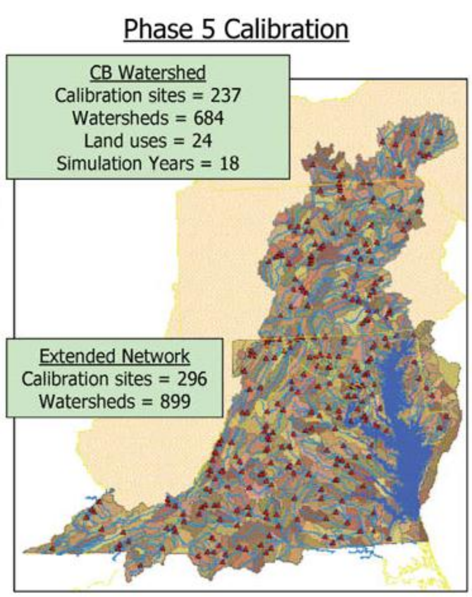
Chesapeake Bay Commission
Follow-up Questions for Dr. Weller

The questions were submitted by individual members of the Chesapeake Bay Commission and staff for purposes of gathering information, and do not necessarily reflect a collective position or point of view of the Commission as whole. The answers are those of Dr. Weller respectively, and should be attributed as such.

CBC questions are in italics, responses are in plain type.

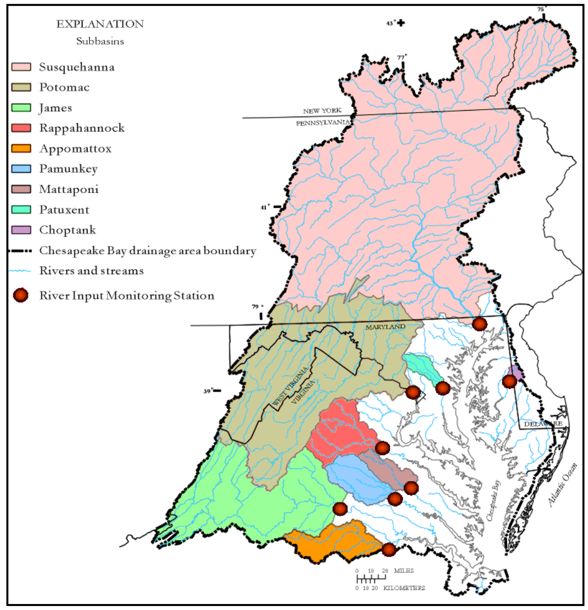
1. How many stream monitoring points are used to calibrate the Chesapeake Bay model? What percentage of the 64,000 square mile Bay watershed can these monitoring points accurately represent? Do you concur with RA Garvin's assessment that the model has limitations at the finer scale? What causes the limitations at the finer scale? Has STAC previously reviewed the model's precision at the local scale?

RESPONSE: The CBP model uses 237 calibration/validation sites within the Chesapeake watershed for flow, 215 for total phosphorus, 200 for suspended sediment, and 115 for total nitrogen (Table 1, STAC 2011 and Table 11-1, USEPA-2010a). There are also additional calibration sites outside the Chesapeake Bay watershed (see map below). These non-Chesapeake sites are available because the states supported expanding the model to cover all of Virginia, Maryland, and Delaware. The expanded coverage facilitates statewide consistency in water quality analysis and regulation, and consistency of local efforts with regional Chesapeake Bay activities (USEPA 2010b).



Map of CBP model calibration sites (Figure 1-7a in USEPA 2010b).
.

The CBP model calibration stations include the nine major "River Input" monitoring stations (see map below). Just those nine stations together measure the discharges from about 80% of the watershed. The hundreds of other calibration stations include sites that represent the area downstream of the nine river input stations and sites that provide much additional information on the major river basins (see map above).



Nine river input monitoring sites (red circles). The upstream area draining to each site is shaded (USGS 2010).

A 2008 STAC review panel considered the limitations of the CBP model at finer scales (page 5, Band et al. 2008). Like R.A. Garvin, the committee concluded that the CBP model does have limitations at finer scales. The STAC review committee wrote that the current CBP model implementation is not appropriate for development and implementation of TMDLs at the local watershed scale. The committee defined local watersheds as watersheds smaller than the segments of the CBP model, which translates roughly to watershed smaller than 66 square miles in area and producing a mean annual flow rate less than 100 cubic feet per second (cfs) at the watershed outlet. The limitation arises because the CBP model is built on county level data and a river network that accounts for streams with mean annual flow larger than 100 cfs. The committee wrote that this resolution is suitable for full watershed or major tributary scale analysis. The STAC review suggested one possible solution--the CBP model framework could be implemented for smaller watersheds using information from local sampling and measurement, and spatial data from higher-resolution local sources.

2. You mention that the 5.2.3 model was calibrated with stream monitoring points. Has the 5.3.2 model been validated? Should it be validated before being used to predict water quality improvements?

RESPONSE: The CBP model *has* been validated. In this context, “calibration” refers to adjusting model parameters to achieve the best match of model predictions with monitored data on water discharge and nutrient concentrations. In “validation,” model predictions are compared to monitored data that were *not* already used in model development or calibration. This provides an independent test of model skill in predicting water and nutrient loads. The CBP model was calibrated to data collected during the years 1985-95, and validated with data from the same stations for a separate time period (1995-2005). This strategy was recommended by STAC (Band et al. 2008) and implemented by the CBP modeling team.

3. On page 5 of the STAC review committee's report, the committee concluded “It is unclear where LimnoTech obtained the notion that the EPA expects TMDLs to be accurate to a single pound because no TMDL has or will ever likely obtain such accuracy, and most watershed modelers would concur that such *a goal is folly." But in Appendix Q, EPA has assigned very specific N, P and sediment loads, sometimes expressed to the billionth of a pound. How literally will these load reductions be interpreted when measuring sufficient progress?*

RESPONSE: Appendix Q, which is titled "Detailed Annual Chesapeake Bay TMDL WLAs and LAs," is a supplement to the TMDL documentation (available at USEPA 2010c).

Appendix Q is a spreadsheet that presents CBP model output summarized with some additional mathematical formulas, and the numbers have the full precision offered by computer calculations (Gary Shenk, USEPA-CBPO, personal communication). As an example of computer precision, entering the simple division problem "=5/7" into a spreadsheet cell generates the fraction 0.714285714285714. The high level of precision that computers automatically produce should never be interpreted as an indication that real-world quantities are known to that high level of accuracy or precision.

The heart of your question seems to be "How far above the TMDL assignments would loads need to be for EPA to make a judgment of insufficient progress?" This is a policy question, not a science question, and it is really an issue that should be discussed by EPA and the states.

4. One of the core corrections the STAC made in its review of the LimnoTech report was to add into LimnoTech's cropland load figures the additional load that NRCS calls "Background" in the CEAP. LimnoTech agreed that this was an error and corrected it in the update they issued earlier this week. Why is the background load so large? The now corrected number that results from adding in the "Background" load goes up to slightly more than 2 million tons (Table 3, Page 3 of the LimnoTech November Update). Wouldn't that make the background load larger than the load from a cultivated acre? Can you work with the CEAP team at NRCS to help us to understand this issue?

RESPONSE: The STAC calculations (STAC 2011) were later endorsed by LimnoTech in its correction (LimnoTech 2011b). Those calculations indicate that the CB-CEAP model estimates a load of 2,018 tons of sediment delivered to Chesapeake Bay from all agricultural sources, of which 1,040 tons come from cropland. Let's focus on the cropland load because the CB-CEAP model (USDS-NRCS 2011) estimated "background loads" only for cropland, (not for other agricultural or non-agricultural sources). Correctly including for the cropland background load raised the total cropland delivered load from LimnoTech's original underestimate of 448 thousand tons (Table 3, LimnoTech 2011a) to the corrected estimate of 1040 thousand tons (STAC 2011; Table 3, LimnoTech 2011b). LimnoTech's original underestimate accounted for only 43% of the delivered cropland load, and LimnoTech's original underestimate of loads per cultivated acre (204.1 pounds/acre; Table 3, LimnoTech 2011a) also accounted for only 43% of the corrected estimate (474 pounds/acre; STAC 2011; Table 3, LimnoTech 2011b).

The CEAP team reported information that can be used to estimate the load from cultivated cropland due to "background," which is the load that would be expected if the cropland were converted to a grass/tree mix with no tillage or nutrient addition (USDA-NRCS 2011). Those calculations show that across the entire watershed, most of the nutrient load delivered to the Bay from cropland (97% of the delivered crop nitrogen and 93% of the delivered crop phosphorus) came from crop activities (tillage and nutrient addition). Only a small amount of the nutrients came from background (4% of the delivered crop nitrogen and 7% of the delivered crop phosphorus). In contrast, 57% of the cropland sediment delivered to the Bay (596 thousand tons) comes from background. As you point out, the background component *is* larger than the 43% attributed to cultivation (444 thousand tons).

It does make sense that the background load is a higher percentage of the cropland load for sediment than it is for nitrogen and phosphorus. The scarcity of nitrogen and phosphorus often limits plant growth (that's why we must add fertilizer to improve crop production). Ecological processes in natural ecosystems (like forests and grasslands) are very effective at holding on to scarce nitrogen and phosphorus. Much of the nitrogen and phosphorus in natural ecosystems is incorporated into living and dead vegetation or tightly bound to subsurface soil particles. The nitrogen and phosphorus are not available to cause water pollution, so background loads from forest and grassland are very low. The situation for sediment is very different. All ecosystems (forest and grasslands as well as croplands) contain vast amounts of soil. Forest and grasslands are typically better at holding soil in place than croplands, but forests and grasslands still contain huge amounts of soil that can be eroded to deliver sediments to streams and so contribute to background sediment loads. Current sediment delivery also depends on historical land use activities. Erosion from land clearing and agriculture has deposited huge amounts of sediment in floodplains, streams, and river channels. Even if the erosion due to cropland tillage were stopped completely (as in the hypothetical USDA-NRCS "background" scenario), those legacy sediments in and near streams from past agricultural activities would still be available to contribute to high background sediment loads.

5. If an individual model is really only useful for its designed purpose, at its designed scale, is there any way for different models to relate to each other at all for decision-making purposes? For example, the current Chesapeake Bay Watershed Model appears to be accurate for planning purposes only at the basin scale, but other models exist that have been designed for farm-level planning. Are there any protocols by which these different models can be integrated or bridged? What would be required to do so?

RESPONSE: First, let's rephrase your initial premise. STAC did not conclude that a "model is really only useful for its designed purpose." STAC said that models have different purposes, and those different purposes inevitably lead to differences in model assumptions, input data, model frameworks, and model results. STAC would also say that a model would be expected to perform best when applied for its designed purpose, but might still provide useful information when applied in other ways. For example, the CBP model may perform best for basin scale planning and have limitations for setting local TMDL allocations (see response to question two). Even so, the CBP model can still provide information that is useful to local planners.

The Chesapeake Bay partnership already uses a suite of models to accomplish its objectives. In trying to understand the sources and fates of nutrients and sediments in the watershed, the partnership has used the USGS SPARROW model to address some questions where that model is more effective than the CBP model. STAC believes that USDA's CB-CEAP model may provide better field-level understanding of some questions than does the CBP model, and STAC has recommended some analyses that would use the CB-CEAP model independently of the CBP model (STAC 2011). STAC has also recommended that some of the underlying data and knowledge gained from the CEAP studies could be assimilated into future versions of the CBP model. USDA and EPA had already thought of that idea and are actively working to accomplish it. Developing better ways to more effectively apply multiple models in Chesapeake Bay management is an area of current interest and active interaction between STAC and the Chesapeake Bay partnership.

References

Band, L., T. Dillaha, C. Duffy, K. Reckhow, and C. Welty. 2008. Chesapeake Bay watershed model phase five review. STAC Publication 08-003, Chesapeake Research Consortium, Inc., Edgewater, MD.

LimnoTech. 2011a. An updated Comparison of load estimates for cultivated cropland in the Chesapeake Bay watershed. LimnoTech, Ann Arbor, MI.

LimnoTech. 2011b. Corrections to "Comparison of load estimates for cultivated cropland in the Chesapeake Bay watershed." LimnoTech, Ann Arbor, MI.

STAC 2011. Review of the LimnoTech Report, "Comparison of Load Estimates for Cultivated Cropland in the Chesapeake Bay Watershed. Committee for the ANPC/LimnoTech Review, Scientific and Technical Advisory Committee to the Chesapeake Bay Program, STAC Publication 11-02, Chesapeake Research Consortium, Inc., Edgewater, MD.

USDA-NRCS. 2011. Assessment of the effects of conservation practices on the cultivated cropland in the Chesapeake Bay region. U. S. Dept. of Agriculture, Natural Resources Conservation Service, Washington, D.C.

USEPA. 2010a. Phase 5.3.0 Watershed Model Documentation. Section 11: Riverine Simulation. ftp://ftp.chesapeakebay.net/Modeling/P5Documentation/SECTION_11.pdf.

USEPA. 2010b. Phase 5.3.0 Watershed Model Documentation. Section 1: Watershed Model Overview. ftp://ftp.chesapeakebay.net/modeling/P5Documentation/SECTION_1.pdf

USEPA. 2010c. Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment. U. S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html.

USGS 2010. Chesapeake Bay River Input Monitoring Program. http://va.water.usgs.gov/chesbay/RIMP/map.html