High Rock Lake

Technical Advisory Committee

Watershed Model Review

Comments and Responses

Prepared for

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1.0 Introduction

The High Rock Lake Technical Advisory Committee (TAC) reviewed the High Rock Lake Watershed Model, developed by Tetra Tech, Inc, under EPA Contract. The TAC received the initial model on January 25, 2012. During the initial round of review, some model errors were discovered and addressed. Due to the resulting model changes, a revised model was provided to the TAC for review on March 9, 2012. Final review comments were due by April 25, 2012.

Several TAC members provided comments on the watershed model: City of Salisbury, the North Carolina Department of Public Health Onsite Water Protection Branch (DPH OWPB), Town of Kernersville, the North Carolina Division of Water Quality Non Point Source Unit (DWQ NPSU), Alcoa Power Generating, Inc. (APGI), and the Yadkin-Pee Dee River Basin Association (YPDRBA) and the North Carolina Department of Transportation (NC DOT) submitted joint comments that were developed under contract by LimnoTech. NC DOT also submitted separate comments.

This document contains the relevant comments submitted by reviewers and the responses to those comments. An initial letter was sent to the TAC by DWQ on May 9, 2012 to summarize the main model review comments that resulted in changes to the model. This letter is attached to this document in Appendix A.

2.0 City of Salisbury

1. Table 2-2 – Descriptions for assessment units 12-(108.5)b2, b3, and b4 do not match figure 2-1.

   Response: *Table 2-2 was updated to reflect these changes:*

AU	*New Description*
12-(108.5)b2	*Yadkin River from Buck Steam Plant to a line across High Rock Lake from downstream side of mouth of Swearing Creek*
12-(108.5)b3	*Yadkin River from downstream of mouth of Swearing Creek arm of High Rock Lake to downstream side of the mouth of Crane Creek arm of High Rock Lake*
12-(108.5)b4	*Crane Creek arm of High Rock Lake*

2. Table 3-11 – 2^{nd} Creek WWTP capacity is 0.03 MGD.

   Response: *Table 3-11 reflects maximum permitted flow, which is correctly shown as 0.09 MGD for 2^{nd} Creek.*

3. Table 3-11 – Town of Cleveland discharges to Third Creek.

   Response: *Table 3-11 was updated accordingly.*

4. Page 1 identifies "water supply" as a designated use of High Rock Lake. There are no public water supply intakes in High Rock Lake.

   Response: *There is no water supply intake in the lake itself; however waters are protected for water supply and the relevant WS-IV and WS-V classifications reflect this protection. This sentence was revised to include the word protection.*

3.0 DPH OWPB

1. Figure 3-7 (page 3-24) should be updated to reflect OWPB recommended revisions, which were semantic and intended to highlight the fact that graywater and straight pipe discharges are illegal. This is a minor change and does not alter the application of the model but sets a precedent in separating actual malfunctions from willful bypasses.

   Response: *Figure 3-7 has been updated.*

2. Page 3-24: The model lacks figures for population outside of the public sewer service area (and thus presumably on septic). Although this information will undoubtedly be included in supplemental files, a summary of these figures should be included either in this section or as an Appendix since population is the basis for assigning potential loading from this source.

   Response: *This information has been added to Appendix C.*

3. Page 6-2: The model states that "The atmospheric contribution is thus embedded within the nonpoint source categories." Which nonpoint categories are referenced here?

   Response: *The nonpoint source categories include water, urban (non-MS4 and MS4), NC DOT, forest, pasture, and crop. Septic systems are not included as a nonpoint source category here as septic systems are modeled as point sources in this application.*

4. Parameters in Tables 6-2 through 6-9 should be listed in the same order in all tables.

   Response: *Two columns were interchanged in Table 6-6 (TP% and TSS%). This has been corrected.*

4.0 Town of Kernersville

1. Table 3-1 on page 3-6 provides a listing of 16 "Land Cover Categories". I could not find a definition for each category listed under the heading for "Land Cover Description". Will you provide a definition for each category, or provide a link to an appropriate resource document?

   Response: *The following sentence has been added to Section 3.4.1 to clarify the land cover descriptions: "With the exception of NC DOT (road right of way), the land cover classification scheme was adopted from the USGS National Land Cover Database (NLCD) 2001 classification descriptions (http://www.mrlc.gov/nlcd2001.php)."*

2. Table 5-9 on page 5-17 includes a listing for six (6) land uses. The nutrient loading data cited for each land use was taken from sources generated on or before either 1994 or 1997. Why was data not incorporated into the watershed model that has been generated from nutrient yield/loading studies completed much more recently and conducted in North Carolina?

   Response*: The intention of Table 5-9 is to provide general bounds on nutrient loading rates. Chapra (1997) and Novotny and Olem (1994) provide a synthesis of many national-scale studies and are frequently cited in this regard. While a variety of individual North Carolina site or watershed-scale analyses have been published more recently we are not aware of any recent comprehensive summaries of NC loading factors. Nonetheless, several additional references have been cited to North Carolina studies.*

3. In Table 5-9 for the land use category of "High Density Residential/Commercial", the range for TN is between 1.6 to 10 lb.-N/(ac/y); that range has an average of 5.8 lb.-N/(ac/y). Yet, Figure 5-8 indicates a TN yield value for HDR of 10 lb.-N/(ac/y). In Table 5-9 for the land use category of "Medium-High Intensity Industrial", the range for TN is between 2.0 to 11 lb.-N/(ac/y); that range has an average of 6.5 lb.-N/(ac/y). Yet, Figure 5-8 indicates a TN yield value for Ind. of 14 lb.-N/(ac/y), which is higher than the cited range and well above the average of the cited range. Additionally, there does not appear to be a corresponding, comparative value for an "Urban" land use between Table 5-9 and Figure 5-8. For purposes of the watershed model, how broad can a "general agreement" be between cited data and simulated data for nutrient yield/loading, and still be reasonable?

   Response*: Table 5-9 shows typical loading rates from the national literature. Additional variability is expected between individual sites and from year to year. The high density residential/commercial group had a mid-point (not an average) of 5.8 lb-N/ac/yr in Table 5-9. After final revisions to the nutrient calibration, the model produces an area-weighted average of 10 lb-N/ac/yr across all individual hydrologic response units (HRUs) for the High Density Residential/Commercial land use; however, the loading rates for individual HRUs for High Density Residential/Commercial land uses range from 1 to 17 lb/ac/yr, depending on hydrologic and slope characteristics as well as calibration adjustments to match instream observations*

   One reason that urban loads are relatively high in the High Rock watershed is that rates of atmospheric deposition of N are also relatively high in western NC. Most atmospheric N that is deposited on impervious surfaces is washed into streams. On average, impervious surfaces are estimated to load about 18 lb-N/ac/yr.

4. Table 6-2 and Table 6-3 on page 6-3 list nine (9) categories for sources of pollutant loading. Will you provide a definition for each category included in this table, or provide a link to an appropriate document? Sections 3, 5 and 6 contain different listings for categories of land uses and sources of pollutant loading that, for purposes of the watershed model report, have different meanings and have established no linkage between categories. Both Section 5 and Section 6 address nutrient yields/loadings, but the categories of land use in each section are not relatable.

   Response: *The derivation of model land units from the land cover categories was described in the High Rock Lake Modeling, GIS Information Memo distributed to the TAC on November 3, 2010 as well as in Section 3.4.4 of the report.*

5. Are septic systems located within an "Urban MS4" counted twice?

   Response*: Septic systems are represented separately from the other categories. Septic system loads are applied in the model only for locations outside of sewer service areas. Legacy septic systems located within sewer service areas are represented as part of the general background concentration in ground water. In both cases, septic system inputs are not counted twice.*

6. Are the nutrient yields/loadings for all MS4's expected to be the same?

   Response*: Unit-area nutrient yields and loads are expected to vary between different HRUs, and, as a result, will not be the same for all MS4s. The differences arise from the following factors, among others:*

   - *Different soil hydrologic properties and slopes lead to different amounts of runoff and different partitioning between surface and subsurface pathways, resulting in differing loads from pervious surfaces.*
   - *Differences are further amplified by differences in sediment yield rates, which are determined by a combination of soil erodibility, slope, and surface runoff. Most of the phosphorus load as well as the load of most organic forms of nitrogen in surface runoff are associated with the movement of sediment.*
   - *The model has been calibrated to reproduce instream observations at multiple monitoring stations. This calibration process resulted in local variations in parameters, especially those that control the groundwater loads of nutrients.*

5.0 DWQ NPSU

1. P. 5-16 Loading rate increases from the prior model report are significant and raise questions. Are these rates reasonable? The reference used to support them in Table 5-9 (Chapra,1997) has such an extremely broad range of reported yields (e.g., 0.4-44 lbs/ac/yr for ag) that it may not the best for assessing "agreement with the literature ranges", particularly with nitrogen. For example, several NC piedmont studies on forest have documented N loading rates in the 1.5 – 2.0 lbs/ac/yr range (Swartley et al. 2010, Oblinger et al. 2002). Reported N-yield rates in Figure 5-8 are over two times those amounts. Values for Crop (B & C) are similar when compared against a recent NC study for Chatham Co (5.62 TN lbs/ac/yr Line and Osmond, 2010). Based on these results, the following statement should be changed:

   > "Table 5-9 shows literature values on nutrient loading rates for various land use categories used to assess the reasonableness of land-based generation of nutrients in the High Rock Lake watershed model application. The simulated average unit area loads in Figure 5-8 and Figure 5-9 are ~~in~~ toward the higher end of the reported ~~general agreement with the~~ literature ranges." [you may want to include some reasons why here, too]

   A better reference for comparison may be other HSPF applications or NC research studies. I've included some and have others if needed. The most supportive research for the Figure 5-8 ag and forestry rates is research from the late 1980's in Guilford County by the USGS (Harned, D.A. 1995). That study was monitoring runoff from crops (grain and tobacco) and forest and had rates that were high but still several lbs less than those in Figure 5-8.

   There are a couple of reasons for concerns over the rates. First, they get at the model's credibility. Loading rates are something that stakeholders more easily relate to and if they appear as unreasonable as they do, more effort will be needed to establish the model's credibility during the stakeholder process. A second concern is that if we use these rates in developing nutrient strategy requirements for sources such as new development, the rates will be incomparable with our existing tools to manage these sources (e.g., Jordan tool).

   ***Response**: Model calibration was revised several times. In particular, correction of errors in the assembly of total N from observation required adjusting the N loading rates upward, although some other changes resulted in reductions. The comments above do not refer to the final model, but are still relevant. For example, final N loading rates from forest are 3.5 lb/ac/yr for B soils and 4.0 lb/ac/yr for C soils.*

   It is important to note that the final model is calibrated to observed data at multiple locations, including locations that are individually dominated by forest, agriculture, and urban land uses. Thus the total load estimates are consistent with the observed data. A second important point is that the model load estimates incorporate loading by groundwater pathways, which are often omitted or not fully captured in small-scale land use studies that focus on storm event loads. The average model estimates of stormwater forest loading rates for total N without ground water load are 0.9 and 2.2 lb/ac/yr for forest on B and C soils, respectively, in line with the cited storm runoff studies.

We have revised the text regarding Figure 5-9 and Table 5-9 as requested. We have also included additional citations and discussion regarding local data on nutrient loads.

Regarding overall NPS loading rates, the rates included in the calibrated model are those necessary to achieve mass balance, assuming that point source loading estimates are reasonably accurate. The partitioning of load between individual upland nonpoint source load categories is admittedly uncertain and could be refined if future intensive monitoring studies are undertaken.

6.0 APGI

1. Boundary Conditions - We understand that W. Kerr Scott Dam was used as an upstream boundary condition, however, it is not clear if the inputs for this boundary condition include both water quantity and water quality. If water quality inputs from W. Kerr Scott Reservoir were included in the Watershed Model, the Model Report should include an explanation of water quality inputs to the High Rock watershed from the W. Kerr Scott Reservoir, including the length of record, parameters, frequency, and location of the water quality observations used.

   Response: *As discussed by the High Rock Lake Technical Advisory Committee, the outflow from W. Kerr Scott Reservoir is treated as a boundary condition for the High Rock Lake watershed model. Little monitoring data is available for the reservoir. Due to its size, and the lack of frequent water quality monitoring, the water quality of outflow from this reservoir is treated as approximately constant in time. The NC DWQ Intensive Survey Unit collected five monthly samples of water quality in the W. Kerr Scott Reservoir outflow in May through September 2009 (Whitaker, 2010). The High Rock Lake watershed model is thus forced by daily flows from W. Kerr Scott Reservoir, coupled with constant concentration assumptions. Section 3.10.1 of the report already documents the flow assumptions. This has been expanded to note the constant concentration assumptions, as provided in the following table:*

   Constant Concentration Assumptions for W. Kerr Scott Dam Boundary Conditions

Parameter	***Concentration (mg/L)***
Total Suspended Solids	*11.0*
Nitrate plus Nitrite Nitrogen	*0.166*
Ammonia Nitrogen	*0.102*
Total Phosphorus	*0.042*
Dissolved Oxygen	*7.96*

2. Animal Operations and Loading - Section 3.4.3 and Appendix D discuss animal operations which can be significant sources of nutrients and can have export coefficients much higher than other agricultural operations. The Model Report states that the influence of these operations is not explicitly modeled in HSPF, but rather, "an area weighting calculation was performed using animal densities (count/hectare) for pasture land…" However, applying animal operations to a pasture export coefficient likely underestimates the nutrient loading of these animal facilities, because animal operations are concentrated areas of nutrient loading typically categorized as point sources. We do not believe using a pasture export coefficient in the Watershed Model is appropriate for intensive animal operations. This ultimately greatly affects the allocation of the load as well as the cost and type of nutrient management strategies that are used to meet the TMDL. We recommend splitting the animal operations from the pasture land use and assigning a higher phosphorus and nitrogen export coefficient to them. If the pasture export coefficients were adjusted to reflect the presence of these more intensive agricultural operations, then additional information describing how this was done should be included in the Model Report. Cattle (beef and dairy), chicken, and broilers were considered for animal operations but pigs can also have a significant impact on the nutrient loading within a watershed. If there are no pigs in

the watershed, we ask that this be stated in the Model Report. If there are pigs in the watershed, we ask that Appendix D of the Model Report be revised to reflect the presence of these animals.

Response: *Animals on pasture are accounted for in the general pasture loading rates. As stated in the report, "there was not enough information available to explicitly represent the impact of animal operations in the watershed model; instead, loading associated with animal operations is incorporated into the general pasture land use classification." The sentence has been clarified to refer to "loading associated with animals on pasture". For confined animals, manure is spread on fields and is incorporated into the loading from the general cultivated crop and pasture/hay land uses. This has been clarified in the report.*

Because it was not possible to simulate animals directly in the model, cattle and chickens are used as indicators of farm animal density and other species are not tabulated. This information was used in a qualitative manner to identify areas in which nitrogen and organic matter buildup rates and phosphorus soil concentrations are likely to be elevated. Cattle are of particular interest as they have high numbers are likely to be on pasture, while chickens are a major source of manure in most of the watershed. Density of hogs and swine is generally low in the counties that intersect the High Rock Lake watershed compared to cattle, with less than 500 animals per county on the 2007 agricultural Census, with the exception of Davie County (7,998 hogs and swine in 2007) and Surry County (20,686 in 2007).

3. <u>Nutrient Calibration</u> - The phosphorus export coefficients for forest land cover used in the Watershed Model are at the high end of the published range. Since much of the total phosphorus (TP) entering High Rock Reservoir is likely adsorbed onto soil particles, it seems reasonable that the TP coefficients for forest and agriculture should be roughly proportional to sediment yields for those land uses. However, the Model Report contains information suggesting that this is not the case, including the following:
   - Average sediment yields (t/ac/yr) presented in Figure 5-2 show that agricultural/developed land sediment yield exceeds sediment yield from forest land by nearly an order of magnitude.
   - Figure 5-9 shows that the average annual areal phosphorus yield from agricultural/developed land and forest differs by approximately a factor of two.
   - Tables 6-2 through 6-9 show a difference between the annual average load by source (ton/year and percent by total) between total suspended solids (TSS) and TP for the forest land category. All tables show that TP percentages for forest are twice as much or more than TSS percentages.
   - Figures 6-10 through 6-17 show simulated annual average TP source loads (ton/year). Total phosphorous loads shown for forest are relatively high compared to other land uses.

   Using lower TP export coefficients for forest would result in a large difference in predicted loads from watersheds such as the Roaring River, which is more than 70% forest. It is not clear how the phosphorus export coefficient for forest was selected. We believe the TP export coefficient for forest may be too high, which would over-attribute phosphorus export from forested lands to the reservoir. As a result, these forest lands and associated phosphorus loads may be considered natural and not be subject to reduced allocation under the TMDL and future nutrient management strategies. We recommend reevaluating the TP export coefficient for forest used in the model and revising the model accordingly.

Response: *The calculation of nutrient yield rates presented in previous versions of the report was a simple, unweighted average across all the modeled hydrologic response units and has been revised. Inorganic phosphorus in storm washoff is generally associated with sediment load, and indeed is directly simulated in the model based on sediment potency factors. However, the total phosphorus load includes components associated with organic matter loading and components associated with groundwater discharge. The groundwater component of dissolved phosphorus is generally at low concentrations; however, because the total phosphorus load from forest is small this becomes a relatively large proportion of the total load. Considering only the surface washoff of inorganic P, the average loading rate for cropland predicted by the model is 2.1 lb-P/ac/yr, while that for forest is 0.14 lb-P/ac/yr.*

The inclusion of subsurface loading pathways in a continuous simulation also accounts for the apparently high phosphorus loading rates relative to some literature studies. Many of these studies report only surface runoff loads from small watersheds during storm events and do not account for the long-term, incremental loading due to subsurface pathways.

The cited case of the Roaring River suggests that the simulated loading rates from forest are not too high. As noted, this watershed is predominantly in forest land cover, yet the annual load appears to be slightly underestimated by the model.

4. Sediment Calibration - The Model Report states "One constraint applied to the reach sediment calibration was to keep the simulated bed sediment conditions near steady state over the course of the simulation, while allowing some channel degradation in headwaters and developing reaches, and sediment aggradation in impounded or backwater reaches." The Model Report goes on to explain that "Collection of data on channel morphology and form evaluation of individual stream reaches could further inform and improve this portion of the model." We agree that an evaluation of channel morphology in individual stream reaches would inform and improve this portion of the model. Given the constraints applied to simulated bed sediment conditions, the model may not be directly applicable to all hydrologic events. An extreme precipitation event may have a high potential to modify bed composition and channel shape. During and immediately after such an event, the model would be ill-suited to accurately predict composition and quantity of eroded or deposited sediments.

   Given the importance of sediment and sediment load in any water quality assessment of the Yadkin River basin, it is critical to ensure that the sediment calibration is done as precisely as possible. We recommend including additional clarification in the Model Report as to the meaning of "near steady state". In addition, absent the additional data on stream channel morphology, we recommend that the Model Report provide a more detailed discussion on how the approach used for the sediment calibration may affect the model's ability to accurately predict sediment load, and in particular, how the approach influences the applicability of the model under extreme events. If data are available, a discussion of model performance during an extreme high flow event during the calibration or validation period would help to determine the adequacy of the model to predict sediment movement during these events.

Response: *The model is constrained to not allow catastrophic changes in bed depth (massive degradation or massive aggradation of tens of feet of sediment) over the course of the simulation because this is not consistent with information about the watershed. The model does allow significant scouring during individual storm events, but this is typically balanced by subsequent deposition during moderate flow events.*

The text in question was modified for clarification as follows: "One constraint applied to the reach sediment calibration was to keep the simulated bed sediment conditions near a dynamic steady state over the course of the simulation, while allowing some net channel degradation in headwaters and developing reaches and sediment aggradation in impounded or backwater reaches. This constraint means that model parameters are selected so that aggradation or degradation of the bed by tens of feet is not allowed, as this is inconsistent with observations. Significant scour can still occur in high flow events, but this is largely balanced by subsequent deposition during moderate flow events."

The model attains a good calibration to sediment, as is shown in Appendix F. We agree that additional information on channel morphology and sediment processes could improve the model, as well as the general understanding of sediment processes in the watershed. One useful technique would be to use atmospheric radionuclide data (e.g., cesium-137, lead-210, beryllium-7) to determine the fraction of stream sediment that originates from surface sources in recent contact with the atmosphere, which helps to distinguish the relative proportions of sediment derived from upland surface erosion versus channel bank erosion processes.

5. <u>Storm Water Point Sources from Industrial Activities and Construction Projects</u> - It is not clear how storm water point sources from industrial activities (as designated at 40 CFR § 122.26) or storm water point sources from major construction projects involving land clearing are included in the Watershed Model. We ask that information be added to the Model Report on how these were included.

   Response: *The model is intended to represent typical loading rates under 2006 land cover. This includes a high-intensity developed land use class, which covers industrial and intensive commercial activities. The model also includes a "Barren" land use classification that represents loading from construction and forest clearcut activities based on the 2006-2007 imagery. Data were not available on rates of construction disturbance by subwatershed and year, so the conditions observed in 2006-2007 are considered as representative of average conditions and average rates of construction disturbance.*

6. <u>Land Cover and Imperviousness (Section 3.4.1)</u> - The Model Report states that land cover and impervious data for the High Rock Lake watershed were developed from data provided by the North Carolina Center for Geographic Information and Analysis (CGIA). CGIA used 2006 and 2007 satellite imagery to create land cover and impervious area coverage for the state of North Carolina, and the Model Report states that land cover and imperviousness were further revised by the North Carolina Department of Transportation (NC DOT) in 2009 to better represent DOT areas within the watershed. While the 2006 and 2007 satellite imagery is currently the best and most recent source of land cover and imperviousness information, we suggest noting in the Model Report that as development in the watershed continues, the land cover and imperviousness should be updated to remain representative of existing conditions.

Response: *The watershed model calibration report is intended to document model development and calibration. While we agree that the land cover and imperviousness should be updated for future use, this is an issue for model scenario application and not directly relevant to the model calibration report.*

7. Soils (Section 3.4.2) - The Model Report states that HSG A soils were combined with HSG B soils while HSG D soils were combined with HSG C soils, because there were such small amounts of HSG A and D soils in the watershed. Figure 3-4 shows a continuous area of HSG A soils in the northern corner of the watershed locating in subbasins 103, 104, 106, 108, and 109, which are part of the upstream drainage area for calibration point 02113850, Ararat River near Ararat. We suggest including a discussion in the Model Report of how the aggregation of HSG A with HSG B soils might bias the modeling results in these subwatersheds.

   Response: *The HSG classification is a general index to infiltration capacity, but not an exact indicator as the HSG classifications are primarily based on information on soil texture characteristics and not on actual infiltration tests. Final infiltration parameters are based on calibration to multiple gages – including calibration to the Ararat River gage. Higher infiltration rates for relatively undisturbed land uses (forest and pasture) were required to achieve calibration for this gage (e.g., 0.37 in/hr for Forest B in the Ararat area versus 0.15 – 0.18 in/hr for Forest B in the South Yadkin basin), consistent with the greater proportion of A soils. Because of the calibration to individual local gages it is our opinion that no significant biases are introduced into the model by the aggregation of A and B soils.*

8. Hydrologic Response Units (Section 3.4.4) - The Model Report states "Urban land was not designated as HSG B or C because they were considered disturbed lands". We suggest including an explanation in the Model Report on the basis for assigning properties to urban, pervious land cover.

   Response: *Pervious land in urban areas is often highly modified due to soil compaction, removal of native topsoil, and introduction of imported sod. For many urban areas, NRCS does not identify a soil HSG. Thus, it is not practical to base hydrologic properties for urban lands on reported HSGs. Instead, urban pervious lands were assigned a single calibrated value for infiltration for each calibration area.*

9. Weather Data (Section 3.5.2) - Tables 3-7, 3-8, and 3-9 show only four weather stations. We ask that all fourteen weather stations be included in the tables.

   Response: *The cited tables are intended to provide general information on the range of weather conditions in the watershed. The other ten stations provide similar results. All weather data has been provided in the WRDB database.*

10. Water Quality Calibration Approach (Section 4.3) - The subsurface movement of nitrogen can be an important source of nitrogen loading. We suggest including an explanation in the Model Report on how the subsurface movement of nitrogen was incorporated in the model, either explicitly or implicitly.

    Response: *Subsurface movement of nitrogen is described in Section 4.3. The HSPF manual provides more information on how subsurface movement is modeled in HSPF.*

11. Hydrology (Section 5.1) - Although the estimates of total volume error are all within the designated calibration goal of 10%, the majority of the total volume errors are positive. This represents a small, but potentially significant model bias. Ideally, the distribution of volume errors would be centered on 0.0%. The Model Report should include a discussion of potential model bias and how a bias in flow rates would influence sediment and nutrient loading to High Rock Reservoir.

    Response: *Total volume errors by gage range from -3.6% to +8.2% in the calibrated model. The model evaluation criteria were met for the hydrologic calibration (which was the primary goal), including both annual and seasonal volume error targets. It is not feasible to attain zero errors at all stations. As the volumetric error targets are within the range specified for an excellent quality of fit, using a unified parameter set across multiple gages, there is not evidence of a significant bias in the hydrologic calibration.*

12. Export Coefficients - We request that a table be added to the Revised Model Report that provides the export coefficients used for nitrogen and phosphorus along with the sources and justification for the selection of specific coefficients.

    Response: *Nitrogen and phosphorus are not simulated with export coefficients. Rather, the model specifies buildup and washoff coefficients for inorganic nitrogen, inorganic phosphorus on impervious surfaces, and organic material, sediment potency factors for phosphorus washoff from pervious surfaces, and concentrations for subsurface flow pathways. Differences in loading rates between different land uses are in large part a function of differences in hydrology (total runoff and partitioning between surface and subsurface flow paths) and erosion. The specification of values for the nutrient parameters is discussed in Section 5.4.1. Complete details may be seen by examining the model input files.*

7.0 YPDRBA/NC DOT (prepared by LimnoTech)

1. Comment 2.1. Focused, high flow monitoring data were missing from the WRDB submitted to the TAC on January 25, 2012; however, these data were included in the WRDB submitted to the TAC on March 9, 2012.

   Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A.*

2. Comment 2.2. Calculated TN values are missing from the WRDB versions submitted to the TAC on January 25, 2012 and on March 9, 2012.

   Response: *The purpose of the WRDB is to provide data in documented and traceable form. TN is a derived-data calculation that can be performed by interested parties by summing Total Kjeldahl Nitrogen and Nitrate + Nitrite concentrations.*

3. Comment 2.3. The high flow monitoring data collected for 2008-2010 were excluded from the total suspended solids (TSS), total phosphorus (TP), and TN calibrations for the South Yadkin River near Mocksville location (station Q3460000) in the draft HRL WSM submitted to the TAC on January 25, 2012. This omission was corrected in the second revised draft submitted to the TAC on March 9, 2012.

   Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A. The high flow monitoring data was used for water quality calibration and the revised result is included in the final watershed model report.*

4. Comment 2.4. The TSS, TP, and TN datasets used to calibrate the Muddy Creek location were incomplete in the draft HRL WSM submitted to the TAC on January 25, 2012 because they did not include samples collected at DWQ ambient monitoring station Q2720000. This omission was corrected in the second revised draft submitted to the TAC on March 9, 2012.

   Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A. Data from the DWQ ambient monitoring station Q2720000 was used for water quality calibration at this station and the revised result is included in the final watershed model report.*

5. Comment 2.5. There appears to be a possible discrepancy between the DWQ and the YPDRBA TN datasets for Hamby Creek.

   Response: *This is a data analysis comment outside the scope of the model development and will be addressed separately.*

6. Comment 3.1. Nitrate and/or nitrate plus ammonia data were erroneously used to calibrate and validate modeled TN. While the calibration of TN has been improved in terms of instream model-to-data comparisons, we feel that the approach taken to address the issue does not accurately represent watershed processes and sources that generate nitrogen loading; specifically, in terms of the inorganic versus organic nitrogen species. The primary concern we have with how the TN calibration error was addressed is in regard to routing a portion of the TIN load generated from the land to the ORN pool at the point of entry to the stream network (i.e., the transfer of load from the land to a reach). The most reasonable and scientifically sound

approach would be to divide the TIN into fractions of nitrate and ammonia based on instream data, which is the approach that is implied in the HRL WSM report (see p. 4-5 of the HRL WSM report). However, in contrast to the approach implied in the HRL WSM report, the model immediately transfers a portion of the TIN load to the ORN pool using an arbitrary scaling factor that is not based on the instream TIN data. This is particularly important because the ORN in a reach is essentially “unreactive”, and the only loss processes impacting this nutrient pool is sinking or settling or transport to a downstream reach. This is in complete contrast to nitrate or ammonia, which are both readily available for algal uptake.

The impact of this misrepresentation of watershed processes and sources that generate nitrogen loading, specifically in terms of the inorganic versus organic nitrogen, could result in an inaccurate attribution of nitrogen loads to source categories. In terms of eutrophication processes, inorganic nitrogen has the biggest impact on water quality because it is readily available for algal growth. Any management controls will likely focus on controlling and reducing the inorganic fraction of TN. The current model configuration includes a hardwired bias toward point source load contribution compared to nonpoint sources, with the exception of cropland, because a portion of the TIN load generated from nonpoint sources is instantaneously transformed to an unreactive and unavailable form of nitrogen (i.e., ORN) that will have little impact on water quality. In contrast, point source loads do not receive the benefit of having a portion of their TIN load instantaneously transformed to an unreactive form of nitrogen; instead, their TIN load is immediately available for algal growth in the watershed tributaries or in High Rock Lake. Therefore, there is a potential bias built into the HRL WSM in terms of how the model will predict the effectiveness of specific management actions for point sources versus nonpoint sources in achieving eutrophication endpoints.

In addition, the misrepresentation of watershed processes and the sources that generate inorganic and organic nitrogen loading could also potentially impact how the model responds to management practices applied to reduce TIN loading.

Response: *This comment was based on the preliminary version of the watershed model report and is no longer reflective of the final approach. In the preliminary version it was the case that TN values calculated from observations were inadvertently incomplete. Tetra Tech discovered this error through standard model QC review shortly prior to the TAC providing comments. After review of the issues, observed TN concentrations were corrected and both N and P were recalibrated in the model. The recalibration effort included fitting to individual N and P species (organic and inorganic) as well as total concentrations.*

The watershed model does convert a small portion (20%) of the inorganic N load simulated on the land surface to refractory organic N in the stream network. It is well established that the greatest rates of uptake and retention of N in stream networks occur in headwaters streams by riparian vegetation, periphytic plankton, bacteria, and fungi – but those low-order stream segments are not explicitly represented in a model at the scale of the High Rock Lake watershed model. Thus, uptake of inorganic N in low-order (unsimulated) streams is accounted for by routing a portion of the upland inorganic N load to refractory organic N, representing vegetative material that does not quickly decay in the stream system. The reactive or labile fraction of organic N from the land surface is represented in HSPF through the CBOD variable. A transformation from inorganic to refractory organic N is not represented for fertilized crop land uses because these systems are typically N-saturated.

It should be noted that "unreactive" organic N is represented in the watershed model as not transforming to bioavailable inorganic N within the stream network due to short residence times. Once this organic N reaches the lake it is added to the general organic N pool and is subject to breakdown processes that regenerate bioavailable inorganic N. Thus, it is not correct to state that the organic N simulation is "unreactive and unavailable" relative to the listed impaired waters. To the extent that algal growth in the lake is nitrogen limited it will be sensitive to inorganic N loads, labile organic N loads, and so-called "unreactive" organic N loads from the watershed.

7. Comment 3.2. The TN unit area loads (UALs) in the HRL WSM report did not match the TN UALs calculated from the draft HRL WSM submitted to the TAC on January 25, 2012, but do match in the version submitted to the TAC on March 9, 2012.

   The UAL comparisons were somewhat complicated by the following factors:

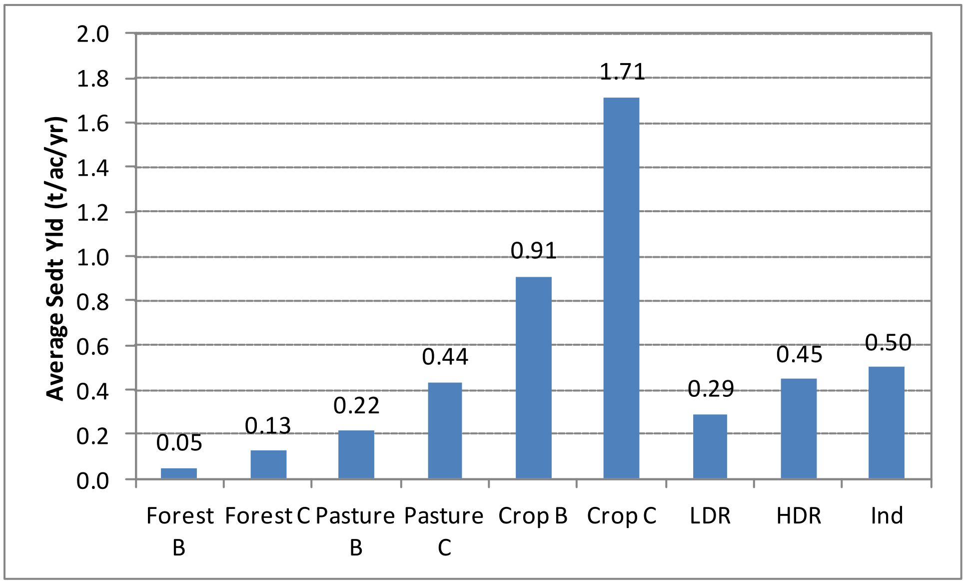
   - Loads documented in the report are broken out by land use categories that do not correlate with the land use categories in the model. Specifically, it is not known how the pervious and impervious "urban", "urban MS4", and "NCDOT" land segments are divided or aggregated into the "LDR (low density residential)", "HDR (high density residential)", and "Ind (industrial)" land use categories.

   - Loads are only presented in the form of bar chart figures (see HRL WSM report Figures 5-2 (p. 5-9), 5-8 (p. 5-17), and 5-9 (p. 5-18)), and it is difficult to ascertain the exact quantity for each UAL. A best estimate for each UAL based on the TSS, TN, and TP report figures was used to compare reported loads with those independently calculated using the model output.

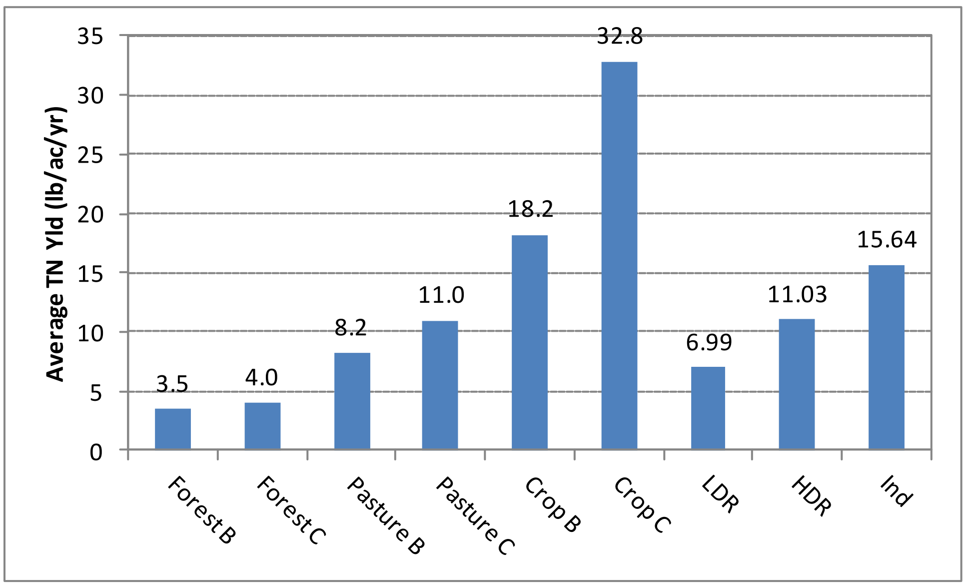
   Response: *The TN unit area loads did indeed change between the draft report submitted on January 25, 2012 and the revised version submitted on March 9, 2012. This occurred because the nitrogen simulation was recalibrated following the recognition that some of the total nitrogen observed data calculations omitted organic nitrogen.*

   The "urban", "urban-MS4", and "NCDOT" land use categories are those used in the model to describe different pervious and impervious land fractions. The pervious and impervious fractions are simulated separately in the model. Literature values for loading coefficients do not exactly match up with these categories, and represent the net load from pervious and impervious areas. The figure represents LDR as 5 % impervious, HDR as 40% impervious, and Ind as 80% impervious and the loading rates are created as weighted sums of the pervious and impervious loading rates.

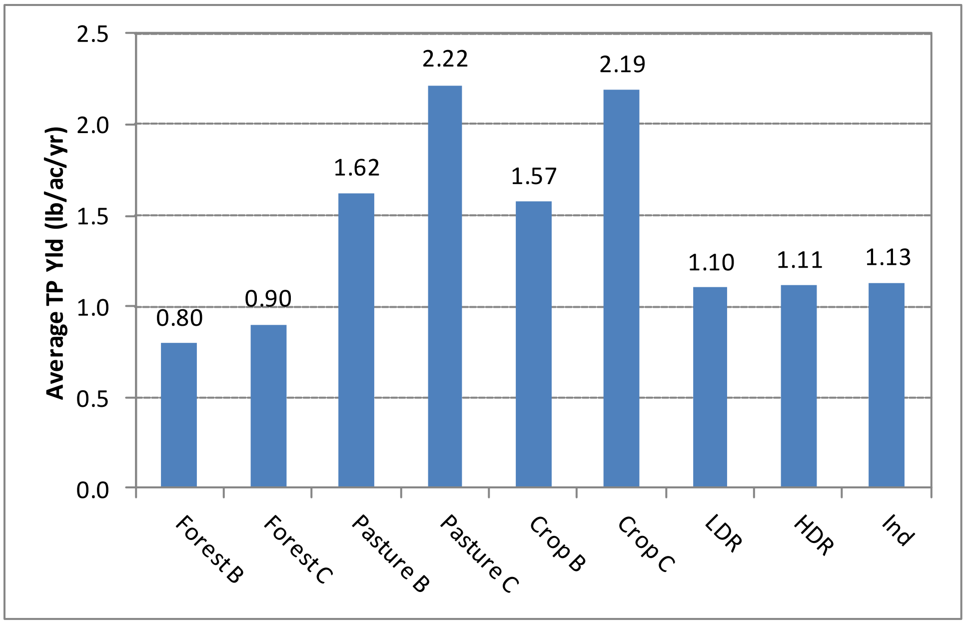
   The report purposefully does not provide exact values for the model average loading rates because these are subject to considerable variability between HRUs and from year to year. The graphical presentation is intended for a more qualitative comparison. To satisfy the request made in the comments versions with average loading rates over the period of simulation labeled are shown below, but not included in the report.



Average Sedt Yld (t/ac/yr)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.05
0.13
0.22
0.44
0.91
1.71
0.29
0.45
0.50
Forest B
Forest C
Pasture B
Pasture C
Crop B
Crop C
LDR
HDR
Ind



Average TN Yld (lb/ac/yr)
35
30
25
20
15
10
5
0
3.5
4.0
8.2
11.0
18.2
32.8
6.99
11.03
15.64
Forest B
Forest C
Pasture B
Pasture C
Crop B
Crop C
LDR
HDR
Ind



8. Comment 3.3. The pervious land segment "water" does not produce reasonable loads for TSS, TP, or TN.

   Response: *In the final model, the "water" land use provides zero (net) loads of TSS and TP. The average TN loading rate is 6.5 lb/ac/yr, attributable to atmospheric deposition. The "water" land use is employed to represent small ponds and other isolated water features that are not explicitly simulated in the reach network. Other land uses are not routed through the water land use. The net loads attributed to the "water" land use are believed to be reasonable.*

9. Comment 3.4. Plots and statistical summaries should be provided for all of the calibration and validation stations (e.g., Second Creek near Barber, Roaring River at Roaring River, etc.).

   Response: *Plots and statistical summaries for all stations are presented in the appendices to the report. Only selected results are presented in the main body of the report.*

10. Comment 3.5. Phytoplankton chlorophyll (i.e. phytoplankton biomass) concentrations in streams in the watershed are significantly underestimated.

    Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A.*

11. Comment 3.6. Model instabilities occur in approximately 17% of the tributary reaches.

    Response: *The comments regarding model instabilities are misleading. The supposed instabilities that were identified are all for pollutant concentration; however, concentration is not a state variable in the model. Instead, the model simulates flow and pollutant mass, providing output for concentration derived as mass divided by flow. When flow goes to zero, the concentration becomes undefined, leading to the apparent instabilities. In addition, the HSPF model shuts down computation of a variety of water quality transformations when flow depth goes below 3 inches to prevent model code instability. This can sometimes lead to very high* *concentrations being reported in small streams as they are drying up – due to a small residual load being divided by a near zero flow volume. The important point to recognize is that these situations occur only when flow and pollutant mass are very small; thus these apparent instabilities have no impact on simulated loading to the lake.*

The majority of the supposed instabilities identified in the comments are for situations in which the daily average concentration is negative, described as a physical impossibility. The comment fails to recognize that the HSPF model produces a missing value flag of -1 E32 when concentration is undefined due to storage volume being equal to zero. The negative values for daily average concentrations occur exclusively in small streams when at least one of the constituent hours has an undefined concentration that has been set equal to the missing value flag of -1 E32.

12. Comment 3.7. Not all of the flow or water quality data were evaluated or presented in the model calibration and validation documented in the HRL WSM report.

    Response: *The model is compared and calibrated to flow and water quality monitoring at multiple stations throughout the watershed. The comparisons include stations for which relatively long time series of data are available.*

13. Comment 3.8. An incorrect model reach is used to assess model-to-data comparisons for Muddy Creek.

    Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A.*

14. Comment 3.9. The calibration and validation "mean error" (noted as "%BIAS" or "concentration relative error" in the HRL WSM report) values and other statistical comparisons presented for the Abbotts Creek near Lexington station (Q5930000) appear to be incorrect. This appears to be the result of incorrectly generating the Abbotts Creek graphical and statistical comparisons using a different HSPF reach than that indicated in Table 5-7 of the HRL WSM report (i.e., Reach 133).

    Response: *This comment refers to the initial version of the watershed model report. Tetra Tech subsequently confirmed that the Abbotts Creek monitoring data were being compared to the wrong model segment. This error was rectified in subsequent versions of the report – resulting in improved fit of the watershed model predictions.*

15. Comment 3.10. The "concentration median error" statistics presented for various water quality calibration/validation locations in Appendices F and G of the draft HRL WSM report submitted to the TAC on January 25, 2012 are not sufficiently documented, and consequently, it was not possible to verify these results. Additional documentation was provided in the revised HRL WSM report submitted to the TAC on March 9, 2012 for this metric; however, even with the improved documentation, it still has not been possible to verify the results provided in the report.

    Response: *Concentration median error is the median of the individual signed differences between daily average simulated values and observations, presented as a percentage. It is not clear why the commentor is unable to reproduce the results.*

16. Comment 3.11. Mass is created in the model when the organic matter generated from the land is partitioned into biochemical oxygen demand (BOD), organic refractory carbon (ORC), ORN, and organic refractory phosphorus (ORP) and transferred to a tributary (i.e., reach segment).

    Response: *This comment is incorrect and misleading. Mass is not "created" in transfer to the stream; rather there could be a valid debate as to what fractions are appropriate to assign in the transfer (stoichiometry of organic matter). As noted in the comment, generalized organic matter washoff is simulated on the land surface and then separated into CBOD, ORC, ORN, and ORP at entry into the stream network. In HSPF, ORN and ORP are refractory organic nutrients, not subject to quick breakdown within stream transport, while labile organic nutrients that are subject to breakdown are included within the simulation of CBOD (a small portion of the total nutrient load from nonpoint sources). All of these are valid and non-overlapping components of organic matter, so no mass is being artificially created. As noted above, the organic fractions that are considered refractory with respect to stream transport in HSPF (relatively rapid) are added to a slowly decaying pool or organic material within the lake model and thus do not remain refractory in regard to the lake. The stoichiometry of organic matter contained within the present model is believed to be reasonable, but could be refined in future if detailed studies are undertaken.*

17. Comment 3.12. The TIN atmospheric dry deposition load input to the model is less than what is presented in the HRL WSM report.

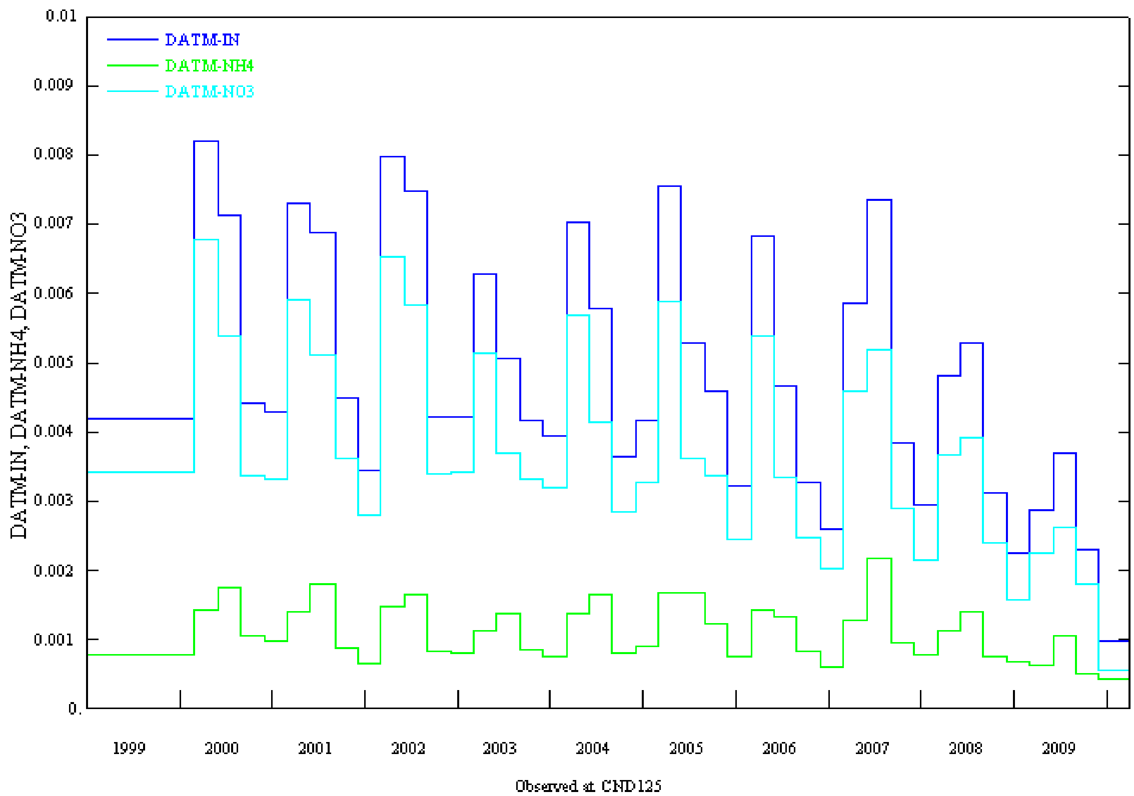
    Response: *Both the discussion and Figure 3-11 given in the report are correct. The additional Figure 33 provided in the comments is incorrect.*

    Dry deposition of N is represented in the model as lb/ac/yr – as N. Results in Figure 3-11 were already converted to mass as N. The dry deposition series are linked to the model from the binary data storage files HRLWeather.wdm as follows:

```
WDM2   36 DD01   ENGL       DIV  PERLND 101 280 EXTNL  PQADFX 1
WDM2   36 DD01   ENGL       DIV  IMPLND 119 172 EXTNL  IQADFX 1
WDM2   37 DD02   ENGL       DIV  RCHRES   1 145 EXTNL  NUADFX 2 1
WDM2   38 DD03   ENGL       DIV  RCHRES   1 145 EXTNL  NUADFX 1 1
```

    Here, series 36 is dry deposition of total inorganic N, the proper input for the GQUAL nutrient balance on the land surface, while series 37 and 38 are the nitrate and ammonia dry deposition inputs (as N), respectively, for use in the reach simulations. The time series on the WDM have a daily time step, although the same value is entered for every day of the month. The DIV flag divides the daily mass into the native hourly time step of the model.

    The time series of loads contained in the wdm as transferred to the model are shown in the following figure for total inorganic N ("DATM-IN"), NH_4-N, and NO_3-N. Note that TIN is correctly represented as the sum of NH_4-N and NO_3-N



The graph that was presented with the comment shows only the unionized component of nitrate (NO_3-N) and omits the larger ionized component (HNO_3-N). Both components should be included in the sum of nitrate-N deposition to water and in the sum of TIN deposition to upland. It is believed that this graph was obtained from an incorrect and outdated version of HRLWeather.wdm in which the HNO_3-N component was omitted. The version of the model presented in March 2012 includes both HNO_3-N and NO_3-N in the dry deposition sums.

18. Comment 4.1. It is not standard practice to model a pervious land segment as "Water."

    Response: *See Comment 8 above.*

19. Comment 4.2. The HRL WSM contains parameter values that are outside ranges that are considered typical and expected. If it is determined that an estimated parameter value is appropriate and reasonable for a specific watershed or site location, then an explanation should be provided in the documentation to describe the unusual conditions in the watershed and why the selected parameter is appropriate.

    Response: *In this comment, parameters in the model were compared to ranges cited in BASINS Technical Notes 6 and 8, and a few cases, primarily for minor parameters, were identified in which model values are set outside of the cited ranges. In several instances, these parameters are set to atypical values to address special circumstances not covered in the Technical Notes. For example, the "water" land use intentionally has interception and interflow set to zero, as* *these processes are not considered part of the hydrology of the water land use. Similarly, Manning's "n" coefficient for impervious surfaces is set to a relatively high value to account for the presence of some peak flow detention in the watershed that retards flow. In other cases, values determined for the model (e.g., LSUR, the average length of the overland flow plane) come directly from GIS analysis) and produce some values outside the recommended range.*

The approach taken to upland sediment simulation differs from that anticipated in Technical Note 6 because KRER is based on a formal analysis that combines the USLE K and LS factors along with erosivity, instead of being simply assumed to be equal to K. This approach, while technically more accurate, requires changes to other sediment parameters as well. This results in a COVER value of 0.99 for forest (greater than the recommended maximum of 0.98) because otherwise forest would produce sediment yields that are too high and incompatible with the literature.

Certain other parameter values are set to reflect specific goals of the calibration. For instance, the sediment simulation depends on the simulation of velocity and shear stress, which in turn depends on limited information on channel dimensions. In some reaches, the model simulated unrealistically high rates of sediment deposition. In keeping with the calibration objectives of producing reasonable rates of bed elevation changes, unusual values were required in some reaches (e.g., the cited high value of KSAND in reach 117 and the low values of TAUCD in reach 15 and 124, which are set to the minimum allowed by the program). These values likely compensate for poor information and assumptions on channel dimensions, but are appropriate to achieve the calibration goal.

The remaining cited parameters address the snow simulation. We agree that it might be appropriate to reduce the value of SHADE on forest land cover and increase the value of CCFACT on impervious lands. However, snow is not a major part of the hydrology of this watershed, and the cited parameters have only a minor impact on the snow simulation (specifically, they affect the rate of snow melt). Given this, along with the fact that the hydrologic simulation already achieves calibration criteria, it was not deemed necessary to revisit these parameters.

20. Comment 4.3. The HRL WSM contains inconsistent or inappropriate parameterization across various pervious land segment land uses.

    Response: *Several minor issues were raised about the relative assignment of parameters between different pervious land uses.*

    - *DEEPFR is non-zero only for urban lands. We expect low rates of net loss to deep aquifers in the Piedmont where most groundwater ultimately discharges to local streams. A non-zero value is assumed for urban lands to account for a small amount of withdrawal and net loss by wells.*
    - *We disagree that LZETP values are necessarily higher for pasture than for urban land. It is the case that pasture grasses are typically deeper rooted than urban grass; however, urban pervious land also includes a mix of deep-rooted trees and shrubs. As stated in Section 3.3.2, the water land use is intended to represent small ponds not explicitly simulated in the reach network. LZETP values for the water land use represent evapotranspiration drawn by grasses, trees, and shrubs at the margins of ponds, but have a limited impact on the simulation as a very low infiltration rate is specified.*

- *The use of a COVER value of 0.99 was addressed in the previous response. HSPF guidance also discusses use of the complement of the USLE C factor to set the COVER value, and a C factor of 0.01 is appropriate for forest. While BASINS Technical Note 6 cautions that use of a COVER value greater than 0.98 will "essentially eliminate any soil detachment" this statement is not true with the reformulated approach to KRER used in the model. Simulations confirm that soil detachment does indeed occur in the forest land use.*
- *Monthly potency factors for organic matter washoff were initially the same for all pasture and crop land uses. During calibration, a different pattern was adopted for Pasture B to improve model fit at stations dominated by this land use. It may be preferable to have potency factors set the same for Pasture B and Pasture C, but the differences are small.*
- *Inorganic N concentrations in interflow from cropland primarily represent fertilizer loss via near-surface lateral flow pathways. The two sources cited are for shallow groundwater. Interflow occurs through the root zone and is expected to have higher concentrations than shallow groundwater*

21. Comment 4.4. The HRL WSM appears to contain over-parameterization of certain parameters.

    Response: *This comment is more one of philosophy than fact. We agree that parameters should be constrained by data where possible, and that uncertain parameters must be calibrated. For the High Rock Lake water quality model a total of seven monitoring sites were used in calibration. Achieving a fit at all stations required some spatial modification of certain parameters. In the cited case of the upland sediment calibration, the KRER factor varies as a function of soil properties and is thus assigned based on data. KSER is the primary sediment transport calibration parameter. This parameter was initially kept constant by land use; however, to fit observations at all seven stations simultaneously some variability was introduced into the KSER factor for pasture. Pasture was selected for this purpose because the difference in model fit between different monitoring stations appeared to be correlated with the percentage of pasture (one of the dominant rural land uses) present in a watershed.*

    Benthic release rates and sediment concentrations of ammonia and orthophosphorus were varied on a reach-by-reach basis. Higher rates and concentrations were assigned to reaches downstream of major point source discharges, but the final values were adjusted based on model fit at the seven monitoring stations.

    In our opinion, the two cited instances do not constitute inappropriate over-calibration. Rather, they provide useful information that can guide further investigation. In essence, the model assignment of higher rates of phosphorus release to certain reach segments indicates that the monitoring data show additional sources of phosphorus in this location (relative to a simulation using parameters that do not vary spatially) and that a reasonable hypothesis is that this reflects storage of historic nutrient and organic matter loads in the stream sediments.

22. Comment 4.5. It is not reasonable to use the same nutrient parameterization for NCDOT and "urban" and "urban MS4" pervious land segments.

    Response: *We acknowledge that NCDOT generally does not apply fertilizers to pervious land in the right of way, and that inorganic nutrient loading rates from fertilized lawns are likely to be* *higher. However, the pervious urban land category – which encompasses all cleared land associated with urban land uses – also includes large areas that do not receive fertilization. Further, on lawns that are fertilized and maintained it is common practice to collect and compost lawn clippings and deciduous leaves, effectively removing organic nutrient mass from the system. The commenter did not provide an alternative to this approach or alternative parameterization values. Parameterization was based on best available information. Further analyses (external to the model) may be needed to evaluate the extent to which lawn fertilization contributes to excess nutrient loads.*

23. Comment 5.1. The version of the HSPF model used for the HRL WSM application should be documented in the report.

    Response: *The HRL WSM application uses the official release version of WinHSPFLt available at http://water.epa.gov/scitech/datait/models/basins/index.cfm. This link has been added to the references section in the report.*

24. Comment 5.2. The text regarding nutrient partitioning (pages 4-5 to 4-6) should be corrected and revised to accurately describe the methodology used in the model.

    Response: *The text regarding TIN and TIP entry into the stream network is correct as written. It states that inorganic nitrogen and inorganic phosphorus are simulated on the land surface "as general quality constituents" and further that each of these constituents is partitioned at the point of entry into the stream network, including partitioning into dissolved and sorbed fractions "using equilibrium partitioning assumptions." No differentiation is made between dissolved and sorbed fractions on the land surface. It is true that the material is routed in the model to the dissolved form as input to the stream reaches; however, equilibrium partitioning is instantaneous. To satisfy the commentor, the following parenthetical note has been added to the text: "(the model connects inorganic N from the land surface to dissolved N in the stream reach, but equilibrium partitioning to the sorbed form occurs instantaneously)."*

    The commentor is correct that a portion of the TIN is routed to the organic form. The following text was added: "A small portion of the inorganic N is routed directly to organic N to represent uptake by heterotrophic organisms in low order streams (a process not explicitly simulated by the model)."

    The sentence that says "Fractions of the dissolved constituents are set to reflect observed data in the Yadkin River…" has been clarified to read "Fractions of the dissolved constituents are set to reproduce observed data in the Yadkin River after additional instream kinetic reactions." The initial fractionation is just the first step, as mixing with other sources, decay of organic matter, and algal uptake and release all contribute to the final mix at observation stations.

25. Comment 5.3. The documentation is incomplete with respect to assumptions related to the C:N:P stoichiometry for organic matter.

    Response: *The commentor is correct that the stoichiometry of organic matter is not strongly based in data. The stoichiometry of organic matter in HSPF is often assumed to follow the typical composition of plant matter. For instance, the HSPF defaults are that carbon is 49 percent of biomass by weight, while the C:P ratio is 106 and the C:N ratio is 6.62. These ratios* *are, however, affected by land surface processes, particularly decay processes that consume fixed organic carbon as an energy source. The final ratios were thus adjusted during calibration. For pervious lands (other than crop) the final C:N ratio is 3.83 and the C:P ratio is 12.6, reflecting substantial depletion of organic carbon. The following sentence has been inserted into the text: "Final C:N:P ratios derived during calibration reflect a reduction in carbon relative to N and P, and a reduction of N relative to P, with a C:N ratio of 3.83 and a C:P ratio of 12.6.*

26. Comment 5.4. The documentation is inaccurate and incomplete with respect to land-to-reach linkage assumptions.

    Response: *This comment primarily addresses specification of TIN fractions on entering the stream network. See response to Comment 25 above. A higher C:P ratio is assumed for fertilized cropland due to the potential use of phosphorus fertilizers, especially use of chicken manure amendments that are typically elevated in P relative to N agronomic needs.*

27. Comment 5.5. Model and literature UAL comparisons should be presented in the form of a table.

    Response: *See Comment 7 above. The report purposefully does not provide exact values for the model average loading rates because these are subject to considerable variability between HRUs and from year to year. The graphical presentation is intended for a more qualitative comparison. To satisfy the request made in the comments versions of the UAL figures with average loading rates over the period of simulation labeled are shown in Comment 7 above.*

28. Comment 5.6. The summaries of sediment, TN, and TP UALs in the HRL WSM report should explicitly include the "urban", "urban MS4", and "NCDOT" land use categories represented in the model.

    Response: *As has been noted in previous comments, the model was not informed by detailed data that distinguished loading rates among urban land use categories. Instead, within each category there is a large range of loading rates due to the influences of soil infiltration rates, erodibility, and slopes. For example, loading rates for TN from individual HRUs associated with pervious urban land uses range from 3.5 to 12.3 lb/ac/yr. HRUs with lower infiltration capacity and greater soil erosion contribute greater loads of TN. The comparison to literature loading rates is best based on graphical comparison of the (area-weighted) central tendency of model simulations. Loading rates for individual HRUs may be calculated from the model output.*

29. Comment 5.7. The NCDOT sediment UAL documented in the HRL WSM report appears to be inconsistent with model output for impervious and pervious land segments associated with NCDOT.

    Response: *The sentence in question has been removed from the report. TSS loading from NCDOT right of ways has been adjusted and recalibrated based on the references provided from DOT (see the May 9, 2012 letter provided in Appendix A). This results in a good agreement between observed and simulated EMCs, as has been documented in the response to comments above.*

30. Comment 5.8. The documentation is incomplete in regard to the stratified regression equations used to estimate data-based monthly loads for TSS, TP, and TN.

    Response: *While the load comparisons are important they should also be approached with caution due to the considerable uncertainty in estimating loads from scattered point-in-time measurements of pollutant concentrations. The general description cited in the comment is correct. An example for TSS at the Yadkin River at Yadkin College station is provided below.*

    Water quality data for this station is stratified at 1.5 times the median flow, based on visual observation, or 2,760 cfs. Separate regressions are undertaken for flows above and below this level. These regressions predict the natural log of concentration based on the natural log of flow. For TSS, the regression equation for flows less than the stratification break point is: Ln (TSS) = -0.750668 + 0.478464 ln(Q), and, for flows greater than or equal to the stratification break point, Ln (TSS) = -5.86505 + 1.244952 ln(Q), where Q is flow in cfs. The regression predicts the central tendency of the natural logarithm of concentration based on the natural logarithm of flow. Load estimates for individual days are then estimated as a function of daily average flow, with a correction for the back-transform from logarithmic to arithmetic space, and summed to form monthly totals.

    For a majority of the water quality stations (Yadkin River at Yadkin College, Yadkin River at Enon, Roaring River, Second Creek, and Abbotts Creek), a breakpoint at 1.5 times the median flow appeared reasonable. A breakpoint of 1.0 times the median was used for Yadkin River at Elkin and South Yadkin River, while a breakpoint of 2.0 times the median was used for Muddy Creek.

    Note that TN loads are not estimated with the stratified regression approach; rather, they are estimated using a stratified averaging estimator. If any members of the TAC wish to undertake a detailed analysis of the comparison of simulated and predicted loads we will be glad to provide the calculation spreadsheets.

8.0 NC DOT

1. Before the modeling process began, NCDOT provided estimates of potential sediment yields from unpaved roads in the event that EPA decided to model these road types explicitly. It is unclear from the report how unpaved roads were included in the model but it appears that they were not modeled as a separate category. Regardless of how NCDOT unpaved roads were modeled, it appears that the model is overestimating sediment from NCDOT right of way (ROW). As reported, the central tendency of the model estimate of loading from NCDOT ROW is about 0.71 tons/ac/yr. As a general comparison using Schueler's Simple Method, 0.71 tons/ac/yr equates to an event mean concentration of approximately 140 mg/L. Table 1 provides a summary of roadway ROW event mean concentrations (EMCs) as reported in seven recent North Carolina studies. When compared to transportation research in North Carolina, this value appears to be on the high end of reported EMCs for the NCDOT ROW (Table 1). Based on the EMCs in Table 1, the watershed model appears to be simulating concentrations above the 85th percentile of TSS data available in the ROW.

   In the High Rock Lake watershed, approximately 5% of NCDOT roads are unpaved and 95% are paved. If unpaved road areas are to be combined with other NCDOT categories in the model, please adjust the model specification such that annual sediment loads from the NCDOT landcover better reflect the proportion of paved and unpaved roads.

   Response: *Comment addressed in May 9, 2012 status update letter provided in Appendix A.*

2. Please provide a summary of unit area loads associated with the eighteen NCDOT PERLND and eighteen NCDOT IMPLND categories in the report. Please also identify the literature sources used as a benchmark for evaluating model calibration and NCDOT loading.

   Response: *The final update to the watershed model included recalibration of loads from NCDOT land uses. These were compared to the set of literature sources provided by NCDOT in their initial comments. The final model appears to be consistent with literature sources on loading from roads.*

   Predicted unit area loads for individual pervious HRUs vary widely depending on hydrology, soil erodibility, slope, and local precipitation. Unit area loads from impervious HRUs have a smaller, but still significant range. For TN, the predicted loads from individual NCDOT pervious HRUs vary from 0.5 to 28.8 lb/ac/yr, while the loads from individual NCDOT impervious HRUs vary from 11.6 to 26.6 lb/ac/yr (mostly due to atmospheric deposition). For TP, the predicted loads from individual NCDOT pervious HRUs range from 0.08 to 3.66 lb/ac/yr, while the predicted loads from individual NCDOT impervious HRUs range from 0.81 to 1.54 lb/ac/yr. These are total loads by both surface and subsurface pathways and include the nutrient content of organic detritus. A spreadsheet analysis of loading rates from all individual HRUs can be provided upon request.

3. The watershed model appears to include eighteen NCDOT PERLND and eighteen IMPLND categories; however, no mention or description of these categories is provided in the report. Please provide a description of these categories including an explanation on how the NCDOT paved, unpaved, and vegetated ROW areas are apportioned in the IMPLND and PERLND categories. Additionally, mean annual sediment loads from NCDOT pervious categories 11 and 14 are much higher than the other NCDOT land uses. The difference appears to be the result of

a KRER value for this land use that is higher than the other similar land use types. Please explain why these particular NCDOT categories have much higher values.

Response: *The 18 NCDOT "categories" in the model are hydrologic response units (HRUs), which represent (within the NCDOT land use) different weather stations. The soil erodibility parameter KRER for each NCDOT HRU is summarized based on an area-weighted average of the erodibility calculated from USLE K factors and LS factors for this land use within the precipitation polygon (see discussion in Section 5.2 of the text). Slope is also assigned based on the average within the region. The 11th and 14th HRUs in the NCDOT land use are associated with weather stations in the mountains at the western edge of the watershed. Higher sediment yields for these HRUs are primarily associated with a combination of high slopes and greater rainfall in these areas.*

The previous version of the report omitted the map showing weather station assignments and the discussion of HRU numbering. This has been rectified.

4. Comment 3.6 in the attached interim list of comments drafted by Limno Tech identifies model instabilities in approximately 18% of the tributary reaches. If EPA chooses not to correct these instabilities, we request that the relative TSS, TN and TP loads associated with the periods of model instability be evaluated and reported in order to determine the relative impact of these periods on loading to the lake.

   Response: *See previous responses on this issue (Comment 11 in Section 7.0). The supposed model instabilities are not actual instabilities. State variables in the model are sediment and nutrient mass, not concentration. There are no instabilities in the simulation of mass. However, concentration can become "unstable" when flow is zero or rapidly declining toward zero. Dividing a very small load by a zero or near-zero flow can result in a very large concentration – but does not affect the delivered load. Limno Tech's supposed identification of negative concentrations arises from failure to recognize that HSPF sets a missing value flag of -1E32 when flow is zero at the start and end of a time step. Because conservation of mass is maintained and mass transport is not impacted, there is no need to correct for the supposed instabilities.*

5. The analysis of pollutant loading in Section 6 of the watershed modeling report presents source characterization and other information that could be valuable in developing management strategies. For all figures and tables in Section 6, please identify if loads presented are generated at the source or delivered to the lake.

   Response: *As stated in the text, Section 6.1 presents loads delivered to the lake. Section 6.2 presents loads at the source.*

6. The watershed model report appears to use both "total suspended solids" and "total suspended sediment" interchangeably when referring to TSS. If a distinction is intended between solids and sediment, please note this distinction or consider using consistent terminology throughout the report.

   Response: *The correct terminology for TSS is total suspended solids. This has been corrected in the report. In flowing streams total suspended solids is typically assumed to be approximately equivalent to total suspended sediment.*

APPENDIX A

May 9, 2012 NC DWQ Letter to High Rock Lake Technical Advisory Committee

NCDENR

North Carolina Department of Environment and Natural Resources

Division of Water Quality

Beverly Eaves Perdue
Governor

Charles Wakild, P. E.
Director

Dee Freeman
Secretary

May 9, 2012

High Rock Lake Technical Advisory Committee,

The purpose of this letter is to provide a status update on the High Rock Lake Watershed Model review process. Extensive sets of comments were provided on the first and second draft of the High Rock Lake Watershed Model Report. These comments range from editorial corrections to substantive technical questions. We believe that the majority of these comments can be addressed through insertion of corrected or clarifying material in the report or through a separate response to comments. Due to the volume of comments it will take some time to complete these document revisions.

We thank the reviewers for their detailed scrutiny of the model. This scrutiny did identify a limited number of actual or apparent errors that need to be corrected before the watershed model is ready for use, as well as some misconceptions about the model framework. This letter provides a brief summary of the responses that have been undertaken to address some of these issues. Further detail on these and other comments will be provided in the forthcoming final watershed model report and response to comments.

NCDOT Suspended Solids Load Rates. NCDOT provided summaries of a variety of studies on suspended solids event mean concentrations in runoff from DOT right-of-ways, and suggested that these indicated that unit area loading rates in the model were too high for this land use. A rigorous comparison to the model was not provided in the comments, as the model report summarized land use in terms of loading rates, not EMCs. Tetra Tech undertook a direct comparison by converting model simulated storm loads from DOT right-of-ways to EMCs. The comparison to the studies provided by DOT did indeed suggest that loading rates in the model for this land use were too high. Accordingly, Tetra Tech revisited this portion of the model.

The studies provided by NCDOT show median EMCs ranging from 12 to 77 mg/L and 85th percentile EMCs ranging from 49 to 415 mg/L, and thus do not provide an exact target. In addition, it is likely that larger loads arise from a limited population of problem sites and occasional extreme storm events that may not be well represented in the cited studies. Nonetheless, the model values should show approximate consistency. Accordingly, the solids transport capacity for runoff from DOT right-of-ways was reduced, resulting in revised model EMCs that have a median of 68 mg/L and 85th percentile of 161 mg/L, consistent with the ranges in the cited studies.

It should also be noted that the bar chart showing unit area loading rates for solids did not correctly calculate the sums for developed land categories, which are simulated as separate pervious and

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impervious fractions in the model. The rates for low density residential, high density residential, and industrial categories should have been displayed as from 0.29 to 0.63 tons/ac/yr.

Because the solids load from NCDOT is a small fraction of the total solids mass balance it was not necessary to recalibrate the entire solids simulation and the quality of model fit remains acceptable.

Riverine Algal Simulation. Comments from the TAC suggested that riverine algal concentrations (as chlorophyll *a*) should be higher than are simulated in the model. The evidence for this is not very clear, as the monitoring data that were presented are primarily either from small lakes in the watershed or from backwater areas where tributaries enter High Rock Lake. Nonetheless, Tetra Tech agreed that it is a reasonable assumption that riverine planktonic algal concentrations should be higher than was simulated in the previous model version. Therefore, algal growth in the slower-moving river sections was increased, primarily by reducing background light extinction coefficients. The resulting model simulates periodic blooms in the lower Yadkin River above High Rock Lake, which appears reasonable, although not well documented by field data. In particular, it was confirmed that chlorophyll *a* concentrations simulated in Lake Thom-A-Lex (the only lake in the watershed that is explicitly simulated) are consistent with observations.

Muddy Creek Station. It was correctly noted that the report compares water quality model results to observations at the wrong location in Muddy Creek, as the water quality monitoring station is not coincident with the flow gage. We thank the commenter for pointing this out. Using the output from the correct location in the model network provides a much better fit to observations at this station.

Atmospheric Nitrogen Deposition. TAC comments noted an apparent error in the specification of dry atmospheric deposition of inorganic N, which appeared to be too low. Tetra Tech did a full QC examination of these data and found that the raw data and subsequent spreadsheet processing are all correct, but that the time series stored in the binary WDM file had become corrupted at some point. Repairing this issue results in a slight increase in upland loading rates (the impact is small because deposition onto the land surface is still subject to the accumulation limit of the buildup-washoff formulation) and an increase in total nitrogen deposition to water (also with a small impact because the water area is a small fraction of the total watershed).

Nitrogen Transformations. The previous version of the model transformed a fraction of the inorganic nitrogen from the land surface directly into refractory organic N. This was essentially a shortcut approach to rebalance organic and inorganic N by changing the linkage rather than by changing the upland accumulation rates. As requested, this feature has been removed and the linkage from upland to reach cleaned up, so that total inorganic N is routed to nitrate and ammonia in the stream and the nitrogen component of organic matter is routed to refractory organic N and labile organic N (represented as a fraction of BOD in HSPF). In fact, the changes to the riverine algal simulation, coupled with the other changes noted above, meant that it was no longer necessary to alter the upland inorganic N predictions by routing some to organic N, and the resulting model fit to observed nitrogen species is better than in the previous iteration.

Nutrient Unit Area Loads. TAC comments correctly noted that the figures presented on unit area loads for nutrients inadvertently omitted the labile organic component. This component has now been included, which results in slight increases in loading rates for total nitrogen. (It is important to note that this affects only the output summary and does not impact the model itself). At the same time, the other changes noted above, such as the increase in atmospheric deposition, required some minor readjustments of the inorganic N calibration. In particular, model fit is improved by reducing the loading rates for inorganic N from forest, consistent with comments that the N loading rate for forest appeared higher than reported in other studies.

Connection of Nutrient Loads to the Lake Model. A full description of the connection of the watershed model to the lake model is not provided in the watershed model report; instead, it will be provided in the forthcoming lake model report. Unfortunately, stakeholders have received the incorrect impression that the watershed model output of total N and total P is assigned directly to the lake model and then partitioned into different nutrient species based on in-lake observations. This is not the case: instead, watershed model output for inorganic and organic N and P components are linked directly to the corresponding WASP state variables – as is requested in the comments.

Once Tetra Tech finishes reviewing the comments and making the appropriate revisions to the model and report, DWQ will distribute the revised materials to the TAC. The revised report will include a response to comments as an appendix. The lake model review will follow.

We again thank the reviewers for their thorough examination of the draft watershed model. Model review is an essential component of model development and we thank the TAC for serving in this role.

Sincerely,

Pam Behm

Pam Behm
Acting Supervisor, DWQ Modeling and TMDL Unit

CC:
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