Lower Susquehanna River Watershed Assessment Team Responses to the "Review of the LSRWA: Scientific and Technical Advisory Committee Review Report"
August 2014
Annapolis, Maryland
STAC Publication 14-006

Background

As requested by the Lower Susquehanna River Watershed Assessment (LSRWA) Team in the fall of 2013, the Chesapeake Bay Program partnership's Scientific and Technical Advisory Committee's (STAC) sponsored an independent scientific peer review of the June 2014 draft LSRWA report and its supporting technical appendices. STAC responded to a series of charge questions posed by the LSRWA team during their review in a report entitled "*Review of the Lower Susquehanna Watershed Assessment: STAC Review Report.*[1]" A complete copy of the STAC Review Report is provided in Attachment I-7 of Appendix I of the LSRWA report.

Overall Comments and Responses

-The LSRWA Team's responses below are framed around the charge questions (**in bold)** posed to STAC**.** Specific excerpts from the STAC review report are included in text denoted by From STAC. The response is included in text denoted by *LSRWA response;* response is in *italics.* If language in the main LSRWA report or any of the appendices was altered due to a STAC comment, this is indicated in the respective LSRWA response as well.

Question 1: Does the main report clearly define the goals, strategies, and the results/conclusions of the study, and also present adequate background material at a level suitable for understanding by non-technical audiences?

A. From STAC "The goals stated in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment) and appear not to be the study's original goals."
…"The inconsistency between the stated goals and the general strategies followed is an issue that propagates throughout the analysis for the entire assessment."
…"It appears that the goals as presently listed in the Introduction to the main report were not the original goals of the study.

LSRWA response: The LSRWA goals were deliberated and established by the LSRWA team back in 2011. The study goals have never changed. The study was always focused on sediments and associated nutrients. The strong nutrient emphasis/importance became apparent near the end of study once the full suite of model scenarios were run and evaluated. The study did evaluate nutrient loads and transport processes via the Chesapeake Bay Environmental Modeling Package (CBEMP).

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[1] Chesapeake Bay Program Scientific and Technical Advisory Committee. 2014. *Review of the Lower Susquehanna Watershed Assessment: STAC Review Report. August 2014. STAC Publication 14-006. Annapolis, Maryland.*

B. From STAC: "Both the Executive Summary and Chapter 9 of the main report (entitled "Assessment Findings") present four categories of conclusions that generally correspond to each other. Within the individual context of the Executive Summary or Chapter 9, each set of conclusions is well written and easy to follow and understand. Their general content also includes the most important results and conclusions of the study. However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting. This review recommends that the four categories of main results/conclusions be presented in the same order in both the Executive Summary and in Chapter 9 and the headers be made more consistent and compelling."
…."However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting."

LSRWA response: The Executive Summary and Chapter 9 headings have now been made consistent as much as possible. The executive summary and Chapter 9 (findings) have different purposes. The executive summary's purpose is to be a standalone document that summarizes the study background, process, findings and recommendations, while Chapter 9 focuses on findings.

C. From STAC "Although the background material within the main report is indeed presented at a level suitable for non-technical audiences, this review recommends that large portions of the background material (specifically all of Chapter 2, 50+ pages in length) be moved to an Appendix. The remainder of the main report never refers to Chapter 2."

LSRWA response: Section 2 has been removed from the main report and made into a supporting technical Appendix as recommended.

Question 2: Are the alternative sediment management approaches clearly described and documented? Does this background material provide supporting evidence for the finding and conclusions of the study with regard to alternative sediment management approaches?

A. From STAC "Further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction."

LSRWA response: The LSRWA team agrees that costs in the report focus on sediment management removal/reduction. Nutrient reduction specific strategies and associated costs warrant further analysis. The premise for sediment management strategy development was: "The focus was on managing and evaluating sediment loads with the understanding that there are nutrients associated with those sediment loads; thus, in managing sediments, one is also managing nutrients. However, it must be noted that the relatively low importance of sediment from the dam as a stressor to Chesapeake Bay water quality and aquatic life versus nutrients was not known until late in the study process. For that reason, management measures focused primarily or solely on nutrients were not considered in this assessment."

B. From STAC: "This review recommends that further caveats be included throughout the report to clarify that the dollar-based cost estimates regarding alternative sediment management approaches are specifically for reducing cubic yards of total sediment in the reservoir, not for achieving broader goals regarding nutrient reductions. The dollar-based cost estimates in Table 6-6 are reported in the Executive Summary (p. ES-4) and elsewhere in the assessment report. Wherever the dollar-based cost estimates are stated, their meaning with regard to increasing reservoir capacity rather than improving water quality should be more clearly indicated. The report should also emphasize that further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction."

LSRWA response: The premise for sediment management development is stated in report:

> *"This assessment included a survey-level screening of management strategies to address the additional loads to Chesapeake Bay from the reservoirs' bed sediment scour. The focus was on managing and evaluating sediment loads with the understanding that there are nutrients associated with those sediment loads. The reason for this is that nutrients are contained within the dam sediments..."*

The evaluation included upland and in-reservoir strategies along with impacts to water quality and costs associated with those improvements. The LSRWA team agrees that the costs presented do not correspond with and were not calculated for strategies focused on nutrient removal/reduction only, and that more analysis is warranted on nutrient specific reductions and costs. This is included as a recommendation in the report.

C. From STAC: "For example, a one-time major dredging in the region just upstream of the dam, followed by bypassing from further upstream to slow subsequent infill, might have longer lasting effects. These more complex scenarios are clearly beyond the scope of this report, but they should be mentioned and acknowledged as worthy of exploration."

LSRWA response: The LSRWA Team agrees with STAC comment/recommendation. The following language was added to the Chapter on Developing Sediment Management strategies:

> *"The alternatives were selected to offer a realistic range of costs for potential solutions. Whereas the representative alternatives were chosen due to their apparent viability relative to other similar strategies, no rigorous comparisons were conducted nor were the alternatives optimized (e.g. to more effective) through a detailed design process. Furthermore more complex alternatives were not developed (e.g. combining additional BMP's in conjunction with dredging)."*

D. From STAC "The economic analysis and comparison of the alternatives could be further enhanced by considering, and at least discussing in qualitative terms, other possible co-benefits (and possibly co-costs) of the alternatives. For example, in addition to reducing loads to the Bay, many of the BMPs provide other ecosystem service benefits such as improved water quality upstream from the Bay, carbon sequestration; water storage/flood control, recreation benefits, etc. (see USEPA report EPA/600/R-11/001 for an analysis that includes some of these co-benefits)."
LSRWA response: The LSRWA Team agrees this would be a valuable exercise, however, conducting such an evaluation was but not within the scope of this current effort. More site-

specific analyses would be required to back-up statements about ecosystem service benefits that are mentioned above. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts (possibly co-costs) along with co-benefits could be performed in any future, project-specific NEPA effort.

E. From STAC: "Similarly, dredging activities may entail aesthetic disamenities (i.e., external costs), which would have the opposite effect by increasing the total costs of this set of alternatives."
LSRWA response: The LSRWA Team agrees but more site-specific analyses would be required to back-up these statements and were outside of the scope of this effort. The following language added to the Chapter on Developing Sediment Management strategies:

> *"It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort."*

Questions 3 & 4: Does the main report provide clear, supporting evidence for the results, findings, and conclusions of the study? Does the report adequately identify key uncertainties in the model applications which, with better information, could change the predicted outcomes of the alternative management scenarios evaluated in this study?

A. From STAC: **"**Although there is no single accepted procedure for reporting uncertainty in the context of scenario modeling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided."
…"Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. For example, if storm sediment transport can hardly be measured to within +/- 50%, model predictions can hardly be expected to be better (for example, in Appendix A, an error of about this range is indicated for predicting reservoir scour)."

LSRWA response: Sources of uncertainty were identified for each of the model analyses and ranges for some of the modeling estimates in the main report were provided where they were available. Unfortunately, as noted in the STAC review comment above, methods of uncertainty estimates for an integrated model system, as was used in the LSRWA which combines four large and complex models of the watershed, airshed, reservoir, and estuary, have yet to be developed. In any case, the level of uncertainty analysis in the LSRWA was consistent with what was applied in the model scenario analyses supporting development of the 2010 Chesapeake Bay TMDL. Quantifying uncertainty in application of linked complex mechanistic models of this type is extremely difficult to impossible. The standard technique involves making a large number of simulations with varying inputs and examining the resulting change in outputs. The resources to *do this were unavailable to this study. In fact, we do not know of any comparable study where uncertainty was rigorously examined in this fashion. The authors put a lot of effort into describing sources of uncertainty and potential impacts. The readers will have to consider these and create value judgments regarding model uncertainty. For the specific HEC-RAS example, the highest predicted error for scour in table A3 is about 50%. However scour is only about 30% of total sediment transport, so the scour error is actually about 15% of total sediment transport. The following language was added in the introduction to the Modeling Tools and Application Chapter of the main report:*

> *"In regards to uncertainty model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes. The uncertainty in model results can be described in quantitative and qualitative fashions. Quantitative measures are usually generated through multiple model runs with alternate sets of inputs and/or parameters. The number of model runs quickly multiplies so that this type of quantitative uncertainty analysis is impractical for complex models with numerous parameters and extensive computational demands. A qualitative, descriptive uncertainty analysis is the practical alternative in these instances which is what was done for this LSRWA effort."*

B. From STAC: **"**1) Stated sediment discharges from the Conowingo Dam are inconsistent with the literature. The report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data." "… Also on p. 190, the report indicates that,' The total sediment outflow load through the dam… increased by about 10 percent from 1996 to 2011…' These results are so strongly at odds with other published numbers on this subject that some explanation and discussion is certainly required.

LSRWA response: We are not sure exactly what is meant by literature values. There are not sufficient measurements of the inflowing sediment to the Conowingo reservoir to develop either an observed time history or a reliable rating curve. There are some observations of sediment load into the entire 3 reservoir system, but the mitigation of these loads by the presence of the upper 2 reservoirs must be modeled. Given these uncertainties, the modelers elected to allow a relatively high inflowing sediment load into the Conowingo reservoir; so that the scour potential was maximized (a low load could reduce scour potential by making sediment supply limiting). Regarding comment on the 10% increase from 1996-2011, hydrology is key. Language is already included that this 10% is specific to a 4 year AdH simulation period (2008-2011) of hydrology comparing 1996 bathymetry to 2011 bathymetry. This statement in the report means that, for the same 4 year water and sediment inflow hydrograph, model runs using the 2011 starting bathymetry yielded 10% more sediment exiting the Conowingo reservoir than did model runs using the 1996 starting bathymetry. This is somewhat different than conditions forming the bases of various analyses of Hainly, Hirsh, and Langland investigative studies.

C. From STAC: "Reduced deposition associated with reservoir infilling has been neglected. The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo

Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour….”…….“This issue underlies a significant weakness in the report, which is that it focuses its inquiry on the impact of large, but infrequent, scour events rather on the total impact of the change in trapping efficiency of the reservoir system. The review recommends that all statements that indicate that reservoir trapping of sediment and associated nutrients is unchanged in the absence of scour be removed”

LSRWA Response: Both increases in scour and decreases in deposition were modeled by AdH. There are no artificial constraints on the model to retain a constant rate of deposition. The LSRWA Team agrees that the Chesapeake Bay impacts were primarily evaluated in the context of NET scour events or additional scour over varying bathymetries. However 1996, 2008, 2011 and full reservoir deposition were simulated, compared and presented in report. Perhaps the concept of dynamic equilibrium needs to be emphasized more in these statements, the time scale that we are referring to here is important.

“Dynamic equilibrium does not imply equality of sediment inflow and outflow on a daily, monthly, or even annual basis, or similar time scale. It implies a balance between sediment inflow and outflow over a long time period (years to decades) defined by the frequency and timing of scouring events. Sediments (and associated nutrients) that accumulate between high flow events are scoured away during storm events, whereby accumulation begins again. Over time, there is no net storage or filling occurring in the reservoirs.”
The LSRWA team agrees with the STAC comment that lower flows will cause scour as the reservoir fills. The report language has been edited to state that:

> *“The study did not differentiate between increased scour and less deposition as a reason for an increase in solids at lesser flows but most likely is a combination of both.”*

D. <u>From STAC</u>: “Grain size effects within and exiting the reservoir were not sufficiently considered. The combination of two grain size effects – (i) changing grain size in time in the reservoir and (ii) the greater effects of fine sediment in transporting nutrients - mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. “…Grain size effects within and exiting the reservoir were not sufficiently considered….” “ The review recommends that the concept of dynamic equilibrium be clearly qualified in the report to indicate it does not yet apply to sediment grain size, and thus it does not yet fully apply to the flux of fine sediment or associated nutrients.” “…Thus, the dynamic equilibrium that is described in the report is changing over time, and it would be worthwhile to try to predict how many cycles of deposition and scour might be required before the dynamic equilibrium becomes less dynamic.”

*LSRWA Response**:** The LSRWA Team deliberated much on concept of dynamic equilibrium, which the report defines in simplest terms as no more long-term net trapping. Dynamic* *equilibrium also means, even at this end state, things in the reservoir will still change, for example grain size. In general we can agree that grain size and nutrient composition/flux will continue to change over time. But the overall definition of dynamic equilibrium as utilized in the report is adequate for the purposes of presenting the finding that long-term net trapping has ceased.*

Grain size implications are an interesting consideration. USGS indicates that a study done by Bricker (USGS) indicated that it would take 5,000 years for grain size to shift fully to sand and larger grain sizes. The grain size of the reservoir bed may change over time as the reservoir fills. Grain size was not considered explicitly (although grain size sorting was implicitly modeled). However, these effects, although important, are likely impossible to meaningfully quantify without significantly more and better field and laboratory observational data. These grain size effects fall well within the uncertainties of what is known. A qualitative discussion of grain size effects could be helpful, but attempts to quantify this are limited. This limitation is not due so much to the fidelity of the model as it is due to the uncertainty of the data. Grain size shifts and effects can be simulated with the AdH model, but the model cannot be validated to observed data, because there are not sufficient observed data to validate to (to within a reasonable range of uncertainty). So this must be considered qualitatively, as a discussion. How might this trend alter the load of fines downstream and hence the water quality? Although it might allow less storage of fines over time, it might also prevent the mass erosion of older stored fines, if they are buried under sands. A conceptual analytic model might be of some use here, or even some parametric numerical model runs, as long as it was made clear that these are unvalidated runs.

Regarding nutrient composition, the data to develop a nutrient budget based on possible alteration in grain size does not exist. We were fortunate to find data on particle nutrient content without regard to grain size. Determination whether the reservoir is in equilibrium or not with regard to nutrients is an impossible task. We would need a historical record of particle nutrient composition and content, a comprehensive accounting of nutrient storage and loss in the bottom sediments, and projections of future trends in nutrient load and particle composition. Any statement as to whether the reservoir is in equilibrium with regard to nutrients is speculative. The report does not state "assumed that if sediment was at equilibrium, then nutrients were also." The report is rightfully silent on this topic.

E. <u>From STAC</u>: "The HEC-RAS modeling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report." "Limitations of HEC-RAS model were not made sufficiently clear in the main report".

LSRWA response: The LSRWA team disagrees that HEC-RAS was largely unsuccessful. The team knew it had its flaws for this system, which is why the team used a 2D AdH model for Conowingo. However, application of this model helped the team understand conceptually that there is still scouring and deposition in the upper two reservoirs. Also, HEC-RAS was successful in calibrating the hydraulic (flow) for the simulation period and size distribution. It provided AdH a valid starting point for inflow into Conowingo Reservoir. These inflow numbers were increased due to the problems with mathematical computations in HEC-RAS related to sediment *transport. The issue was the magnitude of the sediment transported at Conowingo. Language has been revised in HEC-RAS discussion of the main report to read:*

> *"For the LSRWA effort, the HEC-RAS model outputs provided a relative understanding of the reservoir sediment dynamics, indicating all three reservoirs are active with respect to scour and deposition even in a dynamic equilibrium state (the upper two which have been considered to be in dynamic equilibrium for decades). Additionally the boundary-condition data from the HEC-RAS model were helpful in the calibration of the AdH model, especially by improving information on the inputs into Conowingo Reservoir."*

HEC-RAS is designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). Thus the model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediments) and active scour and deposition. Limitations of the model most likely resulted in 1) less than expected deposition for the 2008-2011 simulation and 2) less than expected erosion (scour) for the Tropical Storm Lee seven day event simulation, when compared to other approaches and estimates. If a more detailed evaluation of the upper two reservoirs is required in the future, application of the AdH would be more appropriate.

F. From STAC: "The AdH model was not fully validated, and the AdH model was forced by boundary conditions outside the range of observed values. This means that the AdH model alone was not reliably predictive, and until the AdH model has been improved, observations should instead be emphasized to support the most important conclusions of the LSRWA study…." "Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated…" "The AdH model was not calibrated, but instead the authors use what they refer to as a validation approach…" "The tenuous nature of the model validation is made more uncertain by the fact that the values for the key boundary condition (critical bed shear stress for sediment entrainment) in the final selected model fell largely outside the range of values measured by the SEDFLUME or were unmeasured and taken from the literature."

LSRWA response: Not sure what is meant here by "fully" validated. Estimated data from AdH was compared to the actual measured data at Conowingo for total load transport and particle size. The validation of the AdH model was limited, primarily because the quantity and quality of the available field data are limited. Further validation against this limited data would create a misleading impression of confidence, since the uncertainties associated with the observations do not allow for "full" calibration and validation. The model was shown to match several integrated quantities well, which demonstrates that the general sediment scour and deposition behavior of the reservoir is well represented in the model Then, the model was subjected to gross sensitivity experiments, to determine the expected trends and behavoir of the reservoir and expected future behavior. These trends are consistent with what is known about the historic behavior of the reservoir.

The validation to integrated properties is undertaken partly because there are not sufficient data to validate the mode better. To do this, one would require a much more comprehensive history of sediment loading, a wider selection of SEDLUME cores, more information on settling velocities, consolidation rates, bioturbation, etc. That is, both the stratigraphic history and the processes that govern stratigraphic development must be observed. Since these data don't exist, the model is validated to the degree that the data allow, and the model is relied upon only inasmuch as it predicts "integrated" results (i.e. fraction of total load being eroded, sediment equilibrium arguments).

The critical shear stress was utilized essentially as a calibration parameter. The erosion rate constants and exponents were indeed taken from the SEDFLUME results, but the critical shear was increased beyond what was observed in the surficial SEDFLUME layers. There may be some allowance for this inasmuch as the SEDFLUME data may have been collected when the reservoir was in a less consolidated state than when the tropical storm event took place. But, in reality, these values were adjusted because these adjustments resulted in the best qualitative and quantitative fit against the observations.

It is true that the model could be improved, but it is not true that the model is of little use. It provides valuable insight into the sediment dynamics of the reservoir that is consistent with what is known. It also provides supporting evidence for the general conclusion that the reservoir is in dynamic equilibrium with respect to sediment storage and release over long term (multi-year) time scales. The AdH modeling effort is not designed to be reliably predictive in all aspects of sediment behavior, since the paucity of available field data make this effort beyond the skill of any model. Rather, the AdH effort is designed such that the main thing it seeks to evaluate is the general character of the sediment storage and release trend of the reservoir (i.e. whether the reservoir is approaching dynamic equilibrium) and approximately what percentage of the outflow from large storm events is associated with scour. With respect to these questions, the AdH model demonstrates the ability to predict what is known, and the future predictions are consistent with the observed trends. So the question is, are these general conclusions likely to change significantly, even if more data were available and better model validation were achieved? Although we disagree that the model is of little value, we agree that it is worth thinking through the possibilities associated with this question.

G. <u>From STAC</u>: "References to differentials as small as 0.1% (for example, see table 6.7) imply accuracies in characterizing the sedimentary system that could not be confirmed by any type of measurement known by the reviewers. However, if qualified as model results and indications are in relative terms, there may be value in such numbers as long as all such values are qualified as "well within measurement error." Hence, "we cannot infer any significant change" should be stated up-front based on results of such analyses. In many of the modeled scenarios, the changes in attainment of water quality criteria with fairly large management actions would appear to a non-technical reader to be very small. For instance, p. 135 states: "…estimated…non-attainment…of 1 percent, 4 percent, 8, percent, 3 percent…" One should ask if such estimates are statistically significant."

LSRWA response: The LSRWA Team agrees with the main point that since all of the water quality assessment results estimated in the LSRWA Report with estimated relative differences *ranging from 0.1 percent to 8 percent are from relative differences with a base scenario, the scenario estimates, though seemingly small, have merit. In most cases the base scenario was the Chesapeake Bay TMDL Watershed Implementation Plan (WIP) Scenario, which is estimated to fully attain the state's Chesapeake water quality standards. The base scenario was compared to key scenarios of Conowingo infill generating the percent differences described in the LSRWA Report. Existing language in main report states:*

> *"EPA provided a first order estimate of the degree of Susquehanna River watershed nutrient pollutant load reduction needed to avoid estimated increases in DO nonattainment of 1 percent in the deep-water and deep-channel areas; this analysis is described further in Appendix D. A rough estimate of the load reduction needed Bay-wide is about 2,200 tons of TN (4.4 million pounds) and 205 tons of TP (0.41 million pounds) to offset the DO nonattainment in the deep channel and deep water areas. Estimates of the nitrogen and phosphorus pollutant load reductions from the Susquehanna River watershed needed to offset the 1-percent increase in DO nonattainment are about 1,200 tons of nitrogen (2.4 million pounds) and 135 tons of phosphorus (0.27 million pounds)."*

H. <u>From STAC</u>: "Similarly, in appendix A, p. 25, the net deposition model indicated that ~2.1 million tons net deposition in the reservoirs occurred in 2008-11. This is the difference of two order-of-magnitude larger numbers (22.3M tons entered the reservoir, 20.2M tons entered the Bay). There is a rule-of-thumb in sedimentology: ±10% in concentration or transport is 'within error'. Does the precision of the computed difference fall within the margin of error in these metrics?"

LSRWA response: The HEC-RAS model did not perform well when compared to actual data. However the LSRWA team was testing for "significant change." Error bounds are presented in Appendix A (Attachment 1) for estimate of equation based regression scour and sediment loads transported into and out of the reservoir. This is just a simple subtraction of the in's and out's of Conowingo reservoir. The team already surmised that the estimate was under predicting the amount of deposition. It does fall within 10% of the metrics as presented, but that does not mean it's correct. It is also important to note that much of this load is "wash load" in that it passes through the reservoir without significant interaction with the bed. Therefore, with respect to erosion and deposition dynamics, the "within error" calculation should not include the wash load. .

I. <u>From STAC:</u> "If optimally constrained by observations, reservoir calculations may have reasonable accuracy and precision when averaged over longer timescales, but less accuracy over shorter timescales. However, the key timescales for many biological processes are much shorter than those of an annual sediment budget, and this could be a major source of uncertainty in the predictions of the efficacy of the sediment management scenarios. This disparity in process timescales is important to address in the text and in the conclusions of the study."

LSRWA response: This is a good point. Regarding the AdH model, utilizing erosion rates characterized by the SEDFLUME observations, erosion tends to occur rapidly in response to a rapid rise in the hydrograph. Hence, the eroded sediment from a rapid rise is pulsed rapidly *into the Bay. So, although the results are presented as integrated quantities, the model output to the ecological model does include this rapid pulse. The CBEMP model results ultimately hang on the assessment of attainment of water quality standards. Since the DO water quality standards have a space and time assessment that's considered to be relevant to living resources in the designated uses of Chesapeake Deep Water, Deep Channel, and other regions of the Chesapeake, the issue was largely addressed in the development adoption of the states' Chesapeake Bay water quality standards.*

J. From STAC "Anoxic volume days appears to be a variable that is relatively more sensitive to the model scenarios presented in the report (e.g., Table 6-8). This suggests something alluded to in the report on several occasions that a large fraction of the deep water in Chesapeake Bay is sitting on the threshold of being anoxic, and seemingly small changes in concentration (0.2 mg/l) lead to substantial relative changes in anoxic volume. It is worth clearly stating that the high sensitivity of this one criteria to small changes in load stands out among the other variables (e.g., chlorophyll-a, chl-a). It strikes the reviewers that changes in chlorophyll and dissolved oxygen associated with "normal" inter-annual variability in climate and nutrient loading are much higher than those associated with additional Conowingo Dam-derived nutrients as simulated here. One might conclude that given this fact, that the potential effects of dam-derived particulates are trivial."

LSRWA response: At places and times, the predicted response of Chesapeake Bay water quality conditions to scoured Conowingo nutrients is indeed small compared to inter-annual variability. Relatively small changes in dissolved oxygen can trigger a failure to meet rigorous state adopted Chesapeake Bay water quality standards. So even apparently small changes can be consequential. As suggested by the reviewers, it is the summer hypoxic period that is of concern and small difference in DO during this period make big differences to living resources as reflected in the development of the DO water quality standards.

The following language has been added to Appendix D:

> *"The Deep-Water and Deep-Channel DO water quality standards are on a knife-edge of attainment with the State Watershed Implementation Plans (WIPs). Achieving the Deep-Water and Deep-Channel DO standards in the 2010 TMDL was difficult and required management actions that went far beyond what was needed for sediment and chlorophyll (except in the case of James chlorophyll). The annual difference in DO generally ranges from about 12 mg/l in the winter to near hypoxia/anoxia conditions in the summer in the Deep-Water and Deep-Channel regions of the Chesapeake largely due to DO solubility differences with temperature and also due to the summertime presence of the pycnocline. But it is the summer hypoxic period that is of concern and a small difference in DO during this period makes big differences to living resources as reflected in the development of the DO water quality standards."*

K. From STAC: "The relevant statement from Hirsch (2012) is:' The discharge at which the increase [i.e., the increase in suspended sediment concentrations at the dam] occurs is impossible to identify with precision, though it lies in the range of about 175,000 to 300,000 cfs.

Furthermore, the relative roles of the two processes that likely are occurring – decreased deposition and increased scour – cannot be determined from this analysis.' "

LSRWA response: The reference to Hirsch has been removed from the text.

L. From STAC: "First, the events in excess of 150,000 cfs happen on average about 3 times per year (not once every two to three years). The number of such days (with daily mean discharge between 150,000 and 300,000) is about 11 days per year. Second, it is not clear that the increase in sediment loads in the 150,000 to 300,000 cfs range is really a result of scour."
LSRWA response: The LSRWA team disagrees with this comment regarding flow frequency. USGS calculations of the hydrologic record (Appendix A, Attachment 1) show that exceedance numbers for a 150,000 cfs is about once every year, 300,000 cfs is about every 2.1 years. The LSRWA Team agrees that we do not fully understand what is going on at the lower and more moderate flows which is why the report contains a recommendation to evaluate this more closely.
The report language revised to state:

> *"On average, in this dynamic equilibrium state, a major scour event will occur once every 4 to 5 years. Minor scour events with trace amounts of erosion will occur every 1-2 years (150,000-300,000 cfs); while at lower flows sediment (and associated nutrients) will accumulate until an erosion event occurs again. In the flow range of 150,000-300,000 cfs it is not fully understood if this increase in sediment load to the Bay is due to an increase in scour or due to a decrease in deposition in the reservoir itself; it very likely could be a combination of both and warrants further study."*

M. From STAC: "At bottom of p. 190 the text reports on reductions in TN, TP, and TSS as 19, 55, and 37%, respectively, for the past 30 years for loads "to the lower Susquehanna River", referenced to http://cbrim.er.usgs.gov. This could mean loads delivered to the upstream end of the reservoir system or loads delivered at the downstream end where the river enters the Chesapeake Bay."
LSRWA response: The STAC comment is correct about trends in flow-adjusted concentration. WRTDS can estimate trends in loads, but it currently cannot estimate error ranges around the estimates. Until that is resolved USGS will not publish trend in loads.
The report language has been revised to read:

> *"Over the past 30 years, due to widespread implementation of regulatory and voluntary nutrient and sediment reduction strategies, nutrient and sediment loads to the lower Susquehanna River are significantly lower than what was delivered in the mid 1980s. Flow adjusted concentrations of total nitrogen (TN), total phosphorus (TP), and suspended sediment concentration declined by 30, 40, and 45 percent, respectively between 1985 and 2012 at Marietta, PA (see http://cbrim.er.usgs.gov/)."*

N. From STAC: "Nutrients associated with fine sediments, not with the total load of sediments, are the main water quality concerns. The report acknowledges that sand-sorbed P is more or less inconsequential in P transport. However, all sediment-discharge values are expressed as "total loads." Since P transport is closely tied to fines, and presumably very closely tied to clay-size particles, transport metrics computed for fines, and particularly for clay-size particles, might yield different conclusions than those derived from "total" load comparisons. It is also important to clearly define what is meant by total load. Sedimentological nomenclature denotes "total load" as all material in transport, be it defined as bed load plus suspended load (with caveats), or bed-material load plus washload"

LSRWA Response: the report is referring to bed load plus washload, all sediment available. This is further refined in outputs as bed load and loads out of the reservoir, or total delivered load. For HEC-RAS specifically, transport equations in HEC-RAS are designed to move bed load. However, a transport curve with properties of the cohesive sediments is also included in the estimation of total transport from one cross-section to another in each time step. In addition, bed load transport is not a substantial part of the total load (<10%).

Language has been added to the main report's glossary clarifying that total load includes all material in transport (includes bed load plus washload (sediment) load).

Question 5: Are the recommended follow-up evaluations and analyses (Section 9.1) complete and comprehensive as well as clearly stated to enable the next phase of work to continue under the Partnership's Midpoint Assessment?

A. From STAC: "One of the outcomes of this study should be to identify areas where our scientific understanding may be insufficient to achieve management goals, and to suggest future scientific studies to provide this knowledge. Follow-up studies need to consider the full range of hydrologic conditions, from moderate to high flows, which generally do not result in scour (but still reduce the deposition of sediment-associated nutrients in the reservoir), all the way up to the very high but very rare events that do result in scour. The emphasis in the future should shift from the relative vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients."

LSRWA Response: The LSRWA team fully agrees. Studies are now underway by USGS, MDE, and Exelon entitled "Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program focused on the Conowingo and the other two Lower Susquehanna reservoirs that are examining the fate and effects of nutrients mobilized from the Conowingo Reservoir from very high (>400,000 cfs) and moderately high flows (>100,000<400,00 cfs). The studies will be used to support Chesapeake Bay Program (CBP) partnership decisions on Conowingo infill offsets as part of the Partnership's Chesapeake Bay TMDL 2017 Midpoint Assessment. The ongoing research and field work on the mobilization and fate of nutrient from the Conowingo Pool will be applied to an integrated analysis using the CBP's partnership's suite of Chesapeake Bay watershed and estuarine water quality/sediment transport management models. Recommendations 1 and 4 already include language on evaluating moderate and lower flows and understanding bioavailability of different forms of nutrients.

The following language has been added to Recommendation #1, bullet #1:

> *"Determine the detailed characteristics and bioavailability of sediments and associated nutrients likely to be scoured within Conowingo Reservoir. The*

emphasis in the future should shift from the relative vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients."

B. From STAC: "A key question is how to proceed to do the "adjusting" of the TMDL milestones to account for increased sediment-associated nutrients passing out of the reservoir. "…That issue is thus the following: how much of a decrease in loads delivered to the reservoirs and/or increase in reservoir trapping efficiency would be required? The logic behind this resistance to including treating the sediment load as a penalty is expanded upon in the following two subsections: The negative impacts of sediment input to the Chesapeake Bay (relative to nutrients) are overstated by present TMDLs and are overemphasized in management priorities…"
"…Key recommendations of this review in this regard include: (i) that the effect of the change in overall "trapping capacity" must be accounted for (the LSRWA analysis done so far relates only to increased scour and not to total trapping capacity), (ii) priority should be given to accounting for the added particulate phosphorus, and (iii) the additional sediment load (other than associated nutrients) should NOT be an additional burden on TMDLs. Calculations by Hirsch suggest that the net loss of trapping efficiency by Conowingo may be in the range of 2300 tons of phosphorus per year. The basic question facing the midpoint assessment then is: what would it take in terms of upstream phosphorus management in order to overcome the impact of ~2300 tons of phosphorus? This estimate is not highly accurate. The team that did the LSRWA report has the simulation expertise and capacity to test these estimates, but they have not yet performed this specific simulation. The follow up to this LSRWA effort really needs to address these estimates and replace them with better ones if they can (including uncertainty bounds)..."
"…The effectiveness of BMPs in reducing sediment loads to the Bay may be overstated by present TMDLs." "…The possibility that sediment BMPs may not lead to a major reduction in sediment coming from the upstream watershed needs to be considered as a real possibility in considering management actions. Models alone cannot answer this question; only more direct measurement in places downstream of BMPs can fully demonstrate whether they are effective..."

LSRWA response: Once the "Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program" studies examining the fate and transport of nutrients, including both phosphorus and nitrogen forms from Conowingo infill are complete in 2016, the Chesapeake Bay Program partnership will work with the LSRWA modelers to incorporate the new salient information into the full suite of the CBP partnership's Chesapeake Bay watershed and estuarine water quality/sediment transport models. Analysis and review of the synthesis of research, field work, and modeling will enable a complex and comprehensive quantification and programmatic evaluation of the options for Conowingo infill offsets by the CBP partners as part of the Partnership's Chesapeake Bay TMDL 2017 Midpoint Assessment. Ultimately a decision of how to achieve the states' Chesapeake Bay water quality standards in the presence of the current dynamic equilibrium in the Conowingo Reservoir will be made by the Partnership in 2017.

The LSRWA team notes that sediment management is important throughout Chesapeake Bay watershed to improve freshwater river habitat impaired by excess sediment, maintain floodwater conveyance, improve water supply quality, reduce reservoir infill and in the case reducing silts and clays, improve water clarity and support survival and growth of SAV resources in tidal *headwaters. It's important to note that the 2010 Chesapeake Bay TMDL does not manage for sand erosion input loads, only the fines, and recognizes that the sand erosion can be beneficial to habitat and SAV resources.*

The LSRWA team agrees with the STAC comment regarding the effectiveness of BMPs in reducing sediment loads to the Bay and that it may be overstated by present Chesapeake Bay TMDL. As previously described, sediment management is important throughout the watershed. Nevertheless, because of sediment storage throughout the watershed the lag time for sediment (and associated nutrients) delivered to the Chesapeake tidal waters could be on the order of decades to centuries. Decision rules in the Partnership development Chesapeake Bay TMDL and the jurisdictions developed WIPs account for sediment load reductions at the tidal Bay as soon as the sediment management BMP is established. While there are obvious disconnects between science and the practice, the Chesapeake Bay TMDL and the jurisdictions WIPs encourage implementation of management practices that reduce sediment and nutrient loads in the tidal Chesapeake Bay. Both share the core goal of the implementation of all required practices, treatments, and technologies by 2025 needed to achieve all the states' Chesapeake water quality standards. The establishment of the practices is what's required by 2025, not water quality standard attainment. There is an explicit understanding in the Chesapeake Bay TMDL that because of sediment and nutrient lag times, water quality standards attainment will lag management implementation. Regarding how to determine the effectiveness of BMP's; monitoring alone might not answer that question. The question of scale and the fact that the vast majority of streams have huge sediments supplies from disruptive historical land use practices, make this extremely difficult to detect change.

C. <u>From STAC</u>: "There are a variety of technologies that can be applied using *in situ* sensors to collect an essentially continuous record of sediment concentrations and flux for use in inferring sediment-associated nutrient transport, including inference of grain size distribution."

LSRWA Response: USGS is trying to secure long-term funding to get an instrument deployed (a partner is required to match 50/50). In the short-term Exelon will be funding the placement of in situ monitors at Marietta, Holtwood, and Conowingo locations.

D. <u>From STAC:</u> In addition, Recommendation 1.2 would be better written as something like: "Determine the quantity and nature of the sediment-associated nutrients transported downstream under current conditions (dynamic equilibrium) versus conditions that prevailed in previous times when the reservoirs had substantial trapping ability.

LSRWA response: The report text language revised as recommended in the above STAC comment.

E. <u>From STAC</u>: "Could a higher P:N ratio cause a shift towards more blue-green algae that have an ability to fix N from the atmosphere, so that even with decreasing N loads from the watershed, the N available in the Bay might not decline due to this ecological shift? In any case, the emphasis in the future should shift from the relatively vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients. Future studies should also test the sensitivity of the biogeochemical model simulations to the reactivity of the scoured material for both nutrient release and water column and sediment respiration, which are linked. The latter influences DO directly. This could potentially require additional state variables to represent different pools of particulate matter in the sediments and water-column. Surely, scoured materials and other solids are deposited in sediments, where diagenesis releases nutrients back to the water column to fuel algal growth. But before these materials are deposited in sediments, they could fuel respiration directly in the water-column. They should also contribute to sediment oxygen demand, or in the case that sulfides are released to the water column from sediments, to lagged water column oxygen demand."

LSRWA response: The nutrient limiting to phytoplankton production varies with time and location throughout the Chesapeake Bay. In the future, the CBP partners could look at modeled response of nutrient limitation to alterations in the Conowingo Reservoir nutrient budget. The composition and reactivity of the particulate materials carried out of Conowingo Reservoir are large sources of uncertainty, as acknowledged in the report and in subsequent presentations and meetings. A study is planned to specifically address these issues. A study is also planned to examine the fate of and transport of particles swept over the Conowingo outfall into the Bay. Additional efforts with the model are not warranted until the results of these studies are available.

F. From STAC: "Develop and implement management options that offset impacts to the upper Chesapeake Bay ecosystem from increased nutrient and sediment loads. "It is suggested here that, once more, the phrase "nutrient and sediment loads" in the above recommendation be changed to "sediment-associated nutrients".

LSRWA response: The report text language revised as recommended above in STAC comment.

Question 6: Do the technical appendices provide the necessary documentation for the models and their applications in support of the study's results, findings, and conclusions?

Appendix A

A. From STAC: "The Estimator model was used in Appendix A in spite of the fact that its originator, Dr. Tim Cohn, has indicated his doubt as to whether it is adequate for use with "hysteretic" suspended sediment. Although it well may "work" in this relatively large river – larger rivers with smaller peak-to-base-flow discharge ratios and more languid precipitation-runoff responses tend to exhibit less hysteresis in suspended-sediment concentrations than smaller rivers – additional analysis might be required to confirm or refute that assumption."

LSRWA response: The USGS recently conducted a comparison of load estimations using both ESTIMATOR and WRTDS for the 9 major streams in the Chesapeake Bay watershed. Results indicted very good load and trend estimates with both models although WRTDS had a lower error and variance. The problem with ESTIMATOR is with "runaway quadratic estimations" where due the use of squared terms, if a high value is associated with a high flow value then a non-linear fit is needed for the relation. This can sometimes lead a bias and overestimation of load.

B. From STAC: "Concern was expressed regarding the exclusion from the sediment transport curve of the high suspended-sediment concentration value (2,890 mg/L, at USGS gage 01578310 [Conowingo] on 9/8/2011) in Appendix A, p. 12, Figure 7. There is rumor of a similar 'high outlier' in 2004. The transport curve in Figure 7 may well effectively be discontinuous with a major break around 400,000 ft3/s. The two transport-curve sections might be nearly parallel. It is possible that the present curve is valid for flows ~≤ 400,000 ft3/s, and the new curve that would reflect natural increasingly sediment-laden flows plus scoured material is valid for flows ~> 400,000 ft3/s."

LSRWA response: The graph has been updated to include this point.

C. From STAC: "A promising approach would be to develop a particle size-to-flow relation and apply it to the transport curve resulting in two (or three) curves, including a fines-transport curve (the principal metric of interest). The concept is graphically similar if mechanistically dissimilar from a discontinuous suspended sediment transport curve that has been shown to occur when flows transition between subcritical and supercritical regimes."

LSRWA response: This was attempted to help build a transport curve for the HES-RAS model, but the lack of and the variability of the particle size data did not produce a discernible relationship.

D. From STAC: "The ESTIMATOR was used to project changing sediment load over time. However, in looking at the USGS NWIS site there is only very limited information about actual sediment concentration and load data collected – a number of years during the period between 1979 and 1992 at Marietta, and presumably grab samples, but apparently no continuous record at Conowingo. Given all of this there is some skepticism about how well we really know the comparison between sediment loads at the two stations, especially going back to the early 20th century. "

LSRWA response: The comparison going back to the 20th century was based on various studies, including data from other agencies, compiled yields, and extrapolation from long-term flow record at Harrisburg, PA to Marietta, PA then mass balance to upper Chesapeake Bay. The estimated loads definitely have large errors, but does provide an indication of past to current historical trends.

Appendix B

A. From STAC: "The SEDFLUME results from a small number of cores account for a large fraction of Appendix B. But there is insufficient explanation as to how these results were translated into the parameter set utilized in the six material zones in the model. Given the variability within each core from one shallow layer to the next, and given the variation in particle sizes longitudinally as well as variation laterally across the reservoir in depth and modeled velocity, perhaps there is no way at this point to account for spatial patterns beyond the simple selection of six longitudinal zones; and perhaps it ultimately does not make much difference what choices one makes. But it is odd that so much space was devoted to the empirical results without explanation as to how they were actually applied or what difference the spatial pattern of parameter values within different zones might make, particularly given that a 2d model is being used. In calibrating the model, the authors varied critical shear stress parameters at shallow depths and maximum scour depth to keep the model from scouring too much sediment, but the discussion of how this was done did not make much reference to differences among zones or within zones. The way this issue was handled is not explicitly addressed in the text even though the small number of cores is identified as a source of uncertainty."

LSRWA Response: The critical shear stress was utilized essentially as a calibration parameter. The erosion rate constants and exponents were indeed taken from the SEDFLUME results, but the critical shear was increased beyond what was observed in the surficial SEDFLUME layers. There may be some allowance for this inasmuch as the SEDFLUME data may have been collected when the reservoir was in a less consolidated state than when the tropical storm event took place. But, in reality, these values were adjusted because these adjustments resulted in the best qualitative and quantitative fit against the observations.

B. From STAC: "p. 4 Figure 1 shows in graphical form the same information that is provided in Table 5-6 of the main report but in each case the citation simply says "provided by USGS". How do we know that by 1959 (first paragraph, p. 5) there was a relatively constant inflow of 3.2 million tons/yr of sediment flowing into Conowingo?"

LSRWA Response: This information is gleaned from the 2009 USGS report referenced in the document. The report can be found here: http://pubs.usgs.gov/sir/2009/5110/pdf/sir2009-5110.pdf.

C. From STAC: "pp.5-6 The Exelon revised HEC-6 study concluded that scouring flows above 400,000 cfs were net depositional in Conowingo? Not net erosional? Given conclusions provided elsewhere in both the main report and appendices, this is confusing."

LSRWA Response: Page 27 of the report discusses some of the reasons for this. The basic idea is that scour does not necessarily equate to net scour. For example, the upper section of the reservoir appears to scour, but a significant part of this material is sand, which appears to redeposit within the reservoir in the lower reach.

D. From STAC: "p. 22 Under model validation the statement is made that "The maximum sample depth was only about 12 inches due to highly consolidated sediments in deeper layers preventing penetration of the sampling tube." If this is the case what does it say about the actual potential for scour in a large flood event?"

LSRWA Response: It implies that there may be a practical limit for the total volume of scour. However, for his study, this practical limit was not systematically investigated further, as the large historical event studied here (in 2011) did not achieve this level of scour in the reservoir.

E. From STAC: "p. 23 Here it says that although samples represented only the top foot of sediment, the model sediment bed was about three feet. It appears from later discussion of choices made for calibration purposes that the three-foot depth had to be modified in order to match better with other information. The choices made here are not always clear."

LSRWA Response: The erosion properties at depth were unobtainable due to the inability to achieve core penetration. This implies that these sediments are stiffer than the surficial sediment, but not necessarily unerodable. Therefore, the model was supplied with layers at depth that were, in general, less erodible than the surficial layers. The properties of the deeper layer had to be approximated.

F. From STAC: "p. 25 This shows the flow-concentration curve for Conowingo and highlights both the variability at high flow and the existence of only a single point at the upper end of the curve. It would seem appropriate to try to quantify the uncertainty associated with use of this curve and develop a range of values in order to see how this uncertainty might affect conclusions and comparisons. The USGS curve for prediction of scour as a function of Q has upper and lower bounds; so should the sediment concentration rating curve."

LSRWA Response: This curve is for sediment outflow from the reservoir. Although significant uncertainty is indeed present in the data, a formal uncertainly analysis was not undertaken, because the data were not utilized significantly in the validation of the model. The primary use of the rating curve data was to extract grain size trends (that were qualitatively compared to model data) and to estimate integrated quantities, such as net sediment load. Although there was no formal uncertainty analysis, a general discussion of uncertainties in the data, including the hysteresis effect, is included.

G. From STAC: "p. 27 The major trend was that most of the scour occurred in the upper 1/3 of the reservoir where there is more sand which constitutes 50% or more of total bed sediment. A significant amount of deposition occurred just upstream of the eastern end of the dam. Was this mostly fines or more sand? What is the effect of the changes here on the particle-size distribution of the deposit as a whole?"

LSRWA Response: It is not known for certain, but some indirect evidence, as well as general sediment principles, implies that this deposited material is mostly sand. This indicates a redistributional effect within the reservoir with respect to sand, at least for this particular flow event. This implies a preferential trend toward the storage of coarser sediments over time. However, the increased availability of these sandy sediments in the lower reaches of the reservoir may also make them more likely to be available for transport out of the reservoir for large flow events in the future, so the trend could be more complex than it seems.

H. From STAC: "p. 28 Model validation involved a parametric model study where bed-property values were manipulated and results compared with USGS scour load prediction. Was any consideration given to whether properties might vary with depth or distance from the shoreline?"

LSRWA Response: Consideration was given for the variation of properties both spatially (based on the spatial distribution of the SEDFLUME samples) and at depth into the bed (based on variation of the SEDFLUME properties with depth into the cores, and also based on the observed trends toward a stiffer bed at depth into the bed).

I. From STAC: "p. 29 The choice of limiting depth available for scour to one foot seems like a reasonable one for a lower bound, given what was learned from coring and laboratory tests."

LSRWA Response: Only if it can be assumed that the limit of penetration implies the presence of a very stiff substrate. However, it is possible to have a layer that is difficult to penetrate with a push or gravity core, while still potentially erodible with higher shear stress (for example, sand rich substrate can exhibit this property).

J. From STAC: "p. 31 When fitting parameters to compute erosion rate – is it not possible to develop some scheme for projecting variation in relevant material properties either longitudinally or laterally? Given that a 2d model is being used and given the spatial patterns of texture and cohesion, this seems like an element that ought to be considered – or else reasons why it cannot be done should be articulated."

LSRWA Response: See response to I. There is variability in the applied properties, based on the SEDLFUME core distribution. The critical shear was indeed adjusted (essentially calibrated) in a more general sense, but the other erosion properties were assigned the distribution of values dictated by the SEDFLUME cores. Figure 10 on page 20 shows how the distribution of cores was applied at Zones in the model.

K. From STAC: "p. 33 The authors argue that the uncertainty associated with applications of AdH is made manageable by basing conclusions largely on simulations of management scenarios in which only one variable is changed. This amounts to saying, in effect, 'the model worked OK for a hind cast, even though we had to use boundary conditions that were outside of the measured range or unknown, and we have not documented that the internal workings of the model are making reasonable predictions. So, if we only change one part of the model we can hope that it will reliably calculate the change in system performance.' However, one application of the AdH model was to evaluate scour and deposition relative to different reservoir bathymetry. These applications are not of the change-one-thing-only management scenario type and instead directly depend on the fidelity of the selected model."

LSRWA Response: Although the model is only validated to integral quantities, they are 3 separate integral quantities. The models general agreement with all of these quantities demonstrates that, at least in a bulk sense, the model is behaving as the real reservoir does, and for similar reasons. So the model results can be relied upon to make these same types of integral predictions as long as the forcing conditions that the model is subjected to are not extended far outside of the existing conditions (and they are not in this exercise).

L. From STAC: "p. 33 In discussing role of alternative bathymetry – do these alternatives assume spatially invariant bed material properties?"

LSRWA Response: No. They assume the same property distribution that was used in the model validation, which in turn is based on the SEDFLUME core data (see response to J).

M. From STAC: "p. 37 Do these flow fields try to account for the change in flow distribution at the outlet when the gates are opened during high flows? It is pointed out elsewhere that dam operations should be incorporated in the model for future studies – this would seem to imply that this is not the case here."

LSRWA Response: No. the dam operations are not included. Hence, the influence of dam operations on the distribution and storage conditions of sediments in the lowermost reaches of the reservoir (especially sandy sediments) must be considered an additional source of uncertainty in the results.

N. From STAC: "p. 44 The 2008 to 2011 period was somewhat atypical in terms of the frequency of days above the 400,000 cfs scour threshold. If we look at the frequency of days over 400,000 cfs during the 4-year simulation period it comes out to an average of 1 day per year above the threshold. If we look at the entire period from 1977 through 2012 the frequency of days above the threshold is about 0.5 days per year. Thus, the choice of 2008-2011 as the simulation period will overstate the importance of scour increases as compared to a simulation period that was more typical."

LSRWA Response: Possibly. However, a more conclusive way to estimate this might be to integrate the inflow hydrograph against the net scour curve for the entire period of record, annualize the result, and compare this to same annualized quantity for the 2008-2011 hydrograph. This was not done for this study, however, as the focus of the study was just to establish the sensitivity of a given inflowing hydrograph and sediment load to changes in reservoir bathymetry.

O. From STAC: "p. 60 In discussion of limitations posed owing to need for a more sophisticated approach to simulating flocculation – is there any way to estimate how much difference this might make to overall conclusions?" "In the same paragraph it is suggested that field methods are needed for sampling storm concentrations or turbidity over the entire storm hydrograph. Presumably standard methods can be used for the samples for either concentration or turbidity without having a human operator have to stick a bottle in the flow (as apparently was the case for the single sample taken near the peak during Agnes). Is the issue one of how to deploy sensors or automated samplers in the vicinity of the various gates built to accommodate high flow?"

LSRWA Response: Some investigation of the influence of flocculation was made by simply investigating different settling velocity values. However, the implementation of a robust flocculation model would allow for less parameterization of the model, which improves its predictive reliability. There are methods available for collecting data during high discharge conditions, so this could be done if the investment were made.

P. From STAC: "Appendix B-1, Figure 3: One must be careful of drawing straight lines in log-log space that depict a transport curve. At some point, the relation must tail to the right, given that sediment concentrations have absolute limits."

LSRWA Response: This is true, although these limits are above the well above the concentrations given here.

Q. From STAC: "Appendix B-1, Section 5-1: The total annual estimated sediment yield delivered to downstream reservoirs is cited here as 4.2 million tons; but there are multiple other estimates in these documents, mostly less than this value – there needs to be more consistency among these cited values, or else an explanation as to why they are different."

LSRWA Response: I think the confusion might lie in the fact that this section is discussing an estimate of the sediment load into the uppermost of the 3 reservoirs (i.e. the discharge from the river into the reservoir system) whereas in other places in the report the sediment load being discussed is either sediment load from the upper two reservoirs into Conowingo, or the sediment load from the Conowingo into the Bay.

R. From STAC: "Attachment B-1: "Evaluation of Uncertainties in Conowingo Reservoir Sediment Transport Modeling" -- This section is misnamed. The section provides a useful discussion of different elements of flow and transport through reservoirs. Its basic purpose is to justify the use of a depth-averaged 2d model (AdH) rather than a fully 3d model for the simulation. Their conclusion that a 2d model is sufficient is reasonable (assuming proper calibration/validation). Alas, although uncertainties play a small role in the discussion (basically relating to uncertainties that might arise from reducing 3d flow field to 2d), the section provides no discussion of overall "Uncertainties in Conowingo Reservoir Sediment Transport Modeling." This is unfortunate, because those uncertainties are large and largely unexplored in the study."

LSRWA Response: General uncertainty is discussed throughout the report. Uncertainty is not formally quantified in the report, partly because the paucity of available data might render any such formal quantification deceptively meaningful. That is, without sufficient data, even the attempt to quantify uncertainty is, well, uncertain. This section discusses, among other things, the limitations of using a Quasi 3d model (where sediment stratification effects are represented in a semi-analytic sense) rather than a fully 3D model. Hence, it is a useful supplementary document that goes into some detail about the general processes that govern reservoir sedimentation, and how the modeling framework selected influences the results of the modeling.

S. <u>From STAC</u>: "Appendix B-1, Section 9: This section presents an AdH model of flow and transport on Susquehanna Flats. No discussion is given of any calibration or testing of the model in this environment, and one must presume that it is uncalibrated and untested. The roughness assigned to the flats with SAV and without SAV (winter) is sufficiently large that the majority of the flow and sediment transport occurs through the dredged channel. This is a reasonable result. The authors then reach a conclusion that is unsupported by the model and quite possibly incorrect: "the relatively higher bed roughness of the shallow flats will tend to continue to route the majority of the flow through the dredged navigation channel below Havre de Grace. Thus, discharge of sediment from Conowingo Dam due to bypassing or flushing operations will have minimal impact on the flats area, with sedimentation occurring in the dredged navigation channel or below the flats area." Just because most of the water and sediment go through the channel does not mean there will be no impact to the flats. If flow extends on to the flats, the authors have not demonstrated in any way that sediment carried in that flow will not deposit on the flats. In fact, this is how floodplains are formed. If turbid water is being discharged from the dam, one can deposit sediment wherever the water goes. Estimates can be made from the sediment concentration and residence time of water over the flats."

LSRWA Response: We agree in principle. The fact that flow is diverted to the main channel does not mean that deposition of fines will not take place in the SAV areas. The model does not show much deposition there, and deposition is being modeled there, but, as the reviewer points out, the model was not validated, So this effort may require some more work and further consideration, or at least further examination of the existing model results.

T. From STAC: "Appendix B-2, Summary and Conclusions. This section is misnamed and should be changed to only "Summary". There are no conclusions stated here."

LSRWA Response: Concur.

U. From STAC: "Appendix B-4 includes the following on its first page: "…sediment in transport in suspension is directly related to sediment particle size and the degree of turbulence." Density could also be a factor, particularly if it is true that some 10% of reservoir sediments are coal particles."

LSRWA Response: Concur.

Appendix C and D

A. From STAC: "One significant area could use a bit more attention. The period of the CBEMP model simulations is different from the period of the HEC-RAS/ADH scour simulations. The watershed loading scenarios are not the actual scenarios observed during the CBEMP simulation period, but rather projections based on expectations for watershed management practices under two different conditions (2010 implementation and TMDL achieved). The major storm simulation presented uses sediment-associated nutrient concentrations from a different storm entirely, not the simulated storm. As a result of all of these juxtapositions and substitutions, it is unclear exactly what is being simulated and why – the runs do not ever appear to be representative of actual conditions. While the final scenarios make sense and are very revealing, the reasoning behind their construction is hard to follow. A summary of the PHILOSOPHY of scenario construction, not just its mechanics, would help. This description should occur right after the introduction of the modeling tools used, and it should be addressed to an audience that is not familiar with standard practice in the CBP."

LSRWA response: The following language was inserted in Appendix C at the head of Chapter 3 Scenario Procedure and Listing Overview.

> *"The LSRWA makes use of existing tools and methodologies as well as new tools and applications developed specifically for this study. The use of existing models and practices is advantageous to the study since these tools could not be developed within the time and budget limitations of the LSRWA. The individual models within Chesapeake Bay Environmental Model Package (Watershed*

Model, Hydrodynamic Model, and Water Quality Model) are documented, have been extensively reviewed, and have lengthy application histories. The use of these existing tools provides some disadvantages and constraints, however, notably in the period emphasized in their application.

The AdH model, which computed sediment fate and transport in the Conowingo Reservoir, was a new application created especially for this study. AdH was applied over the period 2008 – 2011, in order to take advantage of recent data collected in the reservoir. The application included the Tropical Storm Lee event, which resulted in notable scour and provided an excellent opportunity for model calibration and validation. This period was not represented in the CBEMP, however, for which the primary application period was 1991 – 2000. The resources necessary to acquire raw observations, create model input decks, execute and validate the individual models within the CBEMP for the years 2008 – 2011 was beyond the scope of the LSRWA. Consequently, means were required to transfer information from the 2008 – 2011 AdH application to the 1991 – 2000 CBEMP. The crucial transfer involved combining scour computed by AdH for TS Lee with watershed loads computed by the WSM model for a January 1996 flood and scour event represented by the CBEMP.

The WSM provides computations of volumetric flow and associated sediment and nutrient loads throughout the watershed and at the entry points to Chesapeake Bay. Flow computations are based on precipitation, evapotranspiration, snow melt, and other processes. Loads are the result of land use, management practices, point-source waste loads and additional factors. The loads computed for 1991 – 2000 are no longer current and are not the loads utilized in the TMDL computation. To emphasize current conditions, a synthetic set of loads was created from the WSM based on 1991 – 2000 flows but 2010 land use and management practices. The set of loads is designated the "2010 Progress Run." The TMDL loads are a second set of synthetic loads created with the WSM. In this case, the 1991 – 2000 flows are paired with land uses and management practices sufficient to meet the TMDL limitations.

The AdH model provides computations of sediment load due to bottom scour, but not the load of associated nutrients. Limited observations of sediment-associated nutrients are available at the Conowingo outfall during the 1996 flood event. The composition of solids eroded from the bottom are difficult to glean from these observations, however, since samples at the outfall represent the mixture of solids washed down from the watershed and eroded from the bottom and as with the watershed loads, these observations may no longer represent current conditions. Consequently, the nutrients associated with scoured solids for use in scenarios was derived from observations of nutrients in the bottom sediments of Conowingo Reservoir.

Major storm events occur at different times of the year. In order to examine the effect of seasonality of storm loads on Chesapeake Bay, the January 1996 storm *was moved, within the model framework, to June and to October. The loads were moved directly from January to the other months. No adjustment was made for the potential effects of seasonal alterations in land uses. New Chesapeake Bay hydrodynamic model runs were completed based on the revised flows, to account for alterations in flow regime and stratification within the Bay.*"

B. From STAC: "Interestingly, the long-term impacts of the October Storm on DO seem less than the January storm (-0.25 in Jan from 1997-1999, -0.1 in October from 1997-1999, Figure 6-31). Why would this be? Is more of the January load processed that summer and cycled through the system, while much of the October load is buried over winter? This seems like a point worth investigating."

LSRWA Response: Good points for additional clarification. The text of Appendix D will be expanded to clarify these points as suggested: "The water quality effects in the October and January periods are diminished because of colder temperatures and decreased primary productivity, resulting in less interception of nutrient loads by algae. In the fall and winter a greater portion of the storm- pulsed nutrient load is transported down the Bay to be discharged at the ocean boundary or is lost though denitrification or deep burial in sediments. The long-term impacts of the October Storm on DO were estimated to be less than the January storm (see Figure 6-31 of Appendix C). This is because the simulated January storm load of particulate nutrients scoured from the Conowingo Reservoir was processed during that summer and cycled through the system, while much of the simulated October 1996 storm load was buried or discharged out of the Chesapeake Bay over the simulated 1996-97 winter before the particulate nutrient load was ultimately expressed as a depression of DO in the simulated 1997 summer."

Appendix E

A. From STAC: "…indicates that bathymetric data were acquired in Susquehanna Flats. They were not…"

LSRWA Response: The Appendix language has been revised to state that only sediment grain size data were acquired (vs. bathymetry).

Appendix H

A. From STAC: "A technique known as hydro-suction dredging is mentioned several times in the Appendix but not mentioned explicitly in the report. This technique would be especially useful for sediment bypassing, because it makes use of the huge natural head difference between the reservoir and the river below the dam to maintain flow through a dredging pipe or bypass tunnel. Was this technique considered in figuring the relatively low cost of bypassing, or not? Would it make a difference?"

LSRWA Response: By-passing could be done by various dredging techniques. The LSRWA team used past costs from actual projects of more traditional hydraulic dredging which were presented in the report. Costs for the specific Hydrosuction dredging technique could be investigated in the future but were not in the scope of this effort.

Appendix J

A. From STAC: “The economic analysis uses a different interest rate (or discount rate) for the watershed BMP versus dredging scenarios. Specifically, p. 14 in Appendix J says “estimates of annualized costs reflect a 5% discount rate” for the watershed BMP scenario. However, p. 167 in Section 6 says that “annualized one-time investment costs are based on a 50-year project life and the fiscal year 2014 federal interest rate of 3.5 percent” for the dredging scenarios. Appendix J-2 shows the detailed calculations for dredging scenarios based on the 3.5% interest rate. Proper economic analysis should use the same interest rate to compare across the scenarios.”

LSRWA response: This is an artifact of cost development. The LSRWA team depended heavily on the Chesapeake Bay TMDL work done by the jurisdiction watershed partners in development of their Watershed Implementation Plans (WIP) to develop these watershed management strategies. LSRWA effort utilized costs developed (and processes used to develop these) through Chesapeake Bay TMDL and WIP development processes that were already available for BMP costs. As described in Section 5.2, “the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken.” Dredging/by-passing alternatives (i.e. increasing or recovering storage volume) were developed by LSRWA team using the 3.5% rate, which was the federal interest rate when costs were developed in the Federal Fiscal Year 2014. Language has been added to the main report to clarify this difference. The costs and the BMPs for the E3 scenario were developed years before the Lower Susquehanna River Assessment Project was initiated. At this point in time it would not be feasible for the Bay Program to re-calculate the costs of the E3 BMPs for a project other than the one for which they were originally intended.

B. From STAC: “Attachments 2 and 3 on pp. 12-13 in Appendix J show the costs by practice across the three states. However, the current information does not make it possible to assess the variation in cost-effectiveness of the various urban and agricultural BMPs in meaningful terms, such as the dollars per cubic yard of sediment removal. Importantly, the cost-effectiveness between practice types typically varies by one or two orders of magnitude. Hence, the current analysis aggregates all practices types and reports an overall cost estimate at $3.5 billion in Table 3 (or Table 6-3). Then the report provides an overall average cost effectiveness of $256-$597 per cubic yard in Table 6-6, and seems to imply that this watershed BMP approach is supposedly the most expensive. But this assessment that aggregates all practice types may overlook the high degree of heterogeneity in costs between practice types.” “…At a minimum, the watershed BMP scenario should provide separate scenarios for the agricultural versus urban BMPs. Compare, for example, the costs for agricultural BMPs in Attachment 2 versus urban BMPs in Attachment 3. This shows that urban represents about 90% of the total costs compared to about 10% for agricultural BMPs. But it is unlikely that urban represents 90% of the sediment load. In fact, there are two urban BMPs (urban infiltration BMPs and filtering BMPs) that represent over $2.5 billion, which is two-thirds of the total costs. The unit costs on these two urban BMPs are much higher than other BMPs, but the analysis is aggregated into a single number for cost-effectiveness of this alternative scenario.

LSRWA response: Unfortunately, the per-unit reductions in delivered sediment for the E3 scenario were not available for the E3 scenario. It should be noted that the per-unit reductions *of each BMP are a function of the number of units implemented, the location of implementation, the programmed efficiencies or land use changes associated with each BMP and the interactions of all the BMPs in a given scenario. If it is important to have the per-unit reductions for the E3 scenario, funding should be provided to the Bay Program for staff time and model runs to develop them. Although this would provide useful information, it is a very complicated request that would be time consuming and costly to address. In order to address this properly the Chesapeake Bay Program partners would need to perform a series of model runs to implement each BMP separately and to the extent outlined in the E3 scenario then assess the sediment reduction and the available BMP units remaining following that model run. This process would have to be repeated again for each BMP until all the BMPs are implemented on all available land, because once a BMP is implemented on a given land use it is no longer available for another BMP. Therefore, the LSRWA team cannot accommodate this request due to the time and resources necessary to run the Chesapeake Bay watershed model for all potential BMP scenarios.*

C. From STAC: Attachments 2 and 3 would be more informative if it included additional columns that provided both the cost-effectiveness in $/cubic yard (or $/ton of sediment) and the total amount of cubic yards (or tons of sediment) for each practice type. The former would provide the ranking in cost-effectiveness by practice type, and the latter would reveal how important this practice is for the overall load reduction. This would allow for a better assessment of the most effective suite of practice types, while not including those practices that are most inefficient. Alternative watershed scenarios could then be designed that look at the option of 100% of the E3 scenario (current analysis) versus another scenario that only adopts 50% of the sediment reduction for the E3 scenario using the most efficient suite of practices. The most effective 50% will be competitive with the dredging scenarios given the extreme heterogeneity in unit costs for ag BMPs in Exhibit 1 on p. 15 and urban BMPs in Exhibit 6 on p. 35 (varies from $0 per acre for conservation tillage to $2,351 per acre for the urban filtering BMP). There is even extreme variation in unit costs within agriculture BMPs that ranges over several orders of magnitude. This further confirms the need to provide disaggregated analysis on the cost effectiveness in $/cubic yard by practice type.

LSRWA response: As stated above, the information needed to address this comment is not currently available. If a "disaggregated analysis on the cost effectiveness" by practice type is needed, funding would have to be provided to the Bay Program for staff time and model runs.

D. From STAC: "There are numerous citations provided in Attachment 4 of the Appendix J on pp. 14-44. But there is no corresponding "References" section to provide the detailed info on these citations."

LSRWA response: References provided.

E. From STAC: "Attachment 4 of Appendix J on pp. 29-33 includes detailed information on "Septic Systems." However, septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. This needs to be clarified. Future analysis should include septic systems particularly if the analysis is expanded to nutrient management options (not solely sediment strategies) because septic systems are an important nutrient load in rural Pennsylvania. “

LSRWA response: Concur that septic systems should be included in future analyses if nutrient management options are expanded. Appendix 4 is simply providing background information on U.S. Environmental Protection Agency Approved Best Management Practices which includes septic systems though they were not analyzed under this assessment other than documenting that these are approved and a possible BMP to be investigated in the future.

Other recommended edits/specific concerns for main report, by page number:

1. From STAC: “ES-2 In multiple places in the main report (ES-2, p. 10, p. 110, p. 141), there is a statement regarding dynamic equilibrium that says, “This state is a periodic cycle.” This statement is very misleading, there is nothing periodic or cyclic about it. The driving event (high flow events of about an annual exceedance probability of 0.2 – a “5-year flood”) is a random event and is not periodic. They may happen in rapid succession or there may be many years between them. All mentions of the equilibrium state being “periodic” should be removed.”

LSRWA Response: No report language altered: The LSRWA Team deliberated for quite some time on how to depict/describe this important concept of dynamic equilibrium to a non-technical audience. Though the storm event may happen in rapid succession or over many years (the average is every 4-5 years which is reported), the process when a storm does occur, still stands, during a storm of this magnitude there is scouring causing mass erosion. Post storm and during lower flows there is trapping and filling, i.e. a cycle that occurs on a periodic basis (on average every 4-5 years).

2. From STAC: “ES-3 2nd paragraph: the text beginning with “Modeling done for this….” is confusing. It states that under current conditions, half of the deep-channel habitat is unsuitable. This is then compared to the 2025 conditions with full WIP implementation and increased scour that suggests that attainment in 3 of the 92 segments will not be achieved due to extra loads of nutrients. It is implied that full WIP implementation should lead to completely healthy deep-water habitat, but a new reader would not necessarily catch this. Perhaps a more straightforward way to write this is to state something like “currently half of the deep-channel habitat is unsuitable for life (non-attainment), and given full WIP implementation in 2025 (which should yield 100% attainment), deep-channel habitat in 3 of the 92 Bay segments (X % of deep channel habitat) will remain as unsuitable habitat due to elevated nutrient loads from dam scour”.

LSRWA Response: Language altered to be clearer: “Modeling done for this assessment estimated that currently more than half of the deep-channel habitat in the Bay is frequently not suitable for healthy aquatic life. However, it was estimated that with full implementation of the WIPs by 2025 (which should yield 100% suitable habitat for aquatic life), DO levels required to protect aquatic life in the Bay’s deeper northern waters will not be achieved (in 3 of the 92 Bay segments) due to loads of extra nutrients associated with increased frequency and the amount of scoured sediments.”

3. From STAC: “ES-3 4th paragraph: The last sentence (starting “Given…”) is a run-on sentence.”

LSRWA Response: Sentence fixed: "The primary impact to the Bay from the Susquehanna River watershed and the high river flows moving through the series of reservoirs is dissolved oxygen and impaired water clarity from algal growth. It is the nutrients associated with the sediments that are the most detrimental factor from scoured loads to healthy Bay habitats versus sediment alone."

4. From STAC: "p. 6 "The Susquehanna River is the nation's 16th largest river, and the source of the freshest water …" What is meant by freshest water? Typo?"

LSRWA Response: Sentence fixed:"and the largest source of fresh water."

5. From STAC: p. 8 "All reservoirs act as a sink….." A sink of what? Sediment? Perhaps it is obvious, but it is helpful to state clearly."

LSRWA Response: "sediment" added in front of "sink.'

6. From STAC: "p. 8 "Due to flow deceleration as the water enters the reservoir, sediment transport capacity decreases, and the coarser fractions of the incoming sediment deposited in the reservoir form a delta near the entrance to the reservoir." Awkward sentence – tenses."

LSRWA Response: Sentence fixed: "Due to flow deceleration as water enters the reservoir, sediment transport capacity decreases, and coarser fractions of the incoming sediment deposits in the reservoir forming a delta near the entrance to the reservoir."

7. From STAC: "p. 8 Last sentence of 5th paragraph: It is worth adding to the last sentence that nutrient-laden sediments are more harmful because they can be utilized to fuel additional algal growth in the tidal waters of the Bay."

LSRWA Response: Suggested language added.

8. From STAC: "p. 9 Last complete paragraph: if the Susquehanna load is 3.1 million tons and 1.2 million tons is released then 59.4% is trapped, not 55%."

LSRWA Response: Percentage fixed. On average the rate is 55-60% if the hydrologic record is evaluated over the last 30 years.

9. From STAC: "pp. 15-16 The flow charts in Figures 1.5 and 1.6 are repetitive but slightly inconsistent. Figure 1.6 makes more sense and may be sufficient."

LSRWA Response: No change. 1-5 and 1-6 are similar but have slightly different purposes. Both are conceptual graphics summarizing the overall (1) modeling components (2) analytical approach of the study for a non-technical audience.

10. From STAC: "p. 16 In notes under Figure 1-6, should "partners of this LSRWA effort" be changed to "partners outside of this LSRWA effort"?

LSRWA Response: Language changed as suggested above.

11. From STAC: “p. 24 3rd paragraph: Would be clearer or more mechanistic to say “…than about 0.3 knots because water movement tends to be slowed by frictional forces in shallow water…”

LSRWA Response: Language changed as suggested above.

12. From STAC: “p. 26 “Snow events” do not cause floods. SnowMELT may.”

LSRWA Response: Language changed to snow melt as suggested above.

13. From STAC: “p. 28 Define saprolite or show in Figure 2-5.”

LSRWA Response: Definition added. “The rock in much of the Piedmont is deeply buried below the surface by crumbling rock that has weathered in place known of as saprolite. Saprolite in the Piedmont can be tens of feet thick. Hard rock in the Piedmont is naturally exposed in landscape settings where the saprolite weathers away, such as along stream valleys and on steep hilltops. Human activities have greatly increased exposures of Piedmont rocks at locations such as roadcuts and quarries.

14. From STAC: “p. 32 “Phosphorus binds to ~~river~~ fine sediments and is delivered to the Bay with sediment.”

LSRWA Response: Language changed as suggested above.

15. From STAC: “p. 32 (1) 2nd sentence: “Ammonia” should be “Ammonium”. (2) 2nd sentence: It is worth noting that although ammonium tends to be less abundant than nitrate in surface waters, it is by far the dominant dissolved N form in deeper waters during warm months. (3) True, nitrite generally contributes little to TN, but nitrite can accumulate to significant concentrations during some times and places, including the region of the pycnocline during mid-summer and after hypoxia/anoxia breakdown in fall. Perhaps adding a line to the sentence to say “….and contributes little to TN for most times and places”. (4) It is worth adding that organic nitrogen comes in both particulate and dissolved forms.”

LSRWA Response: Language revised: *“Total nitrogen (TN) includes nitrate, nitrite, ammonia, and organic nitrogen. As typically measured in labs and for the purposes of this section, ammonia also includes ammonium. Nitrate is the primary form of nitrogen in dissolved form in surface waters. Ammonia is a dissolved form of nitrogen that occurs in surface waters less commonly than nitrate. However, ammonia is the dominant dissolved nitrogen form in deeper waters during warm months. Nitrite is generally unstable in surface water and contributes little to TN for most times and places. Organic nitrogen (mostly from plant material, but also including organic contaminants) occurs in both particulate and dissolved forms, and can constitute a substantial portion of the TN in surface waters. However, it is typically of limited bioavailability, and often of minimal importance with regard to water quality. Conversely, nitrate and ammonia are biologically available and their concentration is very important for water quality (USGS, 1999; Friedrichs et al, 2014).”*

16. <u>From STAC:</u> "p. 34 A factual problem is the statement that indicates that TN, TP, and SS loads from Conowingo have been increasing since the mid-1990's. This is certainly true for TP and SS but for TN the trends have continued to be downward (Hirsch, 2012 reports a decrease of about 3 percent)."

LSRWA Response: Language revised to more accurately summarize what cited references state: "Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of TN, TP, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s. With corrections to account for year-to-year variation in river flows, over the 20-year period from 1990 to 2010, TN and sediment loads delivered to the Bay from the Susquehanna River showed statistically significant declines of 26 percent and 17 percent, respectively. TP loads declined by 7% over this time period, but the trend was not statistically significant (Langland et al., 2012). Environmental management measures in the watershed contributed to this decrease. However, one study has indicated that loads of particulate nitrogen, particulate phosphorus, and suspended sediment from the reservoir system to the Chesapeake Bay are increasing, and attributes this to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)."

17. <u>From STAC:</u> "p. 36 Should define hypoxia in Figure 2-10 (<2.0 mg/L)."

LSRWA Response: Footnote added to figure.

18. <u>From STAC:</u> "p. 37 Section 2.5.2, 2nd sentence – statement is misleading and should be deleted unless qualified by explaining that because of different designated uses and water quality criteria it is not surprising there is a difference in violations. As is, statement is comparing apples and oranges."

LSRWA Response: Statement deleted.

19. <u>From STAC:</u> "p. 45 Figure 2-14 is not clear as to whether or not the metrics are total over a decade or per year."

LSRWA Response: A footnote was added: These amounts are representing annual averages during a particular decade.

20. <u>From STAC:</u> "p. 46 Many species of plankton are capable of motility. Change "and are passively carried" to "and are, by in large, passively carried".

LSRWA Response: Language changed as suggested above.

21. <u>From STAC:</u> "p. 69 Chapter 3 mentions 3 Chesapeake Bay agreements, which may have been true when this section was written. However, doesn't the Watershed Agreement sign in June 2014 count as the 4th Chesapeake Bay agreement?"

LSRWA Response: Correct. Language revised "…. three additional agreements have been adopted since that time."

22. <u>From STAC:</u> "p. 72 2nd to last paragraph: The word "special" should be "spatial".

LSRWA Response: Language changed as suggested above.

23. <u>From STAC:</u> "p. 81 "The HEC-RAS model may not be suitable for ….. , active scour and deposition, and particle size." What does this mean with respect to "particle size"? That the model cannot represent particle size well? Explain so meaning is clear."

LSRWA Response: First sentence of this paragraph discusses this: HEC-RAS is designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). The model actually did well predicting major particle size. This sentence revised to say: "The HEC-RAS model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediments) and active scour and deposition."

24. <u>From STAC:</u> "p. 81 3rd paragraph: Were the boundary conditions generated for the HEC-RAS simulation also used to drive the AdH model? Or was model output from HEC-RAS simulation for the upper two reservoirs used to create the boundary conditions for AdH? Please clarify."

LSRWA Response: All simulations were conducted with the same Susquehanna River flow and inflowing sediment boundary conditions. The 4-year flow period from 2008 to 2011 was simulated in the AdH model. The flow and sediment entering the upstream model boundary (channel below the dam on Lake Aldred) were provided by the USGS from HEC-RAS model simulations of the 4-year flow record. These simulations included all three reservoirs, thus the sediment output from HEC-RAS included bed sediment scour from the upper two reservoirs. The sediment rating curve in the HEC-RAS simulations was developed by the USGS from suspended sediment measurements in the Susquehanna River above the reservoir system. The HEC-RAS outputs (boundary) conditions for flow, sediment load and particle sizes were given to AdH for ERDC use. Ultimately for AdH, ERDC created their own boundary conditions for Conowingo; however HEC-RAS input was a good starting point. The HEC RAS simulations for the upper two reservoirs were used to drive AdH, although the sediment discharge was increased over what HEC-RAS reported, in order to err on the side of higher sediment discharge.

25. <u>From STAC:</u> "pp. 81-83 The models are stated to be "well developed, widely accepted, and peer reviewed. Yet there are virtually no references in Sections 4.1 or 4.2. References are needed here to demonstrate that HEC-RAS and AdH are indeed peer-reviewed models."

LSRWA Response: Language revised to state: "The models were selected because they were well developed, widely accepted, and have had wide use and application." Do not agree that the main report is the place to discuss these models's use in other applications. The models (AdH and HEC-RAS) are built from theory based on scientific and research. They have had millions of dollars invested in them and have been applied by many studies around the country and world. The use of the latter two models has resulted in the successful construction and operation of hundreds of water resource management structures and systems.

A few examples for HEC-RAS use-
The HEC-RAS model data has been used for the Sacramento River Flood Project (CA); Comprehensive Study of Sacramento and San Joaquin River Basin (CA); White Oak Bayou Federal Flood Damage Reduction Project(TX); Mobile Bed Modeling of the Cowlitz River (WA); Flood Plain Modeling in the Kansas River Basin (KS); Flood Cyclone JFY 2010 Mini-Project Indonesia; and Flood Hazard Mapping in the Nan River Basin, Nan Province, Thailand.

HEC-RAS model data use outside of the U.S. Army Corps Engineers (USACE) includes the following:
Endensco, Inc. used HEC-2/HEC-RAS for hydraulic and hydrologic analysis of Route 1 Neabsco Creek in Prince William County, Virginia. The data was peer reviewed by the Virginia Department of Transportation.

NMP Engineering Incorporated performed a hydraulic study of Terrapin Branch. HEC-RAS was used for three design alternatives for the proposed bridge. The data was peer reviewed by the Maryland State Highway Administration.

WBCM was the lead design consultant for Corman Construction who designed and constructed the Hampstead Bypass Project using HEC-RAS to size bridge openings. The data was peer reviewed by the Maryland State Highway Administration.

For AdH:
The AdH model data has been used to construct the Moose Creek Floodway on the Chena River, a joint effort by the Coastal and Hydraulics Lab at the Engineering and Research Development Center and Alaska District Corps of Engineers; and the Jacksonville Harbor (FL) Navigation Project.

Regarding peer review for any USACE study involving construction of large water resource projects (such as those listed above), the models undergo review by the (1) USACE District conducting the study/modeling, (2) another USACE District (3) an independent (non-USACE) panel of reviewers that are designated experts from private companies and academia (4) any local, state, federal, or non-governmental organization requesting to be a cooperating agency on a study (5) general public and (6) USACE headquarters and division offices.

26. From STAC: “pp. 84-85 Figure 4-3 and 4-4: The mesh in all or part of these figures is almost impossible to see – provide insets at larger scale. Insets in the appendix show this more effectively.”

LSRWA Response: Figures 4-3 and 4-4 are copied exactly from Appendix B.

27. From STAC: “pp. 87-89 In Chapter 4, the description of the method for using the 2008-2011 HEC-RAS and ADH predicted scour in the CBEMP 1991-2000 model runs is confusing. It is simply stated that the reader should see Appendix C for the details. More description should be provided in the text of Chapter 4, at least a better overview of the approach and justification for this somewhat tricky (but justifiable) maneuver.”

LSRWA Response: Chapter 4 of Appendix C, Load Computation and Summary is largely devoted to explaining the derivation of scour loads. A paragraph was added at the end of Section 4.3.4 of main report: "Since the AdH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, a procedure was employed to adjust estimated loads of scour from AdH for use in the CBEMP. A procedure to apply ADH calculations to the 1996 storm was developed based on the volumetric flow in excess of the threshold for mass erosion (400,000 cfs). The year 2011 contained two erosion events, an un-named event in March and Tropical Storm Lee, in September. The excess volume for each event was computed by integrating flow over time for the period during which flow exceeded 400,000 cfs. The amount of sediment eroded during each event was taken as the difference between computed loads entering and leaving Conowingo Reservoir. Sediment loads leaving the reservoir in excess of loads entering were taken as evidence of net erosion from the Conowingo reservoir bottom. Net erosion for January 1996 was calculated by linear interpolation of the two 2011 events, using excess volume as the basis for the interpolation (See Appendix C for more detail)."

28. From STAC: "p. 89 "Since the ADH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, an algorithm was applied to adjust estimated loads from the ADH for use in the CBEMP (see Appendix C for details on this algorithm)." This algorithm is not obvious in Appendix C. Should briefly explain here and then explain better in Appendix C."

LSRWA Response: See Response above (#27).

29. From STAC: "p. 92 "documented in Chapter 3"(?) Is this a typo?"

LSRWA Response: Language changed to "discussed in Chapter 3"

30. From STAC: "pp. 97-100 Table 4.2 seems a bit out of context in Chapter 4, referring as it does almost entirely to material in Chapter 6. Although not a requirement, this table would make more sense in Chapter 6 where it is directly discussed."

LSRWA Response: Will leave as is. The idea was to introduce scenarios to reader here and provide results in Chapter 6.

31. From STAC: "p. 112 Are the values in Table 5-4 adjusted for variations in flow?"

LSRWA Response: These values are the total values associated with the 2008-2011 hydrograph: hence variations in flow are implicitly integrated into the analysis.

32. p. 113 In Table 5-5 change "Additional" to "Additional Calculated" and change "Transport" to "Scour-Induced Transport".

LSRWA Response: Will change to "Additional Calculated" but NOT change the Transport to "Scour Induced Transport". The increase could be due to a reduction in deposition.

33. From STAC: "p. 114 Figure 5-4 presents exact same data as Table 5-5. Eliminate."

LSRWA Response: Will leave. Figure provides a visual of curve.

34. <u>From STAC:</u> "p. 114 Bottom: annual influx of sediment to Conowingo is here described as 3.8 million tons/yr over the last 20 years with 2 million being trapped. Elsewhere in the document we see different numbers ranging between 3 million and 4.2 million tons. If there are different estimates arrived at in different ways this needs to be made clear."

LSRWA Response: Estimates always vary depending on total hydrologic years being evaluated. Will ensure that years of evaluation are included in each instance to make this clear. If averages were cited from a reference (for example Langland, 2009) in the LSRWA report those averages with appropriate hydrologic years evaluated are noted.

35. <u>From STAC:</u> "p. 115 Table 5-6 does not explain how the historical loads or more recent loads were calculated – it simply says that the results were calculated by USGS. More explanation is needed. Also indicate that Hurricane Agnes flows were excluded if they were indeed omitted."

LSRWA Response: This table is directly from Appendix A where further explanation is provided. Footnote revised to state that 1972 (year of Hurricane Agnes, not included) and (see Appendix A).

36. <u>From STAC:</u> "p. 131 The reasoning for using the particular combinations of predicted scour, nutrient loading, and water quality modeling to test for the effects of scour is unclear. The procedure was likely valid, but better explanation is needed."

LSRWA Response: The first paragraph under "Scour impacts" lays out the procedure in summary terms. Appendix C provides more detail on each scenario, what went into each scenario and why.

37. <u>From STAC:</u> "p. 135 paragraph 4: It would help if there was some discussion of why two upper Eastern Shore segments (CHSMH and EASMH) had non-attainment in Scenario 3. Does low-DO water advect into them from the mainstem or is nutrient availability enhanced by the breakdown of scoured solids that end up in these tributaries?"

LSRWA Response: Good point and discussion will be expanded to describe the region of contiguous Deep Water and Deep Channel waters in the segments of CH3MH, CB4MH, EASMH, and CHSMH. Language added to Appendix D: "The segments of CH3MH, CB4MH, EASMH, and CHSMH are in a region of contiguous Deep-Water and Deep- Channel waters. These CB segments have similar depths so that advection from gravitational circulation as well as tidal dispersion plays a role in the continuous area of hypoxia among these CB segments."

38. <u>From STAC:</u> "p. 138 Paragraph 2: Oysters are discussed here within a section that otherwise discussed the modeling and simulation activities. Is there a description of how model analysis was used in this report to determine flow and management effects on oysters? Whatever the case, it should be clearly stated where the oyster effects fit into this report and whether or not model simulations were used to understand effects on oysters."

LSRWA Response: No specific modeling simulations were run to quantify oyster impacts. However this resource is of high interest so this qualitative language was added. This paragraph was deleted from this section since the context here is specific LSRWA simulation results (i.e. quantified results). Section 2.7.4 discusses oysters and impacts from storm events summarizing a DNR report on effects from Tropical Storm Lee.

39. From STAC: "p. 138 "Nitrogen loads…exceed phosphorus loads…" Given that P concentrations tend to be an order of magnitude lower than those for N, the statement does not tell the reader much, and might unduly impress those lacking an understanding of nutrient concentrations and dynamics. "

LSRWA Response: A large body of work links Chesapeake Bay hypoxia to nitrogen loading (e.g. Hagy, J., W. Boynton, C. Keefe, and K. Wood. 2004. Hypoxia in Chesapeake Bay, 1950 – 2001: Long-term changes in relation to nutrient loading and river flow. Estuaries 27(4):634-658.; Murphy, R., W. Kemp, and W. Ball. 2011. Long-term trends in Chesapeake Bay seasonal hypoxia, stratification, and nutrient loading. Estuaries and Coasts 34:1293-1309.) Consequently, the notion that scoured nitrogen loads exceed scoured phosphorus loads is exceedingly important. This is not misleading at all. What is misleading is the continued emphasis on phosphorus loading, often to the exclusion of any consideration of nitrogen. However, as discussed in the LSRWA recommendations, an understanding of the relative bioavailability of this Nitrogen (versus total loads) warrants scrutiny to inform management decisions of the Bay.

40. From STAC: "p. 146 Sources of information here are based on "personal communication" with Kevin DeBell, Greg Busch, John Rhoderick, and Jeff Sweeney. It would be better to document and provide references for the original reports used for the BMP unit costs rather than only personal communication. Page 4 in Appendix J-1 similarly only provides personal communications."

LSRWA Response: As described in Section 5.2, "the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken." Citations are included where appropriate (e.g. U.S. Environmental Protection Agency (U.S. EPA). 2010) however personal communication by LSRWA team was required to ensure that LSRWA interpretations of Chesapeake Bay Program work on watershed BMP's/strategies were accurate.

41. From STAC: "p. 167 "This methodology was not applicable for the watershed management representative alternative since management strategies (e.g., BMPs) once implemented, continue to remove/reduce sediment." This statement is not true for many BMPs. For example, vegetative buffers self-destruct if they receive excessive sediment – same with most BMPs that trap sediment rather than reducing its generation. As a result of this incorrect assumption, one might question whether costs are one time."

LSRWA Response: This statement is generalizing here. Nuance added. Language revised to state: "This methodology was not applicable for the watershed management representative alternative since management strategies (e.g., BMPs) once implemented, continue to remove or *reduce sediment (although many BMPs will need to be cleaned out and maintained to continue to be effective)." The point here is order of magnitude. Cleaning out multiple BMPs after a storm is nowhere near what it would cost to annually dredge at the scale discussed.*

42. From STAC: "p. 175 3rd paragraph: The word "waters" on line 4 of this paragraph should be "water"."

LSRWA Response: Language changed as suggested above.

43. From STAC: "p. 180 "costs of bypassing (diminished DO, increased chlorophyll) are roughly 10 times greater than the benefits gained from reducing scour." Indicate exactly where these data are contained in the report. A similar statement also appears in the Executive Summary and on p. 181 and p. 197."

LSRWA response: This comes from Bay model simulations, Appendix C. Language added to main report.

44. From STAC: "p. 192 In the first summary statement below finding #2, the "upper Chesapeake Bay" ecosystem is highlighted to be the area impacted by the dam. "upper" is an ambiguous word in this case, as the simulations suggest that effects can be seen south of the Bay Bridge (e.g., Appendix C)."

LSRWA response: Report is generalizing here, which is appropriate for this Chapter since it is providing "big picture" findings. Actual attainment issues were seen in 3 of the upper Bay segments which is discussed in detail and depicted via figures in the main report and Appendix C and D. Report attempts to provide geographic coverage of Bay consistent with how Bay Program defines areas of Chesapeake Bay.

45. From STAC: "p. 193 Second paragraph, line 5: should "frequently not unsuitable" be "frequently unsuitable"?"

LSRWA Response: Language changed as suggested above.

46. From STAC: "p. 200 Reference to additional management activities that can provide long-term storage includes mention of floodplain restoration. If this refers to floodplain excavation, there is some concern about this appearing as a recommendation without much more study than has been conducted to date. If it refers to some other form of floodplain restoration some explanatory language would be helpful."

LSRWA Response: Will delete specific mention since floodplain restoration is just one example thus is not necessary in context here.

47. From STAC: "p. 201 The report does not make the case for use in adaptive management, as adaptive management is mentioned for the first time in this recommendation. Adaptive management is not mentioned anywhere but in this recommendation. Thus, the phrase should be deleted here."

LSRWA Response: Will leave as is. The section below makes a case for adaptive management in that long-term monitoring will confirm if management practices are actually effective (or not) thus allowing management to be altered in the future.