Scientific Peer Review of the Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek

By:

Paul Montagna, Ph.D.
Harte Research Institute for Gulf of Mexico Studies
Texas A&M University – Corpus Christi
6300 Ocean Drive
Corpus Christi, Texas 78412-5869

Joseph N. Boyer, Ph.D.
Southeast Environmental Research Center, OE-148
Florida International University
Miami, FL 33199

Ben Hodges, Ph.D.
Department of Civil, Architectural & Environmental Engineering
University of Texas at Austin
Austin, Texas 78712-0273

To:

Martin Kelly, Ph.D.
Executive Director
Southwest Florida Water Management District
2379 Broad St., Brooksville, FL 34604-6899

Date:

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EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) has completed a study to establish Minimum Flows and Levels (MFL) for the Lower Peace River and Shell Creek (LPRSC)[1]. The approach was to determine a flow regime that would protect ecology of the river system by analyzing data on historical flows, current flows, and biological responses to flows. The analyses produced salinity habitat zone limits where salinity models were used to determine the flow regimes necessary to protect the habitats. The ecologically relevant salinity criterion for Shell Creek was two (2) psu. The ecologically relevant salinity criterion for the Lower Peace River was two (2), five (5), and 15 psu. The recommended flow regime consisted of allowable percent flow reductions for three seasonal blocks to provide different minimum flows in spring, summer, and fall. A low-flow threshold was not recommended because no statistically significant relationship was found between salinity and biological criteria in either the Lower Peace River or Shell Creek.

The proposed MFL starts with a management goal to provide a "flow that results in no more than 15% reduction in the available habitat relative to the baseline flow condition." The methodology to meet this goal depends on linking assumptions, past practices, data analyses, and salinity models. The District starts with an assumption, that a 15% loss of habitat is acceptable as being protective. This assumption is not explored in the study, but it is based on previous practices. It is true that estuaries exist in a continuum from fresh water habitats to hypersaline habitats, and that alteration of flow levels simply shifts the state of the estuary. This fact implies that in order to determine the limit at which further withdrawals would be significantly harmful to the ecology of the area, the District must determine an acceptable loss of habitat with further withdrawals. Choosing 15% is that management decision. More importantly, the percent-of-flow reduction approach ensures that historical hydrology regimes will be maintained, but with some reduction in flow.

The data analyses and review of previous analyses appear reasonable, and from this the District has defined ecologically relevant salinity criteria to maintain integrity for fish, benthic invertebrates, and plants. The panel is not aware of any data that were excluded from analyses.

One important link in the assumptions is that flow effects are manifested by salinity, because of the dilution of salt water, and that salinity is the main factor affecting biological and ecological interactions. The District acknowledges that factors other than flow affect salinity, and the salinity model is employed to predict salinity under various flow regimens. Thus the critical linkage is: ecological responses > salinity criteria > modeled salinity-flow relationships > MFL recommendations. Error in any of these links will cause error in the end analysis and

[1] Southwest Florida Water Management District, Proposed Minimum Flows and Levels for the Lower Peace River and Shell Creek, Peer Review Draft, August 24, 2007.

recommendations. There are two weak links (i.e., sources of error): the variability of ecological responses to salinity, and the model of salinity-flow relationships. Whereas the salinity model predicts the cyclic nature of salinity patterns well, there is often a large gap between predicted and observed salinities. An improvement would be to perform error analyses so that uncertainty can be explored. Uncertainties of estimates that are products of other estimates can be very large, so the error analysis should explicitly derive the linked uncertainties.

Overall, the District is to be commended for preparing an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. The supporting data and information used to develop the proposed MFL is technically sound. The data collection methods were appropriate, and used in an appropriate manner in all analyses. The District is also to be commended for voluntarily seeking peer review of its technical documents.

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INTRODUCTION

The Southwest Florida Water Management District (SWFWMD) under Florida statutes provides for peer review of methodologies and studies that address the management of water resources within the jurisdiction of the District. The SWFWMD has been directed to establish minimum flows and levels (MFLs) for priority water bodies within its boundaries. This directive is by virtue of SWFWMD's obligation to permit consumptive use of water and a legislative mandate to protect water resources from significant harm. According to the Water Resources Act of 1972, a minimum flow is defined as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area" (Section 373.042 F.S.). A minimum level is defined as "the level of groundwater in an aquifer and the level of surface water at which further withdrawals would be significantly harmful to the water resources of the area." Statutes provide that MFLs shall be calculated using the best available information.

Establishment of minimum flows and levels generally is designed to define thresholds at which further withdrawals would produce significant harm to existing water resources and ecological conditions if these thresholds were exceeded in the future. This review follows the organization of the Charge to the Peer Review Panel and the structure of the Draft Report (SWFWMD 2007). It is the job of the Peer Review Panel (Panel) to assess the strengths and weaknesses of the overall approach, its conclusions, and recommendations. This review is provided to the District with our encouragement to continue and enhance the scientific basis that is firmly established for the decision-making process by the SWFWMD.

The scope of the review is to provide a written report that comments on the documents and other materials used to support the concepts and data presented in the Draft Report (SWFWMD 2007). The three members of the Panel (Montagna, Boyer, and Hodges) participated in a field reconnaissance of the LPRSC on Nov. 19, 2007 to view the aquatic habitats of this tidal river segment first hand. The scope also allows the panel to suggest additional data and/or approaches that might be incorporated into the process used for establishing minimum flows.

The process of analyzing minimum flows and levels for the LPRSC is built upon the analyses previously performed on the Upper Peace River (SWFWMD 2002) as peer reviewed by Gore et al. (2002) and the Middle Peace River (SWFWMD 2004) as peer reviewed by Shaw et al. (2005). The Panel also reviewed comments from the PRMRWSA HBMP Scientific Peer Review Panel to this proposed MFL as well as comments from the Charlotte Harbor National Estuary Program. Most useful was the District's clear, cogent, and consistent response to the varied comments of the PRMRWSA HBMP Scientific Peer Review Panel. Finally, the Panel had access to the Peace River Basin Resource Management Plan (FDEP 2007) and the Peace River Cumulative Impact Study (CIS) Final Report (PBS&J 2007) to further enrich their understanding of the regional ecosystem.

GENERAL COMMENTS

Overall, the District is to be commended for preparing an excellent report that summarizes a large quantity of data and analyses, produced from many studies, into a document that is coherent and relatively easy to read. This is no small task because of the legal, social, and economic constraints of recommending a resource use strategy on such a complex ecosystem. Many support the view that setting MFLs in rivers and estuaries is one of the most daunting tasks facing resource managers today. The District is also to be commended for voluntarily seeking peer review of its technical documents.

The supporting data and information used to develop the provisional MFL is technically sound. The data collection methods were appropriate, and used in an appropriate manner in all analyses. The panel was not tasked with conducting a detailed quality assurance audit although it appears from the report and supporting documents that, to the best of our knowledge, standard procedures and protocols were followed, and no indicators of concern were noted.

The panel is not aware of any data that were excluded from analyses. It is clearly evident that the data used for the development of the MFL was the best information available. Technical assumptions are inherent in data collection and analysis. Throughout the report, the District makes reasonable attempts to describe these assumptions. The approach that is most laden with assumptions is the hydrodynamic and conservative mass (i.e., salinity) transport model. Here again the assumptions appear to be based on the best information available.

Overall, the procedures and analyses are technically appropriate and reasonable, and based on the best information available. Given the large amount of data, previous peer review, and extensive public comment, a wide range of factors were incorporated into the District's analysis and are correctly applied.

The District has obviously paid close attention to the previous peer review of similar and/or related MFL determinations and learned from their recommendations. The most important point is that the District now has a clear management goal, which is widely supported among stakeholders in the community. The Management Goal, as stated in the MFL document, is: to provide a "flow that results in no more than 15% reduction in the available habitat relative to the baseline flow condition."

Overview of the logic behind the MFL

The MFL for the Lower Peace River (excluding Shell Creek) is built on a foundation of the following analyses:

1. The intersection between biogeographic zones and salinity zones is used to define biologically relevant salinity criteria and habitat assessment metrics.
2. A hydrodynamic model is used to predict the salinity regimes over the period 1996-1999 for a range of different flow reduction scenarios.
3. Cumulative Distribution Functions (CDF) for each scenario are used estimate the number of days that for which the Lower Peace River volume/area/shoreline length subject to

one of three different salinity conditions {< 2 ppt, <5 ppt, 8-16 ppt} during Block 1, 2 and 3 time periods, and with the further data subdivision into flows above (high flow) and below (low flow) the median flow.

4. The total area under the CDF curve for any flow reduction scenario is considered to represent the integrated time-space habitat for that salinity range.

5. The difference between the integrated time-space habitats (area under CDF) predicted by the hydrodynamic model under a reduced flow condition and the baseline (no reduction) condition is considered the habitat reduction associated with the flow reduction.

6. A 15% reduction in habitat is considered the maximum acceptable loss, so any flow rate that leads to less than a 15% loss (as predicted by the model) is acceptable.

For Shell Creek, the hydrodynamic model was replaced by a regression model using 1966-2004 data, but the analyses are otherwise the same

There are six questions that need to be answered for validation of the MFL:

1. Does the biological analyses support using salinity zones to define habitats?
2. Does the hydrodynamic model (or regression model) adequately predict the salinity regimes under a variety of flow rates for the purposes of the CDF analysis?
3. Are the divisions used (Blocks, low/high flow, salinity ranges) appropriate for the critical habitat?
4. Is the conflating of space and time in the CDF curve reasonable for habitat prediction?
5. Does the difference between the areas under the CDF curve reasonably predict the habitat loss expected?
6. Is a 15% measure of habitat loss appropriate and supported by the uncertainty of the method?

Overview of the peer review conclusions

Relative to the logic underlying the MFL (as enumerated above), we find that the overall procedures and scientific methods to be sound and using all available data. However, there are three principal deficiencies in the MFL:

1. The error in the hydrodynamic model predictions of salinities has not been adequately quantified, so the underlying physical foundations of the MFL are still open to question.
2. The relationship of the hydrodynamic model error to the error in the CDF curves has not been quantified.
3. There is no error analysis for the area of habitat lost. This error could be substantial because it is a compound function of biological-salinity relationship error, salinity-flow relationship error, and hydrodynamic model error.

SPECIFIC COMMENTS

Benthos response to flow

Starting with a conceptual model to define the factors controlling ecological integrity of the benthos community as it is affected by flow is an excellent idea. The District has summarized these factors in Figure 4-1, and the main sources are well covered. One small suggestion is to change "nutrients" to "nutrients/dissolved organic matter (DOM)," because we know that flows cause loading of DOM as well as inorganic matter. Depending on the source and quality of the DOM, the labile fraction of the dissolved organic carbon, nitrogen, and phosphorus may be rapidly remineralized to inorganic forms. Because of this, loading models must take the DOM pool into account because of the direct effects to primary production and further trophic interactions. The conceptual model is essentially a "bottom up" and thus lacks "top down" controls. For example, all of the physical factors driven by flow can affect predators of benthos, and thus there are trophic cascades that can account for benthic change in the absence of food or nutrient limitation. Typically, trophic cascades are thought of as indirect effects, and in this context all the processes listed in Figure 4-1 are direct effects.

A key concept presented is the coincidence between biogeographic zonesand salinity zones. The zones are introduced in section 4.4.1 and prior to this; Figure 4-3 lists zones. However, the figure caption and first mention of zones should state explicitly if these are salinity zones or biogeographic zones, and text is required to describe how this was determined. Assuming the zone definitions are from analyses performed here, then this should be listed in section 4.3 as well.

The statistical analyses of benthos are very well done, using standard parametric and non-parametric multivariate techniques to discover the relationship between benthos distribution and abiotic characteristics. There is a clear indication of salinity requirements for maintaining ecological integrity of benthos given in Figure 4-4, but a key to the colored lines (as given in Figure 5-11) would increase the value of this chart tremendously.

Fish response to flow

Statistical analysis of the fish data was a little less sophisticated than that of the benthos data, but still adequate to elucidate salinity-fish relationships and identify salinity zones needed to maintain ecological integrity of the fish community. But again, when zones are discussed, there needs to be a specific identification on whether these are salinity zones or biogeographic zones (especially in Figs. 5-7 – 5-10 and Table 5-4 – 5-5). Finally, on page 5-31, there is a switch to "salinity class." What is the difference between a class and a zone? If none, then why is there a need for a parallel construction?

One of the most important analyses in the fish section is presented in Figures 5-11 and 5-12, because this analysis demonstrates a clear indication of salinity requirements for maintaining ecological integrity.

Water response to flow

One important detail that has an enormous impact on trying to perform error analysis is the large degree of variability in the relationship between salinity and flow (Figures 6-1 – 6-4). This is not unusual, and always leads to great uncertainty in the empirical statistical regressions.

Another important finding is that dissolved oxygen is not related to flow, which is unusual but important because it means that dissolved oxygen can be ignored when setting the MFL. However, caution must be taken because if substantial new withdrawals are approved and as flow is reduced in the future, this relationship could change due to the change in average residence time.

Assessment Metrics

Overall, the sections describing benthos, fish, and water, translate well into the biologically relevant salinities and habitat assessment tools, which translates to calculating the volume and bottom are of a salinity range under different flow scenarios.

Modeling inflow versus salinity

A key component of the MFL is to predict salinity under various flow regimes. This leads to a key question: Does the hydrodynamic model adequately predict the salinity regimes in the Lower Peace River under a variety of flow rates for the purposes of the CDF analysis?

The present report and appendices do not provide sufficient information to conclude that the hydrodynamic model is adequate for use with the CDF analysis; however, neither is there evidence that the modeling approach is fundamentally inadequate. The model itself is a state-of-the-art model that is appropriate to apply to the system. However, the present use to predict salinity regimes has not been adequately validated in the MFL (specifically in Appendix 7-2).

There are several issues of concern:

1. The study in Appendix 7-2 is cited as validating the salinity predictions, but is based on a prior study focused on using the model to estimate the Estuarine Residence Time (ERT). The validation of salinity was not a focus of the ERT study, and validation for ERT does not imply validation of the salinity predictions. In general, the model is quite good at representing the water surface elevations, and thus can be argued to be validated for the tracer modeling used to predict ERT, which is arguably a strong function of the tidal and river current fluxes (technically the “barotropic mode”) and only a weak function of salinity fluxes (i.e., the “baroclinic mode”). Unfortunately, the model results for predicting salinities are fairly poor (e.g., Figures C-3 to C-15 in Appendix 7-2), which brings into question the CDF results for salinity concentrations in volumes/areas/shoreline lengths. This appendix could be improved by providing a study focused on validating salinity predictions rather than general model validation for ERT.

2. In Appendix 7-2, the model and salinity field data have been compared in a qualitative manner as simple line graphs that show good agreement in the tidal oscillation (i.e., timing of peak/trough salinity), and very poor agreement in maximum/minimum salinities. One simple improvement to represent the error in Figures C1 – C15 is to graph the difference, i.e., the model minus the observed to demonstrate the scale and patterns of the residuals. The mean of such a graph should be zero (a non-zero mean indicates a bias in longer-term predictions). It would be interesting to see if the model over-predicts or under-predicts salinity in specific seasons, events, or time scales that might affect block and flow regime criteria.

3. There should be a quantitative statistical analysis of the model/field salinity agreement. For example, what is the overall error in salinity prediction and standard deviation? Does this error change significantly during different block/flow conditions? What are the errors in peak/trough salinities and standard deviation? How does this error change in block/flow conditions? The SWFWMD appears to have a significant amount of data that can provide a quantitative understanding of the model error magnitudes during the validation period of 2004. Performing a quantification of the error will provide greater confidence in the underlying model predictions.

4. With a quantitative understanding of the model error in the calibration/validation period (as suggested above), the SWFWMD should analyze the model/data error for the 1996-1999 data set and compare to the error in the 2004 data set. Although the 1996-99 data set is not complete enough or comprehensive enough for model calibration and validation, any available data from this time period can be used to compute model error and compare to the 2004 model error. This effort will provide confidence that the model runs of 1996-99 are sufficiently similar to the 2004 model runs such that subsequent analysis is valid.

5. The quantified error in the model (described above) should be used to estimate the uncertainty/error in the computation of CDF curves. Using a Monte-Carlo method of uncertainty analysis through multiple model runs is neither necessary nor practical. Indeed, unless the error analysis shows particular deficiencies in the previous model, we do not expect additional model runs should be necessary. However, using the quantification of salinity prediction error from the model validation runs, it should be possible to estimate how the error in salinity translates into an uncertainty in the volume/area/length of habitat at a particular range of salinity. This point is absolutely crucial: the MFL depends on a model-to-model comparison of salinity areas under baseline flow conditions and salinity areas under reduced flow conditions; thus, we must know whether the difference between the model results is larger than or smaller than the uncertainty in the model. With the present analysis, we have no evidence that the difference between the baseline and reduced flow conditions is principally a change in some form of model error, or reasonably reflects the actual change in salinity regimes. The approach to this analysis should be documented in an appendix.

The above points should be considered within the context of the 15% estimated habitat loss as a management goal. Recognizing that this 15% is a rough rule of thumb, the modeling should provide management with insight as to the habitat area uncertainty associated with the model predictions. We suggest that the model-produced CDF curves should be accompanied by lower/upper uncertainty bounds based on error quantification. Management should be able to understand whether or not the 15% habitat loss predicted by the model actually suggests a range of 10% to 20% or perhaps 5% to 25%. This information would give confidence in the robustness of the model predictions and analysis methods. It is also important that the managers should be apprised of any bias in the model that would result in a 15% estimate having a biased uncertainty range (e.g. a range of 12% to 30% when 15% is biased to the low side of habitat loss)

Recommendation for Shell Creek and Lower Peace River

We concur with the District's statement: "The greatest changes in flow related habitat and associated biota are believed to occur in those reaches likely to see the greatest changes in salinity, which are the tidal rivers…(A)ssessing freshwater inflows to the harbor is important, but the tidal rivers are more sensitive to potential impacts from freshwater flow reductions, and are the first places to look for significant harm." In addition, "withdrawals cannot cause a violation of established minimum flows and levels for any waterbody that would be affected. (A) withdrawal on the middle segment of the Peace River upstream of Arcadia…could not cause the minimum flow for the middle Peace River (segment between Zolfo Springs and Arcadia) or for the lower Peace River to be violated."

The minimum flows for Shell Creek are determined first, and the maximum withdrawals allowed are included in determination of the minimum flows for the Lower Peace River. While the sequence for establishing minimum flows in these two segments may have little effect on the reach above the confluence of Shell Creek with the Peace River, it is possible that different percentages may have been obtained within each block for the Lower Peace River and Shell Creek had the Lower Peace River MFL determination been made prior to that for Shell Creek, as was done in the report. The recommend assessment of flow reductions is based on individual salinity blocks of 0-2, 2-5, 5-15, psu etc. These salinity zones and blocks are justified based on the biological analyses.

A key assumption is that up to a 15% loss of estuarine habitat is a reasonable and protective management strategy. The District defends this assumption based on past practices and guidance from previous scientific reviews by saying that "changes in available habitat due to flow reductions occur along a continuum with few inflections or breakpoints where the response dramatically shifts. We have found that loss or reduction in a given metric occurs incrementally as flows decline, and in the absence of any clear statutory guidance, believe that the use of a 15% threshold for loss of habitat is 'reasonable and prudent (Shaw et al. 2005)' . . . In some cases, there is a fairly linear decrease with percent flow reduction… and in other cases the reduction is curvilinear… but in all cases there are no clear breakpoints." The review panel agrees with the stated reasons for this assumption.

The Panel expects that the District will have a difficult road ahead in that it must harmonize three separate MFL implementation plans into a coherent whole which will serve to protect, maintain, and even improve the phytical, chemical, and biological components of the whole Peace River Estuary ecosystem. Our continued interest in further developments and resolutions is a given.

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