Cayuga Lake Watershed Modeling
Supporting the Development of a TMDL for the Southern End of Cayuga Lake

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Summary: The objective of this effort is to develop a watershed-scale model that can be used to assess various management strategies for reducing phosphorus (P) loads to Cayuga Lake. The model output will be used to inform P-load inputs to the limnological model under development by the Upstate Freshwater Institute (UFI) for Cayuga Lake. Because we need to simulate loads of different P forms and of sediment, we have are using the Soil and Water Assessment Tool (SWAT) and applying it in a way that captures the patterns of storm runoff better than the standard application, i.e., we refer to our model as SWAT-VSA. The model has been calibrated against measured stream discharge from two USGS gauges (Fall Creek and Six Mile Creek) and we have developed a single parameter set that we have applied to the entire Cayuga Lake watershed. In cooperation with local agricultural management experts, we have developed a generalizable manure management and fertilization rubric; so far we have assumed the distribution of management practices throughout the Cayuga Lake watershed is identical to Fall Creek and we recognize that this needs refinement. We have tested our P-loads against data collected by the Community Science Institute and our estimates are in general agreement and the order of magnitude average watershed loads are of the same order of magnitude as empirical estimates. Note, we have not calibrated the P routines in SWAT.

We are continuing to run diagnostics on the model and incorporating other hydrologic and P datasets into our evaluations and testing. We are working with relevant Soil and Water Conservation Districts to determine the extent to which recommended Best Management Practices (BMPs) have been adopted by producers so that these can be incorporated into the model. We will be using the Chesapeake Bay BMP-reduction factors as a starting point for incorporating BMP-based scenarios into the model. We are also exploring a variety of realistic and hypothetical scenarios to assess model sensitivity to management. A meeting is being planned with producers in the Cayuga Lake watershed to get feedback on model results and potential management scenarios that should be included in this effort.
Background

The Cayuga Lake watershed is located in the Finger Lakes region of Central New York. It forms part of the Great Lakes Basin and its effluent makes its way into Lake Ontario. The Cayuga Lake Watershed is a large watershed encompassing more than 223,000 hectares (ha) which fall in a total of include portions of 7 counties. These counties include Tompkins, Cortland, Cayuga, Seneca, Schuyler, Tioga, and Ontario counties. The location of the Cayuga Lake watershed in relation to these counties can be found in Figure 1.

A wide array of land uses are found within the watershed and include urban areas such as the City of Ithaca, rural areas dominated by agricultural land use, and natural landscapes such as forests and wetlands. A map of the land cover within the Cayuga Lake watershed can be found in Figure 2. Agricultural land use is of special importance in the Cayuga Lake watershed as it accounts for approximately 50% of the land cover and can be broken into two primary categories, cultivated crops and pasture land. Cultivated crops cover approximately 58,000 ha equaling 26% of the total watershed area. Figure 3 highlights the locations within the watershed where cultivated crops are the dominant land use. Similarly, pasture land accounts for 56,000 ha within the Cayuga Lake watershed which amounts to approximately 25% of the watershed area (Figure 4).
Figure 2. Dominant land cover in the Cayuga Lake watershed
As can be seen in figures 3 and 4, cultivated crops are more concentrated in the mid to northern sections of the watershed on both the east and west sides of the lake. Pasture lands, however, are evenly dispersed throughout the watershed with the only exception being the urbanized area at the southern end of Cayuga Lake where the City of Ithaca is located.

The larger Cayuga Lake watershed can be broken down into many subwatersheds. These subwatersheds that contribute to the lake are small, but there are a few large subwatersheds which make up the greatest contribution to the lake. These include, but are not limited to; Fall Creek, Six Mile Creek, Cayuga Inlet, Taughannock Creek and Salmon Creek; these are the most relevant to the southern end of the lake where the TMDL analysis by the New York State Department of Environmental Conservation (NYSDEC) effort is concentrated. A map is provided in Figure 5 outlining the subwatersheds with the larger watersheds highlighted and labeled.
Figure 5. Delineations of the Cayuga Lake watershed’s sub-watersheds, with the major southern sub-watershed highlighted. Note, for modeling purposes we have lumped adjacent, tiny watersheds into single sub-watersheds. Stream gages (orange circles) and Community Science Institute sampling sites (yellow circles) are also shown.
The southern end of Cayuga Lake is currently listed by the New York State Department of Environmental Conservation (NYSDEC) as a 303(d) impaired water body and lists both sediment and phosphorus (P) as problematic pollutants. As a result, the DEC is currently attempting to evaluate the need for a Total Maximum Daily Load (TMDL). The goal of this project is to develop a watershed scale model using the Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) to accurately characterize the inputs of sediment and P to Cayuga Lake from all tributaries under present conditions as well as in future or hypothetical conditions for use in the TMDL evaluation.

**Input Data**

The SWAT is a watershed scale, semi-distributed, quasi-physically-based model (some subroutines are empirical and some are more mechanistic). A number of data sets are required to initialize the model. Spatial data required for initialization include elevation, soils, and land cover. The model uses these data to categorize the landscape into unique hydrologic response units (HRUs); this reduces computational requirements, but also reduces the accuracy of the spatial representation of input data within a subbasin. Other data such as weather and land management can be included in the model in tabular format. SWAT was used with an adaptation to accurately represent the runoff generating processes of the region referred to as variable source area (VSA) hydrology; this adaptation is referred to as SWAT-VSA (Easton et al., 2008).

A number of spatial data are required by SWAT for proper model initialization. The first of these data obtained were a digital elevation model (DEM) from the US Geological Survey (USGS) National Elevation Data set (NED) (Gesch, 2007; Gesch et al, 2002). These data have a resolution of 1 arc-second (approximately 30 meters) and are available throughout the watershed. Spatial and tabular representation of land cover was obtained from the National Land Cover Database (NLCD 2006) published by the Multi-Resolution Land Characteristics Consortium (MRLC) (Fry et al, 2011). This dataset was modified to include other more specific agricultural land uses that are common to central New York such as vineyards,
orchards, and vegetable farms. These additional agricultural data were obtained from the 2010 New York Cropland Data Layer provided by the USDA National Agricultural Statistics Service at a resolution of 30 meters (USDA, 2010). A spatial representation of soils throughout the watershed was obtained using TopoSWAT (Fuka et al, 2013). TopoSWAT is an automated ArcMap tool which combines the Digital Soil Map of the World developed by the Food and Agriculture Organization of the United Nations (FAO) in collaboration with The United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Fischer et al, 2008) with a soil wetness class to give a more accurate representation of soil type and its propensity to generate runoff as defined by VSA hydrology. For a full description of how SWAT is implemented to capture VSA hydrology, see Easton et al. (2008).

Tabular datasets are also required by SWAT to best represent watershed conditions, these include meteorological, land management data, and point source emissions. Accurate meteorological data are vital to optimal model performance; SWAT requires inputs for precipitation, minimum and maximum temperature, relative humidity, radiation, and wind speed. These data were obtained from the Global Historical Climatology Network (GHCN), published by the National Oceanic and Atmospheric Administration (NOAA) through the National Climatic Data Center (NCDC) (Menne et al, 2012). While these data are available during the modeling period for only limited portions of the watershed they provide the most accurate outputs and were therefore applied over the entire watershed when possible.

The second data set crucial to the accuracy of the watershed model with respect to nutrient transport is information regarding land management in the area. An estimation of current land management practices was used to create baseline inputs to the model. Fertilization routines for vegetable farms, orchards, and vineyards were determined based on recommendations commonly made to farmers growing each aforementioned crop in the form of a 10-10-10 fertilizer (Cornell, 2006). Many types of agriculture are practiced in the Cayuga Lake Watershed ranging from large scale Contained Animal Feeding Operations (CAFO’s) to small scale dairy farms with pastured cows, to vegetables farms and vineyards. All of these farmers employ unique land management strategies and it is vital that the inputs to the model accurately
reflect the diversity and spatial distribution of the various land management approaches. To ensure the
accuracy of input data, a group of experts from ProDairy, Ag and Markets, the state Soil and Water
Conservation Committee, and a number of county Soil and Water Conservation Districts were consulted.

Point source inputs of sediments and P from waste water treatment plants was also included in the
model. The Fall Creek watershed contains two waste water treatment plants which discharge into the creek.
The flow from both plants was considered to be one singular point source as the two plants share an effluent
pipe. Daily rates of sediment and P discharges were obtained from the Environmental Protection Agency’s

**Streamflow Calibration and Validation**

A number of stream gages are available from USGS in the tributaries of Cayuga Lake. These gages provide
publicly available, daily stream flow data over varying historical time frames (USGS, [http://waterdata.usgs.gov/ny/nwis/rt](http://waterdata.usgs.gov/ny/nwis/rt)). Two gages in this network were used during calibration, Fall Creek (gage number 04234000) and Six Mile at Bethel Grove (gage number 04233300). These gages were
chosen because they contained sufficiently long records to which the model could be compared and
calibration could be performed. Two other gages were used to corroborate model output; these gages were
located at Salmon Creek (gage number 0423401815) and Six Mile at Brooktondale (gage number
04233286). Figure 5 displays the locations of these gages in the watershed. The SWAT model was validated
and parameterized against stream flow measurements and the Nash-Sutcliffe model efficiency (NSE)
coefficient was used to quantitatively evaluate the performance of the model (Nash and Sutcliffe, 1970).
Preliminary model runs are conducted from 1990 to 2010, and evaluated over 15 years, 1995 to 2010, using
a 5 year warm up period, 1990 to 1995. NSEs are calculated for the aforementioned years or the years in
which stream flow observations were available.
Calibration was conducted using the Differential Evolution Optimization routine (DEOptim) (Mullen et al., 2011). This was conducted on the NCAR supercomputer system to minimize computing time. Parameters currently included in the calibration can be found in Table 1. Output of best performing parameters for calibrations conducted on Fall Creek and Six Mile Creek can be found in Table 2. These parameters were then applied to all four previously mentioned gages to check for performance. The results of this “parameter swap” can be found in Table 3. You can see that Fall Creek parameters work best in the Fall Creek watershed as well as the Salmon Creek watershed. In contrast, the Six Mile at Bethel Grove parameters produce the best outputs at the two gages located in that same watershed. Overall, NSEs are highest in Fall Creek, followed by Salmon Creek, and lastly, Six Mile Creek this seems to suggest that watersheds closer to weather stations perform better; alternatively, it may suggest that the model works better on larger watersheds than on smaller ones with respect to predicting streamflow.

Table 1. Parameters included in calibration of SWAT model

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Parameter</th>
<th>File</th>
<th>Brief Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GW_Delay</td>
<td>gw</td>
<td>The lag between the time that water exits the soil profile and enters the shallow aquifer</td>
</tr>
<tr>
<td>2</td>
<td>Alpha_BF</td>
<td>gw</td>
<td>Base flow recession constant</td>
</tr>
<tr>
<td>3</td>
<td>GWQMN</td>
<td>gw</td>
<td>Depth of water in the aquifer needed to generate return flow</td>
</tr>
<tr>
<td>4</td>
<td>GW_Revap</td>
<td>gw</td>
<td>Ease of movement of water from shallow aquifer to root zone</td>
</tr>
<tr>
<td>5</td>
<td>Revapmn</td>
<td>gw</td>
<td>Depth of water in shallow aquifer for percolation to deep aquifer to occur</td>
</tr>
<tr>
<td>6</td>
<td>Rchrg_dp</td>
<td>gw</td>
<td>Fraction of percolation from the root zone that recharges the deep aquifer</td>
</tr>
<tr>
<td>7</td>
<td>SFTMP</td>
<td>bsn</td>
<td>Air temp at which precipitation is equally likely to be rain as snow</td>
</tr>
<tr>
<td>8</td>
<td>SMTMP</td>
<td>bsn</td>
<td>Threshold temperature value at which snow pack will begin to melt</td>
</tr>
<tr>
<td>9</td>
<td>SMFMX</td>
<td>bsn</td>
<td>June 21 melt factor</td>
</tr>
<tr>
<td>10</td>
<td>SMFMN</td>
<td>bsn</td>
<td>December 21 melt factor</td>
</tr>
<tr>
<td>11</td>
<td>TIMP</td>
<td>bsn</td>
<td>Snow pack temperature dependence on previous days temperature</td>
</tr>
<tr>
<td>14</td>
<td>SURLAG</td>
<td>bsn</td>
<td>Surface runoff lag coefficient</td>
</tr>
<tr>
<td>32</td>
<td>ESCO</td>
<td>hru</td>
<td>Soil evaporation compensation factor</td>
</tr>
<tr>
<td>33</td>
<td>EPCO</td>
<td>hru</td>
<td>Plant uptake compensation factor</td>
</tr>
</tbody>
</table>
Table 2. Parameters values for best performing models for Fall Creek and Six Mile Creek at Bethel Grove.

<table>
<thead>
<tr>
<th>ID Number</th>
<th>Parameter</th>
<th>File</th>
<th>Six Mile Creek at Bethel Grove</th>
<th>Fall Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GW_Delay</td>
<td>gw</td>
<td>688.262</td>
<td>82.410</td>
</tr>
<tr>
<td>2</td>
<td>Alpha_BF</td>
<td>gw</td>
<td>0.039</td>
<td>0.152</td>
</tr>
<tr>
<td>3</td>
<td>GWQMN</td>
<td>gw</td>
<td>193.752</td>
<td>29.154</td>
</tr>
<tr>
<td>4</td>
<td>GW_Revap</td>
<td>gw</td>
<td>0.009</td>
<td>0.192</td>
</tr>
<tr>
<td>5</td>
<td>Revapmn</td>
<td>gw</td>
<td>244.587</td>
<td>443.955</td>
</tr>
<tr>
<td>6</td>
<td>rchrg_dp</td>
<td>gw</td>
<td>0.934</td>
<td>0.107</td>
</tr>
<tr>
<td>7</td>
<td>SFTMP</td>
<td>bsn</td>
<td>1.989</td>
<td>-0.424</td>
</tr>
<tr>
<td>8</td>
<td>SMTMP</td>
<td>bsn</td>
<td>3.430</td>
<td>3.286</td>
</tr>
<tr>
<td>9</td>
<td>SMFMX</td>
<td>bsn</td>
<td>0.127</td>
<td>1.843</td>
</tr>
<tr>
<td>10</td>
<td>SMFMN</td>
<td>bsn</td>
<td>4.805</td>
<td>3.611</td>
</tr>
<tr>
<td>11</td>
<td>TIMP</td>
<td>bsn</td>
<td>0.575</td>
<td>0.553</td>
</tr>
<tr>
<td>14</td>
<td>SURLAG</td>
<td>bsn</td>
<td>0.159</td>
<td>0.246</td>
</tr>
<tr>
<td>32</td>
<td>ESCO</td>
<td>hru</td>
<td>0.528</td>
<td>0.583</td>
</tr>
<tr>
<td>33</td>
<td>EPCO</td>
<td>hru</td>
<td>0.148</td>
<td>0.955</td>
</tr>
</tbody>
</table>

| NSE       | 0.43       | 0.61       |

Table 3. Results of the parameter swapped. Values in the table are NSEs; each column pertains to a parameter set and each row corresponds to a SWAT model initialized to the denoted watershed. Bolded values indicate the watershed to which that parameter set was calibrated.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Parameter Set</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fall Creek</td>
</tr>
<tr>
<td>Fall Creek</td>
<td>0.61</td>
</tr>
<tr>
<td>Six Mile-Bethel Grove</td>
<td>0.39</td>
</tr>
<tr>
<td>Six Mile – Brooktondale</td>
<td>0.33</td>
</tr>
<tr>
<td>Salmon Creek</td>
<td>0.46</td>
</tr>
</tbody>
</table>

We then attempted to combine parameters into one set that could be applied across all the tributaries of Cayuga Lake. A simple mean of each parameter was calculated and the parameters were applied to the model. Next, a drainage area weighted mean was calculated and the parameters were applied to the model. NSEs were once again calculated for the parameterized models, the results can be found in Table 4. As you can see, the area weighted mean produces overall higher NSE values. Note, the model has been set-up for the entire Cayuga Lake watershed even though we are only showing results from a few sub-watersheds.
Table 4. NSE values obtained from applying two new parameter sets to the models. As in table 3, the first two columns are the two parameter sets and each row corresponds to a SWAT model of that watershed. The column labeled years displays the years in which observed data was available and NSEs were calculated.

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Parameter Set</th>
<th>Years</th>
<th>Mean</th>
<th>Area Weighted Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall Creek</td>
<td></td>
<td>1992-2010</td>
<td>0.60</td>
<td>0.61</td>
</tr>
<tr>
<td>Six Mile-Bethel Grove</td>
<td></td>
<td>1995-2010</td>
<td>0.42</td>
<td>0.41</td>
</tr>
<tr>
<td>Six Mile-Brooktondale</td>
<td></td>
<td>2002-2010</td>
<td>0.35</td>
<td>0.34</td>
</tr>
<tr>
<td>Salmon Creek</td>
<td></td>
<td>2006-2009</td>
<td>0.37</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Figure 6. Preliminary Hydrological Results from all four stream gages. Streamflow, located on the y axis, is in cubic meters per second. Values displayed for flow is the daily average for each year displayed on the x axis. Note each plot has a different y axis scale. Red = SWAT, Black = USGS measurements

Preliminary hydrological results for each of the four gages previously mentioned can be found in Figure 6. Streamflow for all four gages plotted on the same axes can be found in Figure 7. The model used
to generate this output incorporated the second set of parameters referred to as an area weighted mean previously.

Figure 7. Streamflow output at each of the four gages. The range of values found on the y axis of each of these plots is identical. Red = SWAT, Black = USGS measurements

Pasture and Row Crop Land Management Inputs

The Cayuga Lake Watershed is dominated by agriculture with approximately 50% of the land used for pasture or cultivated crops. Agricultural land use is frequently a significant contributor of nutrients, like P,
to receiving water bodies. As a result, accurate land management inputs need to be provided to the model in order to be able to effectively predict nutrient fluxes within the watershed.

To ensure the accuracy of model inputs, as previously mentioned, a group of experts from a number of organizations were consulted on local land management practices. This group included Karl Czymmek (Pro-Dairy), Aaron Ristow, Gene Aarnio and Jon Negley (Tompkins Co. SWCD), Amanda Barber and Shawn Murphy (Cortland Co. SWCD), Jason Cuddeback (Cayuga Co. SWCD), and Greg Albrecht (NYS Soil and Water Conservation Committee). These individuals provided expert opinion when possible and conducted farm visits when necessary to ensure accurate characterization of land management practices. Their efforts were focused within the Fall Creek watershed but the data collected will be extended to other watersheds with similar land uses as appropriate. Table 5 summarizes the group’s manure management recommendations which have been incorporated into the watershed model.

Table 5. Fertilization scheme. The second column denotes the percentage of that particular land use included in that fertilization scheme. Note, there were 3 different management practices for pasture land.

<table>
<thead>
<tr>
<th></th>
<th>Percentage</th>
<th>Kg/Ha</th>
<th>Applications/Ha/Year</th>
<th>Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pasture 1</td>
<td>15%</td>
<td>3,300</td>
<td>1</td>
<td>Year round</td>
</tr>
<tr>
<td>Pasture 2</td>
<td>5%</td>
<td>3,300</td>
<td>1</td>
<td>May-October</td>
</tr>
<tr>
<td>Pasture 3</td>
<td>5%</td>
<td>4,600</td>
<td>2</td>
<td>June, July</td>
</tr>
<tr>
<td>Row</td>
<td>100%</td>
<td>2,900</td>
<td>2</td>
<td>May, October</td>
</tr>
</tbody>
</table>

Preliminary Phosphorus Results

The wealth of data available in the southern tributaries applies not only to stream flow but also to phosphorus loads. A number of groups and organizations in the area regularly conduct water quality sampling which provides data for more precise validation of the watershed model. The Upstate Freshwater Institute (UFI) has conducted a thorough sampling campaign of the larger tributaries (UFI, [http://energyandsustainability.fs.cornell.edu/util/clmp/laketribmonitoring.cfm](http://energyandsustainability.fs.cornell.edu/util/clmp/laketribmonitoring.cfm)), the Community Science Institute (CSI) also conducts water quality sampling in the southern portion of the Cayuga Lake
Watershed (CSI, http://communityscience.org/database), and lastly, Dr. David Bouldin has a long record of water quality samples taken throughout Fall Creek beginning in the 1970’s continuing to the present (Bouldin, 2007). The locations of monitoring sites used so far are shown in Figure 5; we will eventually utilize all available measurements.

Model predictions of P were compared to measured P concentrations, but no calibration was done to improve the model’s predictive capacity with respect to P; we anticipate that some calibration may be needed but there were too few storm-event samples in the dataset used to justify this at this time. Figure 8 displays total P exports from the four tributaries mentioned previously and compares them to CSI monitoring data. Figure 9 displays total P export near each of the four gages; axes on these plots are identical to allow for relative comparisons. We have similar comparisons for dissolved P (data not shown here).

**Total Phosphorus Losses (kg/ha/day)**

![Graphs](image)

**Figure 8:** Preliminary phosphorus results at sampling locations near all four stream gages. Total P load, located on the y axis, is in kilograms per hectare per day. Note each plot has a different y axis scale. Red lines = SWAT output, Circles = CSI measurements
Figure 9. Total P output at sampling points near each of the four gages. Total P loading is located on the y axis is in kilograms per day. The range of values found on the y axis of each of these plots is identical. Red lines = SWAT output, Circles = CSI measurements

The average daily loads over the simulated time periods (which was shorter for Salmon Creek than the others) were 1.6 kg km⁻² for Fall Creek, 1.4 kg km⁻² for Six Mile Creek (both gages), and 0.7 kg km⁻² for Salmon Creek. Based on the UFI sampling in 2013, we anticipated Salmon Creek to be higher and although this may be an artifact of the short time period considered in our modeling to date, we need to improve our understanding of the distribution of management strategies outside of Fall Creek. We currently assume the distribution in all sub-watersheds is the same as Fall Creek, which we know is incorrect. Although it may appear we are over predicting P loads (Figures 8 & 9), these data are biased towards base
flow conditions and, indeed, our average modeled values are lower than those determined with the UFI data.

Figure 10 shows the distribution of average P loads over the Fall Creek watershed. In Figure 11 we can see that the distribution is dependent on both land management (an agricultural field in this case) and hydrology, i.e., note that within the field there are areas of high and low P loading.

Figure 10. The spatial distribution of average daily total P loads for Fall Creek. The black square is expanded in Figure 11.
Figure 11. A zoomed-in view of part of the Fall Creek watershed showing how the hydrological (storm runoff) patterns interact with land use to create “P-hotspots” in the landscape.

An important and invaluable dataset that was excluded from the current evaluation of the model was the UFI tributary monitoring dataset. The current preliminary model runs terminate in December of 2010 and UFI data collection began in 2013. While the current model time scale does not allow comparison...
of model outputs to these data, it will be incorporated into validation schemes. This will provide additional insight into model performance and calibration.

**Continued Progress**

SWAT model diagnostics and evaluation are ongoing processes. Our immediate next steps are to test the model against flow and P data from periods outside the one we have been using for calibration with particular attention to 2013-2014 when UFI collected a fairly comprehensive data set for several tributaries. We will also be considering total and dissolved phosphorus individually. Note, we have not calibrated the model for phosphorus at this time because our loads are within the same order of magnitude as empirically-based loads, although we will have a better idea of whether this is necessary after direct comparisons with the UFI data.

We are not totally satisfied with some of our current NSE-values, but we will look at our seasonal probability distributions for flow and phosphorus since, for the purposes of this project, it is more important that we are correctly predicting the average and range of magnitudes than that we correctly predict the load on any particular day; it is worth noting that our model consistently works best for Fall Creek, which is probably due to the fact that the available rain gauges are closer to this watershed than any of the others – a limitation we will have to accept.

We will also be testing the model’s ability to correctly predict the distribution of runoff-generating areas within the landscape, since this is an important factor in potentially investigating strategies for redistributing phosphorus applications within watersheds. We have a large dataset of soil moisture over a relatively large area in the Fall Creek and Cascadilla Creek watersheds (Hofmeister et al. 2015) from 2012-present. Figure 12 shows an example of this type of analysis for a different model we developed (adapted from Archibald et al. 2014).
Figure 12. Dark bars show the distribution of soil moisture measurements from parts of the landscape where our model DOES NOT predict runoff generation and light bars show the distribution of soil moisture measurements from areas where our model DOES predict storm runoff generation; we are simulating saturation excess runoff, which is the underpinning mechanism that explains VSA hydrology. Horizontal lines in the bars indicate median soil moisture, the numbers in the bars are the number of samples each bar represents. The light horizontal line is the soil saturation level. Numbers across the top of the graph are the predicted percentages of the watershed generating storm runoff. Note, except for the very small event on July 15, 2013, the model correctly predicts the areas that are and are not generating storm runoff (adopted from Archibald et al., 2014).

Evaluation of sediment outputs is also needed in the immediate future. Because of the complicated combination of both in-stream and upland erosion that contribute to stream sediment loads (e.g., Nagle et al. 2007), and the fact that the in-stream sources are not well identified (Prof. Emeritus, Dr. Daniel Karig, personal contact), we may have to use empirical relationships to “hard-wire” these processes into the model, i.e., in lieu of trying to mechanistically simulate them.

Although model diagnostics and evaluation are still in-progress, we will begin exploring a number of management scenarios to assess the sensitivity of the model to management. Initial scenarios include, but are not limited to: turning-off point loads, applying all manure in a single month (considering all 12 months independently), applying the same BMP reduction factors as used in the most recent iteration of the Chesapeake Bay model (considering a range of BMP adoption), targeted manure applications with respect to forecasted rain (e.g., no spreading within 3 days of the next rainfall) and location (e.g., no spreading
within 10 m of a stream). Simultaneously, we are in discussions with the relevant Soil and Water Conservation Districts to estimate how much progress has been make in implementing recommended Best Management Practices, so these can be incorporated into our management scenarios.
References


USEPA. Available from: http://echo.epa.gov/?redirect=echo (Accessed April 2015)