculating storage and handling losses (and perhaps nutrient reductions due to feed additives), before calculating ammonia losses.
    - The Partnership recently approved this approach for calculating ammonium losses, and the final documentation will reflect this decision. Literature values for total nitrogen losses from excretion to the field (cradle-to-grave) were combined with literature values for ammonium conservation in an effort to characterize ammonium and total nitrogen loss through the system.
8. The current use of crop application curves to allocate excess manure ignores the fact that for many farms, manure is actually spread first on land operated by the facility. On most farms, vegetables are not likely to be grown in conjunction with those crops most associated with animal operations, such as corn, soybeans and alfalfa. We recommend that the crop application curve procedure be modified with the Economic Research Service's analyses of Census of Agriculture data to incorporate consideration of crops grown within animal operation systems in its analysis of manure distribution within the Chesapeake Bay Watershed.
    - Since the Model operates at the county level, the farm level specificity suggested by the reviewer would be difficult to incorporate. The application curves referenced in this recommendation are used to prioritize applications to certain crops. However, the total manure applications to each crop are based upon a combination of: acres of that crop within a county; average yield for that crop; and percent of application that can be made by organic sources. While the Partnership agreed to prioritize applications to vegetables and grains at a similar level, the combination of these other factors result in very little manure being applied to vegetables. In the most recent Phase 6 Model results, only 3.5 percent of all manure was applied to "specialty crops" – a group that includes vegetables. Conversely, 64 percent of manure was applied to grains.
9. As a further modification of the crop application curves, we recommend considering BMPs, such as New York's Precision Feed and Forage Management Practice, which prioritizes hay over corn. This procedure minimized farm inputs by balancing crop nutrient needs and dollars spent (Ghebremichael et al. 2007). Implementation and nutrient reduction data from the last 10 years may provide additional allocation mechanisms for excess manure.
    - Corn is most commonly the highest priority to receive nutrient application throughout the watershed, but individual jurisdictions can indicate other nutrient application priorities for their states as appropriate. Agricultural experts from New York are currently reviewing the latest Phase 6 Model results to determine if applications on hay and corn match their understanding of production systems in their state. Adjustments may be made to application calculations if warranted following this review.
10. We recommend that the prioritization process of manure applications to crops be revisited and vetted with experts within each state. Transparency should be ensured through the use of written justification for recommended values.
    - The combination of crop application curves with crop yield and acreage data provides final manure application estimates. Agricultural experts from each state within the

watershed are currently reviewing the latest Phase 6 model results to determine if applications match their understanding of production systems in their state. Adjustments may be made if necessary following review. STAC is encouraged to join in this review. Members of the AMS will provide justification for the prioritization process in the final documentation.

11. We recommend that the rate of allowable application above the application goal be reviewed by an appropriate group of regional experts. The justification for how these values were established should be documented and the decision substantiated.
    - The Phase 6 Model has no "rate of allowable application above the application goal." It also has no minimum rate of allowable application other than zero. The tool was designed in such a way that applications could increase or decrease in a smooth, predictable, prioritized fashion across all crops within a county if estimates of available manure and fertilizer increased or decreased. If for example, poultry populations increased 10-fold, the tool would not limit the application of poultry litter in that county. As mentioned in previous replies, STAC is encouraged to join in the review of the current Phase 6 Model results to help determine if rates are reasonable.
12. The Association of American Plant Food Control Officials (AAPFCO) data provides information on the fertilizer form (urea, DAP, etc.) and the amount sold (tons). We recommend using these data to calculate the actual ratio of ammonia and nitrate N in the fertilizer sold (e.g., urea=100% ammonia; UAN=50% ammonia and 50% nitrate) as a baseline and/or as a check against the 75:25 assumption.
    - The Partnership ~~will conduct a review of the AAPFCO data to estimate this average breakdown between ammonia and nitrate, and adjust the assumptions in the Phase 6 Model based upon these results. (Analysis is ongoing.)~~recently completed the analysis suggested by STAC for tons of fertilizer sold in 2012. The results of this analysis indicated that 77% of nitrogen sold was ammonium nitrogen with 23% being nitrate nitrogen. Given the results of this analysis, the Partnership feels the 75/25 split is still appropriate. A description of this analysis along with the assumptions for ammonium and nitrate in each grade will be included in the final documentation.
13. Although hard data are not available to decisively argue for a plateauing relationship at higher yields versus the linear relationships used in the Phase 6 (P6) equations for crop application goals, it is known that major crops cannot always achieve maximum yield. For example, water stress (even in high-clay soils) may restrict corn growth despite an abundance of nutrients. Thus applying more nutrients under the assumption that maximum yields can be approached is not realistic and may result in increased nutrient loss. We therefore recommend that further research be explored to identify and quantify these plateauing breakpoints to further refine nutrient distribution guidelines and procedures.
    - The level of crop physiology modeling needed to address the interaction between genetic capacity of the plant and environmental conditions that would likely be difficult to program into the Phase 6 Model. With that said, the Phase 6 Model bases applications not upon maximum yields, but upon average, countywide yields provided by USDA NASS. These yields do not yet approach literature values for maximum yields,

so the plateauing of applications is not needed for most scenarios. However, if partners wished to research alternative future scenarios with very high yields, a plateau of applications may be needed.

14. We recommend that the list of major field crops subject to double-cropping be revisited, as it appears that there are currently too many land use categories included under “Major Field Cropland Harvested Area,” whose acreage will never be used to double-crop the crops listed under “Major Field Crops.” This would lead to an under-estimation of the amount of identified double-cropped acreage. A suggested list of crop types to be considered under “Major Field Cropland Harvested Area” (for potential double-crop) would only include: i) alfalfa hay; vi) other managed hay; viii) small grain hay; x) wild hay; xiv) field and grass seed crops; xvii) canola; and xviii) popcorn.
    - The Partnership recently approved a new method to calculate double-cropped acres which follows similar logic as recommended by the reviewers. First, harvested cropland acres are compared to acres of harvested grains, hay, vegetables, orchards and area of greenhouses. The difference becomes the double cropped acres. This difference varies by region with larger differences in the Coastal Plain where double-cropping is common, and far fewer acres in New York, where double-cropping is only common about once every few years in an alfalfa or silage cropping routine. Secondly, agricultural experts from each state provided a list of individual crops which would be harvested in the spring and a second list of those harvested in the summer or fall during a double-cropping year. This allows the Phase 6 Model to proportion individual crops into the double crop acreages originally determined. The results again, vary by region. For example, most double-cropped acres in the Coastal Plain are a combination of spring or summer harvesting of small grains and fall harvesting of soybeans. In contrast, most acres in New York are a spring or summer harvesting of small grains haylage with a follow-up planting of alfalfa hay or corn silage. This process will be described in the final documentation.
15. We recommend that the effect of climate change on agricultural forecasting be considered in future forecasting efforts, since climate change may impact crop selection and nutrient inputs.
    - The Phase 6 Model will be used primarily to project the impact of anthropogenic changes to the landscape (including acreages and yields of crops and numbers of animals produced) through 2025, which is a shorter time period than can typically be addressed with climate prediction models. Through follow-up conversations with STAC review members, it was agreed that the current methods for projecting crop yields, acres and animal numbers by placing a large emphasis upon more recent trends will likely accommodate any changes due to climate over the short term forecasting period out to 2025. However, the Partnership will consult STAC if there is a need to estimate changes in agriculture past 2025.
16. We recommend that the alpha and beta weighting factors of 0.8 and 0.2 be reevaluated, and that this be based on the agricultural acres and changes in cropland (or individual crop), and not validated using the poultry or cattle data. Trends in crop acreage cannot be expected to follow trends in animal numbers. In fact, under an assumption that crop acres respond to commodity prices, high feed grain prices would be expected to stimulate more feed grain acreages but reduced animal numbers, as animal production is adversely affected by feed grain prices. The hypothetical example in Table 5-3 shows an approximate 30% error rate compared to actual reported acres (Yt) for Aft from 1987 to 2012. If this large discrepancy exists for other crop types/uses, a new strategy is needed. One potential source of forecasting data would be past, current, and future National Agricultural Statistics Service’s (NASS) Cropland Data Layer (CDL)

maps to look at apparent trends in crop groupings and rotations. Although CDL maps provide less breakdown of specialty crops than the Ag Census, the CDL groupings are at a level more related to the groupings used by Scenario Builder. CDL appears to show year to year fluctuations in overall cropping selection choices (possible relationships to economics, weather and crop damaging insects). Whatever data sources are eventually used to establish the weighting factors, they should be validated, and the hypothesized cause and effect relationship justified.

- The Partnership recently conducted an analysis of the beta and alpha weighting factors for the following groups of agricultural data as reported by the Census of Agriculture: Harvested Cropland Area, Pasture, Cattle, Swine and Poultry. The objective of the analysis was to determine which combination of beta and alpha factors would provide: 1) the smallest residual from the actual reported value across the entire watershed in 2012; and 2) the smallest root mean square error across all counties within the watershed in 2012. The analysis resulted in the alpha and beta factors included in the table below. These will be used in future Phase 6 forecasts of agricultural inputs, and the methods for selecting these factors will be described in the final documentation.

Revised Alpha and Beta Weighting Factors for Agricultural Projections

Category	Alpha Factor	Beta Factor
Harvested Cropland	0.6	0.4
Pasture	0.6	0.4
Cattle	0.6	0.4
Swine	0.8	0.2
Poultry	0.8	0.2

17. We strongly recommend that, in order to improve the transparency of the documentation, references and citations for all of the assumptions and values used in the process (including sources of data used in figures) be included.
    - The reviewers pointed out many general, and specific, areas where the documentation could be improved. These improvements will be made for the final version. Any decisions made using best professional judgment due to limited information from literature will also be described in the final documentation.
18. Concerns were previously raised about the relative evaluation of the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) C sub-factors for the "plow" scenario among states by the Ag Loading Rate Steering Committee (ALULRSC) in its December 17, 2015 report: "Although our Sub-group endorsed the use of RUSLE2 for generating sediment loads and relative loading ratios, our review revealed inconsistencies in the range of sub-factor values evaluated between states and crop management zones (CMZs),…[and] our Sub-group strongly felt that these inconsistencies must be addressed before the relative loading rates as used by Scenario Builder will be a valid representation of erosion rates among states and CMZs." An example of this variability was provided in Table 4 from the ALULRSC report for the "crop residue %" sub-factor for the pasture/range land use. While the sub-factor values were independently estimated by National Resources Conservation Service (NRCS) personnel in each state, no attempt was made to normalize them so that they would be comparable across states. The results were highly variable sub-factor values across states. We support and reiterate the previous recommendation by the ALULRSC to provide a cross-state review of all RUSLE2 C sub-factor values which are used to establish relative values of detached sediment by land use, especially noticeable in pasture.

- The Partnership is currently providing the RUSLE2 C sub-factors to an independent expert selected by STAC for review. The Partnership requests STAC provide any recommendations for changes to these values that result from that review.

19. We recommend applying the buffer credit to the same upland land use from which the buffer is taken, rather than applying it to all agricultural land uses in the land-river segment. If the majority of buffers are related to livestock exclusion, it is incorrect and potentially misleading to apply the filtering credit to cropland.
    - The Partnership's Watershed Technical Workgroup is currently reviewing this recommendation, and will have a response following its December 1 meeting.
20. The Agricultural Modeling Subcommittee – Pasture Subgroup (PSG) has proposed that all (100%) of manure deposited in riparian pasture areas be directly deposited (DD) to the stream. We recommend, instead, that DD be evaluated as a fraction of the manure load in riparian pasture areas consistent with the P532 loads from degraded riparian pasture areas. The PSG analysis in Appendix B indicates that 74% of the directly deposited total nitrogen (TN) load and 38% of the total phosphorus (TP) load would actually be comparable to the respective P532 loads. If the PSG's recommended 100% of deposited manure is used, the livestock exclusion BMP in P6 would get bonus reductions of about 35.5% for TN and 163.8% for TP, over that credited under the P532 version of the model.
    - The Partnership reviewed existing TMDL models developed for VA which assessed the impact of riparian area deposition. Each model had an assumption of the amount of manure deposited within the riparian area that was actually deposited in the stream itself, representing 0 attenuation of the manure nutrients by the land. These assumptions varied, with many models assuming 100 percent. The Partnership has chosen to use the average of these models, which was approximately 70 percent, to represent the amount of manure deposited within a riparian area which has 0 attenuation. That leaves 30 percent of manure deposited within nearby riparian areas which should have some attenuation factor applied to it. Butler et. al, 2008[1] found that of the TN and TP from manure applied to simulated, heavy use riparian areas, approximately 33 percent and 34 percent respectively was exported. These findings and assumptions can be combined in the following manner to estimate manure runoff to streams:
        - TN Fraction Runoff from Riparian Pasture = 0.70 X 1 + 0.30 X 0.33, or 0.80
        - TP Fraction Runoff from Riparian Pasture = 0.70 X 1 + 0.30 X 0.34, or 0.80
21. Suggested sources of additional technical data or scientific findings include:
    a. Nutrient management planners and the extensive non-proprietary data contained in nutrient management plans could be engaged by CBPO to refine model characterization of local farming practices, manure/fertilizer application rates and timing, and conservation techniques.
        - The Partnership is encouraged by the aggregated, countywide results from recent Maryland Annual Implementation Reports (AIRs), in which farmers report manure and fertilizer applications. Similar, future surveys collected by states across the watershed would provide more data to ground-truth and perhaps adjust modeling assumptions in the future.

[1] Butler, D.M., Ranells, N.N., Dorcas, H.F., Poore, M.H., Green, J.T. 2008. Runoff water quality from manured riparian grasslands with contrasting drainage and simulated grazing pressure. Agriculture, Ecosystems and Environment 126 (2008) 250-260. March, 2008.

b. Results presented at the 2016 Soil and Water Conservation Society (SWCS) annual meeting which showed that a majority of farmers sought fertilizer rate and timing recommendations from local fertilizer sales companies and agribusinesses (Embertson 2016). These results deserve careful consideration, and recommendations of the sales companies and agribusinesses should be evaluated in relation to other means of estimation. In particular, fertilizer retailers could be surveyed to refine fertilizer sales by crop type.
   - The Partnership recently began discussions with fertilizer retailers with the objective of improving fertilizer estimates in the future.

c. Updated manure production numbers by animal type would help improve manure nutrient load estimates.
   - The Partnership requests that states provide aggregated laboratory analyses and litter volume analyses for poultry each year in an effort to improve model estimates.
   - The Partnership will soon complete an effort to re-characterize nutrients generated by swine and turkeys, and this information will be used in the final Phase 6 Model, and states will be asked to update this data in the future.
   - The Partnership would like to expand this effort to the cattle and dairy industries at some point in the future.

d. Applied academic studies could be used to better support and/or inform nutrient and land management estimates, including a more comprehensive representation of rotational land management.
   - The Partnership would be interested in developing future STAC workshops that could explore this recommendation further.

e. Mineralized N from previous year manure applications should be incorporated into future versions of the watershed model.
   - Mineralized nitrogen from previous years' manure applications will be considered in Version 6. Please see the response to question 3 for a more complete description.